AN INTERACTIVE COMPUTATIONAL DESIGN APPROACH FOR CREATING ARCHITECTURAL TOPOGRAPHIES

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Gökhan ONGUN

ABSTRACT

AN INTERACTIVE COMPUTATIONAL DESIGN APPROACH FOR CREATING ARCHITECTURAL TOPOGRAPHIES

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The research aims at developing a digital environment for understanding and analyzing natural forces and designing according to the simultaneous feedback given by computational tools. The thesis is an investigation into the concept of interactivity between the designer and computer through the use of computational fluid dynamic tools in a local context of Eastern Netherlands Coast, in response to the already dynamic natural fluid like elements such as air, coastal currents and sand particles. The behavior of these natural elements and forces is significantly dynamic and adaptive to the environment, aspects that can be represented in computer based design environments; hence, the research focuses on the usage of these interactive tools in order to analyze and design. The main problematic developed is to find an alternative solution to the ongoing struggle between Netherlands' coast and North Sea, by creating sand gathering zones in the sea and using these congregated sand surfaces and directed currents as a basis for architectural development. In the scope of the thesis, an exploration of morphogenetic processes in the organic or inorganic development of form is discussed through historical, theoretical and philosophical approaches.

Keywords: Morphogenesis, Self-Organization, Space-Time, Animate Form, Ontogeny, Abstract Machine.

ÖZ

MİMARİ TOPOGRAFYA ÜRETEN BİR ETKİLEŞİMLİ SAYISAL TASARIM YAKLAŞIMI

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Dijital ortamda tanımlanan doğal kuvvetleri anlama, analiz etme ve hesaplamalı araçlar tarafından verilen anında geri-dönüşe bağlı olarak tasarımı şekillendirme sürecinin geliştirilmesi bu araştırmanın başlıca amacıdır. Tez, tasarımcı ve bilgisayar arasındaki etkileşim durumunu, doğu Hollanda kıyıları bağlamında, halihazırda akışkan olan hava, kıyı akıntıları ve bu kuvvetler sayesinde hareket halinde olan kum parçacıkları üzerinde Hesaplamalı Akışkanlar Dinamiği (HAD) yöntemlerini kullanarak araştıracaktır. Bilgisayar tabanlı tasarım ortamlarında doğaya ait akışkan kuvvetleri ve parçacıkları temsil etmek mümkün olduğu için, bu eşzamanlı araçların tasarım ve analiz amaçlı kullanımı üzerine yoğunlaşılacaktır. Hollanda kıyıları ve Kuzey Denizi arasındaki yüzyıllardır süregelen mücadeleye alternatif bir çözüm önerisi olarak, deniz içerisinde kum birikme alanları oluşturulması ve bu birikim alanlarının ve yönlendirilen deniz akıntılarının mimari gelişme mekanları olarak kullanılması hedeflenmektedir. Bu tez kapsamında, tarihsel, teorik ve felsefi yaklaşımlar ile birlikte, formun organik ve inorganik gelişimi üzerinden morfogenez süreçler incelenmiştir.

Anahtar Kelimeler: Morfogenez, Şahsi-Organizasyon, Uzay-Zaman, Anime Edilmiş Form, Bireyoluş, Soyut Makine.

To My Parents & My Brother

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ABBREVIATIONS

NURBS .... Non-uniform Rational B-Spline
CFD .... Computational Fluid Dynamics

CHAPTER 1

INTRODUCTION

Interactivity in design methods (modelling abilities and the possibility of creating instrumental diagrams with the usage of the computer), rather than just being a representational tool for architects, has emerged as a paradigm shift in both design methodologies and the production of form. Mostly the advances in animation and representation tools, which were originally developed for the cinema industry in order to create visually improved and more realistic effects illustrating the natural happenings, has been started to be adapted into the designing processes with the help of the deeper and mathematically enhanced understanding of dynamic behavior of the natural elements they accommodate. Therefore, one can speak of a shift from inert to more dynamic design media and the introduction of time to architecture.

Furthermore, throughout these developments in the computer based dynamic design processes, endogenous behavior of matter and the organizational mechanisms behind the birth of form -'morphogenesis'- became subjects to the field of architecture in order to understand the administrative existence of diagram that is behind the architectural design processes. Morphogenesis is a term formulated for explaining the formal development processes of biological or other inorganic natural entities, starting from the primitive state to the growth towards complex organizations, forms and structures.[1] Through this process, under the influence of the congenital properties of matter, elements of the system adapt and organize in combination with external environmental forces, and as a consequence, start the processes of the emergence of form.[2] Morphogenetic processes can be examined in two different ways; ontogeny and evolutionary populations. Achim Menges (2011) claims that ontogeny is the growth process and development of form of an individual whereas evolution occurs through intrinsic interactions of large populations.[3] The thesis focuses on the elucidation of the morphogenetic development of an individual body -ontogeny- situated in the author's graduation project developed at the Technical University of Delft. The method followed during this formation includes exploring the historical, philosophical and theoretical backgrounds of the project and the reflection of such processes on computational design theory.

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[1] Achim Menges, **Biomimetic design processes in architecture: morphogenetic and evolutionary computational design**. Manuscript submitted for publication, Institute for Computational Design, Stuttgart, Germany, 2011, p.2. Retrieved from: www.stacks.iop.org/BB/7/015003

[2] *Ibid*, p.2.

[3] *Ibid*, p.2.

The developments in the field of mathematics in comprehending the flows and emergence of organizations in nature is directly connected to the advances in virtual reality that computer programs provide. Besides its representational power, the computer starts to become a strong collaborator in order to unleash the morphogenetic processes behind the emergence of natural form with advanced mathematical definitions. In other words, with these contemporary technologies, the behavior of matter in space and the mechanisms by which matter self-organises into variant forms can be explored as extremely close to the actual processes. As a consequence, the momentary appearance of architectural existences can be explored and expanded based on virtual properties such as, time, motion, intensity, population, topology; which derive actual forms through user designed actualization models.

Moreover, besides these new possibilities to explore nature and natural processes, the way of interaction with the design processes is defined from scratch by these advanced technologies. Due to the control of the designer on the existence of every aspect in the virtual environment, it becomes possible to administrate these aspects simultaneously in the processes of form generation. Thus, it is possible to claim that interactive partnership with computer makes it possible to explore morphogenetic processes and as a consequence develop non-standard geometries in combination with the environment. As a result, the dominance of the inert media which concludes with the reduction of certain properties and the uncontrolled oscillation between the virtual and the actual, transforms into a process which is interactive, open to simultaneous manipulations and requiring no reduction of properties. Therefore, all neglected aspects of the design processes start to emerge with the introduction of computational techniques that virtual reality provides for.

The shift in the methods that the designer uses and the interaction of the designer with the virtual environments construct the new thinking mechanisms of the morphogenetic abilities that a process can achieve. Such processes are thought by the most of the designers as the disappearance of the intuition that the designer accommodates, by losing the control over the organization with the historical background provided by him. However, the interaction between computer and designer can be rethought with the understanding of the tools and the morphogenetic thinking capabilities, consequently, the out coming products of such processes start to mimic the uniqueness of natural productions and achieve an open-ended mutative embodiment bonded with the historical frameworks.

1.1 Contextual Background of the TU Delft Graduation Project

Aforementioned theoretical developments and the computational approaches combined with the animation techniques in order to achieve the dynamism that matter provides are discussed in the scope of this thesis. The morphogenetic abilities that are embedded in the matter itself and the virtual processes which lead to the emergence of forms are discussed thoroughly in combination with the usage and the conversion of computational fluid dynamics methods provided by the contemporary tools of animation, to design methods. The creation of an inclusive environment of forces and their effect on the development of form has been the basis of the graduation project developed at Delft University of Technology. Throughout the thesis, the understanding behind the computational methodologies used in the development of morphogenetic processes and the behavior of matter are entwined and discussed for elucidating the graduation project provided. In order to comprehend the dynamic design environment created, based on the progressive natural elements of the project site, it is vital to understand the historical background and reasoning mechanisms developed in the project throughout the design process.

The project is developed in a satellite city, the Scheveningen coast of the political capital Den Haag, which is situated in the northern conjunction of Netherlands with the North Sea. The city had been established as a small fishermen's village when it first developed in the 17th century which had the function of providing food for the wealthy citizens of Den Haag. After the investments made in the leisure based architectural developments in the beginning of the 20th century, the image of the city has shifted from a fishing village towards a city of vacation. In addition to the leisure developments, since the city has a two kilometer long beach for the coastal and water based activities, for the last century the city has been the main daily vacation place for Netherlanders and the physical developments are focused on this aspect of leisure. Moreover, simultaneous to this shift, the beach has become the most important part of the image of Scheveningen by creating events happening in the coast, as well as in water, in order to raise interest to the city. Thus, in time, the aspect of sand and water has become a major attraction for the city and the investments on the increasing relation between the two have raised.

Furthermore, throughout the history of Netherlands, Scheveningen was one of the important bases for struggle with the increasing flood threats coming from the North Sea. Each year, in order to compensate for the decreasing amount of sand migrated with the effect of heavy currents, the Dutch Government developed sand nourishment projects starting at the beginning of nineteenth century. Until the mid-20th century, every ten years, and after the beginning of the global warming every five years and for the last decade even more rapidly, these sand nourishments have been done by the government in order to increase security against flood occurrences. Since the strategic location of Scheveningen for the defense of Den Haag is important, huge amounts of investments for developing contemporary fortification methods against coastal threats have been established by the government. However, the raise in the global warming and as a consequence change in the weather conditions, are going to exaggerate the threat generated by the coastal currents and in order to challenge this threat, innovative and cheaper projects have started to be developed.

Figure 1.1: General view of Scheveningen, it is possible to see four different function zones as well as main landmark buildings whom create the image of the city and the project is located infront of the Kurhaus Hotel, basically to the leisure zone. Image courtesy of the author.

1.2 *De Zandmotor* (The Sand Engine)

In order to upscale the annual nourished amount of sand, the Government of Netherlands developed an innovative approach which they characterize as 'build with nature'.[4] The pilot mega nourishment project called 'De Zandmotor'[5] -The Sand Engine- has been constructed at the three kilometers south of Scheveningen.[6] The purpose of the project is to to create a pre-nourished collection of sediment and by the affect of the natural forces, such as wind and coastal currents, enable these particles to migrate towards the nourishment requiring places in time.[7] Therefore, the nourishment made in the beginning would cease with the abrasion forced by the natural forces in long term simultaneously distributing the included sand particles to the northern coastal areas as far as Scheveningen.[8] Furthermore, the project accommodates a new habitat for immense amounts of animals by creating artificially created natural land on and in the water. In order to experiment the massive investment, the engineers developed beforehand a 'morphodynamic modeling' interface which is named 'Delft3D' and taking the monthly averages of the coastal dynamic conditions as the base.[9]

By using the flood tides -tides moving from south to north- stronger than the ebb tides -vice versa- in the North Sea, designers agreed on a 'hook shape' to direct the migration of sediment towards the northern coastal areas.[10] Subsequently, after the approval of the project, approximately 21.5 million meter cubes (~10,000 m^3/m) of sand nourished to the previously mentioned area in four months in the fall 2011.[11] Since then, the accumulation of sand started to cease and deform as the designer anticipated and the computational models designed for the exploration worked appropriately for understanding the behavior of the forces as well as the movement and distribution of sand. The project implies a successive example for the combination of human experience, intuition and the computational methods in the administration of the natural organizations.

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[4] Mulder, J.P.M. & Tonnon P.K. (2011). **"Sand Engine": Background and design of a mega-nourishment pilot in the Netherlands.** Marine Engineering, Delft University of Technology, Delft, Netherlands, p.4.

[5] Exclusive information about the project can be found at: http://www.dezandmotor.nl/en-GB/

[6] **Mulder, J. P. M. & Dalfsen J.A. (2011).** Current challenges in coastal management in the Netherlands; examples of pilot projects. (Master's thesis, Delft University of Technology, Delft, Netherlands), p.5.

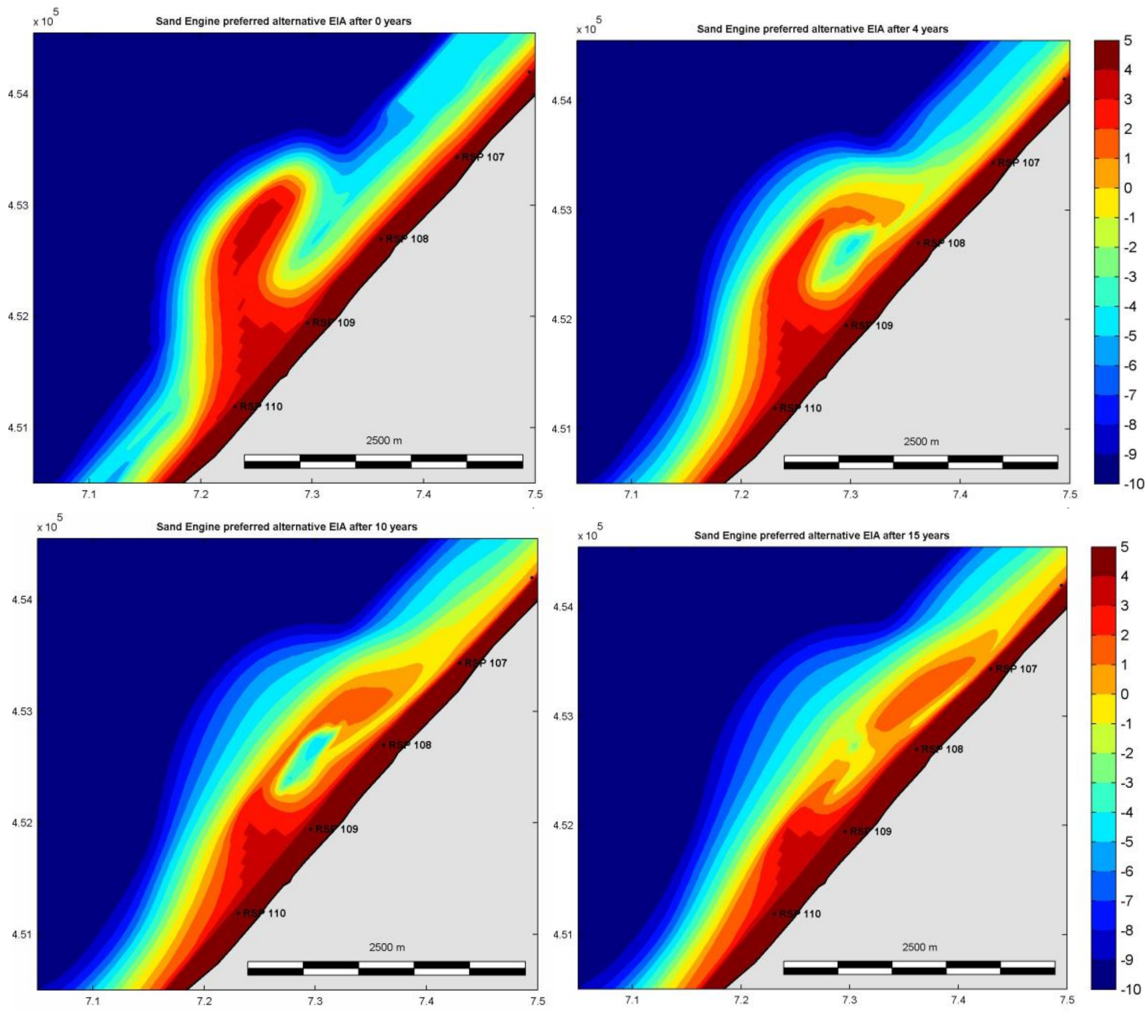
[7] *Ibid*, p.5.

[8] *Ibid*, p.5.

[9] Mulder, J.P.M. & Tonnon P.K. (2011). **"Sand Engine": Background and design of a mega-nourishment pilot in the Netherlands**. Marine Engineering, Delft University of Technology, Delft, Netherlands, p.4.

[10] *Ibid*, p.4.

[11] *Ibid*, p.4.



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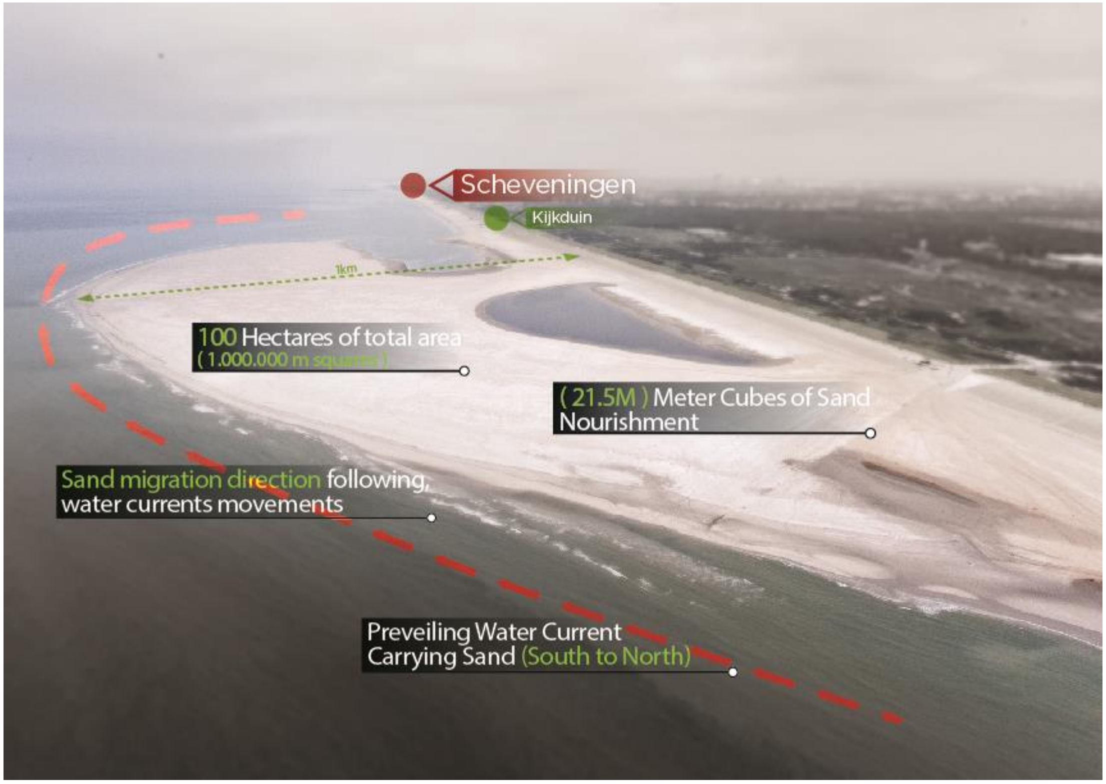

Figure 1.3: Main properties of the Sand Engine. Image courtesy of the author.

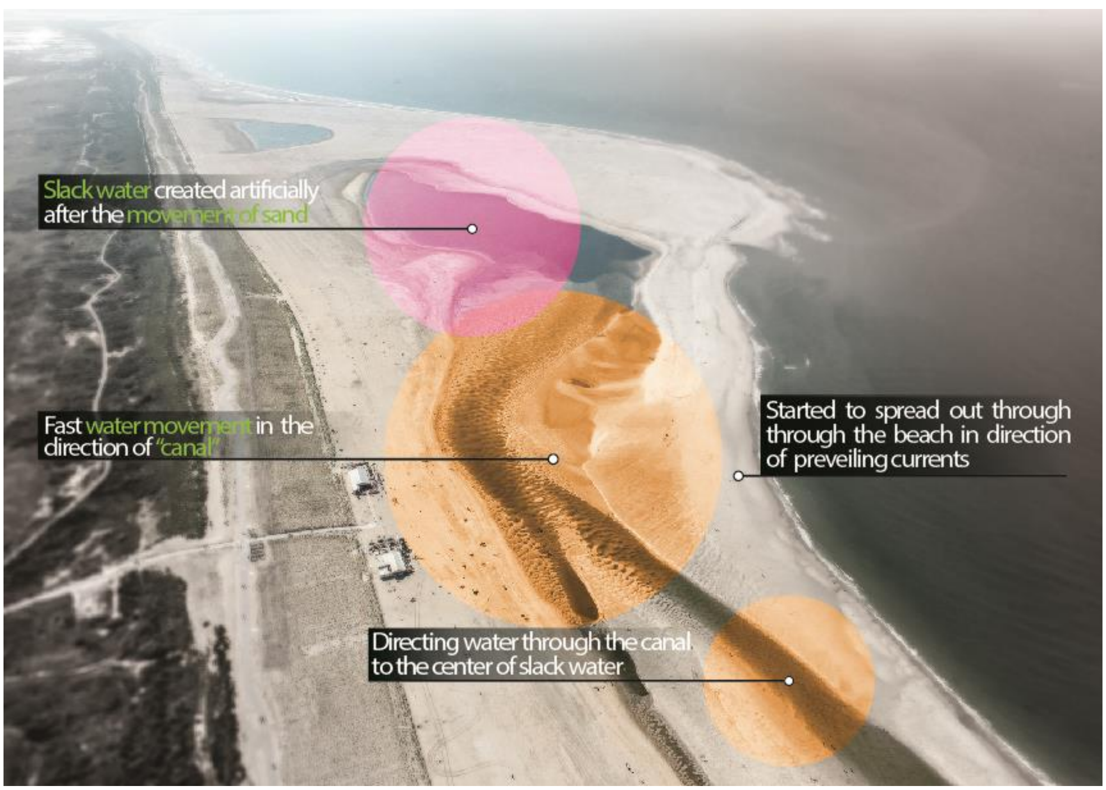

Figure 1.4: Deformations happening on Sand Engine. Image courtesy of the author.

1.3 The TU-Delft Graduation Project Definition

Subsequently, throughout the deformation process which is triggered by coastal dynamics, the sand motor started to give rise to variant forms in a large spectrum in combination with the currents. The conjunction points of emergent forms create strong flows of water or slack water areas which are used extensively by the water sport fans such as fishermen and surfers as the base for their activities. Furthermore, the addition to the beach creates an extensive daily activity place for the local visitors. Therefore, the addendum is not only started to generate different forms via migrating sand but it also emerged new functional abilities for the visitors in combination with the intensive properties provided by the togetherness of water and sand. However, the main problem that still exists in such a mechanism is that of the limited time period that the project is going to be alive. After all the nourished sand migrated and distributed to the northern coasts, the project will vanish and therefore the positive aspects that it brought are going to cease with it as well, thus the 'build with nature' aspect would become a temporary solution which actually does not build but vanishes in time.

Eventually, Scheveningen is one of the extremely important bases for the water sport activities in Netherlands and it has been assigned to the 2028 Olympics by the government officials as the city of water sports games. Furthermore, the city has large amounts of water sports based companies and education centers. These water sport functions annually build their individual pavilions on the beach from March to December in order to be more directly connected to the water rather than being in the middle of the city. The author's graduation project uses this combination between two most important aspects of the city, annotates the similar organization principles behind the Sand Engine Project and introduces water sport activities to the dynamic behavior of the ever morphing behavior of the sand nourishment. The migration of sand is treated as not a negative behavior that ceases in time but by creating 'sand holders' -as it was named in the project- making the sediment to accumulate and create sand islands. Therefore, rather than creating an artificial accumulation of sand and letting it to cease in time, the project reverses the mechanism and collects the migrating sediment in order to benefit from several positive aspects. Firstly, by collecting the migrating sand, the annual nourishment is not necessary; therefore, by only creating sand holders the mechanism creates islands of sands that enlarge the existing beach and enhance the problem of defense. Secondly, by transporting the existing pavilions and the water sport based functions in the city to the sand islands, the project combines two extremely important assets of the city and creates breathing points in the overwhelmed density of the beach and in the city. Thirdly, the divergent forms appearing between manmade and natural dynamic forces, are used to create functional areas which could be utilized by the water sport activities such as; a lagoon for the recreational fishing, fast water stream tracks for the rafting activities, varying speed streams for surfing and completely slack water for yacht surfing marina.

The morphogenetic abilities that nature provides are crucial parts of a system in order to emerge new forms, abilities or functions. Moreover, after the immense developments made in the field of computers and animation techniques, it is possible to control and design these morphogenetic abilities by the computational design methods introduced. The graduation project focuses on the combination of nature and virtual reality that the computer provides for; thus the main purpose is to try designing a controlled environment and mimic natural morphogenesis in consolidation with the designer's approach. The arguments developed for the project consist of a wide range of possibilities in order to explore such collaboration of nature and the functions, nature and the computer. For achieving such a goal, an interactive computational design environment has been developed and the possible logical variations have been developed in combination with the contemporary fluid dynamics methods which represent the interaction between coastal currents and the sand holders.

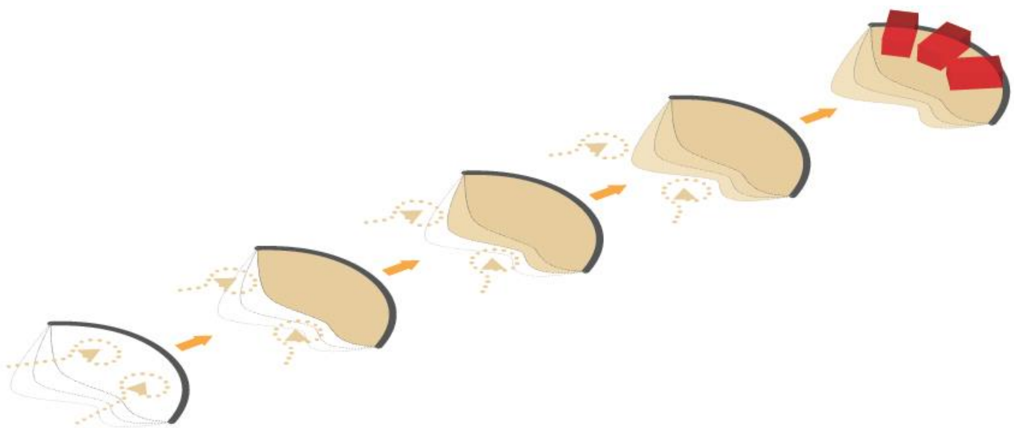

Figure 1.5: Basic principle diagram of graduation project, the image is the courtesy of the author.

In the scope of this thesis, the fundamental properties of natural and computational morphogenesis in combination with the design methods are going to be acutely explored via the developed interactive design model. The formations that the sand islands take with the pre designed sand holder constructions, accumulation and dissipation of the sand particles create a variability of forms. In other words, the system contains a time based flow of forces and an embodiment of historical archetypes. An instant form appearing have clues of the previous organization yet it is pregnant to the possibilities of what kind of forms can emerge afterwards, the instantaneous moment in the body is the accumulation of the previous moment and at the same time it is the historical data for the newborn. Therefore, the overall organization is a sequential formation of matter which is reflected onto the virtual environments by the guidance of animation techniques.

Consequently, to understand the shift in the recognition of the behavior of matter and the design techniques, this thesis focuses on the aspect of time and its consequences on the artistic research following with the Deleuzian philosophy of matter. In addition, the process is about developing a combination of several methods in a single design environment in order to figure out the actualization of self-organization and mimic the attitudes of nature. Furthermore, to guide all these processes, the intuitive approach of the designer within virtual architectural design environments are going to be discussed.

CHAPTER 2

DYNAMICS OF MATTER, ANIMATE FORM AND MORPHOGENESIS

Deleuzian philosophy has been a key architectural design strategy in the last decade, both in developing design methods as well as comprehension and usage of these methods via a contemporary materialist philosophy. Deleuze and Guattari, with their interpretations on different scientific fields and combinations of some terminologies like *evolution*, *thermodynamics*, *differential*, *topology*, connected these varying fields of science and created a wider understanding about what matter is**,** how it exists and how it behaves.[12] This philosophical debate made it possible to apprehend the intensive and extensive differential dynamisms which give matter its form as well as the historical background of matter. Furthermore, in his book Animate Form (1999) Greg Lynn, developed a theory of dynamic fields applied on the matter together with the idea of time embedded in the environment, which can also be superimposed on architectural form in order to achieve more fluid and non-Euclidean geometries and processes of architecture.[13] Throughout this chapter, Deleuzian philosophy of matter will be discussed entwined with its application in the architectural theory by Greg Lynn aiming for an elucidation of the TU-Delft Graduation Project (2012).

As it has been introduced in the previous chapter, the project is dealing mainly with the sand particles affected by the sea currents, accumulating adjacent to the **'**sand holders' which are constructed in the amalgamation of water and sand particles. In order to achieve a dynamic topography to arise on the sea, it investigates on the opportunities of dynamic organization in the design of the temporary buildings that will be built on it. As a consequence, two conjoined elements which are the sand particles and the dynamic flow of coastal currents have been exploited as the fundamental design aspects in the process. Sand particles have been considered as the elements whose movement is triggered and continued with dynamic trajectories of the environment and dynamic coastal currents are studied with their thermodynamic behavior which generates the trajectories for sand particles to appear on the coast in different dynamic topographies. The project's focus is not mainly on the search for contemporary fluid geometries; however, it is a topological exploration about a dynamic topography for typical container pavilions to build on, in varying organizations with the changes. Lynn (1999), advocates that animate form

[12] Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture**, [Web], Columbia University lecture, 2004, Retrieved From; http://www.youtube.com/watch?v=50-d_J0hKz0.

[13] Greg Lynn, **Animate form**, Princeton: Princeton Architectural Press, 1999.

means the embodiment of the virtual motion and force into the shape of the designed building; however, this should not be understood as the building to set in motion.[14] On the contrary, in the author's graduation project, static behavior of pavilions constrained by their connection to earth has been broken and redefined dependent on the animate sand topography which they are built on. This redefined relationship indicates that, animation can also be achieved by changing the static ground into different variations in time and giving the opportunity to the temporary buildings to animate their organization connected with the topography. Thus, being animate is not only to be considered as being animate in shape and form but also the temporariness of the building and the dynamism of the topography; hence, organizations and behavior of the processes can also considered as animate.

2.1 The Effect of Space-Time on the Understanding of Time, Geometry and Animate Form

The project basically deploys a series of morphogenetic processes happening sequentially. As a consequence, through the combination of the sediment with the changes happening in the fluid environment, the overall behavior of the sand islands become dependent on time. The aspect of time and its integration to the space geometry become important as they bring forth the concept of morphogenesis. The discussion of time for defining geometric space is known to have been a main issue amongst famous physicians, philosophers, artists, and architects, with the questions of how time affects geometries and what the consequence of interpretation of time on geometry is.

At the end of 19th century, Euclidean geometric space has been declared as the absolute intuition space by Kant[15]. The problem of the Euclidean definition of space was the positioning of geometric space as a secondary phenomenal existence which was coming after and derived from the appearance of perfect solid bodies - the point, the line and the plane[16]. Later, Descartes defined space as an independent three dimensional continuum which previously existed and accommodated the solid bodies.[17] However, with the following advances in mathematical formulations by Gauss, Lobachevsky and Bolyai, a new apprehension of the geometric space called Non-Euclidean after its disobedience to Euclid's fifth parallel postulate, has confounded Euclid as well as Kantian space and time philosophy.[18] This ambiguous atmosphere has been clarified, with the definition of geometric axioms as mediators explained amidst synthetic a priori and empirical, as pointed out by Poincaré.[19]

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[14] *Ibid*.

[15] Bernard Cache, **A Plea for Euclid,** Any, 24, 1999, p.54-59.

[16] Sanford Kwinter, **Architectures of time: Toward a theory of the event in modernist culture,** The MIT Press, 2002, p.53-100.

[17] *Ibid*.

[18] Henderson (1983), cited in Zeynep Mennan. **The Question of Non Standard Form.** *METU JFA, 2*, 2008, p.171.

[19] *Ibid*.

Subsequently, Einstein's field theory has affected the perception of space and determined the new fourth dimension in the regular appearances of geometry in a way that it is neither separable from time nor reducible to its physical elements which means that it functions as a whole with respect to its substances.[20] Einstein's proof of his field theory and existence of time in the geometrical emergence with the experiment at the solar eclipse happened in 29 May 1919,[21] has proved that the apprehension of space-time is a more complex variant to the geometry of Lobachevsky.[22] Crucial point in this experiment was that the space is formed by the dynamic forces, by proving that even light is bending with the force fields that it encounters. Furthermore, Einstein made it clear that the motion of a liquid and field of matter are not two separate aspects but resembling appearances of forces, functions, vectors, speeds.[23] Therefore, actuality of form and the movement of an object -motion- is dependent on the existence of time and the motion is created through correlation with environmental forces.

Embodiment of time in form has been a topic of discussion by various artists and architects in the beginning of the 20th century. While departing from the Renaissance perspective space - Euclidean Space - which created an obstruction in the artists imagination, cubism differentiated geometry by employing more than three dimensions to form; the fourth dimension as time.[24] Therefore, 20th century has unified the scientific and artistic vision of space-time as geometry is pregnant with infinite possibilities.[25] From the observer's point of view, by examining the object from various directions, from inside and outside, cubism breaks with the Renaissance perspective and includes time in the form.[26] Giedion (1967) advocates that cubism extended into various fields like architecture, which because of its static behavior does not internalize the movement, and gave opportunities for innovative spatial conceptions.[27]

Concurrently, futurism was also developing with the integration of space-time aspect on form. The main concern was not only the object-observer relation but also the movement of bodies,

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[20] Sanford Kwinter, **Architectures of time: Toward a theory of the event in modernist culture,** The MIT Press, 2002, p.53-100.

[21] Manuel De Landa, **Deleuze and the Use of the Genetic Algorithm in Architecture,** Columbia University, CNMTL, Art and Technology Lecture Series, April 9, 2004, retrieved from;

http://www.youtube.com/watch?v=50-d_J0hKz0.

[22] Bernard Cache, **A Plea for Euclid,** Any, 24, 1999, p.54-59.

[23] Sanford Kwinter, **Architectures of time: Toward a theory of the event in modernist culture,** The MIT Press, 2002, p.53-100.

[24] Sigfried Giedion, **Space, time and architecture: the growth of a new tradition.** Harvard University Press, 1967, p.435.

[25] *Ibid*, p.436.

[26] *Ibid*, p.436.

[27] *Ibid*, p.436.

muscles, and automobile.[28] Boccioni (1914) states that, there is not a beginning of the object or an end but, there is a matter continuum of existing intensity differences, which the mind comprehends as lines, curves.[29] Therefore, the quality of an object lies within its inner dynamics embedded in its existence. Matter never stops moving, it is a continuous flow of dynamic forces and substances; thus, the object we observe is in rest which has *absolute motion* within it. Furthermore, the translation of an object in the observable space is *relative motion* which is based on the movement of the object.[30] The main relation between these two kinds of motion is that absolute motion gives the matter its form since the relative motion transforms the form of an object. In other words, space-time which emerges as movement in the appearance of form has been internalized in the form of the futurist art. Correspondingly, similar to cubism, futurist movement in art had influences on architecture as well; Sant'Elia's architectural works included the futurist movement in the contemporary city which was experimentations and search for mobility and change.[31]

The impression of the futurist movement had ended drearily; firstly, because of the early death of the artists and the architects without the possibility of observing the consequences of the movement;[32] secondly, the methods and criterion they used in order to form their geometries was dependent on the intuition of dynamics that matter consists of, thus, their ideas could not reach to the generations after them. Nonetheless, for the last decade, a growing interest in 'animate form' has started to research the effect of movement, motion and animation which is embedded on the contemporary form, which consists further in an authentic exploration of partial intuition methods for creating form via dynamic flows.[33]

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[28] *Ibid.*

[29] Sanford Kwinter, translated the original texts of Boccioni: Pittura, scultura futuriste: Dinamismo plastico (1914) and Archivi del futurismo. Therefore, the citations in the text from Boccioni are derived from the direct quotations of Kwinter from the original texts of Boccioni.

Sanford Kwinter, **Architectures of time: Toward a theory of the event in modernist culture,** The MIT Press, 2002, p.62.

[30] Boccioni defines two kinds of motion which can be observed on the object. 'Absolute motion' is a dynamic law grounded in an object. The plastic construction of the object will here concern itself with the motion an object has within it, be it at rest or in movement. I am making this distinction between rest and movement, however, only to make myself clear, for in fact, there is no such thing as rest; there is only motion, rest being merely relative, a matter of appearance". 'Relative motion' is a dynamic law based on the object's movement. . . . Here it is a matter of conceiving the objects in movement quite apart from the motion which they contain within themselves. That is to say we must try to find a form which will express the new absolute- speed, which any true modern spirit cannot ignore."

Ibid. p.62.

[31] Sigfried Giedion, **Space, time and architecture: the growth of a new tradition.** Harvard University Press, 1967, p.447.

[32] *Ibid*, p.448.

[33] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999.

To summarize, the research for understanding the effect of time on the organization of form had been explored deeply and created an inert and pure understanding of form with the modernist interpretation of the cubist space-time. The investigation provided by futurism on the aspect of movement could not continued with the unfortunate loss of the artists and the architects which could be developed further and created a complete different attitude in the design processes of form. However, with the contemporary advanced computer technologies several designers architects started to research the effect of the dynamic fields and motion on the emergence of form which was also the fundamental basis for the explorations of futurism. In the next topic, embodiment of the aspect of space-time in combination with the movement, motion and animation through precise simulation tools of the natural processes are going to be discussed further.

2.2 Animate Form in Architectural Development

Animate approach is a state of form which consists of movement, motion, dynamics; flows embed themselves in the body of form. It is the contemporary accession of the movement on form after the futurist movement. Since, the advances in the field of mathematics and the implementation of its theories to the realm of the computer, it is effortless to use techniques that the computer provides to designers. Animate form is the usage and the experimentation of animation tools, topological deformation tools, thermodynamic tools, virtual force fields in order to achieve a more sensitive and accurate knowledge of form. Although the futurist movement was also trying to experience the existence of constant motion as the ruling mechanism of matter, because of the shortage of theoretical background and advanced technology, their techniques remained intuitive. However, with the advances in the computer realm it is increasingly easy to comprehend and experiment the existence of motion.

Architecture, because of its aspiration to be timeless, used to be an inert medium of the inert design processes projected onto paper. Although, as it has been discussed, the object is a continuous flow of matter in a dense state that the eye observes in rest, architecture represents an inert thought of form and organizations in the search for permanence.[34] However, animate form is a contemporary way of thinking of architectural form with the usage of animate approach, explained by Greg Lynn as such;

> *Animation is a term that differs from, but is often confused with,* ***motion****. While motion implies movement and action, animation implies the evolution of a form and it's shaping forces; it suggests animalism, animism, growth, actuation, vitality and virtuality. [...] What makes animation so problematic for architects is that they have maintained an ethics of statics in their discipline.*[35]

[34] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.9.

[35] *Ibid,* p.9.

Since architecture is dependent on statics, it represents a single moment on a single surface rather than multiplicities of times.[36] Animate form consists of time, forces, flows embedded on the body of architectural form. The prior concern here is having 'stability' rather than achieving a 'stasis' of the object.

The divergence between stasis and stability resemble the discussion between Euclidean and non-Euclidean. The debate is briefly about a space which is bowdlerized by removing space-time and movement from the emergence of geometry and a definition of pre-existing space which consists of fields, dynamics; therefore time, that makes it possible for the unique geometries to emerge. Similarly, by eliminating the aspect of time in the beginning, stasis becomes the condition of discrete, timeless and fixed architecture which nestles only gravity as the dominant force.[37] In contrast, multiplicity of forces and changing and evolving architectural form refer to *stability* which provides a state of equilibrium regarding not only the gravitational force but also the dynamic forces in the environment, such as wind forces, ground movements, precipitation, and so on.[38] Therefore, when the object's morphogenesis is influenced by the environmental fluidic fields, form becomes animate and creates embedded historical archetype actualized in the reality.[39] The object interacts with the surrounding forces and deforms accordingly in certain intervals of time. The appearance of a deformation is a result of the accumulated past events but is also an instantaneous moment pregnant for the next generation forms to emerge. As a consequence, it is possible to mention that all the historical archetypes creates a conglomeration of moments in now, on the new body, they are the past events that are accumulated; therefore, embedded on the existence of the contemporary.

The author's project uses the environmental forces in order to create a continuously changing dynamic ground for architectural elements to build on. Coastal currents of the North Sea and the wind conditions create the basis of these dynamic fields. These flood and ebb currents and blowing wind are the carriers of sand particles within their energetic existence. The usual state of sand particles is that they are in a continuous movement by the forces in which their environment evolve, thus when they confront an obstacle or in other words a place where the forces become denser, they start to accumulate in certain areas, morph into a stable state and let emerge a 'gradient topography'.[40] This entire process can be described as the use of matter in its thermodynamic environment as the main element in creating form. When the topography of architectural objects become animate, they start to progress from their static behavior to a state of stability. Therefore, whenever the topography creates a new form in a certain time of the year, connections and relations between architectural elements are to be reconsidered accordingly. Thus, as well as the ground, architecture which is connected to its ground becomes animate and starts to reflect on the

[36] *Ibid*, p.10.

[37] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.14-15.

[38] *Ibid*, p.24.

[39] *Ibid*, p.35.

[40] *Ibid*, p.30.

consecutive animate behavior. As a result, static behavior of architectural elements starts to present motion, animation, movement embedded to their actuality.

In the research of topological changes arising in the topographies, advanced tools of computational fluid dynamics have been used in order to experience the movement and accumulation of sand particles. Although, computers are the contemporary design interfaces, in most design fields, they are still considered only as tools for representation purposes. However, since the computers are dependent on precise mathematical axioms and definition of spaces, representational techniques can also be used as alleged methods for design processes. In order to differentiate the usage of computers as representative tools and methodical tools, Lynn (1999) states that computers have well established their position in the architectural field but that the initiation of the aspects time and motion is not simply a visual phenomenon.[41]

In order to use the computer as a methodological interface it is important to comprehend three kinds of Deleuzian thinking methods for the morphogenetic processes; ‘population thinking’, ‘intensive thinking’ and ‘topological thinking’[42]; which are also mentioned as three essential characteristics of organization in the definition of Greg Lynn’s animate form; ‘parameters’, ‘time’ and ‘topology’[43]. In the following sub-contents of this chapter these topics are going to be discussed extensively in combination with their reflection on the author’s project.

2.3 Deleuze and Population Thinking; Parameters

In computer generated research and form processes, a generative algorithm derives knowledge from the evolutionary theories of biology. The Darwinian evolution theory that claims the idea of the survival of the fittest is revised by contemporary scientists so that the evolution of being is now to be considered in large communities of reproduction.[44] In the theory evolutionary theory that Darwin developed species evolve properties that makes them to adjust to their changing environment and enables them to survive, vice versa if species cannot fit to the changes they get eliminated and the fittest ones continue to reproduce However in the contemporary evolutionary biology, species defined as the communities of mutation or spaces of possible next generations.[45] These communities are in the random search of the new mutations to succeed against the filters generated by their environment.[46] The resemblance of this theory to the field of computers is the existence of the parametric inputs which the computer provides to and processes for the designer.

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[41] *Ibid*, p.18.

[42] Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture.** In N. Leach (Ed.), Designing for a Digital World, London, United Kingdom: Wiley-Academy, 2002, p.118.

[43] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.20.

[44] Gilles Deleuze and Félix Guattari, **A thousand plateaus: Capitalism and schizophrenia** (Vol. 2). U of Minnesota Press, 1987, p.48.

[45] *Ibid.*

[46] *Ibid.*

All the internal elements of a biological existence like replicators (genes, memes, and norms), variables, and population resemble to the inner dynamics of a computer based system.[47] Although, in a population which contains these aspects within its inner dynamics, at any single moment an organism evolves, the main matrix for the emergence of form is the population.[48] Thus, population thinking is the creation of a space of random opportunities accommodating variables, replicators, population and selection filters for form to emerge.[49]

Admittedly, parameters are the ruling numerical data of computer aided design which makes it possible for differential geometries in the virtual environment to evolve.[50] In the animation based interactive computer methods which consist of temperature, gravity and dynamic forces, the computer calculates the parameters as sequences alternate to an instant.[51] Therefore they start to represent the existence of time in the virtual environment and give opportunities for dynamic interaction with the shape of object via key framing the numerical parameters.[52] In this way parameters can create a flow of progressive forces which can be benefited in the sententious embodiment of the space-time aspect on the designed objects. Therefore, the techniques start to provide an explicit transition from static Cartesian design space to a more dynamic and time influenced active space of flows, fields and motion.[53] By the same token, this shift resembles to the futurist epoch's investigation of space-time by means of Einstein's relativity theory, field theory, in a way that the appearance and the shape of circulating matter depends on the flow of forces which they are subject to. Thus, the aspect of time, which is neglected by architects in favor of stability against gravitational forces, becomes relative to other objects such as forces, field, flows and starts to generate forms in a fluctuating space of motion. Concurrently, this shift presumes a transition from perfect solid bodies into what Lynn calls a "contextual specificity".[54]

The dynamic and interactive approach used in contemporary animation and special effect programs are especially developed for cinematic purposes, but can be acquainted as design tools by architects as well.[55] This way architects can explore the implementation and the effects of time on their design. The graduation project that the author developed is using these contemporary techniques in the search of the variations that a changing ground provides. Since, the parameters

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[47] *Ibid.*

[48] Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture.** In N. Leach (Ed.), Designing for a Digital World, London, United Kingdom: Wiley-Academy, 2002, p.118.

[49] Manuel De Landa (2011).

[50] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.25.

[51] *Ibid*, p.25.

[52] *Ibid*, p.25.

[53] *Ibid*, p.25.

[54] *Ibid*, p.11.

[55] *Ibid*, p.11.

and their sequential calculation already exist in the tool, the created environment becomes a generic space of infinite possibilities nourished with the intuitive designer approach. The created design space consists of two dimensional flow of dynamic fluid in the animation and modeling interface Maya and the collision of this fluidic field with the representations of so called sand holders. These two aspects, flows and holders, start to collide and the designer begins to deform the holders with respect to the previously defined selection criterion. Whenever a change is made on the sand holders, an obstacle created or a new selection criteria introduced, the flows adapts themselves, in other words re-calculate the sequential numerical population in order to compensate the adjustments exposed. By this way, the possibilities of changes occur in the flows of coastal currents and the accumulation of sand can be observed and designed accordingly. Thus, this partnership increases the amount of possible solutions for designing the process of morphogenesis by means of random occurrences of self-generated geometries. Therefore, the exegeses of population thinking appear in the form of computer generated dynamic flows and its self-adjustment of the numerical population in collaboration with virtual geometries, to create a reproductive space of a wide range of possibilities.

2.4 Deleuze and Intensive Thinking: Difference and Time

Deleuze, derived the concept of intensive thinking in terms of thermodynamics, itself derived from physics, in which the compelling force for matter to take form is considered as one of the key issues in the appearance of time and motion. Differences of intensive properties create motion and movement, and time as a consequence.[56] Deleuze (1968) differentiates the properties of matter into two resembling but completely different aspects, called as; extensive properties and intensive properties.[57] Extensive properties of an object are the divisible quantitative characteristics of matter which might be exemplified as length, area, volume and height.[58] These extensive quantities are similar to the rigorous Euclidean definition of an object in space with only the properties that gives certain coordinates with the reduction of essential dynamic aspects that time, field and flows inscribe. However, intensive properties are the inner, dynamic properties of an object, which are not possible to divide into their smaller portions but change according to the environmental factors or by the association with different objects, such as; temperature, pressure or speed. Although, intensive qualities are not divisible, whenever they have differences between other intensities, they tend to create equilibrium with them. Thus, when there is heterogeneity between two intensities, the aptitude of equilibrium begins to give birth to movement, motion and flows; therefore, time. In order to explain this situation Deleuze (1968) in his book *Difference and Repetition* claims that;

> *Once communication between **heterogeneous** series is established, all sorts of consequences follow within the system. Something 'passes' between the borders, events*

[56] Manuel De Landa, **Deleuze, intensive and topological thinking** [Web], 2011, The European Graduate School lecture series, retrieved from http://www.youtube.com/watch?v=0wW2l-nBIDg

[57] Deleuze, Gilles. **Difference and repetition.** Columbia University Press, 1968, p.24.

[58] Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture.** In N. Leach (Ed.), Designing for a Digital World, London, United Kingdom: Wiley-Academy, 2002, p.118.

> *explode, phenomena flash, like thunder and lightning.* ***Spatiotemporal dynamisms fill the system****, expressing simultaneously the resonance of the coupled series and the amplitude of the forced movement which exceeds them.*[59] *(Emphasis mine)*

The important point to note here is that, when differences of intensities occur in a system or matter, those intensive properties break with their inert situation and start to interact with each other, thus the system starts to include motion and movement without the necessity of any other triggering force, thus unleashing the embedded aspect of motion, time from their bodies. In order to explain the occurrence of motion of intensities, De Landa (2002) advocates that, "[...] differences of intensity are productive differences since they drive processes in which the diversity of actual forms is produced".[60] In order to exemplify intensive properties and the creation of motion, De Landa gives the following example: When a volume of water in ninety degrees divided into two, it does not create two equal volumes of water consisting of forty five degrees of temperature.[61] However, if one creates a box divided into two volumes and fills the parts with air in different temperatures, from the hotter part a spontaneous flow of matter emerges and tries to finalize in an equilibrium state by equalizing the temperature at both sides.[62] The process derived via the difference between intensities tries to abolish the differences; thus, in order to achieve this, it starts to fluctuate in matter and energy.

On the other hand, if the example of "the box full of air with different intensities" is considered as *micro scale*, it is possible to consider weather or sea water movements as the *macro scale* intensity fluxes of matter and energy. For instance, if we consider the world which has different temperature and pressure areas, consisting such as low pressure and high pressure. These kind of differences start to drive processes, whether movements and flows within the sea water, morphogenesis of forms like tornados, rain, snow, vortexes, swells and so on, in order to reach to a state of equilibrium.[63] Furthermore, the local coastal dynamics and occurrence of sea currents in vernacular places are also a reflection of these macro scale intensive differences. However, the term thermodynamics used by Deleuze with respect to physics is not entirely covering these macro scale intensity differences which cannot be cancelled when reached to the equilibrium state. Thus a new definition of this area, from the field of physics again, is almost completely covering this aspect; 'far-from-equilibrium thermodynamics'.[64] This is the term, used by De Landa (1999), consisting of strong flow of matter and energy which, because of its dynamic continuum, could

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[59] Gilles Deleuze, 1968, p.118.

[60] Manuel De Landa, 2002, p.118.

[61] *Ibid*, p.118.

[62] Manuel De Landa, **Deleuze and the Use of the Genetic Algorithm in Architecture,** Columbia University, CNMTL, Art and Technology Lecture Series, April 9, 2004.

[63] Manuel De Landa, **Deleuze, intensive and topological thinking** [Web], 2011, The European Graduate School lecture series, retrieved from http://www.youtube.com/watch?v=0wW2l-nBIDg

[64] Manuel De Landa, **Deleuze and the open-ended becoming of the world**. In E. Grosz (Ed.), **Becomings, Explorations in Time, Memory, and Futures**, New York: Cornell University Press, 1999, p.31.

not cancel itself and become concealed under its extensive consequences.[65] As a result, in these far-from-equilibrium thermodynamics, morphogenesis is not a consequence of forces from outside but matter derives forms via its inner intensive properties.[66]

Far-from-equilibrium thermodynamics, intensive thinking, and their relation with the collected sediment seem as fundamental in the development of the author's graduation project. The coastal currents in the conjunction of the North Sea and of the Scheveningen coast already contain intensive movements occurring in the form of a dynamic motion of water particles. Furthermore, sediment which happen to be in the sea water is in a direct communication with these dynamic movements. The stationary sand particles can be considered as in a state of equilibrium with their weight against the intensive environmental forces. However, whenever the effect of these forces on the particles increases and the equilibrium breaks, in other words when intensive differences occur in the collection of sand in combination with the environment, they tend to move through other places. Therefore, it is possible to claim that the overall system provided here in the definition of the project is based on the emergence of differences in intensive properties. In the development of the project, these intensive properties of coastal currents have been defined in the computational method and used in the design of the sand islands. How this tranformation of actual intensive properties to the virtual environment has been achieved and used in the design process is going to be discussed broadly in the following chapters of the thesis.

2.5 Deleuze and the Topological Thinking; Geometric Topology

Topological thinking, derived from the field of mathematics, is the last one figuring amongst the three ways of thinking that Deleuze provides in his philosophy.[67] In this sub topic, the aspect of topology will be discussed in both the creation of the concept of 'plane of immanence' as well as the reflection of topological qualities on the forming processes of matter.[68]

> *[….] to the formed or formable matter we must add an entire energetic materiality in movement, carrying* ***singularities*** *or* ***haecceities*** *that are already like implicit forms that are topological, rather than geometrical, and that combine with processes of deformation.*[69]

The shift from the understanding of geometry as Euclidean solid forms towards an embodiment of contemporary space-time issues constitutes the fundamental ingredient of topological thinking. As it has been discussed previously on the appearance of the aspect of time within form, Euclid's

[65] *Ibid*, p.31.

[66] *Ibid*, p.31.

[67] Manuel De Landa, **Deleuze, intensive and topological thinking** [Web], The European Graduate School lecture series, retrieved from http://www.youtube.com/watch?v=0wW2l-nBIDg, 2011.

[68] *Ibid*.

[69] Gilles Deleuze and Felix Guattari, **A thousand plateaus: Capitalism and schizophrenia** (Vol. 2). U of Minnesota Press, 1987, p.408.

definition of space provides a Cartesian co-ordinate system based on this understanding of space. However, with the advancement in the field of mathematics via the interpretations of Gauss and Riemann, the understanding of space as an environment covering everything within certain defined coordinates has been changed to the comprehension of the local spaces of ‘intensive geometries’.[70] An intensive geometry is a non-euclidean form, it is a consequence of intensive differences embedded to its non-standard form. The idea of using differential equations in calculating the properties of the local points on geometries makes it possible to identify the intensive qualities of the analyzed incorporate point on the surface.[71] Moreover, with the interpretation of Poincaré on the definition of the topological plane of immanence containing rapidity and slowness, intensive geometries are transformed to the collection of the phases that a system takes in combination with the various intensive properties, which he calls as ‘phase spaces’.[72] Every topological geometry and every topological process is in a state of being rather than being in stasis as finalized form.[73] The actualization of the virtual states embedded on the geometries happens through ‘abstract mechanisms’ which make it possible for the geometry to achieve divergent metric structures at the end of their processes.[74] Therefore, in order to achieve the wide range of possible actualizations of the geometric phases, the collection of matter and the background abstract mechanisms should be thought as topological.[75]

Figure 2.1: Munich Olympics Stadium, Image retrieved from: http://www.architectmagazine.com/Images/tmpF79.tmp_tcm20-1269734.jpg, Last accessed: 01.09.2013

70 Manuel De Landa, 2011.

71 *Ibid*.

72 *Ibid*.

73 *Ibid*.

74 Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture**. In N. Leach (Ed.), **Designing for a Digital World**, London, United Kingdom: Wiley-Academy, 2002, p. 117-120.

75 *Ibid*.

In consideration of exemplifying topological thinking and actualization processes, the design process of Munich Olympics structures by Frei Otto is a fundamental instance in the history of architectural developments. In order to achieve the contemporary animate forms that are provided to the structures, Frei Otto created a container full of soap film with an up and down moving wooden frame which is also including the basic representations of the main structure.[76] Afterwards, by moving the frame up and down, he used the topological deformation capabilities of soap film, which are constrained by the structural representations, and achieved a divergent metric form, which with the natural 'self-organization' processes minimized the surface tension and therefore, made it possible to evaluate the metric dimensions of the structure.[77] In the example, it is possible to comprehend that, with the combination of topological thinking for creating a phase space and the topological properties that are embedded in soap film emerges an intriguing form of final topological entity through the morphogenetic process.

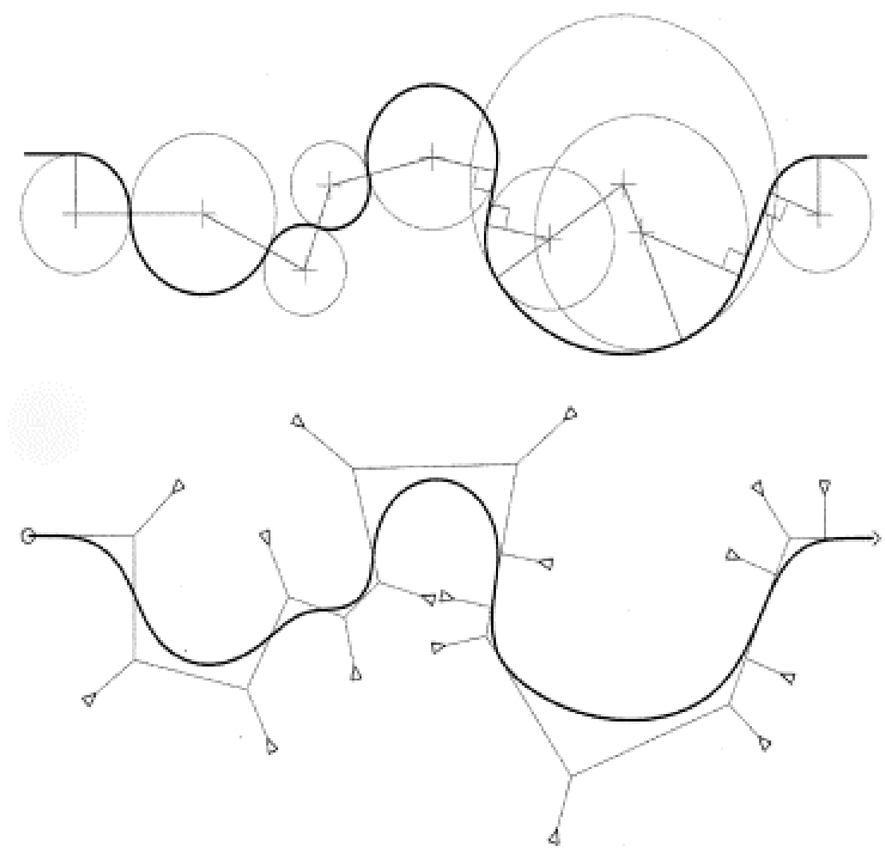

Figure 2.2: Composite curve using the regional definitions of circles, lines and arcs & topological spline with the flow of vectors defined in relation to control vertices. Image retrieved from: Greg Lynn, **Animate form**, Princeton: Princeton Architectural Press, 1999, p21.

[76] Manuel De Landa, **Deleuze and the Use of the Genetic Algorithm in Architecture,** Columbia University, CNMTL, Art and Technology Lecture Series, April 9, 2004, retrieved from; http://www.youtube.com/watch?v=50-d_J0hKz0.

[77] *Ibid.*

The conversion of topological entities to the computer realm provides distinctive possibilities for developments of design models as well as contemporary form progressions. Topological entities are the geometrical definition made in accordance with the differential calculus embedded in the computer programs which are composed of continuous streams of relative values as opposed to the collection of discrete points.[78] Rather than a baroque multiplicity of desultory lines, polylines, arcs and curves, topological entities consist of a continuously combined multiplicity of vector flows controlled by the free standing control vertices providing weights and gravities in the shaping process of spline.[79] This phenomenon consists of a direct reflection of the transition from Euclidean type of solid geometries towards time based differential continuities. The first implementation and the research on such phenomenon in the field of architecture has been made with the interpretation of the natural morphogenetic processes by Antoni Gaudi. In order to design the geometries implemented to his biggest project La Sagrada Familia, Gaudi introduced certain weights to the threads by calculating the necessary weights to deform the threads into their necessary forms for analyzing metric properties of the emerged topological geometries.[80] The emergence of the curves shaped by weights via natural morphogenetic process creates continuous splines and shows similarities to the contemporary computational definitions of splines. Therefore, it is possible to claim that the partnership of the designer with computer definitions reflects natural topological deformations in the virtual environment.

Figure 2.3: Weight model replica of La Sagrada Familia, Image retreived from; http://www.flickr.com/photos/42311564@N00/3567463569/sizes/o/in/photostream/

78 Greg Lynn, **Animate form**, Princeton: Princeton Architectural Press, 1999, p20.

79 *Ibid*, p.20.

80 Manuel De Landa, **Deleuze, Morphogenesis, and Population Thinking,** [Web], The European Graduate School lecture series, 2011, retrieved from; http://www.youtube.com/watch?v=5HSMTUZ64bY.

Furthermore, these changes in the understanding of spline reflect a resembling aspect to the computer generated definitions of surfaces. In the computer modeling programs, there are two essentially used geometry types which are called polygons and Non-uniform rational B-Splines (NURBS).[81] While the polygons are the flat faces which are defined by precise coordinate values of its vertexes, edges and faces, NURBS surfaces are the collection of free form splines defined on their collection tracks in the creation of geometries.[82] Since the polygon models refer to the Euclidean pure geometry definition, NURBS are the intensive geometries which consist of flows of virtual states that are defined by Gauss and Riemann and which make the deformation of virtual surfaces or volumes in nature in precise manners. In other words, it is possible to achieve large amounts of divergent forms from a simple starting point; thus, whenever a change is made in the position of the control vertices of NURBS surfaces, they deform regionally with respect to the assigned values of weight and gravity because they represent continuous flows, so "continuous multiplicities"[83] identified by Greg Lynn (1999) as;

> *A multiplicity is a collection of components that is neither reducible to a single entity nor to a collection of multiple entities. A multiplicity is neither one nor many, but a continuous assemblage of heterogeneous singularities that exhibits both collective qualities of continuity and local qualities of heterogeneity. In the use of topology in design, these multiplicities imply a very different approach to location, as there are no discrete points along a spline.*[84]

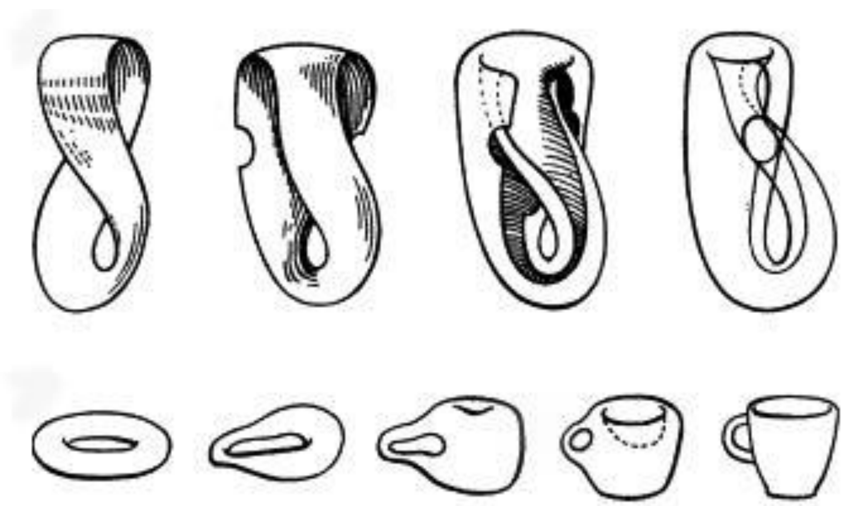

Figure 2.4: Topological deformation research of Mobius to Klein's bottle and torus to coffee cup by Stephan Barr, Experiments in Topology. Retrieved from: Greg Lynn, **Animate form**, Princeton: Princeton Architectural Press, 1999, p22.

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[81] Maya, **Introduction to dynamics,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

[82] Maya, **Introduction to dynamics,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

[83] Greg Lynn, **Animate form**, Princeton: Princeton Architectural Press, 1999, p23.

[84] *Ibid*, p.23

Consequently, the topological possible deformation spaces of geometries can be reflected on the project developed by the author. The dynamic field of flows consists of large amounts of singular, varying and vectorial properties spread in the coastal currents. These singular vector properties are the mechanism triggering the movement of the sand particles; thus, within the water environment, sediment can move according to the velocities and directions provided by the flows. Since these vectorial properties create multiplicities with the neighboring vectors with various formations amongst them, they combine into definitions of splines and the sediment particles start to follow these trajectories provided by the environment. Therefore, the overall accumulation of sand particles starts to deform in time and provides fluidic transformations from one state to another fluently with respect to the occurring regional deformations. The topological system created in the nature, continuously evaluates the environmental forces in the coastal currents and the sequential morphogenesis gets triggered with the end results of divergent forms.

To conclude, the transition from forms of stasis to forms in motion provides a wide range of varieties in the definition of animate forms. The connection of the entities to their environment unleashes and as a consequence triggers the emergence of inner capabilities embedded in the matter itself. Deleuze differentiates the morphogenetic population thinking, intensive thinking and topological thinking models for distinguishing innovative possibility spaces of forms and as a result the form itself. By the creation of the reproductive spaces of populations and embodiment of them with the intrinsic and extrinsic intensive differences, it provides a variability of the states that a collection of matter can take. Therefore, in combination with the properties discussed throughout the chapter, morphogenesis of the animate becomes a transition from the virtual possibility space towards the actualized formations of matter via the abstract mechanisms. These abstract mechanisms that organize the emergence of a topological form are the phenomenal mechanisms which mediate the virtual and actual morphogenetic capabilities of matter. In terms of Deleuze, the 'abstract machine' provides for an organizational machine like behavior with time based intensive properties which are going to be discussed thoroughly in the following chapter of the thesis.

CHAPTER 3

THE ABSTRACT MACHINE AND THE DIAGRAM: SELF-ORGANIZATION IN COMPUTATIONAL DESIGN MODELS

3.1 Virtual and Actual, Abstract Machine as the Mediator

The population that matter creates for enlarging the possibilities of random generations drives fuel from its inner thermodynamic energetic dynamism and morphes into forms in accordance with its topological properties. The combination of these three *sine qua non* properties of matter are the fundamental needs for the morphogenesis.[85] All these internal processes are bonded to each other with virtual mechanisms which organize the cycles and transformation to actualization. As cited in the text of De Landa (1998), Bergson implies that without the open-ended modeling of the future, the past and the present can not contain innovative appearances of the objects, ideas, thus they should be compromised as "pregnant not only with possibilities which become real, but virtualities which become actual."[86] Possibilities are the pre-defined essences which have their resemblances the reality that human senses observe.[87] Thus, the realization processes are the absolute translations of the principles of possibilities which adds nothing to the form as alternative to their reality. However, although meaning of the terms 'virtual' and 'actual' resemble to definitions of the possible and the real, they are the phenomenon which allows emergence of divergent form from the same topological base by unleashing the restrictions of the pre-defined possibilities.[88] In other words, the realization of possibilities is the reproduction of identical productions; the morphogenesis of the virtual by the actualization processes is an open-ended development which formulates authentic appearances. In order to emphasize this transition from virtual to actual, Deleuze (as quoted in De Landa (1998), p.30) advocates that;

> *Actualization breaks with resemblance as a process with no less than it does with identity as a principle....In this sense, actualisation of differentiation is always a genuine*

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[85] Manuel De Landa, **Deleuze and the use of genetic algorithm in architecture**. In N. Leach (Ed.), **Designing for a Digital World**, London, United Kingdom: Wiley-Academy, 2002, p. 117-120.

[86] Manuel De Landa, **Deleuze, diagrams, and the genesis of form**. Any 23, Diagram Work, (23), 2000, p.30.

[87] *Ibid*, p.30.

[88] *Ibid*, p.30.

creation....For a potential or virtual object, to be actualised is to create divergent lines which correspond to - without resembling -a virtual multiplicity. The virtual possesses the reality of a task to be performed or a problem to be solved.[89]

De Landa (2002) calls the ability to hold unleashed existence of the emergence of the virtual as the real which is not yet actual in the world of the material.[90] In this manner, the virtual consists of the properties of something real yet it is not complete in terms of finding its instantaneous appearance in the actual world, thus it is something in motion, movement and it is dynamic. In order to define the dynamism of the virtual, Healy (2007) claims the virtual is intensive as opposed to extensive and because of this property it is not actual but it is real.[91] Thus, it contains differences internalized and in constant motion it is topological. Furthermore, the embedded intensive properties that the virtual displays are the key issues for matter to have variant possibilities of form that it can take in the process of actualization.

Deleuze and Guattari claim that these actualization processes are the mechanisms that they mention as the 'abstract machine' which are not only systematic representational schemas but the internal instrumental organizational appearances.[92] The main important role of the abstract machine is its diagrammatic existence and representation of the motion mechanisms that actual forms produce, thus the abstract machine is connected to its 'concrete assemblages' which they actualize as well as the assemblages that bond to the oscillating machine and exist without it.[93] In order to further explain what the abstract machine is Deleuze & Guattari (1987) claim that;

*An abstract machine in itself is not physical or corporeal, any more than it is semiotic; it is **diagrammatic** (it knows nothing of the distinction between the artificial and the natural either). It operates by matter, not by substance; by function, not by form. Substances and forms are of expression "or" of content. But functions are not yet "semiotically" formed, and matters are not yet "physically" formed. The abstract machine is pure Matter-Function—**a diagram independent of the forms and substances**, expressions and contents it will distribute. (Emphasis mine)*[94]

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[89] *Ibid*, p.30-31.
The original quotation by Manuel De Landa is made from the book of Deleuze, **Difference and Repetition**: Gilles Deleuze, **Difference and repetition**. Columbia University Press, 1994, p.212.

[90] Manuel Del Landa, **Real virtuality**. In A. Menges & S. Ahlquist (Eds.), **Computational Design Thinking** West Sussex, UK: Wiley Publications, 2011, p.147.

[91] Patrick Healy, **The model and its architecture**, Rotterdam, Netherlands: 010 Publishers, 2008, p.106.

[92] Gilles Deleuze and Felix Guattari, **A thousand plateaus: Capitalism and schizophrenia** (Vol. 2). U of Minnesota Press, 1987, p.100.

[93] *Ibid*, p.100.

[94] *Ibid*, p.141.

What they are trying to imply here is that, the abstract machine is the diagrammatic existence that operates matter with instrumental techniques, functions, which is the mediator mechanism in between the virtual to actual. As cited in the article by De Landa (1998), the appearance of such a diagrammatic mechanism and the existence of virtuality is only possible just before the actualization -becoming a concrete assemblage- ends in the morphogenetic processes which also means the disappearance of the difference.[95] Through the same abstract machine it is possible to achieve topologically divergent actualizations which might be completely different in what they display yet the same in progress. In order to comprehend the meaning of the abstract machine thoroughly, Lynn (1999) gives the example of 'orrery'[96] which contains the principles of organization and represents the macro and micro scale -galaxies, solar systems, atom, etc.- harmonically regulated central movements of universal alignments.[97] In this example, the representation of the behavior of these alignments is crucial that it at the same time represents the animate behavior of these systems; thus all this completely divergent and different scale appearances of matter in varying yet resembling organization derives rules from the same abstract machine. As a consequence, the appearance of abstract machine provides a shift from regular abstraction achieved by the reduction of certain aspects from the form to achieve an absolute inert organization through an instrumental animation and motion based diagrammatic models of morphogenesis.[98]

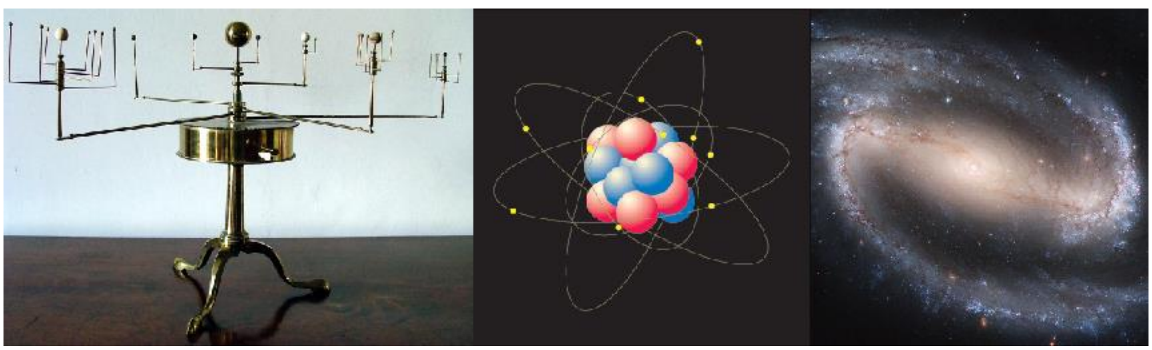

Figure 3.1: The Orrery device, an atom and a galaxy sharing the same principles as represented in the orrery. Orrery is the representation of the abstract machine behind such processes. Images retrieved from; http://www.arm.ac.uk/orrery/mdpopescu_armobs_orrery.jpg, https://blogs.stsci.edu/livio/files/2012/06/atom-with-electrons.gif, http://tinyurl.com/ny5rh, last accessed on: 26.08.2013

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[95] Manuel De Landa, **Deleuze, diagrams, and the genesis of form**. Any 23, Diagram Work, (23), 2000, p.31.

[96] Orrery is a mechanical device for developed for representational purposes of the relative movement and relations between macro and micro scale universal movements planets, particles and forces. All the pieces that are connected to the central rotational mechanism also connected to eachother therefore whenever a partial movement triggered overall system starts to move. However the device not only a representation for the planetary movements but at the same time it represent the relative motion of things.

[97] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.39.

[98] *Ibid*, p.39.

Furthermore, the similar appearances of abstract machine can be observed in 'nature' which gives opportunities to different morphogenetic possibilities with its dynamic attributes. The essential issue to be stressed here is that of the self-organization process that the matter goes into. Process of morphogenesis starts with the trigger of an outer or inner force and drives into abstract machine and the properties it contains unleash a spontaneous spatio-temporal dynamic form which De Landa calls the process as self-organization.[99] The momentarily organization of matter at one topological phase and the transition to another, in order to have a possible state of equilibrium in the system by interaction with the external forces, is the main objective with the embedded organizational principles of self-organization and the abstract machine. According to Achim Menges (2011) articulation of matter in the body of an object is directly dependent on the properties of the matter itself and its information exchange with the environment that contains it.[100] Therefore, self- organization in morphogenetic processes are not only relative to the inner dynamics of the body but also to the influence of the external forces and flows.[101] Michael Weinstock (2004) claims that self-organization is an inner constraint for the body which is dependent on the properties of consisting matter.[102] Therefore, matter organizes in accordance to the material properties and the geometry of the obejct deforms within its virtual boundaries in combination with the environmental forces and flows.[103] In the author's project, the organization of sediment into different topological forms is connected to this aspect of self-organization. The process of the deformation of sand islands with the influence of coastal currents depends on the material properties of sand particles as well as their movements and way of accumulation.

In order to comprehend the self-organization processes via equivalent abstract machines and ending up with variant topologies, De Landa (1998) gives several examples. Firstly; by the interaction with the external forces the soap film starts to take form and emerges with a spherical geometry in order to minimize the surface tension.[104] In the soap bubble form, there is no existence of soap-bubbleness and the appearance of soap film is a simple topological form which contains divergent state of possibilities.[105] That being the case, whenever the soap film confronts with an external force and starts the morphogenetic process within, the molecules it contains self organize

99 Manuel De Landa, **Deleuze and the open-ended becoming of the world**. In E. Grosz (Ed.), **Becomings, Explorations in Time, Memory, and Futures**, New York: Cornell University Press, 1999, p.33.

100 Achim Menges, **Biomimetic design processes in architecture: morphogenetic and evolutionary computational design**. Manuscript submitted for publication, Institute for Computational Design, Stuttgart, Germany, 2011, p.3. Retrieved from: www.stacks.iop.org/BB/7/015003

101 *Ibid*, p.3.

102 Michael Weinstock, **Morphogenesis and the mathematics of emergence**. Emergence: Morphogenetic Design Strategies, 2004, Vol. 74 - No:3 , p.11-17.

103 *Ibid*, p.30.

104 Manuel De Landa, **Deleuze, diagrams, and the genesis of form**. Any 23, Diagram Work, (23), 2000, p.30.

105 *Ibid*, p.30.

into a spherical form in order to contain the minimum surface tension.[106] The same abstract machine which organizes the process appears in the form of crystal as well which also tries to unleash inherent surface minimization by organizing the crystal molecules in a cubical form.[107] To put it another way, abstract machine is an instrumental ability of systems which coordinates the processes of self-organization and it does not always create similar concrete assemblages but the properties and the inner dynamics of matter administrates the emerging topological forms.

The same appearance of abstract machine in constructing not resembling (non-standard) forms can also be observed in man designed objects, environments and architecture. In his article 'Plea for Euclid', Bernard Cache gives an important example for topological appearances in completely different forms which is pretty important for understanding the existence of abstract machine in the man made objects as well; the 'Klein bottle' and the Centre Pompidou.[108] In his description of the elevator of the Centre Pompidou, the visitor goes into the building, through the process of elevating towards upper floors with the elevator, the visitor confronts with varying spatial experiences by going interior, exterior and in between.[109] Furthermore, he resembles this relation of inside and outside to the Klein bottle topology which also contains the relationship and understanding of being in between.[110] As it is able to comprehend from these two examples, even in the designed environments, the usage of the same abstract machine is possible and outcoming concrete assemblages are entirely different of their topologies though using the same organizational principles.

Similarly, the Sand Engine project and the graduation project are the processes of the same abstract machine. In the Sand Engine project the combination of intensive properties of coastal currents and the sand particles create an organization that processed with an abstract machine which ends up with dissipation of the sediment therefore creation of sequential various topological forms. However, in the author's graduation Project, the sand islands created by accumulation of the sediment and therefore creating discrepant topographies form a reverse progress of the corresponding abstract machine. In the first example, the process is propagating the sediment while in the second it collects and organizes. Yet, in both of the processes the final result of this bilateral mechanism ends up with the birth of fluidic topography. In one it resolves the combined sediment but in the other it collects the sediment and rearranges. In one it is destructive, in the other one, it is constructive. One has an end at the point the sediment is finished, the other is infinite since it deconstructs and reconstructs itself. The second includes the first one. They correspond to the same virtual possibility space, include same material properties and emerge in the same environment however the outcome works in the reverse way. Therefore the abstract machine is not a unidirectional but a versatile mechanism.

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[106] *Ibid*, p.30.

[107] *Ibid*, p.30.

[108] Bernard Cache, **A Plea for Euclid,** Any, 24, 1999, p.54-59.

[109] *Ibid*, p.54-59.

[110] *Ibid*, p.54-59.

The movement and the physical states that the sand particles take in the author's project is an archetype for the self-organization process and the abstract machine. The overall system -of matter going into the abstract machine and taking a topological form- resets itself whenever an equilibrium has been achieved and starts to organize itself again because of the far-from-equilibrium behavior of the coastal currents. Therefore, self-organization process happens sequentially and emerges variant topographies by accumulating sand particles in different formations. Thus, the system is a never ending cycle of self-organization processes. Furthermore, the same abstract machine which organizes the overall morphogenetic process is also used sequentially. As opposed to the previous examples of emergence of different topological forms out of the same abstract machine, this time the process uses the same abstract machine progressively with the same matter and energy inputs and creates similar in the principle yet divergent in the appearance topographies.

To summarize with, abstract machine is the diagrammatic instrument of the morphogenetic self-organization processes. It uses matter as the input for its dynamic mechanisms and since virtual backgrounds and the working mechanisms of both matter and abstract machine are intensive -as a consequence time based- singular concrete assemblages emerge in the end of the process. The assemblages does not always resemble but the organizational principles become the same. Furthermore, the abstract does not have to be a unidirectional yet it shows a versatile behavior to construct and deconstruct. The consecutive appearance of abstract machine in architecture is thinking of it as the diagrams of design processes which consist more than it is thought of. The instrumentality that the thinking diagram as the abstract machine makes it able for architects is that the diagram should not be used only as an explanatory representational technique but as an apparatus organizing the architectural elements.

3.2 Actualization Models of Abstract Machine

In the self-organization processes administered by the abstract machine there are two fundamental actualization structures developed by Deleuze & Guattari which are described by De Landa (1998) as 'stratification' and 'meshwork', through the exemplification of geological, biological and social aggregates.[111] Both processes act as an abstract machine behind the virtual reflection of actualized morphological form.[112] However, stratification organizes the articulation of homogenous matter whereas the meshwork is the principle behind the heterogeneous models of articulation.[113]

Stratification or in other words 'sedimentation' is the process of articulation of geological particles in combination with natural forces. In every geological becoming of the morphogenetic natural processes, sedimentation works as the fundamental aspect which creates the layers of divergent

[111] Manuel De Landa, **Deleuze, diagrams, and the genesis of form**. Any 23, Diagram Work, (23), 2000, p.32.

[112] *Ibid*, p.32.

[113] *Ibid*, p.32.

material properties.[114] De Landa (1998) gives the example of the river and the translation of the pebbles with the flows created by the movement of the river, which in the end finalizes the process with the stratification of particles with different sizes, densities and therefore weights.[115] In this progression, the behavior of the flowing river can be thought as the virtual 'sorting mechanism' which segregates the particles according to their properties and designates the landing locations of the pebbles.[116] This way the geological articulation of matter is actualized through the sedimentation process that categorizes homogenous layers of strata.

Meshwork is a completely different actualization process than the creation of self-consistent aggregates in the articulation of igneous rock formations such as granite.[117] In the cooling down process of the magma, matter contained in magma crystalizes in different intervals of time according to their properties in various locations.[118] As a consequence, a heterogeneous collection of divergent material multiplicities emerges in the form of solidified igneous rocks in entirely strengthened combinations.[119]

Since the author's graduation project is about the morphogenetic process of separate homogenous sand particles with the influence of coastal currents, such geological appearance of the stratification model appears of utmost relevance. Throughout the designed process, sand particles are being carried by the coastal current flows in combination with their embedded extensive properties and accordingly land to the designated locations by the flows. Therefore in the emergence of various formations provided in the organization of sand islands, the process is articulated by similar principles behind the emergence of self-consistent aggregates.

3.3 The Instrumentality of the Architectural Diagram

In the history of architecture, discussion of organizational ideas and provision of a representational body for these ideas in the form of diagram has been a continuous interest amongst architects. Most of the time, the diagram appears in the presentations of architects as a mere tool for representing the methodological steps that have progressed in the process of architectural development rather than an interactive interface which provides for a dynamic oscillation between the virtual realm of the architect's thought and the actualized form that the designed object represents. Both procedures for using the diagram as accumulation of explanatory fixity or as an organizational oscillation in motion, articulated by architects have various outcomes and products which are clashing in the ideological background development of the diagram, and therefore of form.

[114] *Ibid*, p.32.

[115] *Ibid*, p.32.

[116] *Ibid*, p.32.

[117] *Ibid*, p.33.

[118] *Ibid*, p.33.

[119] *Ibid*, p.33.

Peter Eisenman (1999) claims that the diagram is a superimposition of the possible phases of a building, articulated thus actualized with the decision mechanisms dependent on the architect's previous experiences.[120] According to the interpretations about the diagram, he advocates that the problem of revealing the diagram as the Deleuzian abstract machine in motion, as forces and flows, neglects not only the notion of presence and sign but also the control of the architect in the design process.[121] In contrast, according to him, the architect is the organizer of the possibilities that are provided by the superimposed historical appearances of forms on the diagrams.[122] In other words, the designer unleashes the mystical properties embodied in the diagram into the necessary partial elements and organizational principles existing in the forms, and afterwards develops the connections in between these elements depending on his/her experimental background.[123] Furthermore, with respect to the context of diagram as the accumulated strata of possibilities, the diagram shifts from a basic explanatory representation towards a collection of unrevealed ideas which are waiting to be re-presented and organized with the interaction of architects.[124]

On the contrary, the interpretation of various contemporary architects extends the discussion of the diagram towards the Deleuzian abstract machine. According to the architects Ben van Berkel and Caroline Bos, the idea of using diagram as a representational means results into a fixation of the oscillation between the ideological plane of immanence of the designer and the object designed, between the thought and the medium, virtual and actual.[125] Thus, this fixation blocks the emergence of innovative structures and architectures while creating types which cannot discard the reproduction of already existing typologies.[126] According to them, the diagram should be thought as a technique preventing the emergences of fixed typological forms.[127] Therefore, they advocate that the architectural product can achieve an open-ended process of organization for developing divergent actualizations of architect's thoughts when the diagram is set in motion and defined as an instrument.[128] As a consequence, they developed their projects with respect to the abstract machine that is put in motion; hence, rather than designing the main object, they focus onto the design of the abstract machine, of the diagram, and according to their past experiences evaluate the final product outcomes of the processes. Thus, the overall process developed becomes

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[120] Peter Eisenman, **Diagram an original scene of writing**, Diagram diaries, New York, NY: St. Martin's Press, 1999, p.33.

[121] *Ibid*, p.30.

[122] *Ibid*, p.30.

[123] *Ibid*, p.35.

[124] *Ibid*, p.35.

[125] Ben van Berkel. & Caroline Bos, **Diagrams - interactive instruments in operation**, Any 23, Diagram of work, (23), 1998, p.21.

[126] *Ibid*, p.21.

[127] *Ibid*, p.21.

[128] *Ibid*, p.21.

a partnership between the diagram and the architect.[129] In order to finalize their interpretation of diagram, they claim that;

> *The abstract machine in motion is a discursive instrument; it is both a product and a generator of dialogical actions which serve to bring forth new, unplanned, interactive meanings. Discourse theory introduces the notion that meanings are not transferred from one agent to another but are constituted in the interaction between the two agents.*[130]

Likewise, Greg Lynn discusses the aspect of diagram similarly in his interpretation of animate form in the development of contemporary architectural form. He claims that the evolution of computer based design processes should be incorporated with the intensive environments which derive the notion of fluids on the emergence of animate form.[131] Furthermore, he argues for the collaboration between computer –as the device which is used as a partner in the actualization of the motion in diagram- and the designer, as such collaboration provides for a positive comprehension of the happenings which they cannot conceive normally.[132] As a consequence, with the usage of computers in the production of the computer based diagrammatic models, the motion of the diagram can be modeled and processes can be embedded into form as animate.

The diagram appears as a powerful tool in form-finding methodologies of architects with contemporary development techniques. With the introduction of computers to the morphogenetic design processes, the development of abstract machines which are set in motion with the ideas and constraints provided by designers has become available as a design tool. Therefore, the incorporation of the diagram set as the abstract machine which is the mediator between the architects mind and the expected actualization of the defined objectives has become possible.

Thinking of the diagram as the superimposition of the possible states unleashed by the architect and the abstract machine, the debate reminds of Deleuze's discussion of possible and real versus virtual and actual.[133] As mentioned before, the realization and unleashing of the possible does not add to the pre-defined formations, on the contrary through the intensive processes organized by the mechanisms in motion, the open-endedness of the production can be achieved as well as the singular and unique forms. In the research of pre-defined possibilities of the superimposed ideas on the diagram, opportunities for distinctive forms do not emerge, rather, the end product resembles to the previous typologies. However, if the idea space of the designer is thought as the virtual and the metric organizations of his ideas are thought as the actual diagram, it becomes

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[129] *Ibid*, p.22.

[130] *Ibid*, p.23.

[131] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.39.

[132] *Ibid*, p.23.

[133] *Ibid*, p.30-31.
The original quotation by Manuel De Landa is made from the book of Deleuze, **Difference and Repetition**: Gilles Deleuze, **Difference and repetition**. Columbia University Press, 1994, p.212.

possible to mediate these two realms and finalize the process with the emergence of non-standard animate form.

To conclude, whenever the diagram is designated as an organizational machine and set in motion, the product starts to contain the continuous multiplicities of the dynamic process therefore becomes animate. The project provided by the author is using this aspect of the diagram in the research of the natural morphogenetic processes in combination with the computer realm. The overall process is the development of the virtual interactive environment as the abstract machine, as diagram, which is set in motion with the usage of computational fluid dynamics tools. In addition, by the interactivity defined in combination with the diagram in motion, the design of the morphogenetic phases of sand islands constitute an animate topography as an alternative to the fixed pavilion typology. In the following chapter, the development of such a diagram and virtual design environment in the scope of the graduation project of the author are going to be elucidated by underlining the fundamental aspects of fluid dynamics methods and the creation of the intuitive reasoning space of the contributor.

CHAPTER 4

AN INTERACTIVE DESIGN METHOD USING COMPUTATIONAL FLUID DYNAMICS

As it has been discussed in the previous chapter, the abstract machine and the instrumental properties that the architectural diagram consists of are the fundamental criteria in the emergence of architectural form. The graduation project which is developed by the author, makes use of these instrumental mechanisms in both the actualization of ideas in reality and the formulation of the design method. The design method consists of creating a virtual environment for interactive diagrammatic purposes and composing the analysis and modeling methods into one; therefore a simultaneous reaction mechanism for interactive reasoning and designing. By the interaction of the designer and computer, the system converts the static behavior of the diagram into a simultaneously changing design environment, thus it transforms the inert diagram into a diagram based dynamic design medium. Throughout the chapter, the development of such an interactive design environment with its properties and its connection to the architectural design methodologies is going to be elucidated and profoundly discussed in combination with the previous discussions of time, matter and the virtual organization mechanism.

4.1 Computational Fluid Dynamics as the Basis of Developed Design Method

Coastal currents that the graduation project uses for creating artificial yet natural topographies are a far-from-equilibrium intensive cumulation of water particles. Moreover, this cumulation is the sediment carrying mechanism in order to accumulate the sand particles while collision with the sand holders designed. Contemporary animation techniques are time-based simulations that mimic the motion of fields, movements of bodies and objects. These techniques are the sequential calculations of mathematical equations developed for imitating movements of natural junctions and movements through keyframing; the aim is the creation of linear morphed or non-linear transformations with dynamic methods.[134] Besides, these animation methods can also collide with the polygon or NURBS surface 'rigid bodies' in order to create the collision effects between fluids and inert objects. Thus, in the assembly of the interactive design method, the usage of computational fluid dynamics and simulations in combination with polygon and NURBS surfaces, are essential. For the development of the dynamic interactive design model under discussion, the contemporary modeling and animation program *Autodesk's Maya* has been used. In order to

[134] Greg Lynn, *Animate form*. New York: Princeton Architectural Press, 1999, p.23.

describe the existence of these dynamic simulations embedded in the modeling program of Autodesk's Maya, developers imply that;

> *Dynamics is a branch of physics that describes how objects move. Dynamic animation uses rules of physics to simulate natural forces. You specify the actions you want the object to take, then let the software figure out how to animate the object.*[135]

Therefore, it is possible to mention that the involvement of the designer is vital in the process for animating the deformation of objects and fields which can not be predicted by designers.Thus, after designing the environment of deformations, the computer program calculates the following sequences and shows the result for the latter developments. Therefore, it is possible to advocate that the method provides a feedback mechanism between the designer's intuition and the simulation. Maya Dynamics consists of several components which make it possible to create these environments, one of which is the fluid effects containing the computational fluid dynamics equations. Developers of Maya elucidate the tool as;

> *Maya **Fluid Effects** is a technology for realistically simulating and rendering fluid motion. **Fluid Effects** lets you create a wide variety of 2D and 3D atmospheric, pyrotechnic, space, and liquid effects.*[136]

Thus, it is possible to comprehend that, computational fluid dynamics methods are the animation techniques for creation of weather, smoke, sea and other intensive force field based movements which are hard to achieve with the traditional keyframing techniques.[137] In the following parts of the chapter, components of CFD simulations will be explained in combination with their usage in the constructed design environment. In order to create a fluid dynamics field, it is crucial to understand two fundamental elements of the model which are; a fluid container and an emitter.

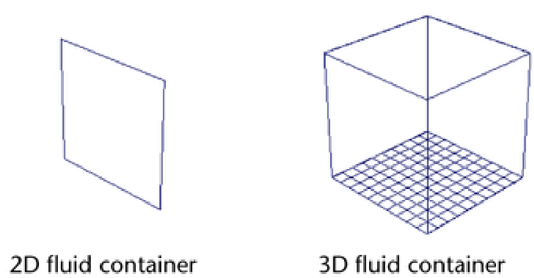

Figure 4.1: Container definitions in Autodesk's Maya, Last accessed; 26.08.2013 Received from; http://download.autodesk.com/global/docs/maya2013/en_us/index.html

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135 Maya, **Introduction to dynamics,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

136 Maya, **Fluid Effects overview,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

137 Maya, **Introduction to dynamics,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

First, the fluid container is the space definition in the modeling environment which accommodates the mathematical calculations of fluid dynamics happening, while the outside of the container remains as an empty usual modeling space.[138] Since it is possible to define infinite boundaries for this tool, the container property has been developed in order not to lay on a huge amount of data for the computer developers that established such a solution.[139] Moreover, the created container is divided into a grid of equation fields called 'voxels' in the size of one unit where the program calculates the partial transformation of the fluid field and later on assembles these small calculations of voxels together to show the final result.[140]

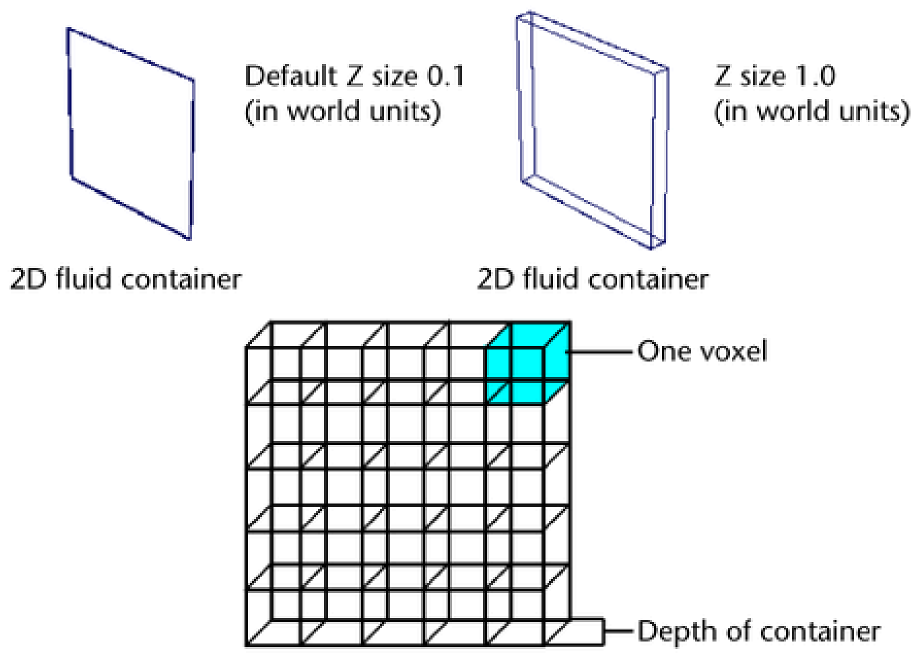

Figure 4.2: Voxels in a 2D container in Autodesk's Maya, Last accessed; 26.08.2013 Received from; http://download.autodesk.com/global/docs/maya2013/en_us/index.html

Basically, the behavior of a fluid can be determined by changing the four parameters, whom are also defining a real fluid behavior; 'density', 'velocity', 'temperature' and 'fuel'.[141] Notwithstandingly, these properties are calculated in various combinations in order to create the realistic fluid behavior. First, density property of the CFD tools are the amount of fluid particles, whom can be thought of the amount of real world substance in one universal unit, in the voxel

[138] *Ibid.*

[139] Maya, **What are the components of a fluid?** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

[140] *Ibid.*

[141] *Ibid.*

divisions.[142] Secondly, velocity, as mentioned by developers of Maya (2014) is a field effect which transforms the values of the other properties, as they implied; it has both direction and magnitude values which defines the track of the fluid calculations in motion which are essential elements of the definition.[143] Thirdly, temperature parameter is determining threshold values for a fluid to get into reactions in its own body.[144] Therefore, whenever the expected movement of the fluid increases or decreases beyond preset climax points, the fluid starts to adjust its variables accordingly to stay in between these threshold values.[145] Finally, fuel property indicates where these reactions take place in the defined boundary of the fluid in combination with the density parameter.[146]

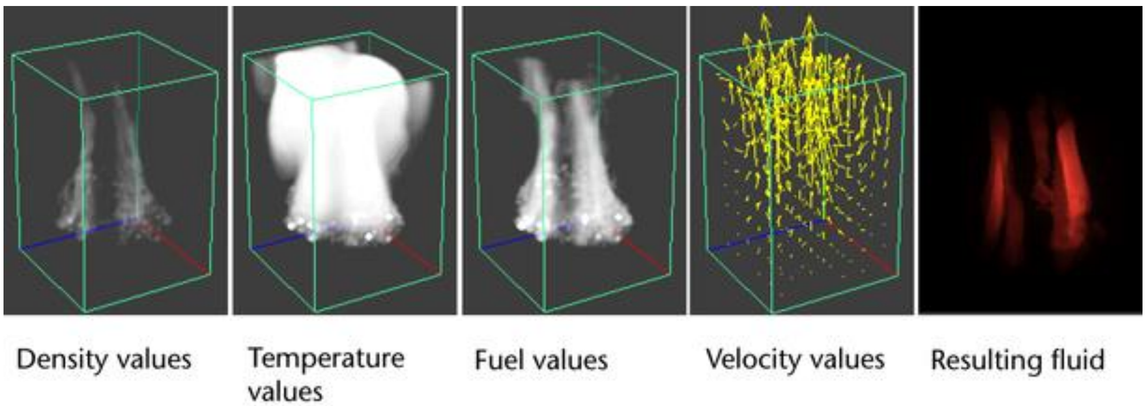

Figure 4.3: Fluid properties in Autodesk's Maya, Last accessed; 26.08.2013 Received from; http://download.autodesk.com/global/docs/maya2013/en_us/index.html

The second vital property is what generates these flow calculations in the borders of the container; the emitter. Within the previously determined animation range, the emitter throws fluid particles to the voxels of the container in varying rates, amounts and other values adjusted by the designer. Thus, whenever a particle goes into a voxel, the parameters of the emitted particles combine with the container parameters and the computer calculates them into a complete fluid behavior. The emitter has also some essential emitting types and properties for creating these realistic simulations. Firstly, all the geometrical attributes created in Maya can be assigned as emitters; thus, the emitting type can be assigned as an omni, curve, surface or volume.[147] As the names indicate, the omni emitter type diffuses particles from a single point, while the others are emitting

[142] *Ibid*.

[143] *Ibid*.

[144] *Ibid*.

[145] *Ibid*.

[146] *Ibid*.

[147] Maya, **fluidEmitter,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

from randomly distributed points on the defined shape.[148] Furthermore, the properties of an emitter are emission rate (percentage), cycle emission, and max-min distances.[149] The rate (percentage) calibrates the amount of particles emitted in a certain interval of time. Moreover, cycle emission reinstating the randomization of emitted particles at specific instantaneous points or in every key frame. Finally the variables maximum and minimum distances determine the location of the new created particle on the emitter which is resembling to the fuel attribute of the fluid container.[150]

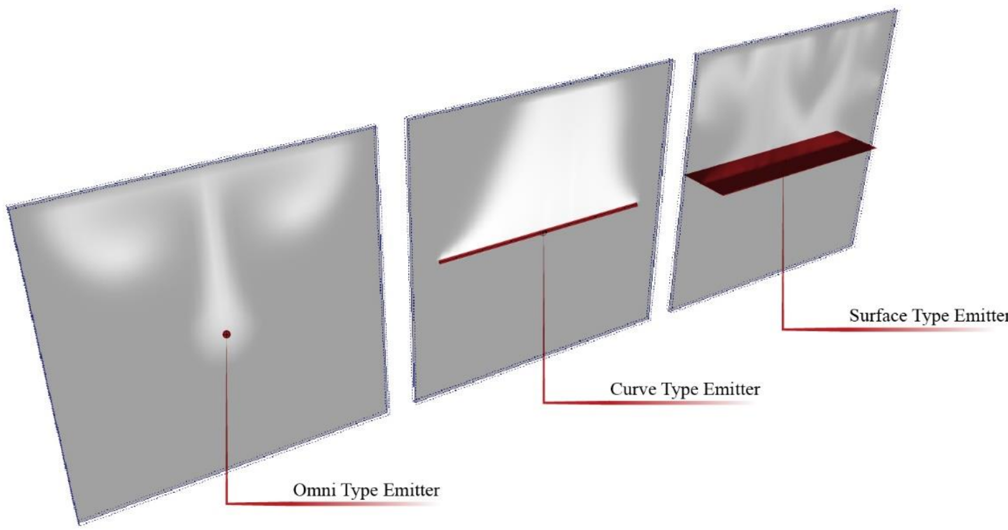

Figure 4.4: Emitter types of the fluids in Autodesk's Maya. Image courtesy of the author.

Another very important aspect of the CFD tools is that they can collide with the geometries created in the Maya modeling environment. Whether the geometry created is a polygon or a NURBS surface, the tool provides for a simultaneous manipulation and translation of the geometries while the simulation is running. Furthermore, by the two different body definitions that can be embedded on the geometries which are 'soft and rigid bodies', it becomes possible to move, deform or make them stationary according to their assigned body type.[151] The property 'soft body' as the name implies makes the entire or the partial geometry deformable; thus, when these partial areas confront with a vector field, they start to translate and therefore deform accordingly while the rigid body does not enable the geometry to deform in any possible way.[152] When nothing is assigned as the body type, the geometry behaves as a rigid body; therefore, it does not get affected from the vector field that the fluid provides, yet the fluid starts to adjust its behavior and flows accordingly

[148] *Ibid*.

[149] *Ibid*.

[150] *Ibid*.

[151] Maya, **Object interaction with fluid dynamics,** Retrieved from Autodesk Maya 2014 Help document, http://download.autodesk.com/global/docs/maya2014/en_us/index.html, 2014.

[152] *Ibid*.

to the collision. Moreover, since the fluid can only exist in the boundaries of the container, the geometry should also be defined in the same boundaries in order to make them collide.

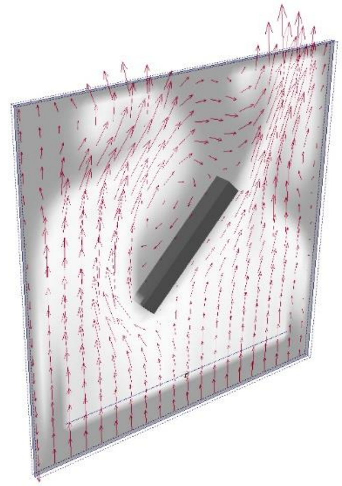

Figure 4.5: Collision with fluids in Autodesk's Maya. Image courtesy of the author.

To summarize, these parameters of both containers and emitters are the sequentially calculated populations for creating realistic simulations of fluids with the collision of sediment, as mentioned in the previous discussion of morphogenesis. Therefore, it is possible to claim that the virtual environments provided by the computer programs are an exact mimicking of the real morphogenetic state of possibilities. Eventually, further use of these parameters are going to be described in the next sub-topic in combination with the actual coastal properties which define the creation of interactive design process.

4.2 Analysis of Coastal Currents and Sand Holders of Scheveningen

In the design process, the intensive coastal dynamics properties of the North Sea have been reflected to the virtual environment by using the computational fluid dynamics simulations. The flood and ebb tide flow movements' effects on the Scheveningen coast of the sea are varying in combination with the over all far-from-equilibrium intensity behavior of the North Sea. Because of the intensive differences occurring between the high and low water areas, transition of water particles emerge and therefore a field of flows occur among them. The prevailing flood tide occurring on the coast is caused by the raise of the sea water and consequently, changes in the dominant direction of flows corresponding to the global changes appearing in the sea. In the North Sea conjunction of the Netherlands coast, flood tides flow from south to north. In contrast, the ebb tide is caused by the decrease in the water level, therefore the flows start to emerge in a less strong existence than the flood tides, also the direction changes accordingly from north to south.

The local appearance of these coastal flows is similar to the overall coastal dynamism of the Netherlands. Therefore, a deeper analysis of the coastal currents has been involved in the model. For the vernacular flood tides, velocity of flows decreases towards the beach corresponding to the change in depth connected to the amount of sediment in the area. So, while receding from the coast, flows become faster. The situation is similar for the ebb tides; however, the strength of the flows decreases as it has been mentioned earlier. These changes in tides emerge three times a day in varying intervals depending on the season which starts with the transition from flood tide to the ebb tide.[153] This aspect of the alternation of flows caused by the tidal differences and the change in the water levels has been considered as a main design element in the process. Since the prevailing migration of sediment occurs in the flow direction of the flood tide, thus the geometry of the provided sand holders should have been designed accordingly in order to collect the sand in the required areas. Furthermore, when the water level decreases in the transition process to the ebb tide, certain areas containing high amount of sediment become visible and a different form emerges. As a result, the design starts to contain a daily change in the appearance, rather than only a long term deformation of the general form which represents another animate behavior of the designed topography. In order to achieve such articulations in the project, analysis of the flows with the necessities of their related functions as well as designing the geometry of the provided sand holders are indispensable.

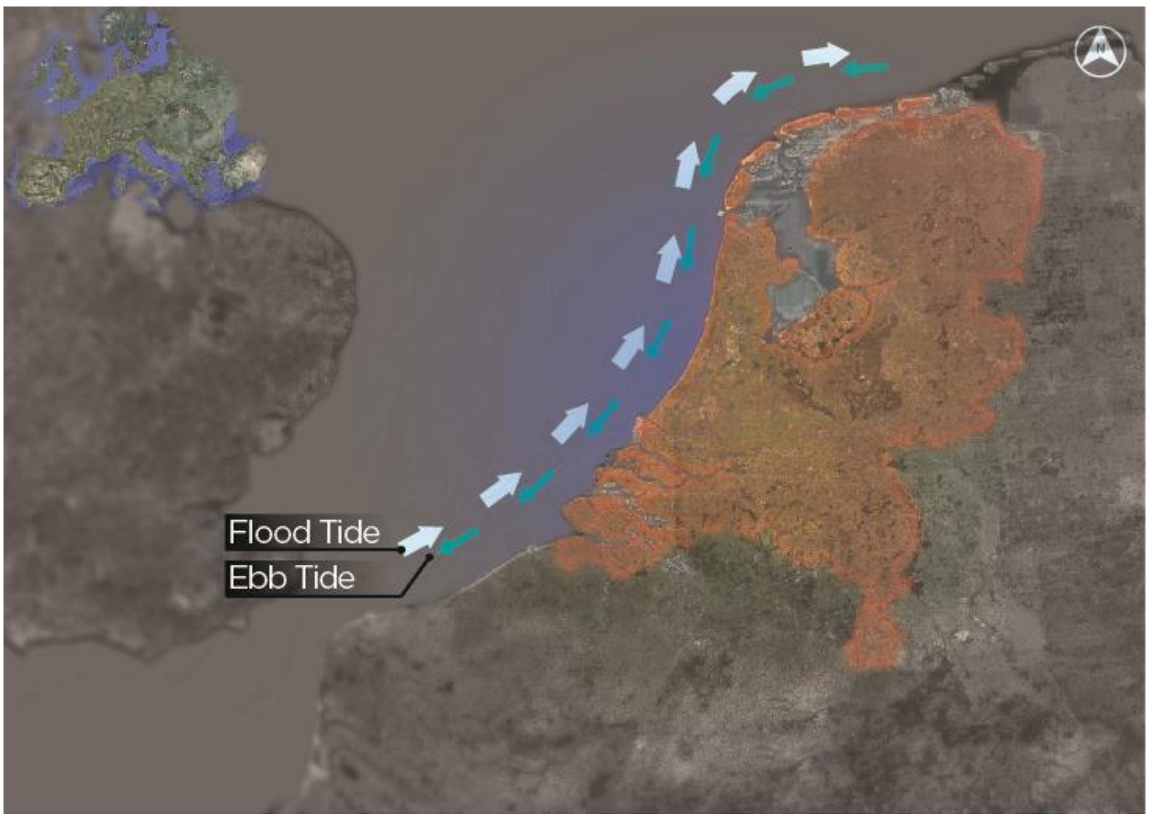

Figure 4.6: Prevailing flood and ebb tide current directions on Netherlands coast. Image courtesy of the author.

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[153] Information is derived from representation of instantaneous coastal currents happened on July, 2nd 2009 video created by the coastal defence company Deltares. The interpretation for the generalization purposes is made by the designer in order to be used in the graduation project.

[153]Deltares. (Producer), **Dangerous tidal currents at Scheveningen beach, July 2nd, 2009** [Web Video]. Retrieved from http://www.youtube.com/watch?v=8ktdTKBQazI, 2010, March 22.

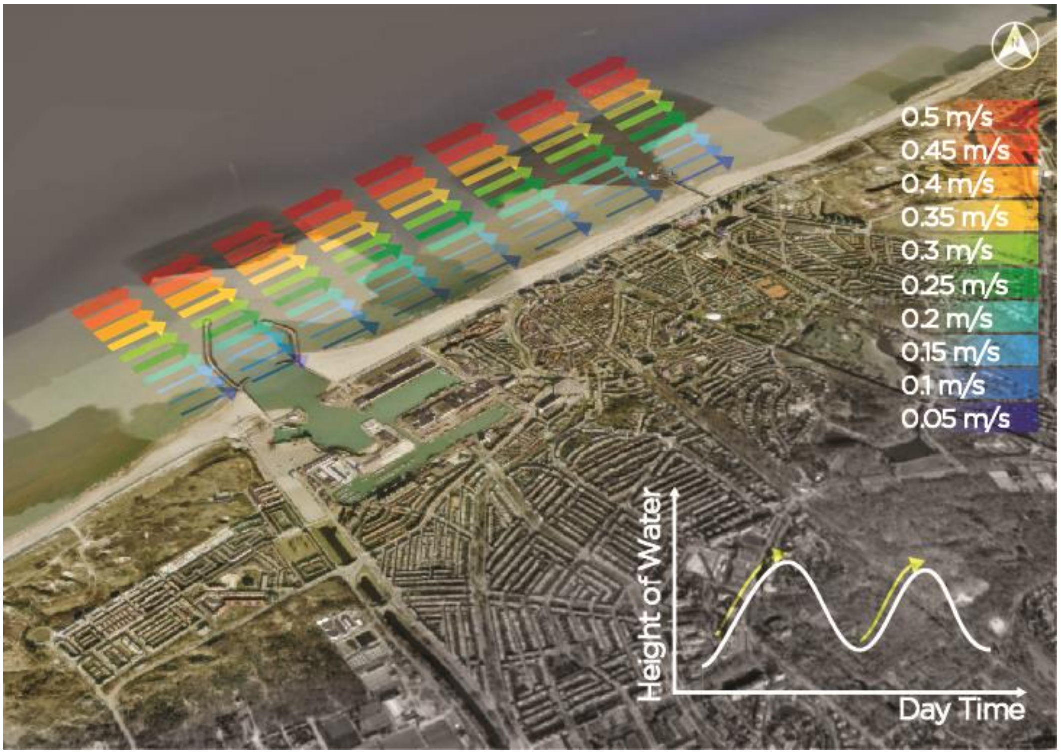

Figure 4.7: Prevailing flood tide velocities on the coast of Scheveningen. Image courtesy of the author.

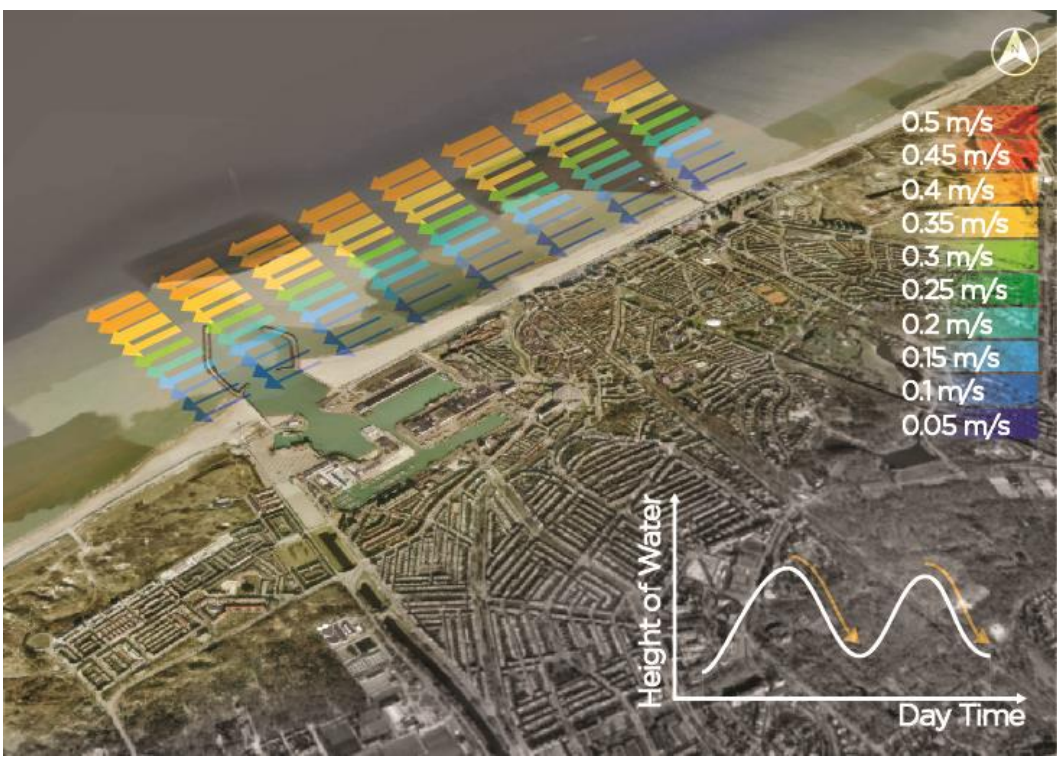

Figure 4.8: Prevailing ebb tide velocities on the coast of Scheveningen. Image courtesy of the author.

Concerning an understanding on the flow behavior, an analysis of the blockages -sand holders- and the flows has been made within the created model in the Maya modeling environment for comprehending a basic knowledge of the fluid behavior. Accordingly, a two dimensional computational fluid dynamic container has been created with the properties of coastal currents.[154] Since it works as a section through a three dimensional container grid, the emitter type has been set to a curve going through the complete dynamic field rather than a surface or a volume. The attributes of the emitter have been adjusted by reflecting the properties of flood and ebb tide coastal currents in the CFD simulation. Moreover, by using the previously mentioned collision property of the dynamic fluids, basic geometries have been collided with the created field in order to observe the directional articulations of the fluid and the changes in the strength. Therefore, the analysis provided for a deeper understanding of the areas where the accumulation happens and how to direct the flows for creating slack areas or using them to enhance the flow speeds. Thus, the overall mechanism served not only as a design tool but also provided for a deeper analysis throughout the design process.

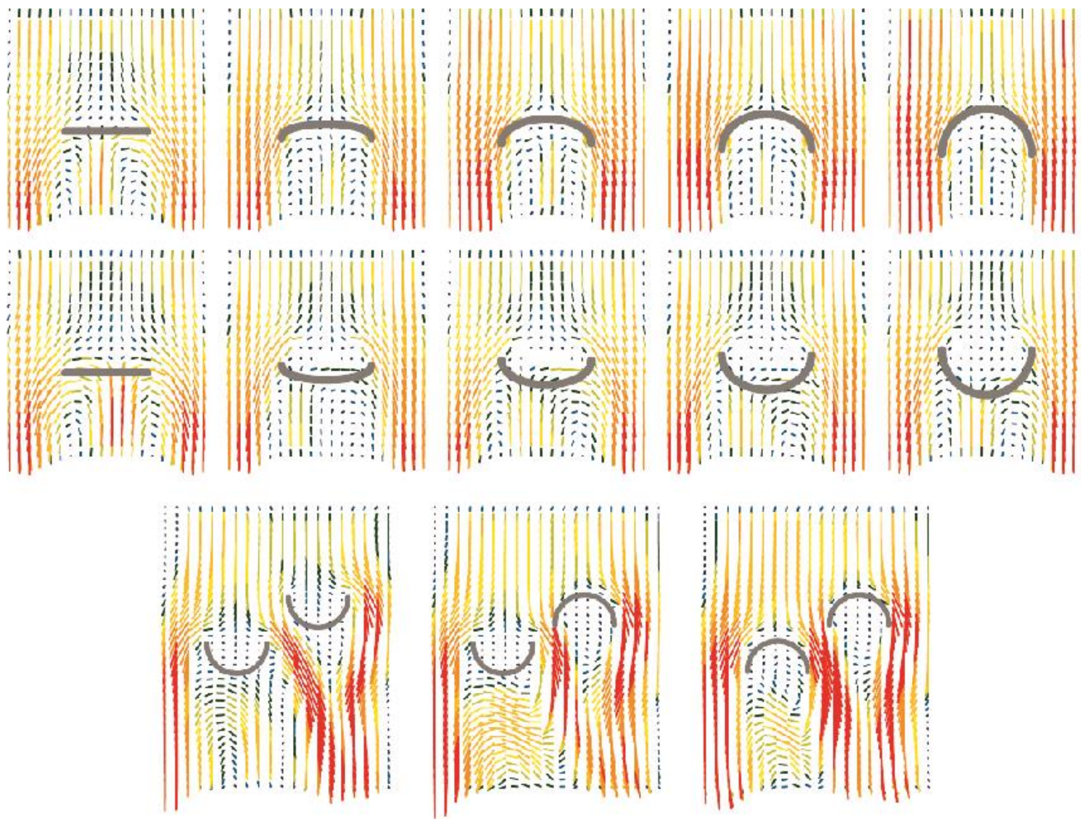

Figure 4.9: Analysis of the primitive geometries in combination with the flows for observing the change in flow behavior. Image courtesy of the author.

[154] Because of the concerns on the performance issues, the analysis of the problem has been reduced from a three dimensional environment to two dimensional containers. As it has been discussed, a container is divided into voxel fields and the increased numbers would boost the calculation amount and time drastically. Thus, a two dimensional approach to the problem is more accurate and it is still possible to understand the behavior of the fluids and reflect the observations to the design process as coherent inputs.

The analysis especially showed the fact that the behavior of sediment can also be animated in combination with the flow changes, which is another tool provided by the program. However, the inner collisions of particles as well as the collision with the holders must be achieved; so that, in the processes of these actions, the data processed in the hardware of the computer becomes enormous. As a result, it starts to slow down and the expectation of interactivity gets interrupted. Since a model which also makes it possible to observe the accumulation processes of sediment, would be a more precise approach to the defined problem, a reduction in the design environment has been made for the expectations of performance. On the other hand, the created design environment is abundant for assuming the reductions happening in the velocities of flows and predicating where could the accumulations occur. As a consequence, in the development of the method it is assumed that the sand particles follow the trajectories created by the fluid environment for performance issues. Therefore, it is possible to advocate that the computer programs provide endless opportunities for the designer, yet he has to choose what to use, what to contain or what to omit in order to combine better solutions for the process. The aspect of the collaboration between the design medium and the designer will be discussed further in the following chapter.

As a result, the analysis has shown some fundamental principles for where the accumulation can occur. Whenever the flow confronts with a convex obstacle, it divides into smaller parts and diffuses towards the areas without obstacles and because of the convex shape of the holder diffused, flow vectors combine with the one next to it and cumulatively, the velocity starts to increase at the sides of the holder. Moreover, because of the turbulence areas appearing at the end of both sides, flows become slower and start to disappear. Thus, the collision of the geometry creates accumulation of the sediment at the concave side where these turbulences happen. On the contrary, the concave shape detaches vectors from the nearby ones and throttles down the flow strength and results in a turbulence area emerging directly in the concave side of the holder. So, similarly, the accumulation of the sediment happens where the turbulence occurs. Furthermore, the analysis showed that the combination of different typologies of sand holders with varying distances in between, creates flows at varying strengths and orientations. Therefore, it is possible to manipulate the inclination as well by differentiating the distances, sizes and combinations of the sand blockages.

4.3 Identification of Selection Criterion

The introduction of functions and the further development of sand holders directly connected to the flow directions and the necessary sediment accumulation. Therefore, certain selection criteria for regulating these connections have been created according to the properties that water sports activities require. The water sports functions that currently exist in the Scheveningen, which consist of touristic water activities, rafting and canoeing, recreational fishing, surfing and sailing; are re-formulated in combination with the designed dynamic environment. The requirements for all of these functions are varying since the usage method of the sea and the necessities are different for all of them.

First of all, the visitors' number and the required open area which should be provided for them is one of the main aspects. In order to calculate the necessary territory, current areas provided for these functions and the pavilions have been researched. Moreover, according to the assumption made for the increase in the visitor amount and the required open area for containing these visitors has been added to the existing values. Therefore, in the end, the cumulation of these values specify the individual area requirement for these functions. In addition, the necessary territory for the sailing and fishing activities should have been defined mostly as water while the others must contain an equal amount of sand topography and water ratios. As a consequence, in the congregation with the main design model, these values are used in defining the places where the functions as well as definition of the relations between functions are going to be introduced.

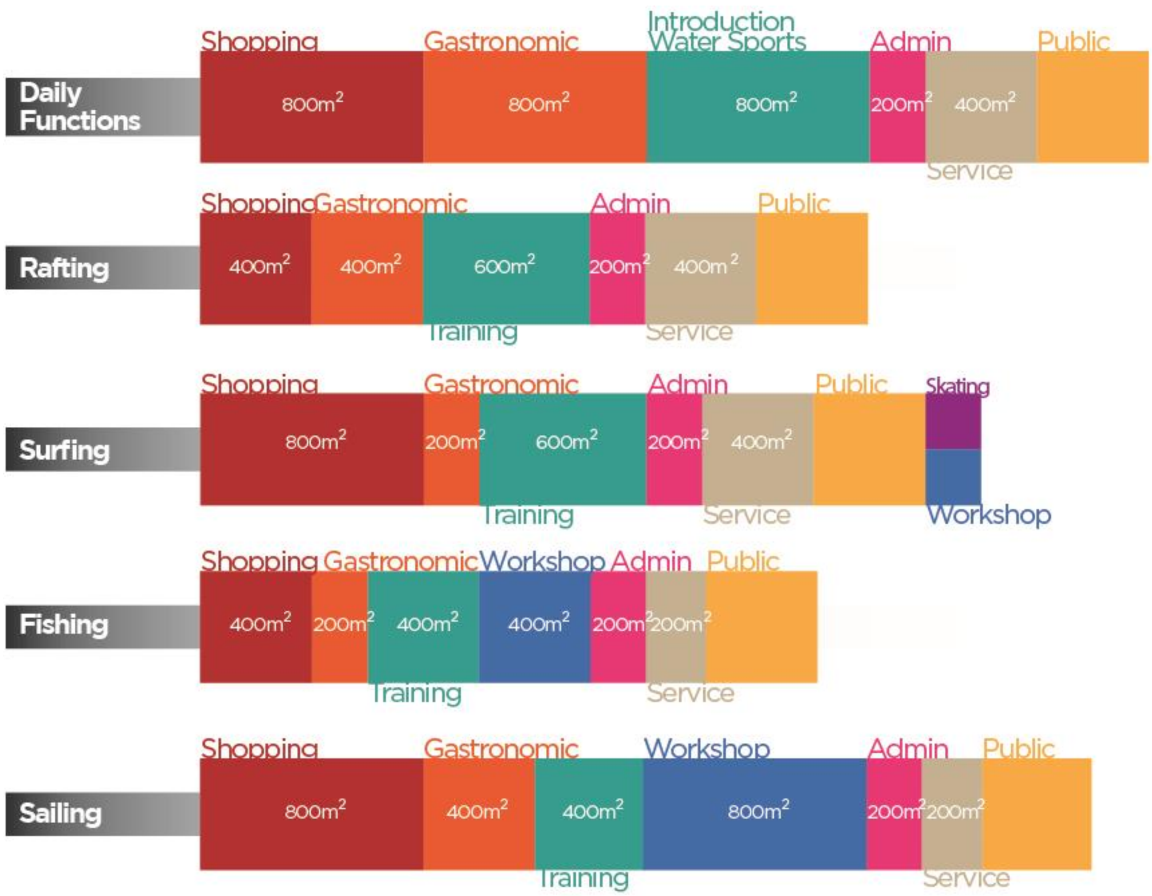

Figure 4.10: Necessary sized for the introduced functions. Image courtesy of the author.

Certain natural and artificial developments -similarly influenced from the Sand Engine- has been interpreted in creating the criteria and relations of the functions with each other. For instance, in the conjunction of Waimea River of Hawaii, to the Pacific Ocean, the local people use morphogenetic possibilities in combination with the surfing activities.[155] The final connection of

[155] **Quiksilver reports -- hawaii 2011/12 -- waimea river** [Web], Produced by www.afternoonrecords.com 2011, Retrieved from http://www.youtube.com/watch?v=U5hcVxcvGY4.
In the video provided, the event is basically shown by the producers yet, since elucidation of the process had not been made by any authorities the explanations are in the sentences of the author, thus interpretations

the conglomeration of the river is blocked by an accumulation of the sediment; thus, the river cannot reach to the ocean and creates a conglomeration of water in an elevated area.[156] A few times a year, locals and tourists dig a thin canal in between river mouth and ocean in order to create a transition of water amongst these collections[157]. In time, water flow created from the river mouth starts to transfer sand particles towards the ocean and as a consequence the size of the canal gets larger and the flows become faster.[158] Moreover, the accumulation of sand appears in several places and surmounting of the water begins on these bumps which are used by the surfers for 'standing wave sessions' in the surfers' terms.[159]

Figure 4.11: Waimea River morphogenesis of surfing flows in the artificial connection between river mouth and the Pacific Ocean.
Retrieved from; http://www.youtube.com/watch?v=U5hcVxcvGY4. Last accessed; 26.08.2013.

A resembling approach for the surfing activity in the program of the project, has been influenced from this surfing aspect. The idea is to develop sand holders which will direct and articulate water for accumulation of sand and creating sand bumps under the stream, therefore by the emergence of swells, enabling the surfers to achieve a controlled environment for standing wave sessions.

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of the event has been made by the author for explanation purposes of sailing function developed in the project.

156 *Ibid*.

157 *Ibid*.

158 *Ibid*.

159 *Ibid*.

Similarly, a resembling approach has been developed to shape the holders of the rafting and canoeing area. However, this time, an artificially developed water park construction in Zoetermeer of Netherlands has been reflected upon the fundamental design principles. In the water park ‘Dutch Water Dreams’, designers have implemented an artificial rafting and canoeing aspect by developing concave and convex shaped niches and bumps in order to increase the flowing waters articulation.[160] In order to create the flows, they designed the beginning elevated point from the end slack water, and in addition, throughout the flowing process, the water confronts with manmade obstructions and starts to develop tough waves for the sportsmen to deal with.[161] The fundamental reflection of this principle on the author’s design project is that its man-made development is combined with the flood tide currents by creating the holders for the canal of rafting and canoeing in the organization of the example. Therefore, it is possible to emerge dynamic waves and partial fluxes of water throughout the canal to provide a connection of the function to the water. In contrast, since creating a habitat for the animals which live in the water is possible only by having calm, not in motion water and conserving of sailing ships also needs a water which is not moving, the functions of sailing and recreational fishing require a slack water. To summarize, the project contains various requirements for all the introduced functions and a combination of these functions should be provided in accordance with the created sand islands by the usage of sand holders.

After the research on the required sizes and necessary organizations, relations between functions have been formulated in connection with the properties of the Scheveningen coast. First, functions have been concatenated according to their needs in depth and notion of being public. Publicity of the functions is defined according to the usage of the regular visitor for water activities; therefore, the ranking from public to less public is as follows; daily water activities, rafting and canoeing, recreational fishing, surfing and sailing. In addition, the depth of water is required for several functions and these values determine the required distance from the main coast. Thus, with respect to the required depth criteria, the sailing function should be located far from the coast in the open sea since the sailing ships require a minimum of five meters of depth, while the other activities should get closer to the coast.

To conclude, constraints have been defined throughout the analysis phase in order to transfer these values to the computational model and create a dynamic and interactive design method. Computational design processes should incorporate clear definitions of the requirements that the overall design will consist of. Therefore, the models and methods created by these techniques can provide for more consistent calculations and results of the defined problem. Since the computer is a collaborator to the designer, the problem definition should be provided to the computer in all its extents. The purpose of these analyses were to create a congenial design environment for the later processes of collaboration with computer. The next subtopic will explain how this collaboration has been achieved by using the contemporary computational modelling and animation techniques.

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[160] After visiting and interviewing the administrators of the organization, interpretations had been made by the author for the development of the rafting and canoeing zone of the provided design project.
More information can be achieved from; http://www.dutchwaterdreams.nl/

[161] Ibid.

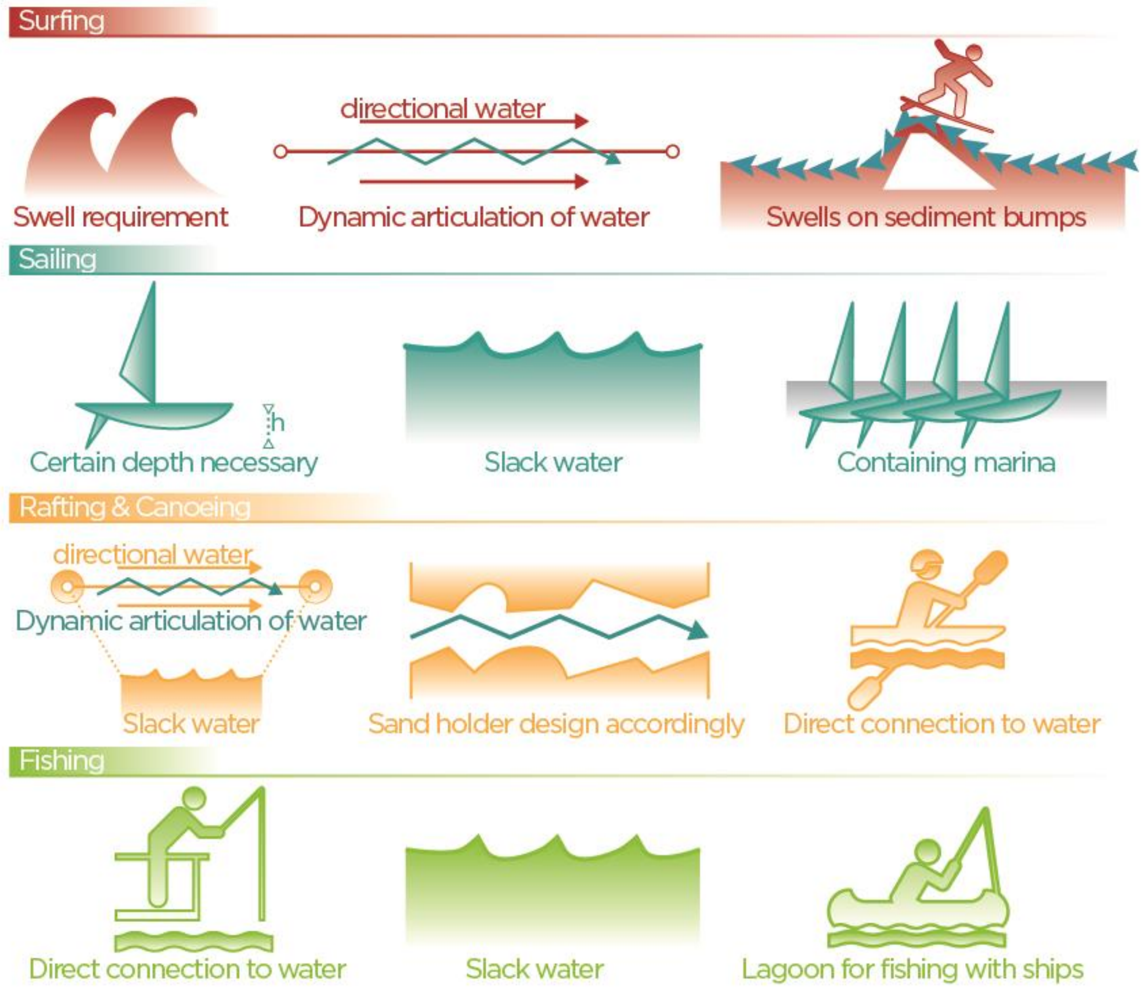

Figure 4.12: Function requirement diagrams of functions. Image courtesy of the author.

4.4 Amalgamation of the Method and Analysis, Emergence of the Design Method

In the transition of collected analytical data to the computational design environments, certain techniques have been used in accordance with the results required. In order to achieve such data conversion, the parametric design tool Grasshopper, of the software Rhinoceros3D has been used. The software provides for wide varieties of mathematical functions interpreted in a designer friendly interface for enabling the designer to create contemporary functions which generate parametric forms. Furthermore, the software can also be used for creating certain analysis environments by the help of parameters which are not pre-defined, but yet can be defined by the designer himself. Another advantage that is provided by the tool is the conversion of these analytical data to constraints, geometries and forces.

By using the plug-in, formulated data of function properties such as function relations with depth, function relations with currents' speeds, connections of functions with each other and necessary land sizes have been transferred to the virtual environment as constraints Since the flow field has been created as a two dimensional environment, similarly, the land values calculated for each individual necessary function in combination with their required water volumes have been represented as circles which cannot collide or intersect with each other. Furthermore, the connections of the functions in between have been assigned to the center points of these circles and been represented as lines going through them, which can stretch and change directions yet still keep all the functions together and as close as possible to each other.

Moreover, the places of these functions are constrained according to the depth and flow speed requirements. Firstly, as mentioned before, the sailing function requires a slack water but also a depth should be provided; thus, since the decrease of the depth is slow at the coast, it should be located at the farthest point from the coast. However, as explained before, if one goes further from the coast, the streams get faster; therefore, it should be located close to the ebb tide direction rather than the flood tide and the design of the sand holders should be designed for blocking these streams. As a consequence, it has been constrained to the farthest part of the ebb tide currents. Secondly, the surfing activity requires the fastest streams for creating the previously explained behavior; so it is constrained to the farthest point of flood tide currents. Thirdly, the fishing function needs a pond with slack water and articulation of water should also have been provided for nesting the pond as a habitat for various fish species. Thus, it is directly connected to the fishing pavilions independent from the other functions. Daily functions are constrained together with the rafting and canoeing functions and connected to the closest point to the coast. Since rafting and canoeing need fast water streams for creating the dynamic water movements, they have also been constrained to the flood tide stream direction. Finally, all these dynamic water streams should have ended with a slack water to collect the sportsmen and connect them to the sediment accumulation again. As a result, a relation between the slack water area and the water streams has been made and forced to move towards the slowest part of the ebb tide flows.

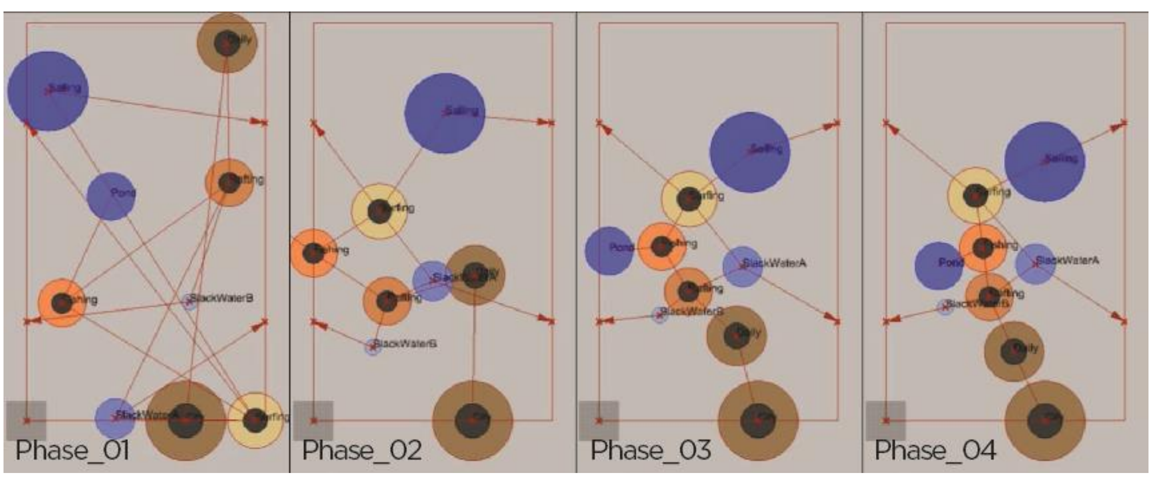

Figure 4.13: Grasshopper constraint model self-organization phases for determining the locations of the functions and water conglomerations. Image courtesy of the author.

All these constraints and the defined areas have been generated on a random two dimensional point cloud with certain boundaries and a whole dynamic relation model has been created with time-based interaction possibilities of functions amongst each other. After achieving the model, the functions and constraints have been freed from their stationary behavior and let to interact with the neighboring zones' moves according to the defined forces. The result has created the fundamental footing for the Maya model.

The footing has been imported to Maya and been placed as the image background for the overall design of the sand holders. CFD representation of coastal currents, whom is large enough to contain the previously developed footing has been created, which was also used for the analysis of the shapes and distances. Moreover, after setting the time long enough for running the definitions, the flows have been let to start. Maya allows the manipulation of geometries while the simulations are continuing; therefore, it is possible to observe the dynamic changes in the flows. As it has been done in the analysis model, however, this time with the capability of manipulating the geometries while the simulation is running, flows allowed to collide with simple geometries and started to design in order to achieve a satisfaction for the criterion defined. Whenever a deformation is made by the designer in the geometries, the flows adjust according to the new collection shapes. Simultaneously, it is possible to observe consequences of the deformation made and continue to deform until reaching the goals that have been defined. By this technique, the overall area, deformations and the shapes of the sand holders, according to the pre-defined norms, have been regulated with the simultaneous reactions of the computer.

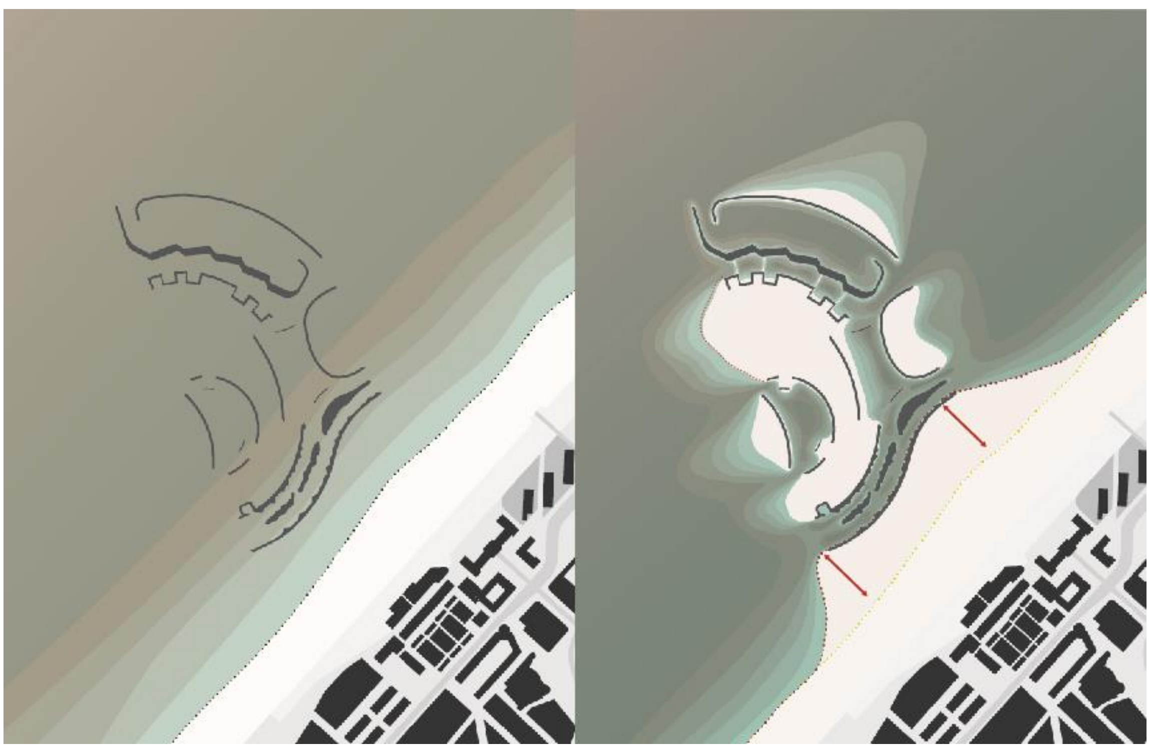

Figure 4.14: Final sand holder design after the interactive and simultaneous design phase with computer. Image courtesy of the author. **Figure 4.15:** Final Phase of the accumulation of sediment and created sand islands. Image courtesy of the author

Moreover, since the collection and the dispersion of sediment are not included in the design method, the accumulation of the sediment has been contemplated with the developed understanding via the observations through the analysis phase. After the determination of the sediment accumulations, the same simulation of flood and ebb tides has been used to control if the correct articulation of functions and sand islands have been achieved. The flows have been sent to the resultant model from the directions of flood streams as well as ebb streams and the behavior of the flows with the created requirements has been checked. Thus, the final result was satisfactory according to the defined selection criterion.

Figure 4.16: Water movements between the sand holders and islands. Image courtesy of the author. **Figure 4.17:** Introducing functions according to their requirements. Image courtesy of the author.

To conclude, by the collaboration of the designer and the computer, the designer makes the instantaneous decisions and simultaneously, the computer creates a reaction; thus, together, they create a cycle of designing, analyzing and self-organization process. The progression has been called as a cycle because it is a never ending, repeating mechanism, but every loop in the system is emerging as an entirely new one which starts from the one before and ends with the one after. It is somehow key framing the effect of the designer on the process, since every decision that he makes is sequentially calculated through the computer and adopted according to the changes. Therefore, it is possible to say that the diagram of the project becomes the design method and also that the overall method can be called as an abstract machine. It changes from the inert materiality of the static representational diagram to a dynamic actualization model in virtuality. The designed environment becomes a mechanism which consists of the possibility of spaces with morphogenetic capabilities. Therefore, the analysis and diagram shifts from being secondary supporting representational support tools, towards being the method of the design and the designed environment itself.

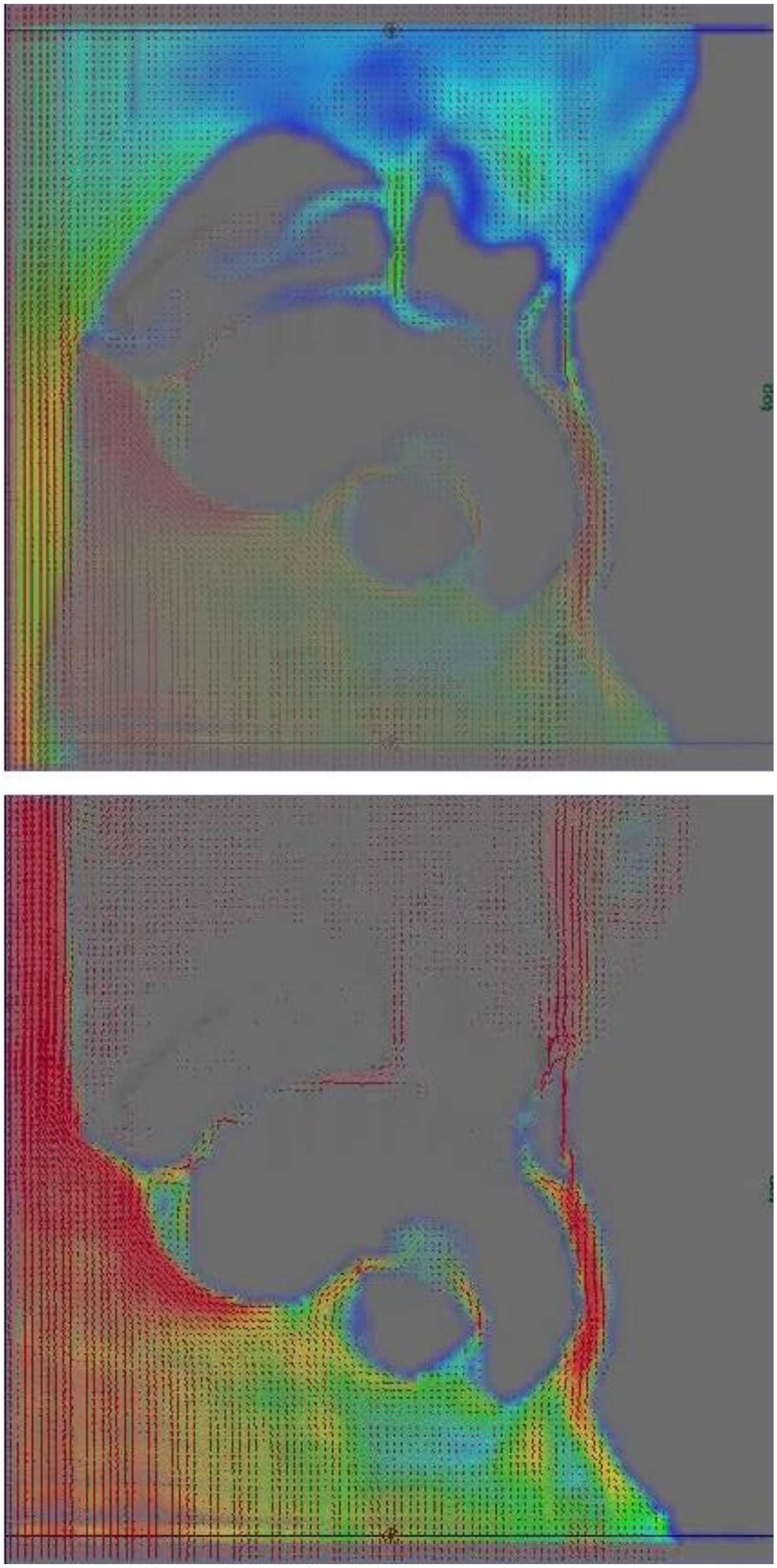

Figure 4.18: Flood tide and ebb tide analysis of the final phase of the sand islands. Areas defined as slack water remains as constructed. Moreover, the required streams and non-stream areas had been achieved as assumed. Image courtesy of the author.

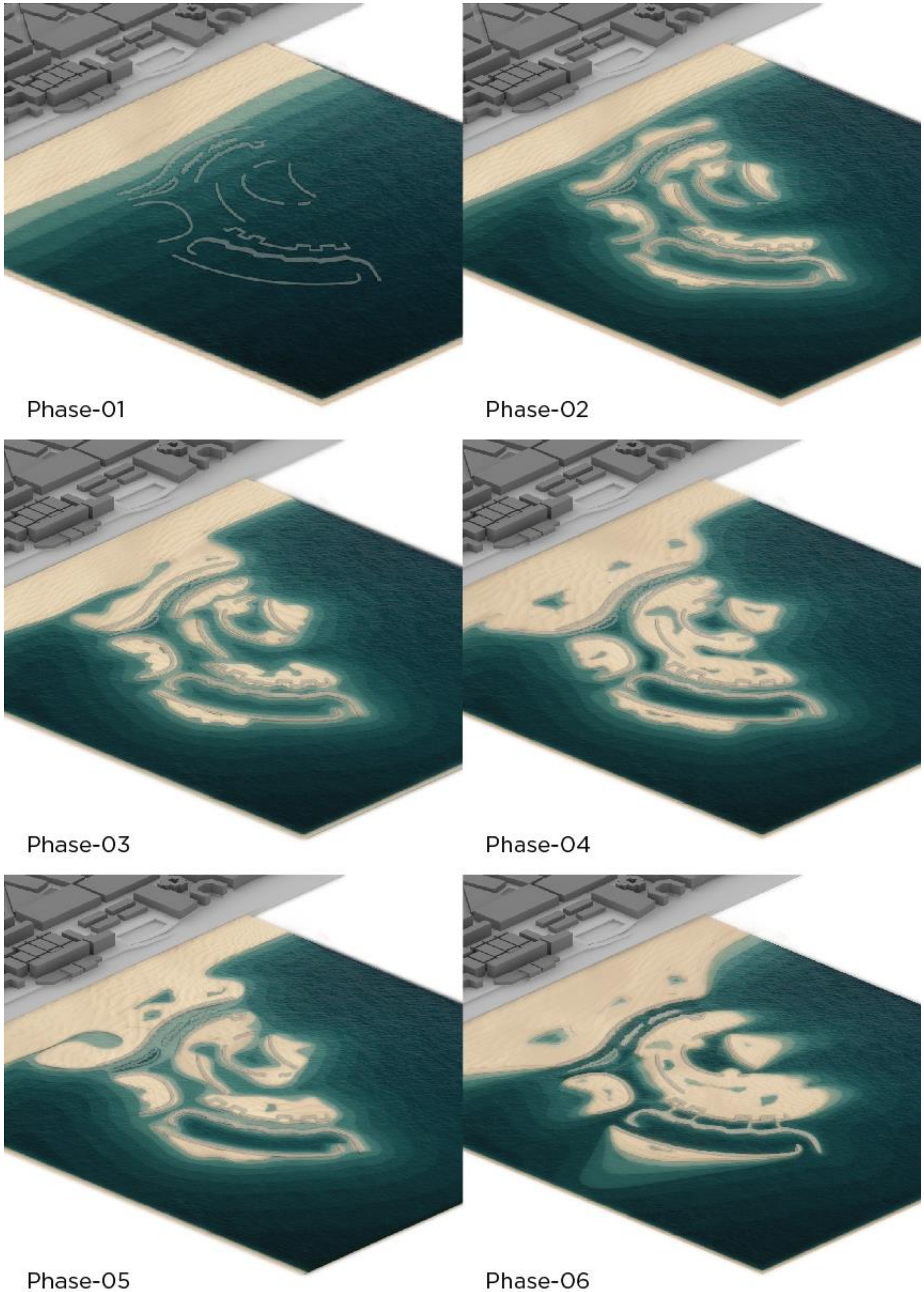

Figure **4.19: T**he sequence of the emergence of sand islands in time. Image courtesy of the author.

CHAPTER V

CONCLUSION

3.1 The Role of Intuition in Design

In the scope of this thesis, the embodiment of the aspect of space-time on form and processes which control the morphogenetic emergences have been discussed in accordance with their influence on the author's graduation project. The understanding of the aspect of space-time has had a huge influence on art and architecture in their history. Transition from pure stasis to achieving a stability in form against the environmental forces became the fundamental issue of the contemporary discussion of animate form. This shift from inert forms towards contextually specified fluidic forms has created the necessity of comprehension of the natural morphogenetic processes. Deleuze's interpretation to these processes makes usage of several topics from variant scientific fields and makes it able to comprehend the form deriving mechanisms behind the emergence of animate form. Since the project is basically a problematic created on the discussion of triggering natural processes for the emergence of dynamic topographies, its presentation and discussion entailed Deleuzian philosophical interpretations via the contemporary computational and animation methods. Through the increase in the calculation speeds and reflection of the contemporary mathematical developments to the field of computers, it is possible to research on the morphogenetic processes of actual happenings in combination with the virtual environments and it becomes possible to design these abstract machines with the intuitive methods provided by the designer. Therefore the designer gains control over morphogenetic processes in collaboration with the computer.

To summarize the project and the processes achieved throughout the development phase, it consisted of a sand island organization situated in the coast of the city of Scheveningen of Netherlands for increasing the security of the coast against the changes happening due to the behavior of the Northern Sea. In order to compensate for the migrating sediment amount, sand holders have been provided to the coast for catching the sand particles in the process of migration with the forces of coastal currents and making these particles to accumulate on the coast for increasing the amount of sand. Since the overall project is dependent and happening in time, the overall appearance of islands are changing shape with the influence of the currents, thus the overall process becomes a sequential morphogenetic event in its behavior. Furthermore, with the introduction of statically developed pre-existing pavilions, the inert existence of these temporary buildings becomes animate in combination with the sand islands.

Deleuzian philosophy formulates divergent but integrated thinking methodologies in order to comprehend the general mechanisms behind the morphogenetic events. Amongst all, intensive thinking and the emergence of time in the organization of dynamic entities form the most important topics for the graduation project. The overall system designed in the exploration of the deformation of form provided by sand islands, intensive differences and properties of water are vital properties which start and continue the process of deformation. In the development of the interactive design method for exploring the particular morphogenesis of sand islands, the intensive properties of the defined system have been reflected onto the computational method. Therefore, it became possible to investigate the growth and latter deformation phases of the islands. The resultant formation of sand islands shows a continuous change in the body of animate form. The entire process has been defined, analyzed and developed interactively with the contemporary computational fluid dynamics simulations that are normally used in the visual animation effects or in the field of engineering. Through their usage in interactive design environments, these simulations reflect the changes provided by the decisions of the designer, and therefore a cycle of decision-making and analysis is being created. Accordingly, the main issue here to address is that the development of the project provides for a collaboration with the computer for research on the morphogenesis of natural environments in virtual environments. The idea of using the computer for representational purposes of architectural elements shifts to the usage of the mathematical background that is embedded in the computer programs for the exploration of design methodologies.

The overall development process provides for a reflexive criticism cycle in the observation of the dynamic change in terms of method. After the problem definition, the process has been separated into its fundamental necessities and analyzed accordingly. These separate fundamental issues have been combined by simple constraints with the parametric design interfaces for the creation of the base analysis with data for interaction with the dynamics tools. Subsequently, all the data analyzed has been combined together with the created computational fluid dynamics environment. The simultaneous design of basic geometries while observing the changes occurring on the behavior of fluid have been finalized and checked with respect to the developed analytical data. After satisfying the predefined constraints of the project, the process concludes itself and previous static temporary pavilions that have been introduced are added on the designed islands.

The combination of the analysis and design method is a replication of the fundamental abstraction of the actual morphogenetic process through the virtual environment in combination with the interactive deformation abilities provided by the developed design environment. The method provides an interactive deformation with the decisions of the designer simultaneous to the changes occurring in flows. Therefore it is both an analysis tool and a design tool based on the collaboration of the designer and the computer. This participation of designer and computer to the dynamic design process can be claimed as the design of an abstract machine for the virtual morphogenesis of the product.

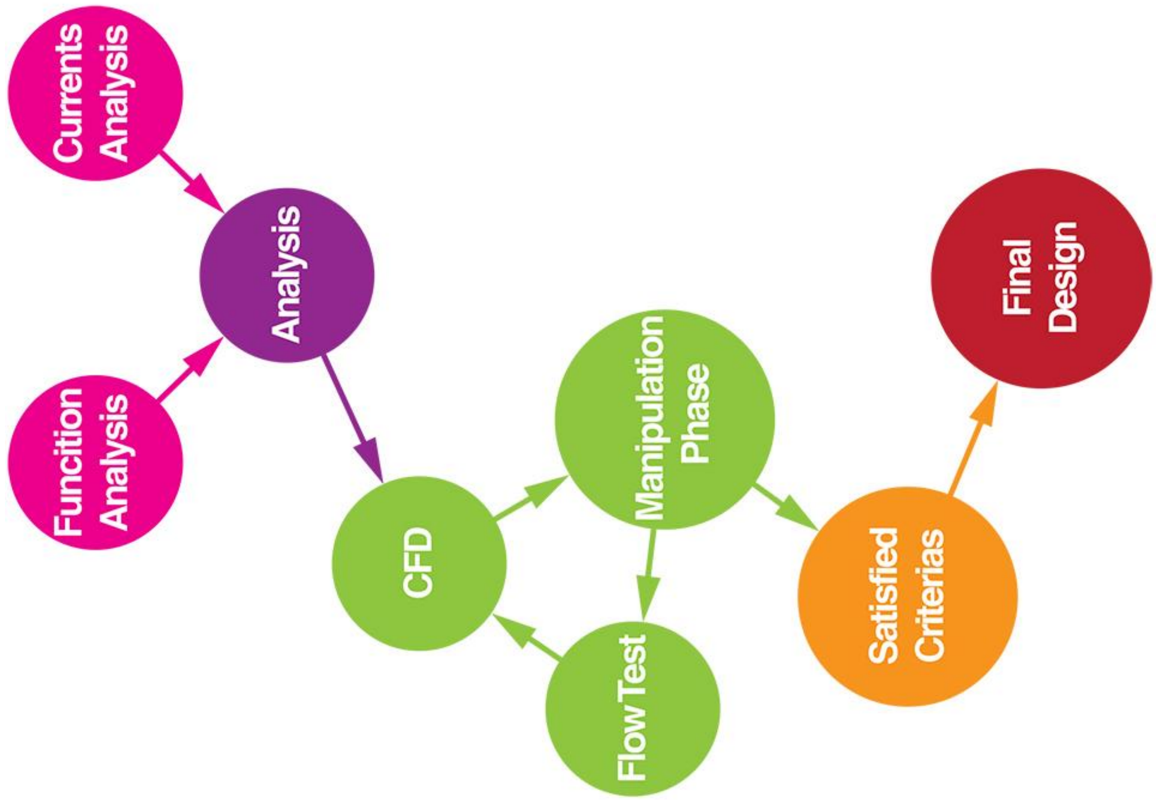

Figure 5.1: The main intuitive process followed in the development of the project. Image courtesy of the author.

As a consequence, the feedback between the intuition of the designer and the analytical calculations made by the computer needs to be considered as a fundamental issue in the process. The morphology of the system designed that the computer has been released to perform the calculations are not possible to comprehend through the decisions of the designer only. Architects used to conceive of the computer as only a representational tool for explaining the organizations and decisions made rather than approaching it as a design tool because of the fear of losing the control over the processes: However, Lynn (1999) defines the 'computer as a pet' rather than a device for the representational purposes[162], which contributes to the actions of the owner as well as controlled and disciplined by the owner again.[163] In order to express the importance of collaboration between computer and designer Lynn advocates that;

> *In addition to the aesthetic and material consequences of computer-generated forms, computer software also offers capabilities as a conceptual and organizational tool. But because of the stigma and fear of releasing control of the design process to software, few architects have attempted to use the computer as a schematic, organizing and generative*

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[162] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.11.

[163] *Ibid*, p.20.

medium for design. The limits and tendencies of this tool, as a medium for design, must be clearly understood conceptually before they can be grasped by a ***systematic intuition****.*[164] *(Emphasis mine)*

Intuition which is the contribution of the designer has been the essential discussion of artists and architects. Basically, the formalist methods that are the continuation of space-time understanding reflecting pure Euclidean thinking have started to include intuition. Giedion (1967) claims that the contemporary developments in art and architecture refused to internalize feelings:[165] Giedion's interpretation (1967) of the aspect of intuition is;

Such symbols, however, are vital necessities. Feelings build up within us and form systems; they cannot be discharged through instantaneous animal outcries or grimaces. We need to discover harmonies between our own inner states and our surroundings. And no level of development can be maintained if it remains detached from our emotional life. The whole machinery runs down.[166]

The term 'systematic intuition' advanced by Greg Lynn is a deliberation made by Deleuze's interpretation of Bergson's 'Intuition as Method'[167] where he debates an understanding of the experience as a consequence of the intuition provided by the contributor in activities of mind for controlling the processes which it develops.[168] He elucidates the basic understanding of intuition as;

Intuition is neither a feeling, an inspiration, nor a disorderly sympathy, but a fully developed method, one of the most fully developed methods in philosophy. It has strict rules, constituting that which Bergson calls "precision" in philosophy.[169]

The defined intuition method contains three basic principles which also created the base of the developed project; the problem definition, the discovery of genuine differences in kind (analysis) and the apprehension of real time (cycles of development).[170] Basically, the problem definition of the processes should be made as genuine ones –in terms of Bergson, 'true'- which enables the

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[164] *Ibid,* p.19.

[165] Sigfried Giedion, **Space, time and architecture: the growth of a new tradition.** Harvard University Press, 1967, p.431.

[166] *Ibid,* p.431.

[167] Greg Lynn, **Animate form.** New York: Princeton Architectural Press, 1999, p.19.

[168] Gilles Deleuze, **Intuition as method,** in H. Tomlinson & B. Habberjam (Eds.), **Bergsonism**, New York, NY: Zone Books, 1988.

[169] Gilles Deleuze, **Intuition as method,** in H. Tomlinson & B. Habberjam (Eds.), **Bergsonism**, New York, NY: Zone Books, 1988, p.13.

[170] *Ibid,* p.14.

possibility of further developments of ideas rather than blocking the proceedings which will occur in the next phases.[171] The reflection of this aspect appears in the problematization of the project, which, with the introduction of computational techniques, converts the question into a genuine and solvable problem. Secondly, since the observation of the contributor is limited to what interests his mind, it is necessary dissecting the problem into its essential parts for sophisticated understanding of the problem and further analysis of the embedded possibilities included in the developed problematic.[172] Similarly, the analysis part of the project has been divided into several important parts for the understanding and interpretation of existing forces in combination with holders as well as necessities of the functions which were going to be introduced to the sand accumulations. Finally, the third and the last principle states that the aspect of time should be incorporated in solving the problem rather than working in inert space:[173] In the design process developed by the author, the design method uses the aspect of time in the interactive design phase.

This design experience has shown that the combination of computational and intuitive methods provides for a deeper understanding and possibility of elucidation of the problem. Rather than the assumption that the architects would lose control on aspects of design, the contemporary techniques provide for a return of the actual intuition of the architect, which had been partially lost in the history of architecture with the reductionist search for the purity of form, and if the process is developed genuinely, intuition can be argued to increase the influence and the contribution of the designer to the emergent processes of form.

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[171] *Ibid*, p.15.

*For the problem def*inition Deleuze also claims the *role of intuition as; intuition decides whether the problem stated is* genuine *or not even if that means making the driving intelligence to turn back against itself.*

[172] *Ibid*, p.24.

[173] *Ibid*, p.31.

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