TITLE

Reconfigurable Architecture

by Ignacio Basterrechea | 18.04.12

KEYWORDS

Interactive architecture, user-driven, kinetic, robotic, responsive environments.

ABSTRACT

The precipitous pace at which technological advancements develop also influence dramatic changes within many fields of society. These changes are not strictly limited to the way we interact with each other, but also the interaction between the physical and digital world. Due to the inherit scale of architecture, these rapid changes have the possibility of threatening the utility of architecture as a whole. For example, public buildings are expected to have a lifespan of minimum 30 years. Therefore, designing and executing these projects pose the risk of rendering the building obsolete even before opening doors for the first time. It is with this initial problem, that the interest of investigating the possibilities of an adaptable (and/or responsive) system that allows the constructions made today to morphologically adapt to future unforeseen requirements.

The research driven design approach of Hyperbody's Graduation studios present the opportunity to articulate the complex relationship between social, environmental, spatial, technological and user based information with physical matter.[i] Furthermore, it is the aim of this article to frame the processes and discoveries of the my graduation project within the current digital-driven design discourse. The structure of this reflection consists of three parts. First, the project would be dissected by stating the initial requirements and challenges, theoretical ground, relevant projects. Then, the project would be described step by step, unfolding how each sub-process was built to assemble the design apparatus. Finally, the results would be presented accompanied by a critical reflection regarding the process.

Concerning to the foremost requirements of the studio, the brief introduced four major challenges to be tackled: creating an architectural embodiment of at least 6,000m², that explores the potentialities of computational techniques, deals with a culturally charged site(NDSM Wharf), and framed within a 30 year time span. It's essential to state that throughout the project computational techniques, specially bottom-up processes such as Swarm Intelligence, has been used as a recurrent theme to tackle with the complexity of articulating such challenges. In the late 1980's, Swarm systems were first introduced into computational means by Craig Reynolds. He named this flocking systems "boids" and defined them by three simple rules: cohesion, alignment, and separation. This rules operate at a local (individual) level, however they translate into a global complex behavior system by the global replication of these simple rules.[ii] Consequently, Stan Allen in his article *From Object To Field* states a relationship between Reynolds' *boids* and the concept of field condition. Allen states:

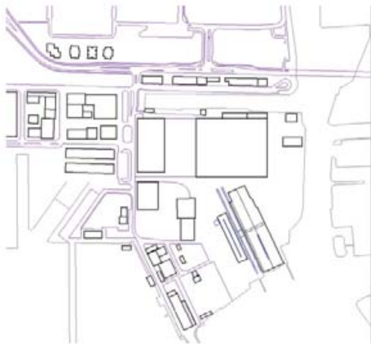
"The flock is clearly a field phenomenon, defined by precise and simple local conditions, and relatively indifferent to overall form and extent."[iii]

Accordingly, tying the concept of swarm intelligence and field conditions allowed a bottom-up approach at mediating complex aspects such as: cultural, historical, and quantitative factors.

Fig.1: NDSM aerial view

The project consist of a Media Center at the NDSM Wharf (Fig. 1). This location on the north side of Amsterdam's Ij was once home of the iconic shipbuilding company. Since the demise of the company, it has become an incubator of art and creative enterprises that have embrace the historical nature of the industrial site. Furthermore, this new creative center attracted maverick creative companies such as MTV and Red Bull seek to be identified with this artistic area.

The location of the project has suffered deep transformations in the last decades. From an entirely industrial site, it has transformed into a creative hotspot in just under 10 years. On the other hand, the pressure for housing required by the city of Amsterdam is certainly a factor that would need to be inserted in the current situation. This uncertainty of the future for the area surrounding the NDSM site reinforces the idea of creating a building that can negotiate the future plans that the municipality has for the area, with the media production nature of its current situation. Then, the goal of the project consists of developing a thread of possibilities in which a building could adapt itself to the ever changing demands of current and future society.



PROJECT

Therefore, the project ought to be a catalyst for a research design exploration of adaptive architecture. By which, the programmatical composition of the building needs to shift in order to accommodate the eclectic necessities of the site. The TV Production Studio for MTV Network and the sporadically, yet high density, events from the NDSM incubators and Red Bull's alternative events, would be a great vehicle to engage program modifications. Furthermore, negotiating between daily base changes and less frequent transformations would be the main point of research.

Fig.3. Ruairi Glynn - Reciprocal

It is important to state that although numerous research has been done in adaptive (responsive) architecture, most of the cases studies deal with top-down processes that dictates an overall intention from the system. For example, the *BMW Museum Kinect Sculptute (2008) by ART+COM* shows the morphological change that a field system can have into recreating predefined shapes. Also, projects that use a voxelized grid of elements that can be pushed or pulled by gestures (such as *MIT Media Lab 's Recompose*) or by a predefined combination of stage arrangements (e.i. *Dynamic Reconfigurable Theatre Stage by Robotics Laboratory and LANTISS*). However, relevant examples to the final intentions of this project can be referenced to *Rauri Glynn's Reciprocal Space* (Fig. 3, 2011) and *Hyposurface*(Fig.4, 2011) *by DECOI*. Which shows the possibilities of a system that could allow spatial transformations at an architectural scale, perhaps an evolution of a *Hyposurface* building system that could modify space and not just be restricted to a surface domain manipulation.

Fig.4. Hyposurface

The NDSM site has a complexity of relationships, ranging from generic places to heavily historically charged structures; from formal structures to improvised enclosures. In addition, several external agents also influence the analysis; such as the municipality's plan for the area, the community's desires and, in this case also, the design preferences of the 7 different designers. It was clear then, that the first step would necessitate mapping this combination of objective and subjective values into a computational mediation algorithm that would embed such aforementioned datasets into an analysis field. This field would facilitate the team, not just, as a passive analysis tool to assess the site but also to actively modify and search iterations of unforeseen possibilities for the desired projects. It is at this stage of the process that a workshop given by the PhD researchers at Hyperbody: Han Feng, Jia-Rey Chang, and Sina Mostafavi, introduced the studio team with a Grasshopper[iv] process that combined an image data extraction method with a neighboring logic search tool. Furthermore, the team built upon this process a search algorithm that would allocate the optimal location for each designer according to their project programmatical composition, as well, take into account external constrains such as the given project size and municipality regulations. The main parameters taken into account into the projects composition were: history, dynamic events, access points, housing, office, culture, and public space.

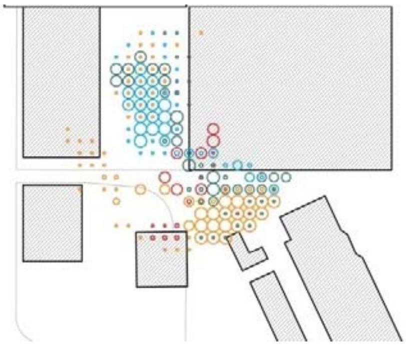


Fig.8. Diagram of top parameters

The formation process consisted of a sequential procedure which initiates by analyzing the designers desired project's composition. Then, the algorithm chooses the highest point of the highest present parameter to start search. Next, the script would analyze the neighbors of such point and assign the next point of the formation to the highest valued neighbor. The process continues as described until the amount of area needed for that parameter is fulfilled and then it continues the search with the next highest value parameter. The outcome of this process was a series of initial formations (Fig. 5) that would become the starting point for the agent based process, which would be described next.

Fig.5. Formations

Building upon the output of the group work, a second workshop given by Hyperbody's PhD researcher Jia-Rey Chang introduced the systems needed to start building our individual project simulation-based process. The main focus of this workshop consisted of: first, explore the possibilities of programmatic simulation in Processing[v], and second, how to expand that potential with the third-party libraries. Specially interest was given to Jose Sanchez's Plethora Project Library[vi] which already have built the basic code of a Swarm System and a Terrain creation methods (Fig. 6). The Plethora library would be an important step stone for my project, as the aforementioned methods were used as the starting ground of my simulations. After the basic understanding of these new computational tools were managed, the process of transforming this into architectural formations started.

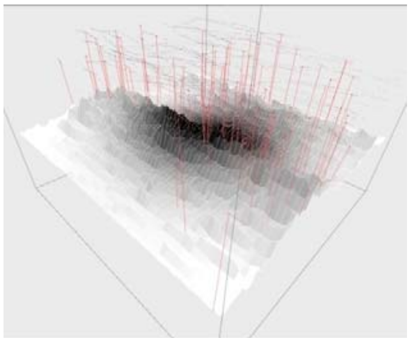


Fig.6 Generic Plethora Agents + Terrain

The basic setup consists of one surface, three agent systems (boids), and transformations paths. These three elements (Fig. 7) working together transform the surface to match the desired typology at the given time. The surface is a field, a field that reads the location of the boids passing through it and react according to the boid's embedded characteristics. The field would react in the following way. One agent would trigger the field, at the specific node it's hovering, to move downwards an X amount, while the second agent would pull the field upwards by Y amount. The third type of agent would reset the location of the field point to the original position. Also is important to note that the transformations occur not just by the behavior embedded into each type of agent, but also the quantity of said agents determines how much of change occurs. The value of this simple logic is that as you add several types of agents and guide them to activate specific nodes of the field, the system can simulate which part the project require transformation, how much do they change and the in-between states. A more detailed explanation of how these transformations paths work will be given later.

However it's imperative to detail the typologies by size, user capacity, shape requirement and entrances. This process was developed first by defining the spatial dimension for each specific function. As mentioned before, creative companies are currently settled in the surroundings of the site. The purpose of the project is to have a media-creation space which can hold TV studios, music concerts, opera, theater, sporting events or cinema within the same space. The first step was to catalog the typologies of these activities by size, in order to group them into three anchor spaces: L, M, S.

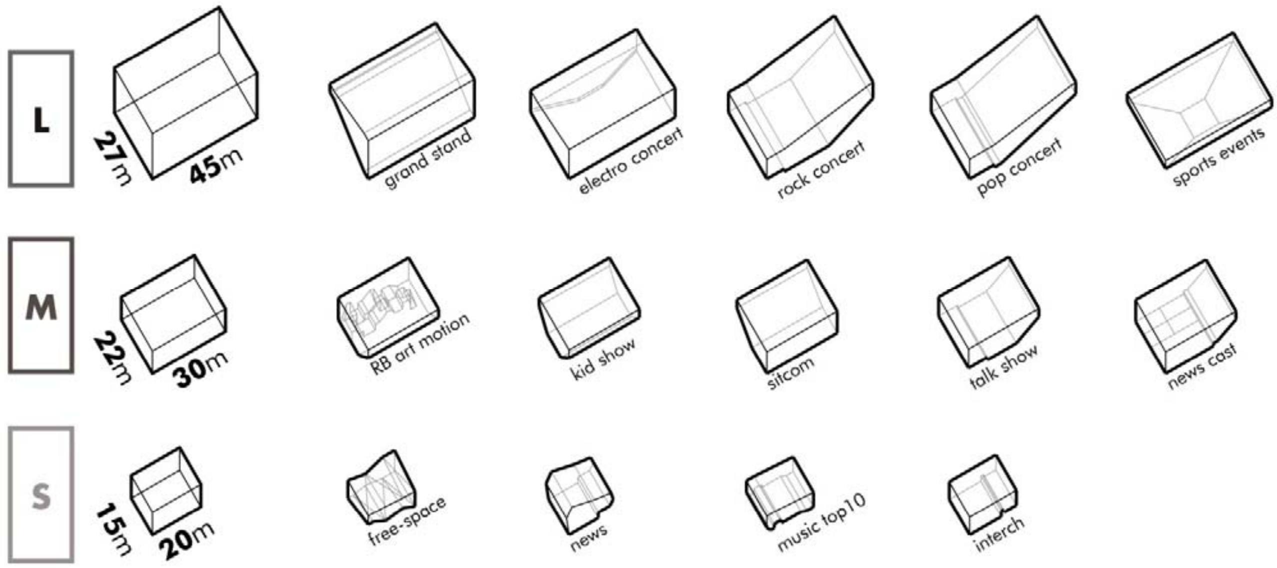
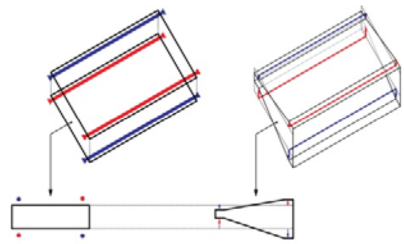
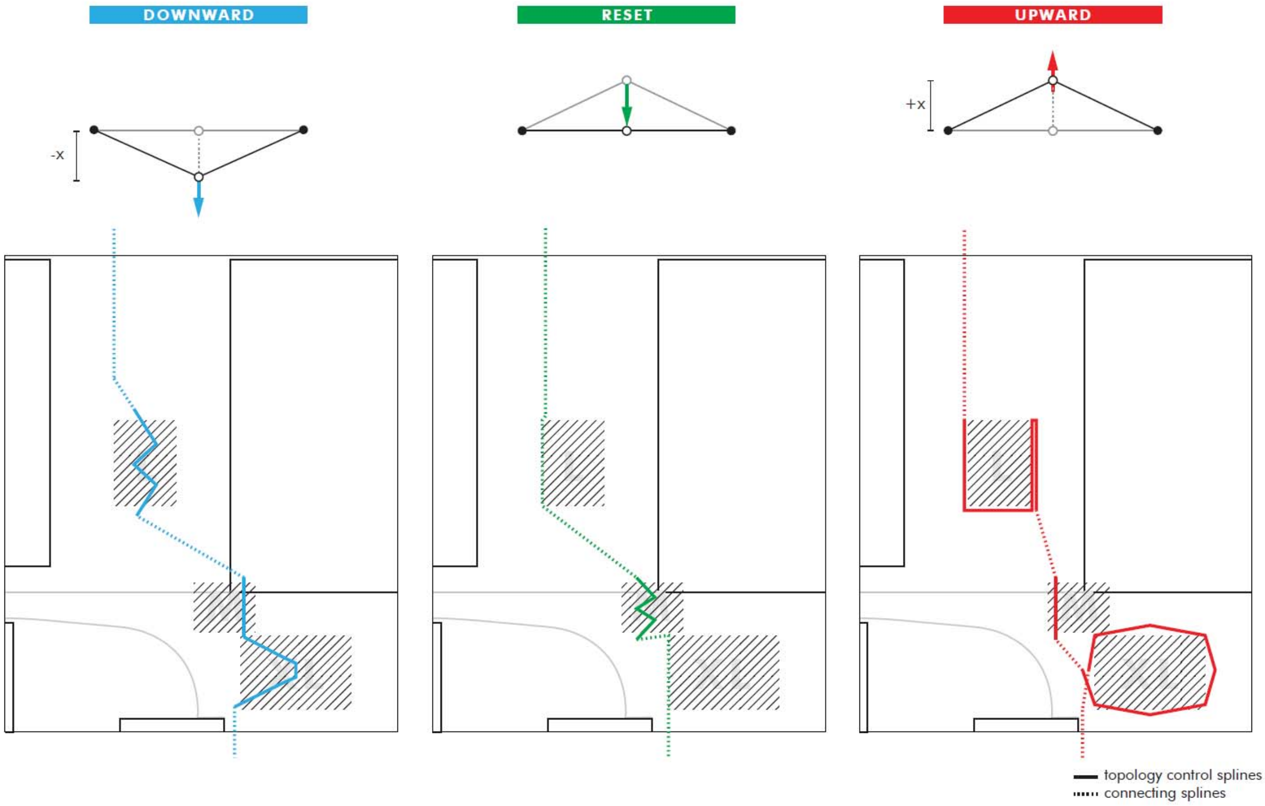


Fig.7. Spatial catalog.

Then, for each activity the typology drivers were created manually based on the transformations that each type of agent will have on the field (Fig. 8).

The next step consist in connecting the topological drivers currently active at each anchor space to create the topology drivers. An important step, as these will become the path which will guide the movement of the agent system between each local anchor space to the other. Foremost, it connects the interior spaces with the flow of users through the site. As the starting and ending point of these topology drivers connects the entrances of the surrounding buildings. Finally, the location of these anchor spaces was optimized the result of the initial location setup groupwork. By allocating each anchor space at the highest concentration of it correspoing value, with an additional contrain to avoid overlapping of a space with another. For example, the *Space L* will be located at the highest concentration of the parameter Dynamic Events as the activities (Sport Event, Auditorium, TV Set and Pop Concert) correspond directly with said parameter.





The setup of the morphological transformation process can be summarize in the following. First, a a field is developed that responds to a multi-agent system. Second, the topology drivers are created to guide the multi-agent system to the specific nodes that each agent action is required. Third, the array of activities are restricted within the dimensions of an anchor space in order to constrain the range of movement. Last, the location of said spaces are optimized by the result of the analysis stage. Therefore, the simulation is run to extract the several iterations (Fig. 10). Subsequently, the next step deals with evaluating the output in order to frame the range of the materialization stage.

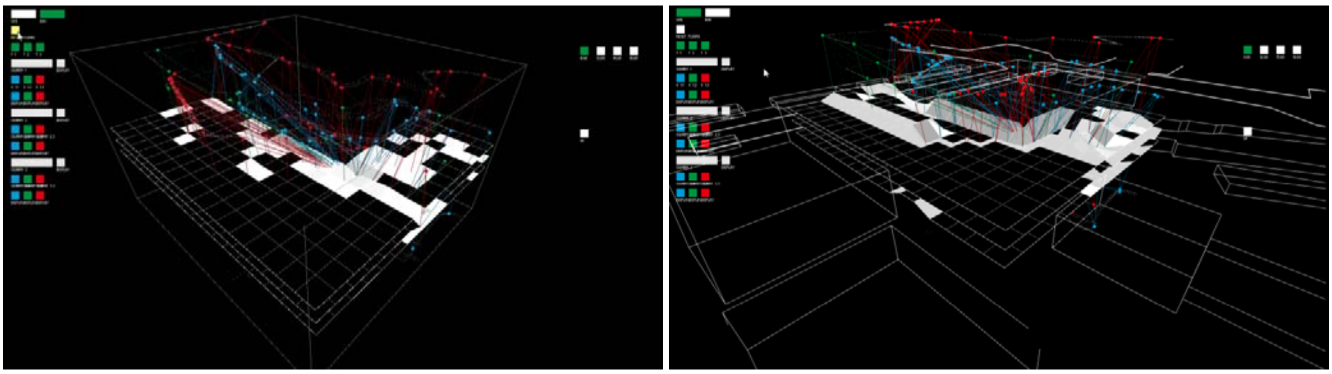


Fig.10 Morphology Transformation Tool

At the evaluation stage, the three main elements to be extracted were: the range of surface type (surface condition), vertical change (column height), and length of the elements connecting the field's nodes (beam length). A Grasshopper definition was created to , first, evaluate which elements change and which ones are static. Consequently, defining the areas of actuation and the areas which remain unchanged and therefore secondary functions can be allocated.

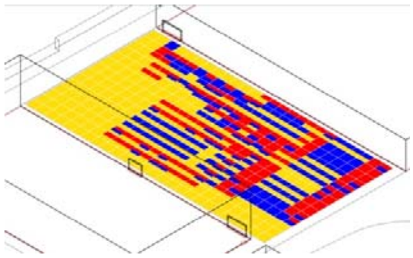


Fig.11. Surface Type Diagram

The surface condition was the first element to be evaluated from the simulation's output. Each surface of the field was evaluated and classified into three conditions (Fig. 11): flat (yellow), 1st degree curvature (blue), and 2nd degree curvature (red). This allowed to identify the different states that each surface undergoes through the different scenarios. This is a key step as the later stage in the project will develop a mechanism to satisfy the transformations that occur. The result of this evaluation showed that the main transformations could be classified into two: a seating area that turned into a deck, and circulation area that also created the enclosure of the activities. Furthermore, the beam (Fig. 12) and column (Fig. 13) analysis measured the amount of change that occur at each element of the field. Subsequently, defining the range of actuation of said elements.

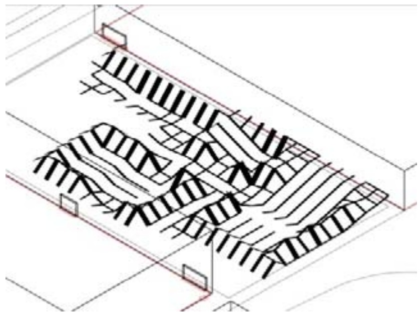


Fig.12. Beam Change Diagram

Although the aim of this research is to show a path in which the architecture can be designed to be transformable. To be actively flexible and change, mutate and adapt the uncertainty of future needs. However, also is important to show a path in which transformable design can be materialized. In order to start thinking and discussing on how these projects could be crystallized. Therefore, a great number of effort was taken into designing a mechanism that could allow this changes. As described in the initial part of this paper, the work of Chuck Hoberman and the research done by Daniel Rosenberg on scissor-pair systems presented an important inspiration. As these systems can cope with dimensions changes while remaining structurally consistent. Consequently, several experiments were done to, first, understand the mechanics of this system in order to develop the mechanism which can turn a flat deck into a seating area(Surface Type 1), and a component that could adapt to several double curvature surface conditions (Surface Type 2).

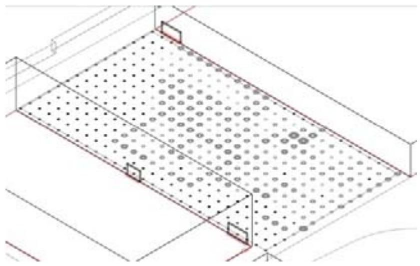
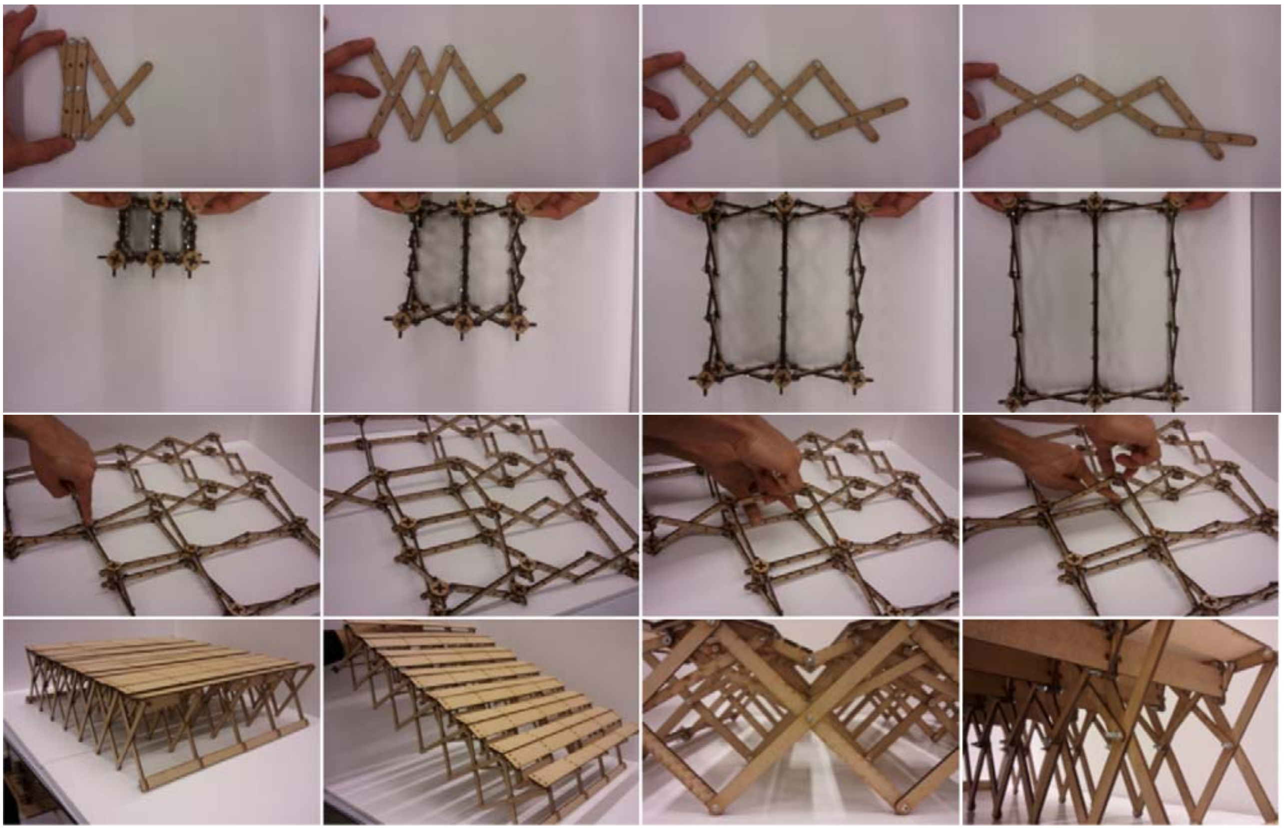


Fig.13. Column Change Diagram



As the mechanism was developed, spatial simplifications of the activities were develop. On one hand, in order to reduce the complexity so the research could be done within the timeframe set. However, great importance was given to the fact that the vertical transformations should be the only actuator and the rest of the transformations should unfold from it. At the end, on top of the scissor-pair beams, a second mechanism would constrain the movement of the seating planks in order for them to be always parallel to the ground. On the other hand, the materialization of the Type 2 surface was developed at a schematic level, by creating a system of sliding triangles which allow the change in distance to be absorbed. The interesting part of the component is that interesting openings occur. These openings could be later refined to respond to acoustic or illumination requirements too.

At last, the project came together by merging the materialization stage into the evaluated output of the simulation. As the corresponding component was assigned to its specific surface condition. Creating a building which can hold a sport event today, but tomorrow an Opera concert, actively transforming its morphology.

Although the project end result might be still at a schematic level, it clearly shows a path in which transformable architecture can be pursued. Throughout the project, the complexity of dealing with a transformable space clearly demands for a multi-disciplinary team of structural, mechanical and computational engineers working together with architects. However, I believe that this research project shows a successful result of how technology has evolved to allow an architecture student to tackle seriously into these projects

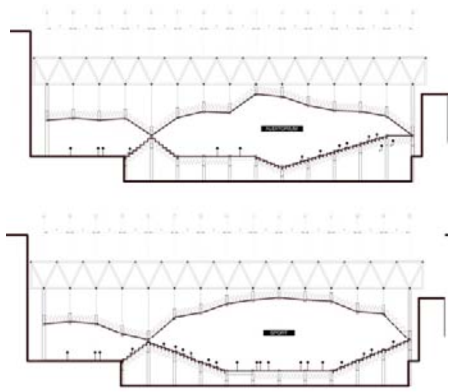


Fig.15. Section of Space L

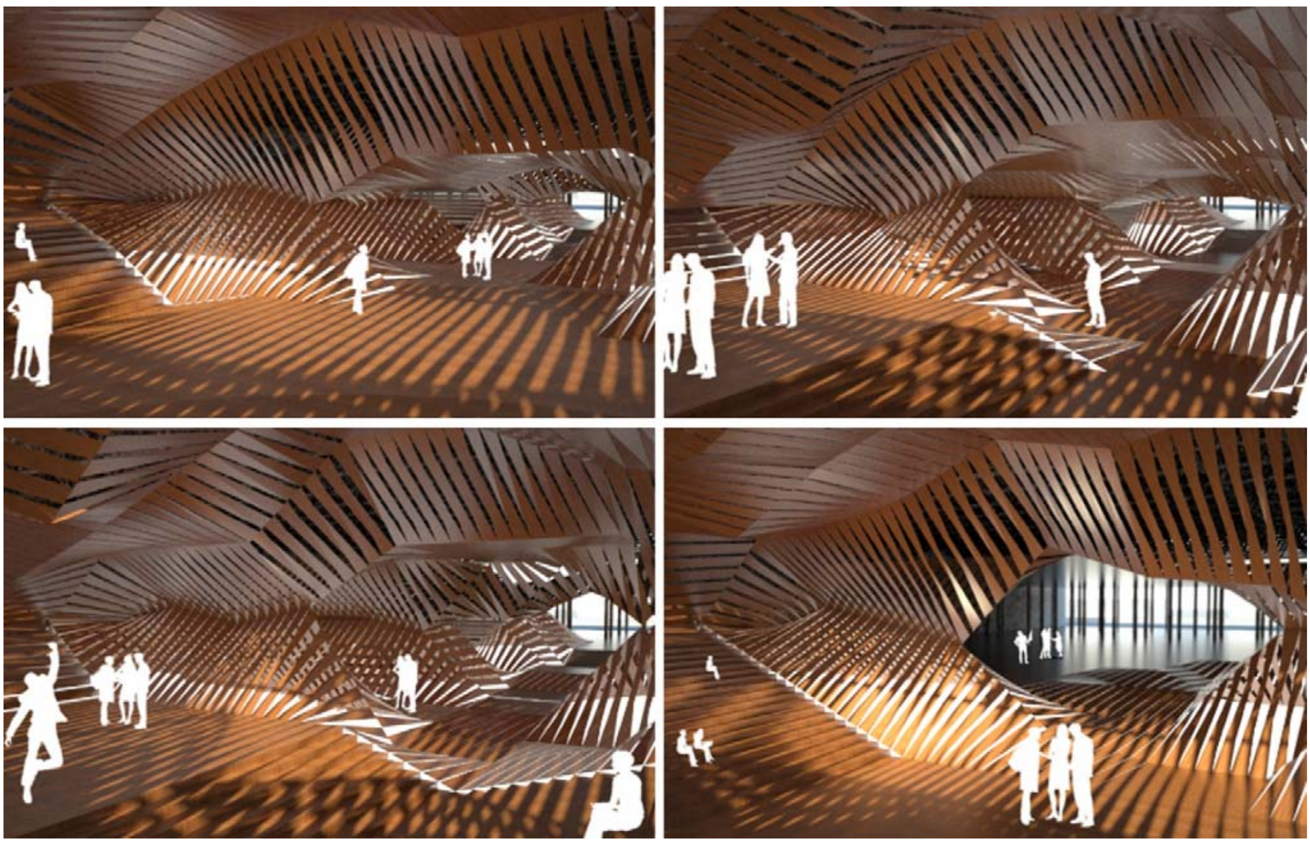


Fig.16. Visualization of transformations of Space L

REFERENCES

- Bier, H. Robotic Environments. Department of Architecture, Delft University of Technology, Delft. 2011
- Bier, H.; Knight, T. Footprint : Delft School of Design journal,# 6: Digitally-Driven Architecture. Delft, 2010
- Bullivant, L. Responsive Environments: Architecture, Art and Design. V&A Publications, London. 2006
- Fox, M. ; Kemp, M. Interactive Architecture. Princeton Architectural Press, New York. 2009
- Oosterhuis, K.; Xia, X.; Slootweg, O. Interactive Architecture # 3: Emotive Styling. Jap Sam Books. Delft, 2010
- +RAMTV. Negotiate My Boundary!. AA Publications, London. 2002.
- Schumacher, M;. Schaeffer, O.; Vogt, M. Move: Architecture in Motion -Dynamic Components and Elements. Birkhauser, Basel. 2010
- Allen, Stan. 'From object to field' in AD Profile 127 (Architecture after Geometry). Architectural Design, vol.67 no.5/6 May/June 1997 / p.24-31.

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[i] Nimish Biloria and Henriette Bier. *MSc3 Design Studio Brief* (Delft: Hyperbody, 2012), 1.

[ii] Stan Allen. *From Object to Field* (AD Profile 127: Architecture after Geometry, 1997) 29.

[iii] Stan Allen. *From Object to Field* (AD Profile 127: Architecture after Geometry, 1997) 29.

[iv] Grasshopper is an add-on graphic programming plug-for the 3D modeling software Rhinoceros, both developed by McNeel.

[v] Processing is a stand-alone program developed by Ben Fry and Casey Reas as a programming sketchbook for designers and artists. www.processing.org

[vi] If interested you can find more information about the Plethora Project at: www.plethora-project.com