Hülya Oral

Interactive Structures In Nature Inspired Design *(Paper)*

Topic: (Architecture)

Authors:

Hülya Oral

Istanbul Bilgi University, Department of Architecture

Turkey

Erhan Karakoç

Istanbul Kültür University, Department of Architecture

Turkey

Main References:

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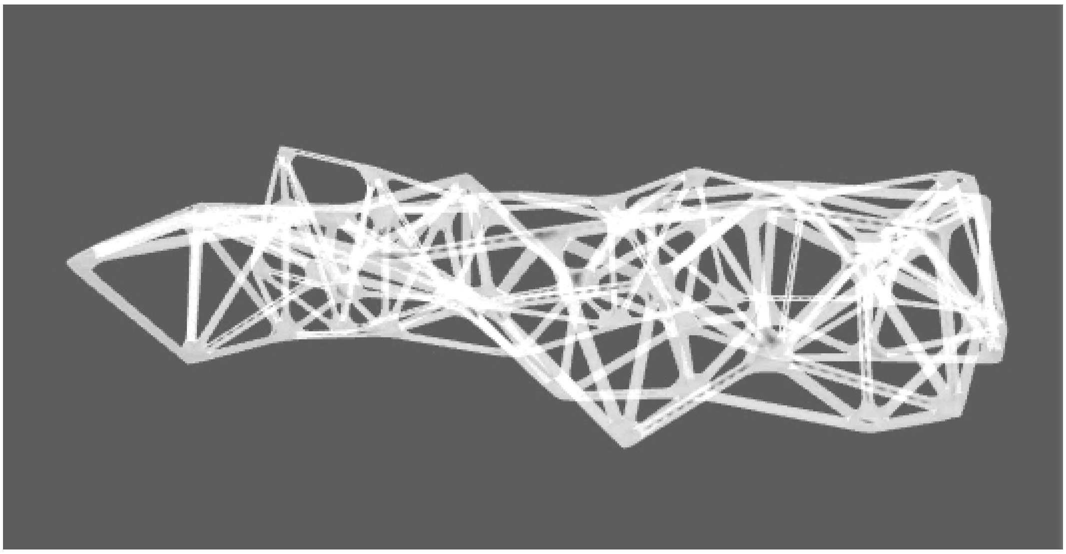
Abstract:

Adapting to change which is embedded in nature has become much more important under the changing conditions of our world. Especially, the orientation of the plants roots' according to the water and leaves according to the sun, which is called tropism is ensured the adaptation of the plants to the changing environment. Thanks to tropisms, the structure of the plant which consists of the xylem is bending, lengthening or widening if it is necessary for adaptation. By this means, the structure of the plant which consists of the nodes and links between them yields the survival of the plant in the extreme conditions.

Agent-based systems are used for the modelling of the complex network systems like the structure of the plants. In such systems, a micro behaviour affects the whole system and ensures the interaction of the structure with the environment invariably.

In this paper, the interactive character of the plants is examined upon the several projects and searched for the architectural potentials. Next, an interactive structure is designed according to the tropism movements of plants. The structure is based on the human movements and density of people as an input following the algorithm flow chart. The inputs affect the nodes of the structure directly and change the coordinates of them. So that, the structural system surpasses the static behaviour and acts in motion. The structure acts as a console or long span beam according to the human density and location of the density and shows some emergent behaviours.

Model has future potentials which can answer the micro and macro scale different architectural needs. Structures are obtained which vary in size and shape thanks to the human interaction of the algorithm. The structures which are obtained can be integrated with the functional needs of any kind of the building and used as a part of the design process. By designating the less and more densified spaces in a building, the algorithm can generate the structure of it. Besides, the macro scale adaptation of the algorithm, urban plans, green areas and infrastructures can be designed. In conclusion, nature inspired interactive structures can be used in different design phases thanks to its potentials and opportunities which serve to the designers.



Example: Image of the interactive structure.

Contact:* *hulya.orall@gmail.com

Keywords: biomimetic design, network systems, agent-based design

Interactive Structures in Nature Inspired Design

B. Arch. Hülya Oral, R. A.

Department of Architecture, Istanbul Bilgi University, Istanbul, Turkey

e-mail: hulya.orall@gmail.com

Msc. Arch. Erhan Karakoç, R.A.

Department of Architecture, Istanbul Kültür University, Istanbul, Turkey.

e-mail: erhankarakocitu@gmail.com

Premise

Adapting to change which is embedded in nature has become much more important under the changing conditions of our world. Especially, the orientation of the plants' roots according to the water and leaves according to the sun, which is called tropism is ensured the adaptation of the plants to the changing environment. Thanks to tropisms, the structure of the plant which consists of the xylem is bending, lengthening or widening if it is necessary for adaptation. By this means, the structure of the plant which consists of the nodes and links between them yields the survival of the plant in the extreme conditions.

Agent-based systems are used for the modelling of the complex network systems like the structure of the plants. In such systems, a micro behaviour affects the whole system and ensures the interaction of the structure with the environment invariably.

In this paper, the interactive character of the plants is examined upon the several projects and searched for the architectural potentials. Next, an interactive structure is designed according to the tropism movements of plants. The structure is based on the human movements and density of people as inputs following the algorithm flow chart. The inputs affect the nodes of the structure directly and change the coordinates of them. So that, the structural system surpasses the static behaviour and acts in motion. The structure acts as a console or long span beam according to the human density and location of the density and shows some emergent behaviours.

Model has future potentials which can answer different architectural needs in the micro and macro scale. Structures are obtained which vary in size and shape owing to the human interaction of the algorithm. The various structures can be integrated with the functional needs of any kind of the building and used as a part of the design process. By designating the less and more densified spaces in a building, the algorithm can generate the structure of it. Besides, the macro scale adaptation of the algorithm, urban plans, green areas and infrastructures can be designed. In conclusion, nature inspired interactive structures can be used in different design phases thanks to its potentials and opportunities which serve to the designers.

– 1. Introduction

Network systems are interdisciplinary systems which are utilized by several scientific fields like biology, computer science, geography, engineering etc. in order to model complex systems. A network is an abstract organizational model, in its broadest sense concerned only with the structure of relationships between things, be they objects or information, which can be applied to the organization of anything from friends lists to genetic algorithms to global military operations [1]. These relational networks are used in both for modelling hierarchical and emergent systems. A network system which defines the complex material or energy system includes performative parameters in itself. These parameters are in relation with flexibility, self-organization and adaptation [1]. In self-organizing networks, a micro-scale behaviour affects whole the system and creates performance based structures which response to the changing environment according to stimuli.

In a self-organizing data network, behaviours can be analysed by agent-based systems. For example, in plants as an example of natural agent-based systems, the water and nutrition which are carried by the xylem are the agents of the network system. Through these agents, new connections in response to the need of water and nutrition are set in the structure of the plant while keep its own structural rigidity. As it is shown in Figure 1, *Luffa cylindrica* has a fibre network structure which is formed after drying. This network system is hierarchically organized to host the inner seeds and to protect the plant. The connections of structure change in time by creating emergent patterns, while plant grows. Thus, the system shows self-organizing structural behaviour which can be adapted to the architecture and urbanism as an information based interactive model.

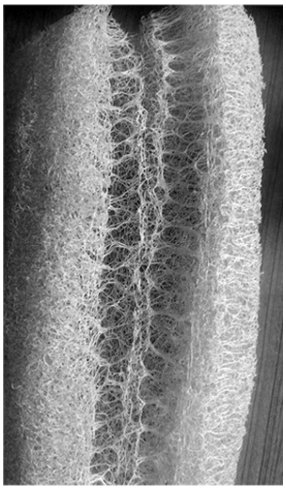


Figure 28: Luffa cylindrical after drying.

In this paper, firstly, the tropism movement in plants as a network system will be analysed in terms of biology and its applications in architecture. Next, a model will be proposed by using a nature inspired method in relation to plant tropism movements within a network system.

– 2. The Movement Systems in Plants

Plants obtain the water and minerals from the soil by their roots while convert light energy to nutrition and oxygen by their leaves. While they satisfy their need, they make change of state according to stimuli in a way that directional or non-directional. These movements are called tropic and nastic movements [2]. Tropic movements are in relation to the direction of stimuli, whereas nastic movements does not depend on it. Thus, nastic movements are not analysed in this paper, because the response to stimuli independent from the direction of it like Venus flytrap which captures pray [3].

2.1 Tropism

Tropism is the growth or turning movement of a biological organism, usually a plant, in response to an environmental stimulus [4]. If the tropism occurs at the same direction of the stimulus is called positive tropism, at the opposite direction is called negative tropism. Some of these movements are phototropism (in response to illumination), geotropism (in response to gravity), haptotropism (in response to touch or physical contact), chemotropism (in response to chemical), traumatropism (in response to one-sided injury), and hydrotropism (in response to water or moisture) [2].

Tropisms which are activated by stimulus play an important role in the growth of plants. According to this tropic movements, a plant can sense the direction of the growth by means of pressure changes and response to it. For example, traumatropism occurs if a plant is injured. The growth of cells in that area of the plant gets slower and nutrition needed for growth is translated to the healthy areas of the plant. Thus, the plant leans toward and creates a curvature which differs in every stimuli.

In plants, these movements occurs according to the change of the agents in the environment. Besides, these movements in the plants are neither totally chemical nor mechanical. All the tropisms, except the behaviour of the Venus flytrap occur by means of the cell growth. For example, roots of the plants in order to find water by turning a corner, make a cell growth at the small area of the plant and the plant leans toward to negative direction of the cell growth [5]. Thus, the plant can survive in extreme conditions with this kind of tropism called hydrotropism.

Figure 29: Hydrotropism of the roots of the wheat plant [6].

As it is shown in Figure 2, roots of the plants lean toward stimulus which is called positive tropism. The body of the plant in contrast to the roots, grows to the opposite direction of the gravity, which is called negative tropism. Thus, the structure of the plant change in time while staying stable.

Both in hydrotropism and gravitropism and also in other several tropisms, plants bend while growing. This is because the concentration of a plant hormone called auxin inhibits the growth at one side of the plant [7]. One side grows much more than the other side of the plant and taller side starts to bend over the other. Different angles are created due to the elongation at different levels. Thus, plant can adapt to the environment and survive in changing conditions.

– 3. Biomimetic Approaches in Architecture

Agent-based systems can be observed in different scales - from building to city as similar as tropisms in plants. These systems are used to model and to analyse the human behaviour in order to understand and simulate the relationship between people and their environment. They are generally applied to ensure the organization of space, to plan the infrastructures, and to model the circulation and guidance elements. In these systems, every agent is in a relation with its environment and responsive to stimulus. Thus, they can be analogically associated with the tropism in plants as they adapts to the change.

A network system defined by nodes and links between them according to algorithms is the one of agent-based systems. In digital design, these nodes may represent a region in an urban pattern or a joint in a structure. As an example for urban network systems, Urban Sprawl Condenser by Sugar Inc. is shown in Figure 3. This project is designed by using a network system which defined by nodes and links and used the method of biomimicry by applying the principles of plants network systems and fibre structures. The model starts with a single node and aggregates according to the algorithms while creating circulation systems and public nodes. These network clusters grow and spread by getting organized. Eventually, an urban plan is created [8].

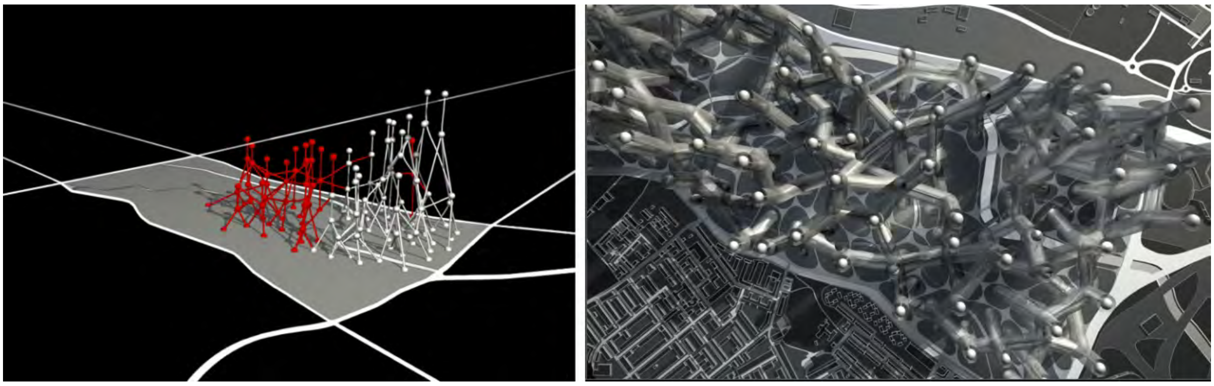


Figure 30: The pattern which is created by aggregation of various urban and circulation nodes [8].

Next, these nodes are designated to host various functions while links between them form the structure of the network as similar as a structure of a plant (Figure 4).

Figure 31: Urban Sprawl Condenser: Inspired by fibre structures of plants [8].

A structural example for network systems is Hylomorpic Project by O-S-A. In this project, various structures with different nodes and links are obtained after several iterations according to the algorithm. Next, they are analysed regarding the stability and materiality for choosing appropriate ones (Figure 5) [9].

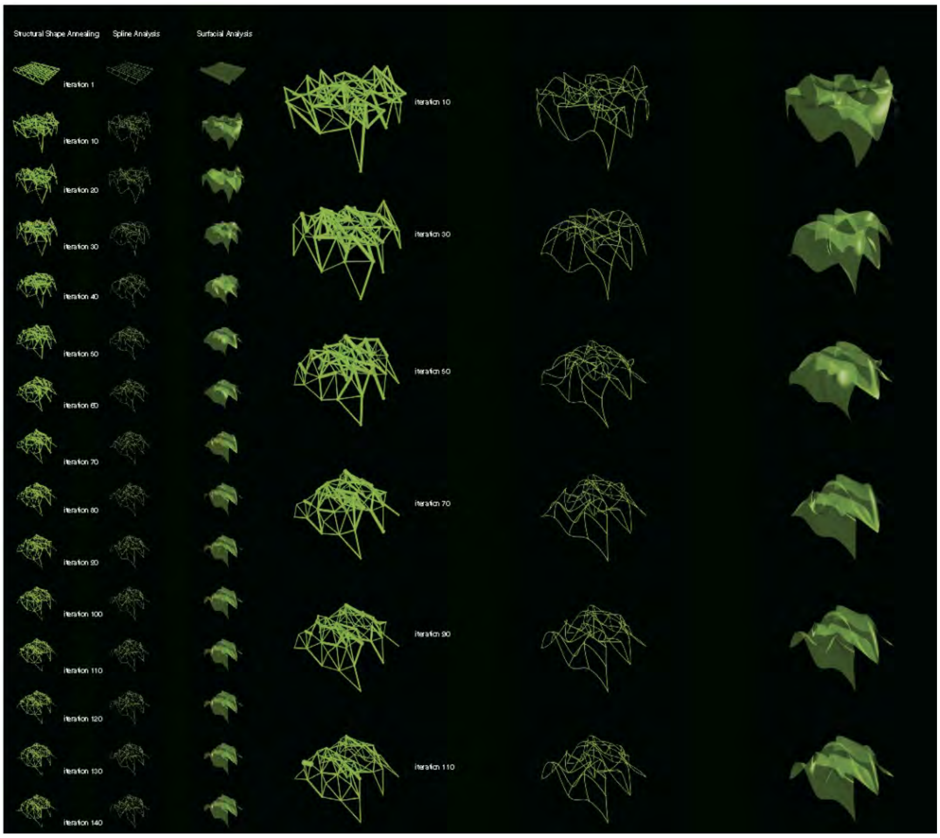


Figure 32: Hylomorpic Project by O-S-A [9].

Both projects uses the network systems to produce the output. It is attempted to adapt the growth of the plants based on the aggregation of nodes and creation links between them in the first example, while in the second example, to generate different kind of structures to be chosen according to criteria of stability. In conclusion, first project gives one design solution in a time, while second one generates several structures according to the algorithm. The model which is created for this paper, the method of the second project is used in order to generate several outputs while inspired by tropisms in plants.

– 4. A Model based on Tropisms in Plants

– 4.1 The Concept of the Model

– Agent-based interactive structure which is inspired tropisms in plants, takes as an input, the movement and density of the people. The structure which itself a regular network system in the beginning, adapts to the changing conditions by creating new nodes and links between them, according to the location and density of people within the structure. The structure can be formed by stimulus due to its self-organizing character. By means of this model, the idea of the constant structure is surpassed by the interactive structure which responses the changing character of today's world.

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– 4.2 The Parameters and Design of the Model

– The inputs which affect the form and tropism of the structure are the movement and density of the people defined by a code written on Processing [10] and adapted by writers for this paper. This structural organism lengthens and shortens in the manner of plants by changing the nodes and links within the system. Thus, spaces are created based on the structural change due to the interaction with human.

– As it is shown in Figure 6, several additional libraries are used in Processing code. “Particles” class is used in order to model and represent the movement of people and “Attractor” class is used to represent the gathering point. The density of the people is controlled by the cardinality of “Particles” class and the position of the “Attractor” is determined by the mouse pointer. As “Particles” follow the “Attractor” their coordinates change.

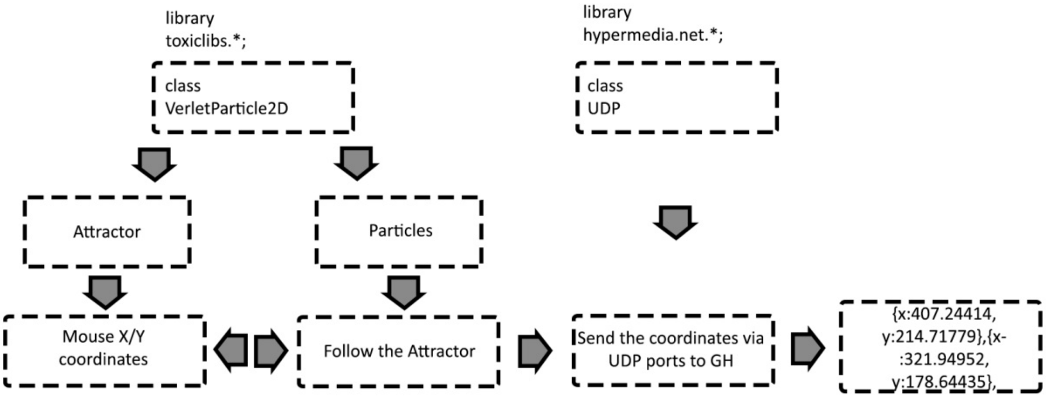

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Figure 33: Flow chart of the “Processing” code.

– As it is shown in Figure 7, the behavior of the people which is simulated in Processing, is transmitted to the Grasshopper by using a port and used as inputs which affects the coordinates of nodes of the structure. People follow the attractor point which can be in different numbers by changing the parameter. Thus, the structure changes dynamically as people move and increase in number. Structural change is constant and creates an event based building system which deploys the internal flow to the outside world and the structure becomes a representation of inner circulation which communicates with its environment. Besides, structure becomes a fragment of a city due to dynamic relation with its residents and orient itself according to this relationship. Thus, the form of structure takes its appearance directly from the present.

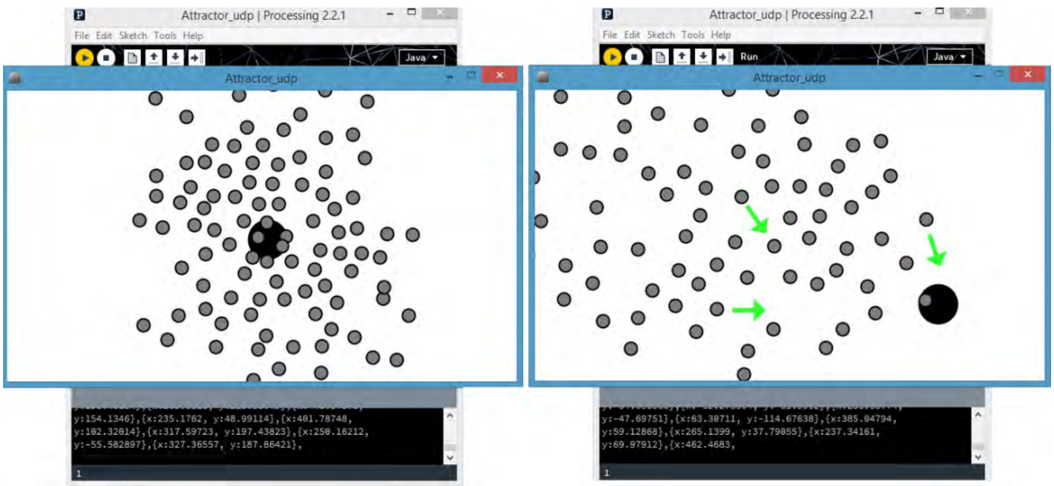

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Figure 34: The diagram which shows the gathering point (Attractor) and the movement and density of the people (Particles).

Various structures can be obtained by means of the formation of the initial network system by applying the algorithm which is shown in Figure 8. These structures are created by linking the X and Y coordinates obtained in Processing and transferred to Grasshopper, according to the radius limitations between two points. Owing to “Exoskeleton” plug-in in Grasshopper, the network system which is obtained, can turned out to be a skeleton with a thickness which can be adjustable. In Figure 8, first line of code shows the skeleton of network derived from arrangement of the point cloud and the second line of code shows the transmitted X and Y coordinates and density of people imported from Processing.

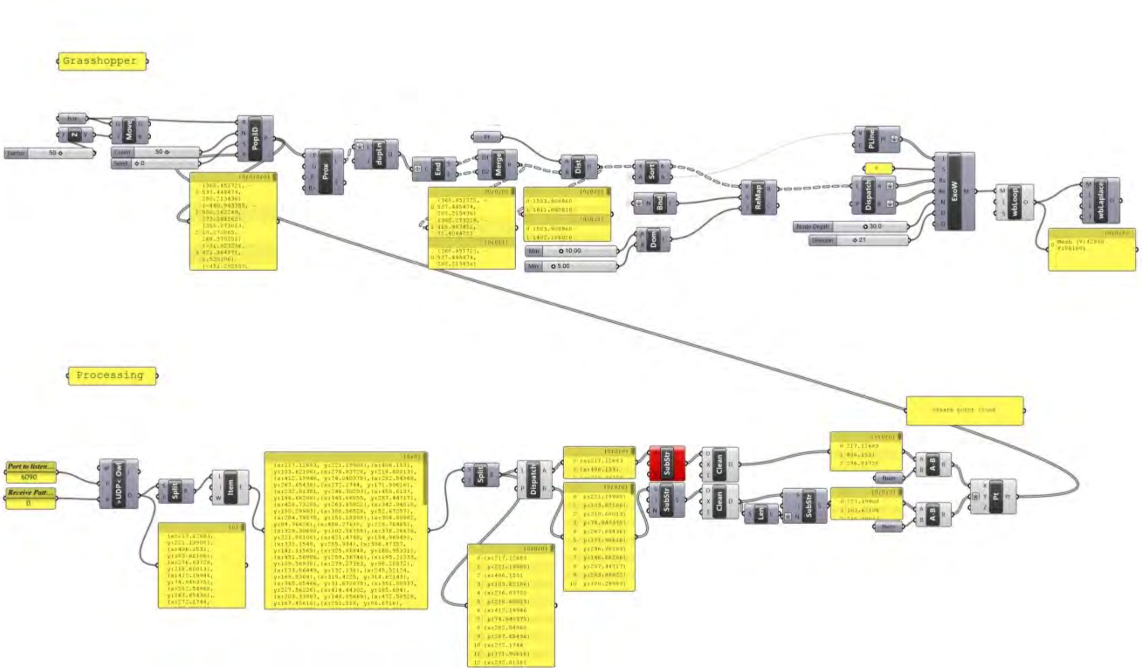

Figure 35: Flow chart of the Grasshopper code.

The structure lengthens as the people approach and shortens as the people move away from the nodes of the structure which are affected. The initial state of the model is shown in Figure 9. In this state, the nodes create almost a regular pattern which is created by a defined box with adjustable dimensions. And, nodes and links created due to the default component algorithm for the initial network.

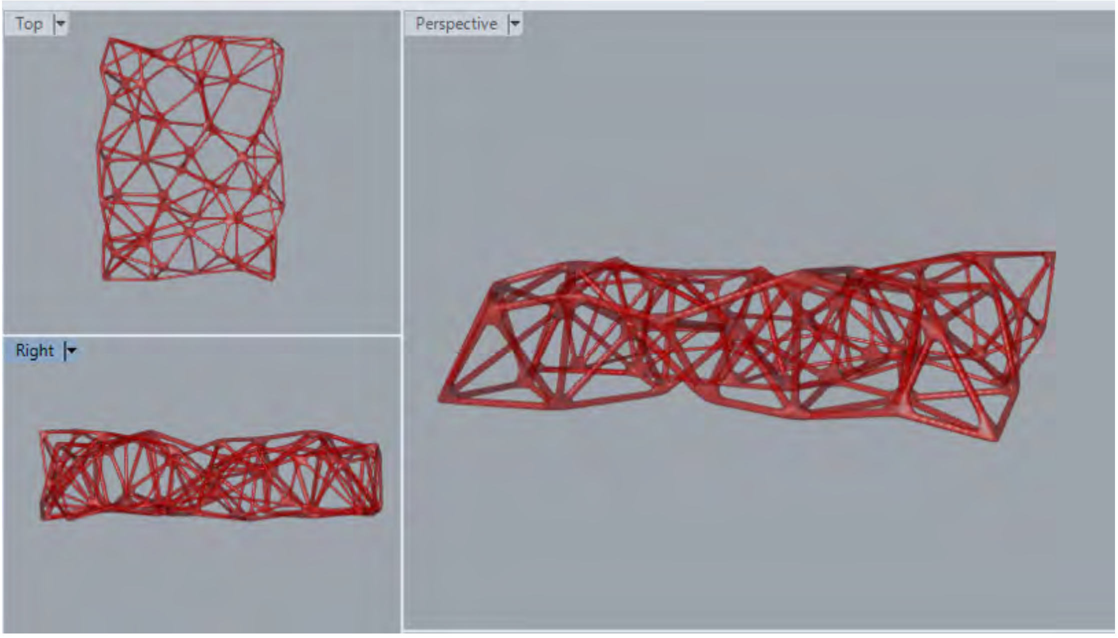

Figure 36: The initial state of the system.

– In Figure 10 and 11, on the right, the movement of people is shown as a Processing code; on the left, the changes in the perspective and elevation of the structure based on the movement are shown. In Grasshopper, the cluster of the people is shown in green as a point cloud. Two programs work in simultaneously as it is depicted. So, dynamic relation of programs creates an adaptive network systems.

– After the code is compiled, if the cluster of people is at the borders of the structure, nodes at these region create a console like structure (Figure 10). If the cluster of people is at the middle of the structure, nodes create openness in the structure like a long span beam to form a bigger space depends on number of people (Figure 11). The model creates emergent structures even it shows some predictable behaviors.

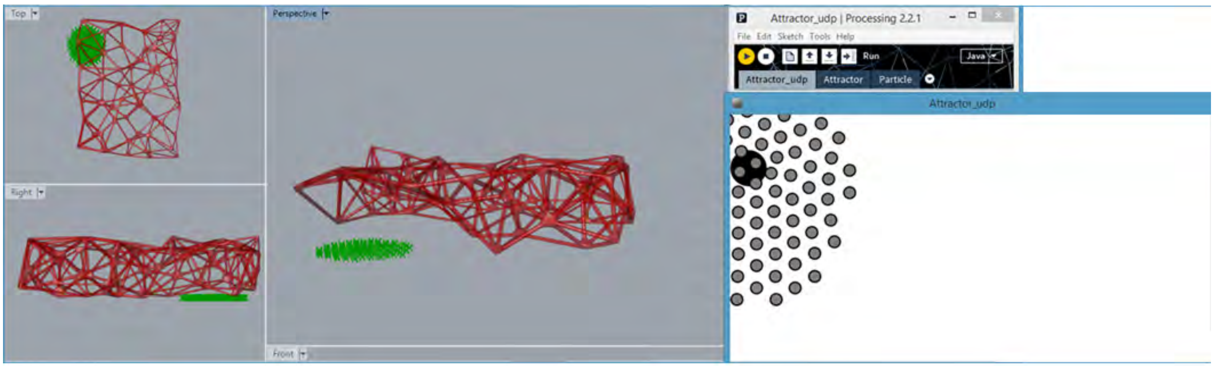

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Figure 37: The diagram which shows the position of people at the border of structure.

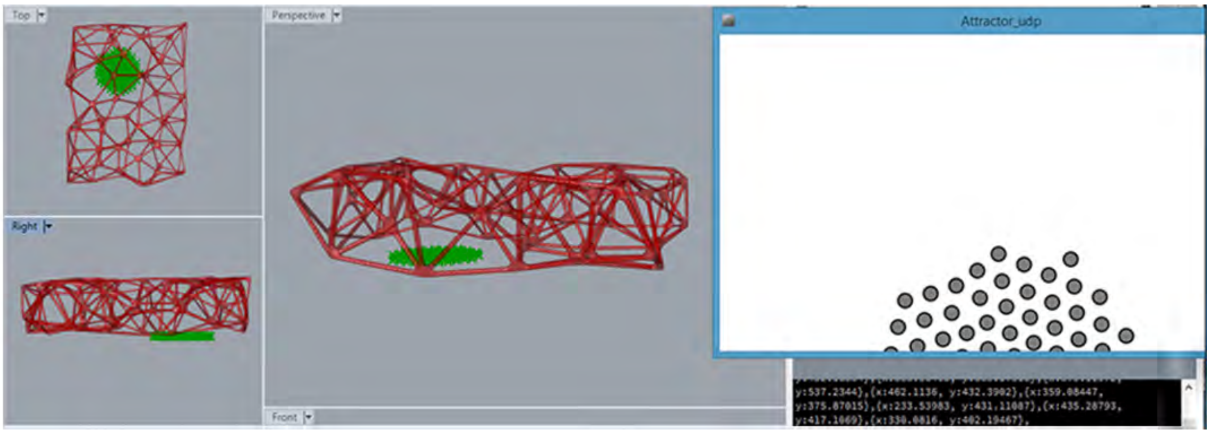

Figure 38: The diagram which shows the position of people in the middle of the structure.

Various forms emerges as people wander inside or close to the structure. These forms can be chosen by the designer and used in first stages of the design or with the structural analysis forms can be chosen according to results. Structural systems which have the different network types are shown in Figure 12 and much more of them can be generated thanks to the algorithm. Changes in position and number of people directly affect the structure and changes nodes and links. As it is shown in Figure 12, some of the structural networks are closed and define a mass while others are open and creates pillars. This network language which created by the digital model can be integrated with functionality and used as a form finding machine. Or, for future applications, structures which are generated, eliminate by analysing static behaviour of each output.

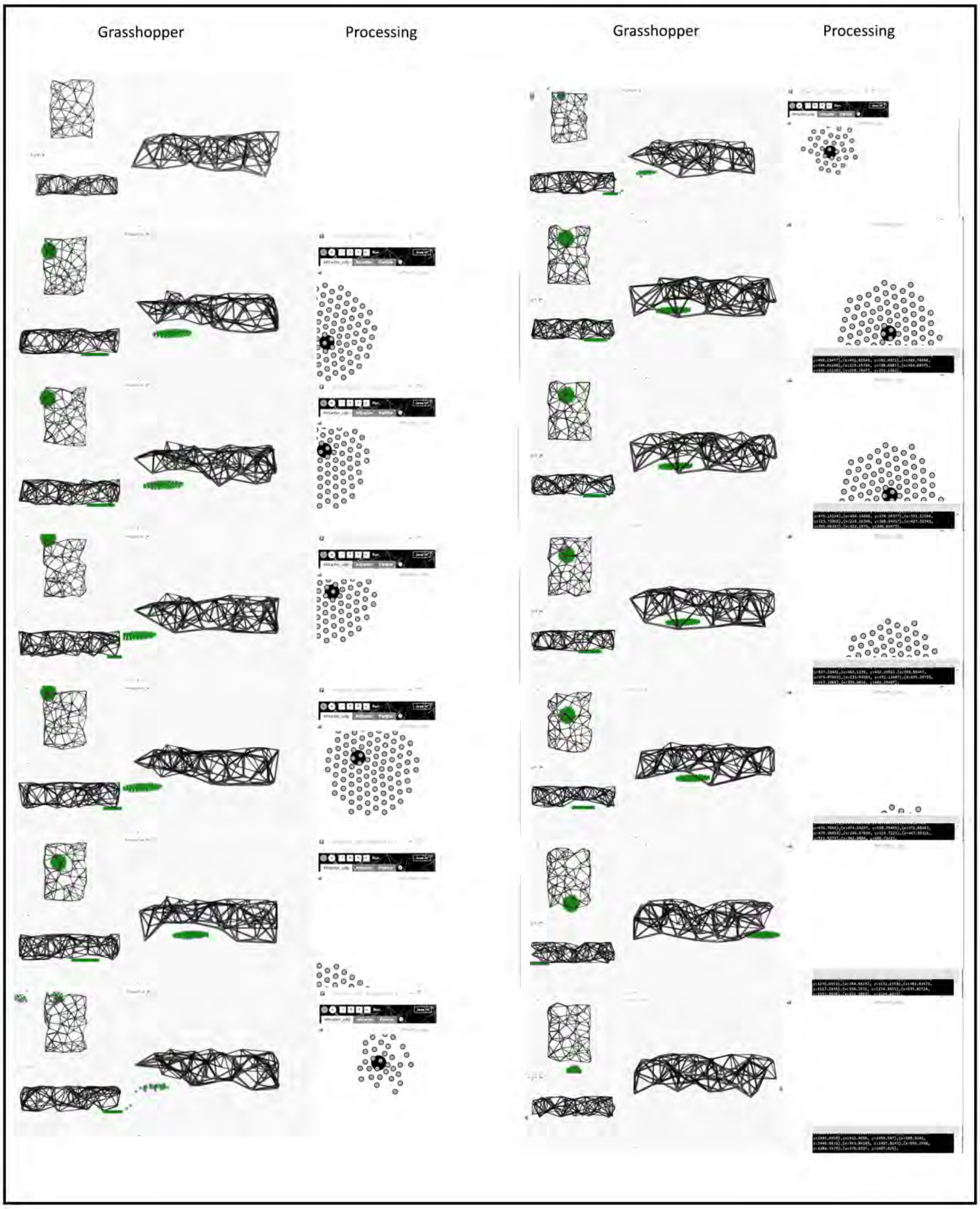

Figure 39: The interaction of density of people and structure.

– 5. Conclusion

The model which is created for this paper has potential to response the architectural needs in the micro and macro scale. Owing to the human interaction of the algorithm, various structures can be created. These structures can be the part of the design process by integrating the functions of the building to the structural element. It is possible to design the structure according to the density and circulation of people in the building. So, the building becomes an interactive entity as it takes people behaviour as an input. The form of the structure is directly in relation with present which makes the structure an event based model defined by dynamic data flow of location of it. Thus, the building can act as a fragment of city which is also derived from data. Despite of the information based character of the model, some emergent structural networks are generated due to ambiguity of the algorithm like in a city.

For future applications, as the result of applying the model to macro scale, various public spaces, circulation networks, infrastructures, green areas and city centres can be designed in the urban scale owing to the network based model. Also this structural network have the ability to adapt to its environment and to sense of the people and bend toward to them as in the plants. In conclusion, nature inspired interactive structures can be used in several stages of the design thanks to its potentials serving to the designer. Besides, the model which is created for this paper, can be analysed regarding stability and material possibilities and improved according to the data which is obtained, for future applications of the model.

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