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Research Article

Interactive Kinetic Canopy with Industrial Architecture Legacy Preservation Approach

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Abstract: Architecture has long sought to improve both in terms of form, space and other elements. Meanwhile, the use of innovative techniques that enhance design is always one of the concerns in the field of design. Biomimetic and Nature-Friendly architecture have always inspired by natural organisms aims to emphasize harmony with the environment. From another approach, contemporary industrial architecture has a valuable place in this knowledge, and the restoration and preservation of this heritage is a serious subject. Using attractive methods like an integration of new technology and monumental heritage lead to a profound impact. To this end, designing a canopy using an interactive and kinetic pattern to value this theme can be effective on sustainable development goals in area. This canopy which is inspired by biomimetic pattern and natural potentials from the site, responses to external motivation and adapts its kinetic movements to follow human interactions. The innovative techniques are involved with choosing a precise geometrical frame and order, kinetic patterns suitable for the project and finally fabrication of an scale model from actual dimensions. By choosing a suitable site that houses building of contemporary industrial architecture such as a railway station, this paper aims at learning from nature to fulfill industrial heritage legacy retention that is in both physical and spiritual interaction with humans.

Keywords: Contemporary Industrial Architecture, Sustainable Development, Smart Canopy, Industrial Heritage, Biomimetic Design

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1 Introduction

Human beings are constantly experiencing different moments at different times in their lives. At first, he is inexperienced and raw to constantly understand his surroundings. "Changing the view that life is intrinsically simple and orderly, and the fact that life is a complicated thing is what every individual is undergoing in the course of his development." (Heckscher 1962) The living space of man always has an inherent order. It is the intrinsic order of a system that has come from interacting its inner complexity with an uncomplicated and adorned comprehensiveness. Indeed, "adaptability of the system is the process of self-organization, which is the tendency of complex systems to evolve towards order Instead of irregularities." (Kaufman 1993)(Figure 1).

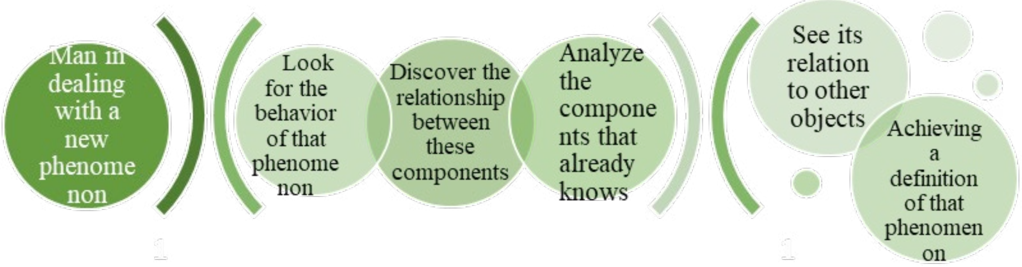


Figure 1. The Diagram of Human Interaction in the Environment - Mahdavinejad, 2014

Now, to design a system that has different components, a model is a sensible thing. This pattern can be inspired by nature. Of course, as Simon says, “we can use the findings of natural science in artificial systems, but its use is limited.” (Simon 1999) Similarly, for reaching in the general order of the natural system, the use of the Voronoi geometric order in the natural environment results in a perfect structure. These structures follow a series of spatial patterns in place. “When an intervention takes place in these places, the entire space patterns will be affected,” (Roggema 2013). In this paper, we have tried to put together such patterns, to design a responsive shell with the ability to interact with the environment and human beings around them. In fact, “every living creature has a protective shell that separates the inner part from the outside, apart from the direct mediator separation between the inside and the outside, so interaction can be best done by the shell.” (Roggema 2013). This interaction between the different components of an intelligent shell requires a language to create the order between its components. This language is called an algorithm. “The algorithms are composed of simple short commands, which together can produce complex results.” (Mahdavinejad 2014). These complex issues could be solved by choosing a suitable site and extending the project ideas in this place to create valuable architectural work alongside an industrial building that needs an architectural idea to preserve its heritage. In the process of the architectural idea of this project, algorithmic geometry plays an important role. “When we look at the design of the algorithm, in fact, for the design process we are asking a question that the entire design process will be to find the answer to that question.” (Mahdavinejad 2014) Therefore, in designing a canopy, attention has been paid to create an interactive space commensurate with the presence of the user. The proposed site is the railway station of Shirgah City in Mazandaran province, Iran.

2 Biomimetic Development and Nature Inspiration

Bionics and biomimetics are key roles in designing a kinetic form that mediates between site potentials and industrial design. Biomimetics is useful and successful in finding inspiration for problem-solving design. (Lopez 2010) We can think in an innovative way to inspire from nature around the site with biomimetics and integrate them into the design process as a part of methodology from the beginning through the assimilation of geometry. (Lopez and Berges, 2012) The most valuable part of using biomimetics is that we can extract design elements and transform them into a kinetic artificial pattern. The development of methodology from different key-roles is an important part to make a novel design. To achieve our goals in combining nature and kinetic form, we use Dr.Tony Buzan learning tool method named “mind maps”. (Buzan,1996) The method begins with a central goal, the target idea, and goes outward in different directions to produce an organized structure composed of key functions. (Lopez and Berges, 2012) Here in the Figure 2 , the structures are leveled by the order of importance and they are developed up to the final level. This method helps us understand the levels of the development process when the product does not yet exist or defined. The final level comes with key features which identify new functions that are called key functions. (Lopez and Berges, 2012)

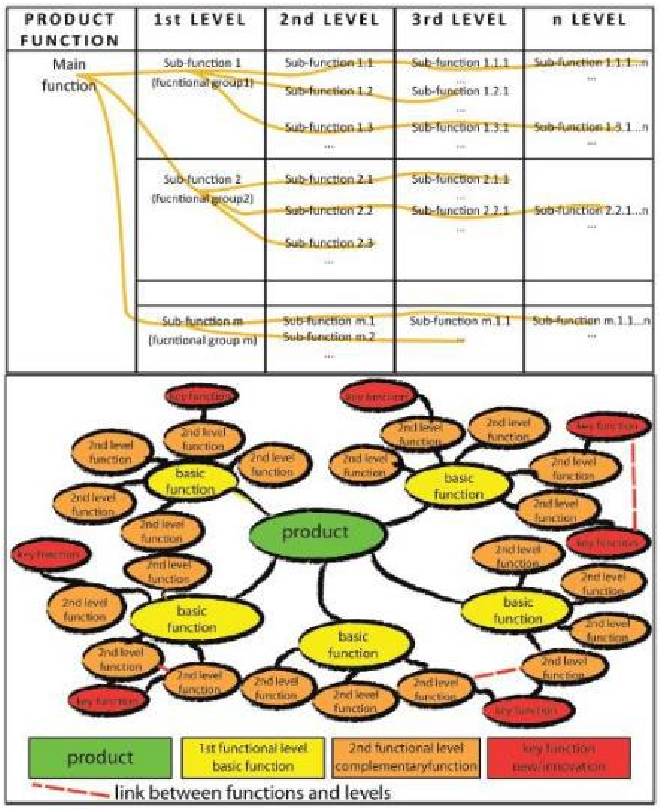


Figure 2. Functional tree and key functions hierarchy in mind maps (Lopez and Berges,2012) from Dr.Tony Buzan “Mind Map” Method (Buzan,1996).

3 Heritage Participation

In recent studies, a lot of focus has been implemented on intangible aspects of industrial heritage. The value has become more sophisticated with a more personal attachment to the area such as human contacts, memories, landscapes, experiences and etc. (Reeves et al. 2011) Here in this paper we propose the model of Oevermann for the participation of industrial heritage and how to preserve the legacy. Studies on different Cases have shown that Planning culture that is related to time and place plays an important role in how conservation is understood and practiced, and therefore how to define and manage the heritage. (Oevermann and Mieg 2015).

The same goes true of the participation process. So, despite the necessity of focusing on tangible dimensions of heritage like the building itself, we concentrate on the positive potential of multiple stakeholder participation related to industrial heritage through time. So, participation is very crucial in the context of heritage programs for the conservation of historical buildings and monuments. (Oevermann and others 2016) Here in the site of Shirgah city, the railway station with about eighty years of the historical background has the potential of preservation approach in the area(Figure 3-4).

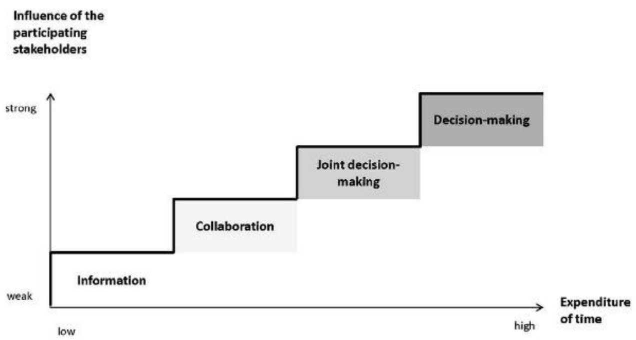


Figure 3. A multi-level model of participation. (Oevermann and others 2016) based on that of SenStadtUm (2011).

Figure 4. The railway station of Shirgah City building, Mazandaran Province.

4 Intro with Concept

The idea of the smart shell in this project comes from Voronoi geometry and geometric order in such a way that the components of the shell are grouped in three layers together. The presence of bamboo trees near the site and their spiritual value as potential on the site made it possible to use their polygonal shape in the design of the geometric system of roof skins(Figure 5-6).

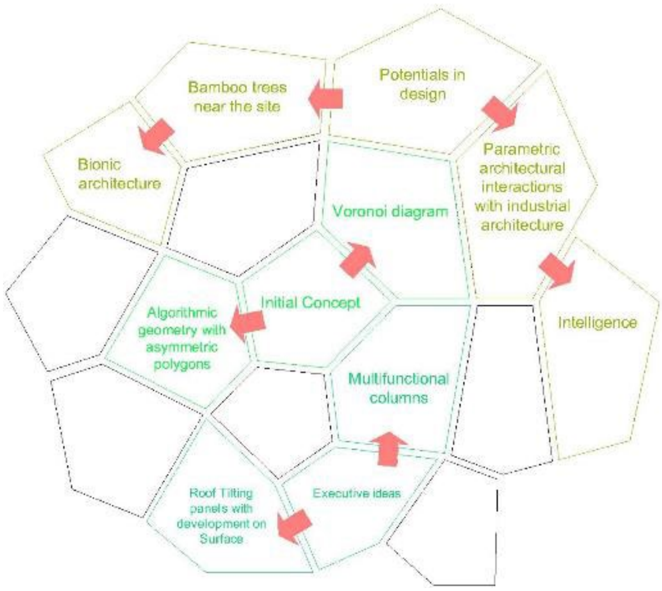


Figure 5. Concept Diagram of Train Station Intelligent Canopy Design.

Figure 6. Bamboo Trees from the view of the railway station balcony.

This geometric system is based on an algorithmic logic. “In algorithmic design, the algorithm is a set of commands that receives information as input, and gives us an answer as an output.” (Golabchi Andiji Garmaroudi Bastani 2011). The response required from this project is the regular movement of the shells in order to direct the user to the desired route (train station exit platforms). This shell is placed under the following diagram in the decentralized network category because the shell forces are moved from the two gravity points to the subfolders and the centers of gravity are connected by a medial joint(Figure 7 and Table 1).

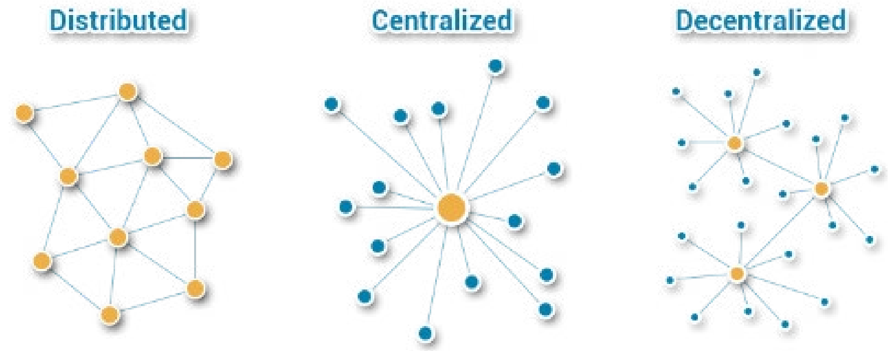


Figure 7. Centralized, decentralized and distributed networks - derived from Baran: Barbabasi, 2003.

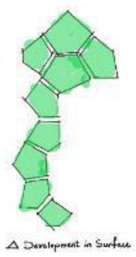
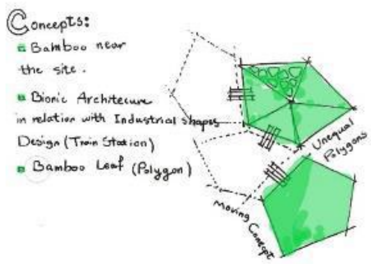
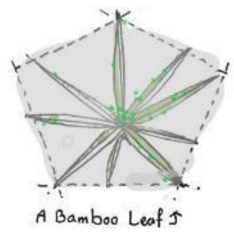
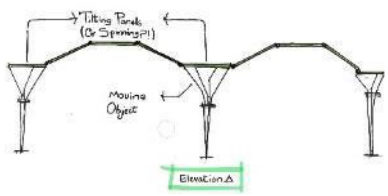
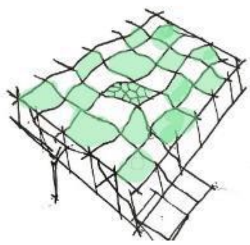
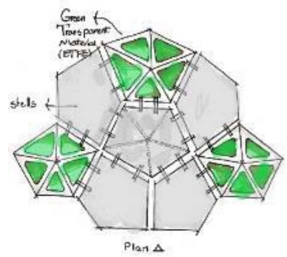
Polygon expansion plan on a Surface	UnderstandingAsymmetric Polygon Relationships	Concept of shell from bamboo leaves
		
The basic idea of the pillars and their movement mechanism	The idea of sinusoidal movements on the surface	Geometric alignment of parts and middle joints
		

Table 1. Hand sketches of initial concepts.

To create an architectural output, we need to organize a series of rules in the processing of algorithmic geometry. In fact, "the designer is not engaged in the process of generating a definitive form, but he puts the rules together and organizes an algorithm that is based on the processing of that form of architecture." (Khabazi 2012). For this purpose, three categories are used in the motor system of the shells. The ceiling is generally divided into two petals. Each of these petals is taken by the pillars derived from the "tree skeleton" that make the structure stable. The five columns below each petal are connected by roof motors and the smart move of the ceiling. Each petal has a central pentagon component as the center of the nucleus and a force distributor to the other components. The second layer also has the task of transferring power to the last levels of the layers, and thus the system of motion in each petal is completed.

Layer Segmentation: Red (central component), Green (middle layer), Blue (outer or outer layer), Orange (joint between two petals)(Figure 8).

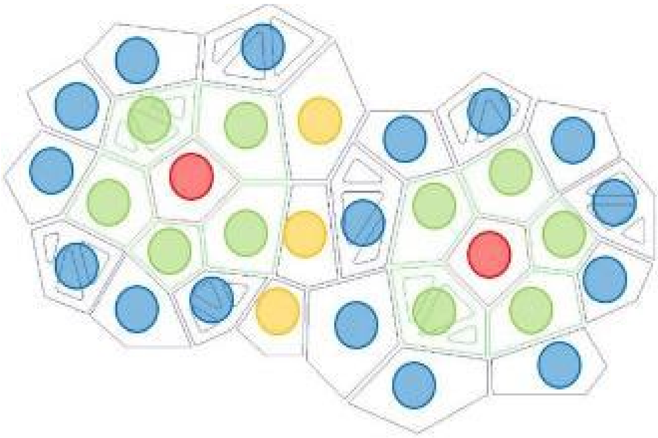


Figure 8. Diagram of the expansion of layers at the surface and transmission of force.

5 Explaining the initial design process

The initial idea of the design of the project's motor system was to create columns in an integrated manner under each of the shells, which would reduce the control factor and increase the risk of the project. By dispersing the tree columns and placing each of them under the layers of the middle layer, control of all three parts of the layers, as described above, was noticeably increased, and gradually it was possible to build a sample on a scale. More precisely, controlling the complexity of the project over time has proven to be more effective(Figure 9).

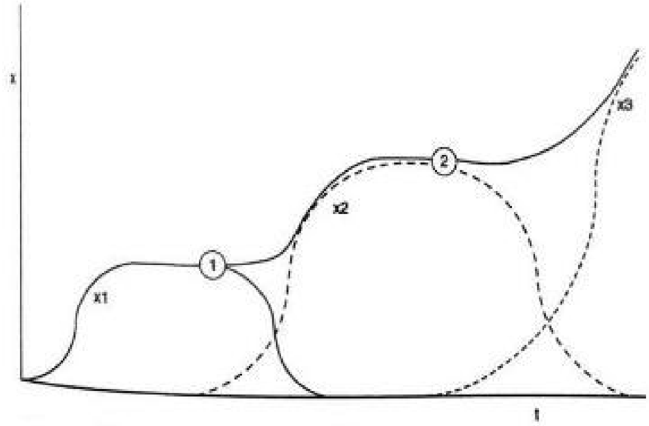


Figure 9. Evolution of a complex system, indicating the increase and decrease of the complexity of the system (x) in relation to time (t) - quoted by Geldof, 2001; Prigogine, 1986.

In the early stages of the mental mapping and design, consideration of the issue is essential and important, and having a "comprehensive approach in order to integrate the required multi-function into the early stages of the design process is necessary." (Yazici 2013)(Figure 10).

Figure 10. The Process of Creative Design - Lawson, 1997.

The secondary idea of the design, which relates to how the components move and interact with the train station, is that by locating the motors under the roof skins and facilitating their movement with two groups of columns on both sides of the platform where the train is stopped. The middle space of the shell petals, which in fact represents the intersection of the joint of the two zones from the ceiling, is the location of the train rails. As the train approaches the station, the smart shell is activated and ready to move. By stopping the train and leaving the passengers, the sensors mounted on the pillars notice the passengers and order the Sinusoid movement of the shells from the middle joint of the two petals to the outside, so as to interact with the passengers, they move towards the exit Platforms. This move can be implemented with the program command to the programmed interface between the computer and the scale model. More clearly, "most design assistance softwares have a set of predefined geometric volumes controlled by their parameters." (Mahdavinejad 2014) This geometric coincidence with the geometry used in the design of the canopy follows the same form. The motion of the ceilings, in addition to the visual appeal of its semi-open environment, is in harmony with the site of the collection and expresses the Bionic form and the Voronoi geometry. "Design, both in terms of form and space, it's configuration heading is intended to mean that parts that are formed together to form a whole are more important than each of their segregated divisions." (Hillier 2007) In addition, with some transparent roof materials, natural green light is brought to the surface underneath the shell to see light and shadow in the project(Figure 11).

Figure 11. The first sample of the model at a scale of 1: 200.

6 The progress made in manufacturing a Scale Model

To make a scale model of this design at a scale of 1: 100, first, several different materials were used. For the crust of the roof we used the Cardboard, transparent sheet and for joint joining the components of the shells of materials that are elastic and yet stable, elastic band used with adhesive binding in order to approach the sample to the actual scale of Voronoi geometry and algorithmic model which cause the shells to be formally balanced logically(Figure 12).

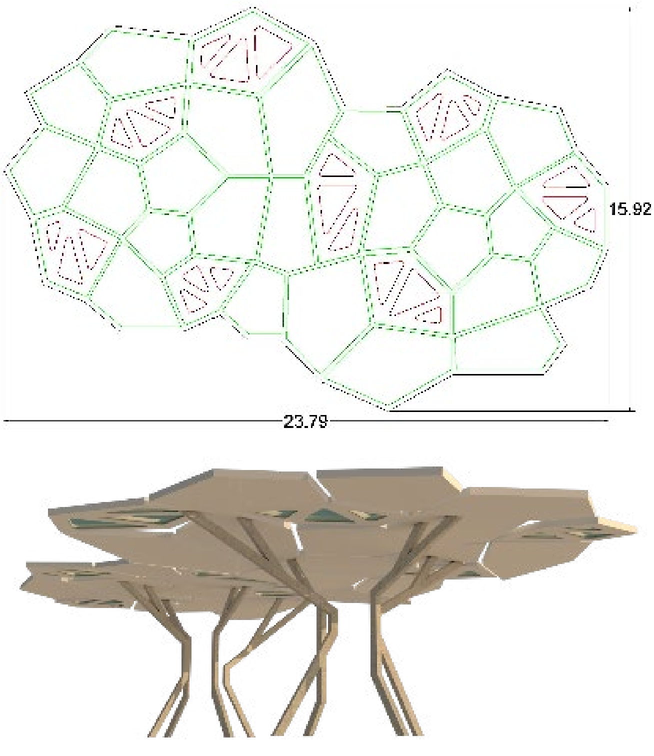


Figure 12. 3-Dimension and size of the roof shell at a scale of 1: 200 in 2-Dimension (in Centimeter).

The central nucleus of the petals, which is an asymmetric pentagon, has logical proportions in its different sides. These ratios increase based on the base module of 0.5. As far as the sides of the central pentagon are concerned, other asymmetric pentagons also find their arrangement around this major component(Figure 13).

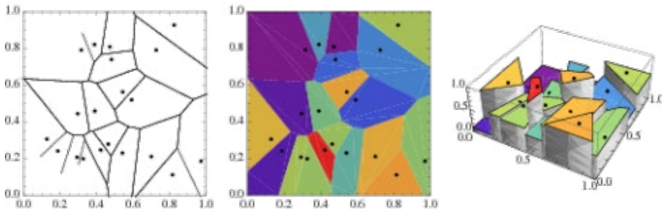


Figure 13. Voronoi geometry in two-dimensional and three-dimensional graphics - mathworld.wolfram.com.

First, it was decided that the final specimen should have two complicated columns, each containing various components of the light cable, with the middle rim core (referring to the initial hand sketch). By pulling each of the cables by the motor The central petal was moved by the cable force as a slider in different directions, but in order to facilitate the control of the mechanical affairs involved in the design, it was decided that the components of the columns should be separated by each of the columns with one Engine with upward force. After the study, the idea was abandoned; Because one of the important aspects of a prototype is its close proximity to real-world construction, and in reality placing the engine underneath the columns and imposing a force that causes the movement of a high-pillar column is nearly impossible and causes a high and irrational cost. In addition to this, it was decided that the scale of work should be smaller due to the weight gain of the ceiling and the increased risk of controlling the movement of the final design. The height of the columns in actual size is in the range of 3.45 to 4.5 meters and the forms are taken from the tree branches. The combination of these elements around a central point evokes a form of a tree(Figure 14-16).

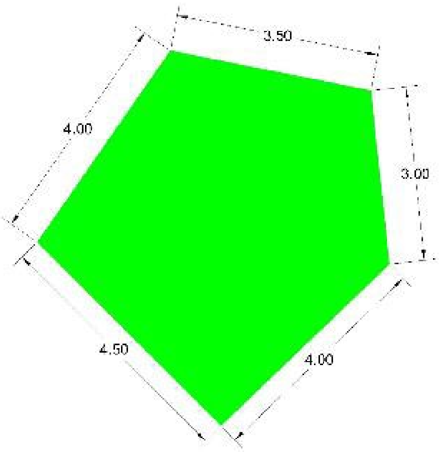


Figure 14. The asymmetric central core used in the design and geometric relationships between its sides.

Figure 15. Frankfurt Airport Pillar Tree Form - pinterest.co.uk.

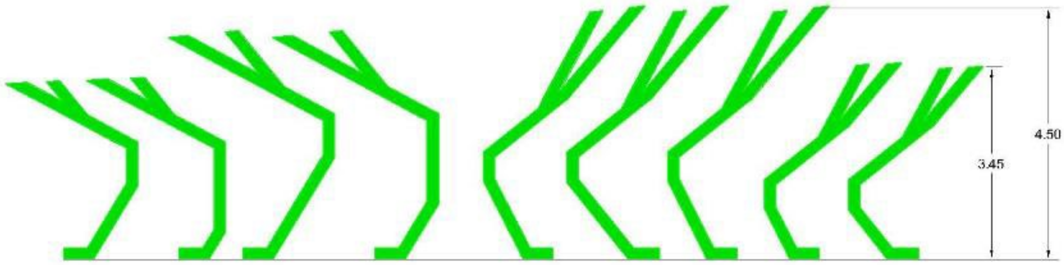


Figure 16. Dimensions and shapes of roof pillars.

Another case was the use of elastic bands with high tensile strength and, as a result, high stiffness. In this way, the finest specimen of the material in the market that could play the role of the joint causing the imbalance between the joint stiffness and the power of the engine in relation to the mechanical system that was intended to move the shells. As a result, there was also an alternative to this. The following table 2 shows the connection between the joints and the process of making the sample on the scale of 1: 100.

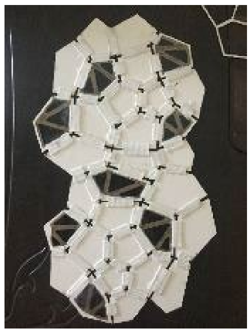
ConstructionMaterials: glue,cardboard,transparent sheet,elastic band	The shell that is made on a scale of 1: 100	Elastic band joints 1: 100 scale
		

Table 2. Details of the scale model in a scale of 1: 100 that did not result in the final build.

7 Considering the final construction and assembly montage

At this stage, the design progress has undergone various processes. In general terms, “the design process involves various stages of conceptualization toward construction, including creating a structure of the problem, initial design, refinement, and details.” (Goel

1992), which is considered at this stage of refining. In the manufacture of the final sample, a similar material was used for the roof crust. The decisive point in modifying the design of this joint load was to use an adhesive paper impregnated with liquid glue with a distance of 2mm in order to achieve the sinusoidal ceiling. The scale of the project reduced to 1: 200 for further control(Table 3).

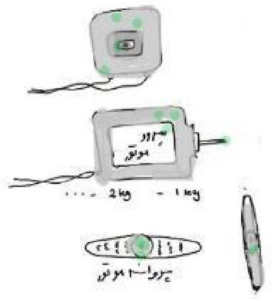
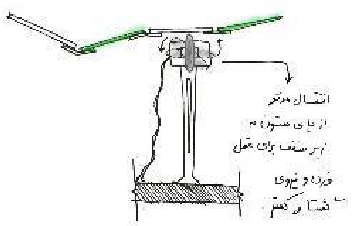
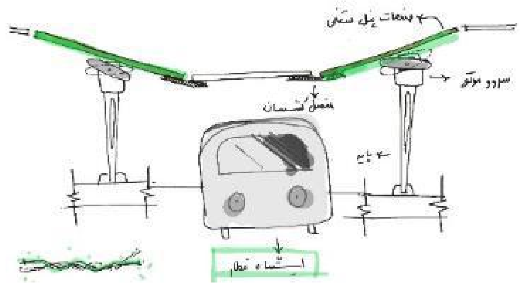
Servo motor and relevant permits	Servomotor location in the Model	The position of the train and the platforms towards the canopy
		

Table 3. Hand Sketches of mechanical components in the project.

For mechanical planning, the movement of the ceilings was done using two servo motors model MG90S with metal gear and a propeller for the purpose of the power transfer between the engine and the roof. The numbers of the crust in the second layer of the petals (the components that are centered around it) are 5, with the same number of tree pillars embedded in each of the components. Each servo motor has a capacity of 2.5V and 1A. In order to move the shells, one of the stacked columns is removed and the servo motor fills the desired column, in order to play the role of the moving arm in place of connection between the column to the roof. The roof crust does not have any connection to the stationary and movable columns and, given the best position for fixed columns, these tree-shaped pillars play the role of the ceiling stability when applying the Servo motors. Two different alternatives were needed to apply sinusoidal forces. The first option is to use the Arduino kits and the introduction of design assistance to the project, and another to provide a controller that can adjust the motor gear movement. By examining how to move the canopy shell, the need to use the programming and logging of software to the project did not occur. More explicitly, “some methods are based on their analysis and are not essentially dependent on computers. This is where the big difference between digital user and designer occurs” (Mahdavinejad 2014) and by precise analysis, the amount of digital logging required at each stage of the project should be controlled. By selecting tester-controller, the amount of computer and software entry in the project was reduced. This controller has the ability to change to a constant, manual control, and the gear reciprocating motion (which is already planned in it). This controller has two inputs from two directions of one-position motor sockets (with a maximum capacity of 3 motors per controller) and the other input power supply (considering the capacity of each servo motor). The servomotor valve change range is from 0 to 120 degrees and each of the motors being 90 degrees contrary directed than the other in steady state to apply the sinusoidal motion of the petals of the roof(Table 4).

-Adapter Specifications	-Tester-controller specification	-MG90S servo motor specification
-Input: 100-240V	- Voltage: 6-4.8 Volts	- Voltage: 6-4.8 Volts, 1A
-Output: 5V, 5A	-Output Amp: 15mA (5.0)	-Angle of movement: 120-0 degrees metal gear
- maximum power: 25 watts	- Weight: 5 grams	-Weight: 13.4 g
		

Table 4. Specifications of mechanical - Electronics components used in the design - eshop.eca.ir.

As one of the petals climbs, the other petal goes down, and this reversible behavior continues as long as the controller transfers the command to the Servo-Motors. A 5V and 2.5A adapter is also used to servomotor's power consumption(Figure 17-19).

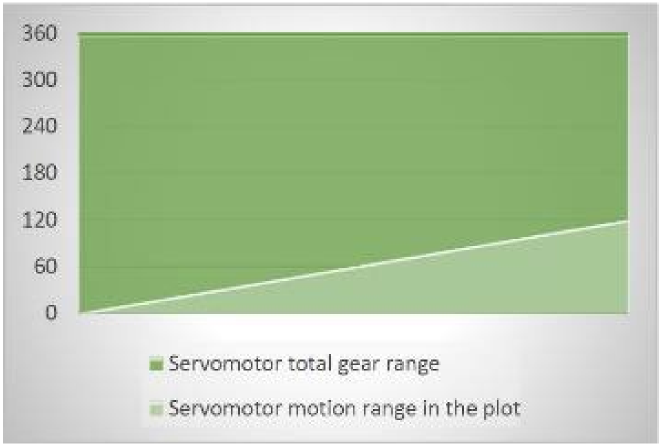


Figure 17. Servo motor propeller sprocket rotation angle in the project (Total range: 0 to 360 degrees).

Figure 18. Controller, servomotor and tree-shaped pillars of the roof.

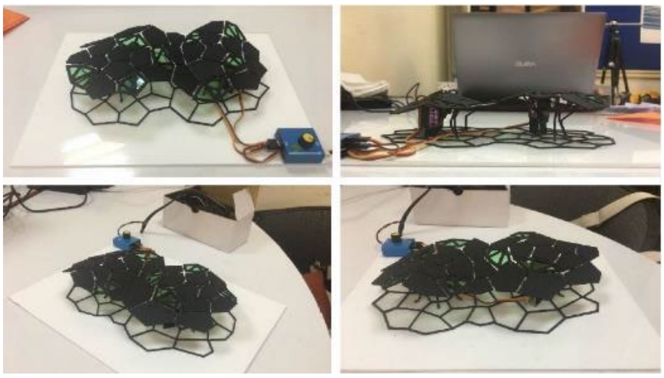


Figure 19. The roof of the structure on the fixed and moving columns of the ceiling.

8 Conclusion

Historical industrial monuments are of great importance in societies, especially in the societies which have occup[ied a considerable number of these buildings at the time of the industrial era of the twentieth century. For this reason, it is not easy to ignore them or pass through them indifferently. Unfortunately, this has become more evident in developing countries due to the lack of potential for managing and preserving the legacy of industrial architecture The building of the railway station is one of the buildings that despite its high historical value as an industrial building of the twentieth century, has not taken proper measures to maintain and restore it properly. Using a heterogeneous view of the historic originality of the building, the failure to repair damaged parts is one that needs to be addressed. But the important and new aspect that was taken into consideration in protecting the industrial value of the building was the use of a modern architectural form with an interactive and complex approach that maintains its attractiveness and good functioning by keeping in touch with its surroundings. Creating an interaction at a moment when a passenger is faced with getting out of the train and reaching the waiting room is a point that the empty space on the site feels. This addition, while adding the function (Canopy) to the project, raises the value of the historical monument and makes sense of importance in the audience. To create this sense, one of the most important tasks of the architects is now in the buildings that need to master and integrate the architecture of yesterday and today in a new way(Figure 20).

Figure 20. The location of the proposed canopy on the site of the train station (post-Productioning).

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