Reflection

Matas Ubarevicius

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Author: Matas Ubarevicius; 4120825; de Vlouw 22, 2611EZ, Delft, The Netherlands; m.ubarevicius@gmail.com; 0622380164

Project Title: Complexity & Urban Agriculture

Case Study Location: New York City, East River Waterfront

Teachers: Nimish Biloria, Henriette Bier, Martin Sobota
Introduction to Research

The purpose of design studio was to create urban agricultural environment. Creating artificial ecosystem is a challenge like no other. To integrate agricultural and densely populated urban environments together demands knowledge in biology, city planning, engineering, computation and automation. These areas help understand and model various forms of parametric interactions between abstracted entities, which can lead to multiple layers of collective structure and organization. This project will thus formalize some basic ideas of complex systems theory in a field of non-standard and interactive architecture through modern object oriented programming, scripting and simulation methodologies. While specifically designing active urban agricultural environment with functions of food production, education, research and service, project will focus on adaptation to local energy and material resources, existing socio-economic and functional city fabric. The aim is to create scalable, symbiotically working architectural project, which effectively uses opportunities and resources, embedded in East River Waterfront area of New York City in order to supply the local community and site visitors with high quality food, agricultural education and enriching experience.

Research Question

How self-sustaining agricultural system can be implemented in dense urban environment by creating mutually beneficial parametric relationships?

Methodology, Approach and Research

Qualitative and quantitative analysis methods were employed when researching existing situation in East River Waterfront at New York City and when building a knowledge base on agricultural environments (biological aspects of plant growth, most important parameters that influence crop metabolism and photosynthesis, etc.). Technical aspects of greenhouses, their structural and architectural solutions, control and automation systems were investigated. Various computation and simulation techniques, like agent based modeling, conceptually related with complexity science were used to optimize and test the design concepts. Object oriented programming in C++ and parametric scripting in Rhino Grasshopper served as tools for creating a virtual architectural model.

The research question derives from the initial assumption that urban and agricultural environments are complex parametric systems, which in this project can be joined into one symbiotically working assembly. By following this thought, parametric map in the research phase was created to analyse how different parts of the building, which embed aquaponics system and additional functions can be integrated between each other in most efficient manner, being as close in between resource flow as possible. Figure 1 shows the mapped network with nodes representing functions of the planned building.
After mapping what sort of parametric relationships need to exist in the building I researched the site so that this network could be established in physical form. To do this I made various types of simulations in the existing site to know solar radiation levels, various wind and water flow aspects in the site. **Figures 2, 3, 4, 5 and 6** show these simulations and approach on how best locations were abstracted into computable highest speed wind/water pathways, etc. This data was further used in next round of agent based generative algorithms.

**Figure 2. Photosynthetically active radiation values in the environment**
Figure 3. Wind flow simulation in the East River Waterfront

Figure 4. Water flow simulation for two directions, as this is a tidal zone
Urban context in terms of functional and social surroundings was also analyzed and converted into attraction/repulsion locations for further simulations. Research on surroundings was mostly based by the currently implemented project in the East River Waterfront which is developed by NYC municipality. This project tries to rejuvenate the waterfront with new pedestrian and cyclist pathways, shopping malls, open markets (where my building would also distribute grown food) and many other functions. Some parts of the project were already implemented, some are still in the
planning stages. Figure 7 shows the urban functional context that is yet to be and towards which I also adapt my building. Figure also indicates where most people enter the site when going from subway and bus stations. These locations are also mapped into further agent based simulation as attraction/repulsion points for certain functions.

![Figure 7. Urban context analysis](image)

When all these research investigations were done and abstracted into geospatial information, it was imported into custom, agent based spring type generative simulation running physics engine to spatially optimize relational parametric network between different functions that I mapped in the beginning and which is shown in Figure 1. The custom simulation was written in C++, using openframeworks libraries and bullet physics engine. This simulation was a crucial step of research, joining analysis with first design intentions – generative formations. The idea was that this simulation can output various suggestions that I, as a designer can judge or analyse further in next step of simulations and pick the best one that I think has highest architectural potential. What simulation does is basically simple, but quite complex. It solves non-linear problem when trying to negotiate between various embedded locations that attract certain functions, while at the same time keeping distances between functions themselves relatively close. The whole network thus finally is forced to settle into a logical configuration. Simulation is generative, which means the user can make as many formations as he prefers and save the ones he thinks can be further developed into functional design. Figure 8 shows this simulation in action.
After making generative simulations 8 different formations were derived, best one was chosen by analysing both – parametric aspects and architectural opportunities. Having chosen the formation, methodology for embodiment strategy was created.

On practical level this project incorporated actor-network simulations and with those it reflects some of the Latour’s theoretical conceptions about architecture, but even more these simulations mirror what Nimish Biloria calls open systemic networks:

‘Conceptualising and appropriating architecture as an open systemic network provides the designer with opportunities to explore creative methods pertaining to dynamic data flows as well as real-time information processing in order to achieve an intelligent response from the designed entities. The future of architectural space is thus visualized as a transient, real time behavioural body...’

Project also embeds kinetic adaptation abilities, allowing some parts of the building to constantly adapt to changing environmental conditions, this resonates to some of Latour’s and Yaneva’s ideas about building on the move:

‘Rather than peacefully occupying a distinct analogical space, a building-on-the-move leaves behind the spaces labeled and conceptualized as enclosed, to navigate easily in open circuits. That is why as a gull-in-a-flight in a complex and multiverse argumentative space, a building appears to be composed of apertures and closures enabling, impeding and even changing the speed of the free-floating actors, data and resources, links and opinions, which are all in orbit, in a network, and never within static enclosures.’

This quote in a way sums up the theoretical challenge for a later embodied state of actual project that I developed.


Relationship between research and design

Relationship between research and design in this project is iterative. This can be explained with the following example. Information derived at each step of initial case study research was further abstracted into relevant geospatial information, translated into generative simulation, from where formations were derived. Solar and wind analysis on these formations helped establishing the formation, which best suits current design intent for greenhouses. Further research on this formation gave indications on which sort of topology best suits parametrically optimized infrastructural network. Figure 9 shows an example of how generative simulation result was further automatically translated into iso-surface configuration for automatic comparison analysis, shown in Figure 10.
When best formation was chosen, it was developed into architecturally meaningful embodiment based on different functional requirements for different functions. The whole shape of the building was made in such a way as to allow maximum exposure of the outer skin surfaces to the environment, so that the resource intake would be made as high as possible. These skins were developed around infrastructural and structural pathways, which have input and output functions for resources. These pathways also redistribute resources if function generates extra. This balances the whole system out. The maximal exposure of surfaces and developing skin around structural core also allowed to use those continuous surfaces as double skin facades, creating possibilities for natural ventilation throughout the building in various seasons. Greenhouse pods that are on water increase water speed underneath and have generators that produce electricity for the whole building. Because water current changes 2 times a day in the river (as the site is tidal estuary), these pods adapt to the current and through adapting generate large amounts of energy. This energy is used to pressurise the water flow which travels through double skin facades and is used for evaporative cooling. Figure 11 shows the overall design.
Figure 11. The whole building
Two approaches were used in the building. One strategy involved creation of optimized and scalable greenhouse pods and the other creation of discretized modules on continuous topology on the hub building, which joins the greenhouses with the city. This allowed the hub part to have looping and continuous spaces that formed around the infrastructural and structural core of the building and allowed the building to work as a whole when manipulating wind, distributing fresh air throughout the double skin façades and inner spaces. Hydroponic pods and aquariums with fish, on the other hand need to be treated in a different way, because the system must be much more flexible in time. Both technologies and circumstances may vary for the pods, when choosing how much and which variety of foods to grow. When this happens pods may need to be changed and reassembled. The building from continuous topology thus fragments itself into pods, creating rich volumetric expression which reflects functional differentiation of the project.

The relationship between the theme of the studio and the case study

As the theme of the studio was to develop urban agriculture, New York City was chosen to be a case study location for its rich environmental characteristics. The agricultural system, developed on the water could also be scaled up easily and applied in many different city environments. This is very efficient, as it was demonstrated through this project. For growing plants, there are large amounts of photosynthetically active radiation and additional energy/material resources on water. Majority of large cities are settled around water. This has a potential to be used as a growth bed for locally made food. Tapping into this potential could provide cities with food that does not need to be transported from far away locations and thus more sustainable.

Self-sustaining aquaponics system, which was developed in this project is built on water and has many opportunities to make use of water, wind and sun. When direction of the river flow changes, it pushes pods to rotate to another side, making huge force and a lot of energy. This principle was derived from discussions with building technology consultant Martin Sobota and was further evaluated with maritime engineer in TU Delft – Mirek Kaminski. Although more energy is actually produced by the generators, which sit underneath each pod, every opportunity to take additional resources should be used in buildings like these – bodies, which work symbiotically with their environment.

Other functions of this building are also related with urban agriculture, like food storage, processing, distribution spaces, others are needed for educational purposes like auditorium, open teaching kitchen, restaurant, where visitors can taste locally made food. The outer space of the building allows visitors to interact with the building, go on sunny terrace, enjoy the building, the views and the whole waterfront, see figure 12. The intention with the hub part was to develop an artificial landscape, where spaces intertwine and create looping connections, although still are attached to their infrastructural cores.
Figure 11. The terrace
From this perspective, it can be seen that the whole building was organized around this idea of symbiotically working complex systems (urban and agricultural). Because of that I believe the design answers the intent and theme of the studio.

**The relationship between the methodical line of approach of the studio and the method chosen by the student in this framework**

Hyperbody studio is developing high end methodologies in the fields of non-standard and interactive architecture. This project reflects on both of these fields. Non-standard approach is mostly evident in the way the functional aspects of the building relate to its spatial and formal expression. Discretized modules and aquaponic pods are each unique, serving its function requirements, collecting energy resources and taking the most of the environment. Interactivity is achieved when allowing building to adapt to changing water currents. This adaptation generates energy and spectacular architectural shift 2 times a day for visitors of the building.

**The relationship between the project and the wider social context**

The value of the project in a wider scientific and socio-cultural context should be evident not only by analysing finished design, but when understanding deeper methodological research and development aspects. Project tries to provide a practical example on how new computational methods can help shaping informed architecture. Such digitally enriched architecture provides the basis for future development and research in the fields of non-standard and interactive architecture. Experience gathered when integrally solving conceptual, technical, computational or structural problems provides additional value for the fields of Building Technology and Architectural Engineering.

It is important to say that the theme of urban agriculture is now discussed intensely throughout the world. From scientists, engineers and architects to governments and private capital companies. There are many ways in which cities can grow food and thus it is important to brainstorm out of the box solutions. After consultation with Mirek Kaminski it is obvious that this project, although not solved in terms of engineering to the last bit, offers very interesting way even for maritime engineers for agricultural buildings to be built in the future.

**How and why the approach did or did not work, and to what extent.**

To a great extent iterative bottom-up simulation-design process worked well in this project and although sometimes top down decisions had to be taken, even in these moments I was always informed by bottom up simulation results about the circumstances which force me to make these decisions. It is a rather difficult methodology, but rewarding one. In principle there should be larger teams of specialists who collaborate when designing and testing such urban agricultural environments. Although it was possible to use high end simulation and optimization techniques in this project, I believe this approach could be taken to a higher level by further collaborating with
scientists and engineers, which work in fields of agriculture, maritime engineering, building technology, robotics, etc.

Currently aquaponics systems mostly are built by enthusiasts and there are only few examples of larger scale investigations. Approach used in this project for aquaponics system which taps into natural resources available in densely populated NYC works well. It clearly illustrates where and why it is possible to create suitable environments for plants and people.
Figure 11. Bridges
References
