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Abstract

"*By 2050, demographers estimate there will be an additional 3 billion people [in the world].*"[1] With this steady rise in population comes the responsibility to feed them. Under current farming practices, "*extra landmass as large as Brazil would have to be cultivated to feed [these additional people]*"[1] In 2015 it is speculated that 26 cities will have a population of 10 million or more. A city of this size requires at minimum, 6000 tons of food per day.[2] As these cities grow larger, new ways to provide food must be implemented in order to maximize local production.

Providing local healthy food options creates sustainable cities and enhances local economies. In order to facilitate these self-sustaining cities individuals must augment their role within the food chain of their urban environments. City dwellers must become empowered producers rather than uniformed consumers. As producers, individuals and communities can create their own food. By doing so, they provide alternative access to healthy fresh sustenance, create and support local businesses and in turn, fosters sustainable urban neighborhoods and communities.

Urban Networked Aquaponics System (UNAS) is an open source, semi-autonomous networked eco-system; it leverages Aquaponics[3] to produce both edible fish and produce while outputting organic fertilizer. The project is a set of modular components used to create food production in unconventional urban environments. The eco-systems' components can be built at various scales in order to capitalize on a diverse landscape and maximize production in a limited space. The eco-system is operated via a network of sensors used to track the environment and provide users with an interface for understanding outcomes, maintenance and education.

Problem

1 Skyfarming, Chamberlain. http://nymag.com

2 Drescher et al., Urban Food Security, 2-3

3 Defined by The University of the Virgin Islands Agricultural Experiment Station as a recirculating system where nutrients, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes, are absorbed by plants cultured hydroponically (without soil).

Food Deserts are described by the 2008 Farm Bill as, an area in the United States with limited access to affordable nutritious food, particularly such an area composed of predominantly lower-income neighborhoods and communities. Looking at the United States Department of Agriculture's Food Desert Locator, *(Figure 1.a)* of the lower 48 states it is evident that there are many areas lacking access to nutritious food, at affordable prices.

"Solutions must grow from place," according to Sim Van der Ryn and Stuart Cowen.[4] It is therefore important to examine the issue of food security within the area that the research must take place. If we take a closer look at the data, we see that the United States Department of Agriculture (USDA) deems food deserts in the New York City to be non-existent (*Figure 1.b*).

According to the New York Daily News, the USDA's map claims only 26,000 New Yorkers live in a food desert: while city officials estimate 3 million people within the New York live in food deserts.[5] This highlights the fact that there within this problem there is not support from the National Government. Solutions for this issue will not come from the top-down and therefore must come from the bottom-up. In order to begin to solve these problems the local communities who are afflicted by the problem must participate in the solution.

Design Question

Recognizing that the problem of Food Deserts in New York City will not be solved by the USDA is important, however once that point is acknowledge the work truly begins. Asking individuals to participate in solutions is not always successful. It is vital how we approach this particular problem to clearly understand the needs of the communities being affected. In hopes of combating Food Deserts in America we must ask ourselves - what are the systems, methods and technologies that are needed in order to empower individuals and communities to become participants in local, healthy and sustainable food production?

Guiding Questions

Having completed an initial prototype of the project as a mini-thesis the semester prior to Thesis Studio 1, this course became an opportunity to step back deeply analyze the problem, and its potential solutions. Using Professor Scott Pobiner's pre-defined Modules as a framework for the examination, enabled further exploration of UNAS. A series of questions were raised based around each module in order to shape and determine the logical outcomes and adoptions of the project moving forward.

> *Social*
> What are people's perceptions about food? Do people know where their food comes from? How involved are people in their meals production? What are paths which meals take to get to individuals? Who will need to participate in order to augment

5 'Food desert' Status Denied to 3 million New Yorkers Without Grocery Stores, Lucadamo. *New York Daily News*. http://articles.nydailynews.com current food production? Who/What are the Stakeholders, Partners, Users and Sites needed to be involved with the project?

Conceptual
What are the roots of agriculture, and how do they relate to society? What is the link between culture and agriculture, where did this connect come from? What are historical instances of the use of agriculture? How have these instances shaped the landscape of society? How were the largest early civilizations/cities able to approach high output agriculture to support growing populations?

Technical
What are the technical hurdles associated with aquaponics, semi-autonomous systems and recirculating systems? Which techniques and methods are the most efficient for users to capitalize upon? How can we plan effective modular systems, at various scales?

Methodological
What are the methods others are using in approaching urban agriculture? Do the systems succeed or fail? What are the key learnings/take aways from these methods? How can these be implemented to benefit the project?

Evaluative
How do we evaluate the success of the project? How can we determine the scales of success? What are the key elements needed in order to evaluate the project? Are there levels of success?

Prototypes

Throughout the semester a series of prototypes were created in order to better understand the previously mentioned modules. In each module prototypes or research was initiated and led the way to fully understand an agricultural solution. In addition to module prototypes and research, was a set of exploratory prototypes in the creation of hardware elements to foster a productive eco-system.

Social
Starting with this module it was important to quickly acknowledge the path of people's meals, as well as their perceptions about where this food came from. In doing this, a direction was fostered, and a greater outline of participants was acknowledged.

An initial user chart was created to understand who might be involved with the process (*Figure 2.a*). With this information a simple prototype was executed on fellow graduate students. The purpose was to understand their perceptions of the ‘food chain’ and how their recent meals fit into it.

Students were given a stack of cards with images of organizations and locations from the list (*Figure 2.a*). Participants were asked to arrange the cards according to their last meal eaten, to gauge their understanding the path that meal took to get to them. While admittedly a very menial prototype, it served a unique purpose in facilitating the creative process and brainstorming the social scenarios. One common thread, the use of stores/markets lead to an analysis of the network we purchase food from, and how we, as consumers can potentially offset and supplement said network, as producers.

In the end, a more robust participant outline was created (*Figure 2.b*) as well as an understanding of the social connections that happen around food. The examination of this prototype then fostered research into neighborhoods and food culture in New York, and led to the acknowledgement and integration of the Food Desert as an agricultural issue. A document was created to show the juxtaposition of what communities as consumers versus producers would look like, and how small New York shops could integrate into this model (*Figure 2.c)*.

Conceptual

In order to examine the conceptual nature of the project a research prototype was created as a way to understand agricultures role and benefits throughout societies. Five different scenarios throughout history were examined for their unique contributions related to agriculture and its way of creating, facilitating, or empowering a community of people.

A document was created outlining the advancements. For each item, the Mechanism, Means, Method, Task and Benefit were recorded and began to shape the key areas in which the project would need to be grounded (*Figure 3.a*).

In the end this prototype leads to the understanding of three main conceptual areas, in which the project must focus as an agricultural advancement. These three areas - the Aesthetic, the Cultural and the Technological emerged to showcase a balanced focus for the work. The Aesthetic is the opportunity to create beautiful spaces within with agricultural techniques, as seen in the Gardens of Babylon. The Cultural, is prevalent in each section (*Figure 3.b*). It is highlighted in the need for people to be involved through labor, distribution and planning. Last is the Technical; in this sphere there was a realization that the dual production of Aztec Chinampas is actually a technical advancement. This distinction lead to the integration of the modern dual production method of aquaponics.

These findings helped to conceptually frame the projects major needs in order to design an agricultural advancement, similar to five key adaptations outlined (*Figure 3.a*). The results also helped to identify areas of further growth specifically as related to the technical requirements of the project, which became the next section of focus.

Technical

Entering the technical module the project had a framing from the conceptual examination. The result was that the solution was to create a dual producing, integrated environment, with cultural support. The technical module provided the opportunity to understand how these 'concepts' could be implemented into working solutions.

In order to approach this module in digestible manner, the technical module was divided into three key areas to examine, Scalability, Modularity and Affordability. Scalability became apparent for users to be able to manage a system of any size using the tools provided. Whatever the implementation a user needs the same system of control over this technology to manage it. Modularity arose as a need for individuals and communities to implement things within their unique spaces. Finally, Affordability was identified need for individuals to be able to be able to build and pay for these systems, without extravagant costs. All of these areas were identified through the previous module examinations, the social and conceptual.

In the hope to create a scalable and manageable system a series of sensors and controls (*Figure 4.a*) were proposed to support users in their aquaculture endeavor. According to the F1-Recirculating System by Family Farms, this type of aquaponics unit is capable of producing a pound of fish and a pound of fresh vegetables for each gallon of clean water used. This proved the promise of dual farming as a key method for solving the problems of Food Deserts. It provides the ability to grow both fresh vegetables and healthy proteins, creating a well rounded meal. In order to justify the use of sensors and their needs, a document was created outlining their role within the proposed system (*Figure 4.b*).

The items within the scalable section fostered the ability for these systems to become modular, due to their connection to the internet as a data means. Once networked these gardens possess the ability to then become hubs for one farmer to visit as needed. A system of alerts and real time information to users micromanages the focus making system maintenance to be theoretically easier. If the sensor network can provide that for users, than an individual or community can capitalize on a variety of locations for their garden in a close region (*Figure 4.c*) as a way to stagger crop harvests and take advantage of limited urban spaces.

The last aspect of the technical module is the element of affordability. This became its own section of the prototypes, seen in Filtration as its prototypes spanned the majority of the courses time period and provided a great deal of growth and learning. A variety of experiments in the components needed to build cost effective aquaponics ecosystems for production were conducted. This technical examination found that there are ways which filtration and water flow can be built without the need to purchase expensive patented solutions. In designing affordable components, users have greater accessibility for adoption of the system as well as a greater benefit in the ratio of costs to production.

Methodological

The methodological module provided the opportunity to examine successful projects, in order to understand the methodologies they implemented. During this time period a variety of precedent projects were researched. Three projects were highlighted as key precedents to UNAS. The rationale for their role as a precedent was articulated and then each project was examined by a framework, in order to best understand its approach and results.

Each precedent was outlined by its Approach, Medium, Planning and Result. The three projects analyzed were Fritz Haeg's Edible Estates, Britta Riley's Window Farms, and Ken Rinaldo and Amy Youngs', Farm Fountain. These projects showcased themselves as the most relevant to UNAS, and their successes, warranted further analysis (*Figure 5.a*). In the end, this task facilitated a keen understanding of the competition's strengths and weaknesses, as well as avenues for adoption and an outline of what makes successful projects in Urban Agriculture.

The exercise highlighted the need for community involvement, through the methodology of both Edible Estates and Window Farms, and their success being related directly to fostering communities of people. Farm Fountains inability to foster a community highlighted a disconnect and a potential area of growth for them. Overall the methods for success were noted and are key to set the methodology for which UNAS must observe. At the same time this analysis facilitated the projects analysis into the Evaluative Module.

Filtration

This section serves to acknowledge the filtration specific needs of this project. Specifically it is important to note the integral needs to develop filtration for small scale aquaculture, using only accessible inexpensive materials as highlighted by the affordable section of the Technical Module.

The initial prototype(v00.0) was created based off the fore mentioned mini-thesis project from the semester prior, Spring 2011(*Figure 6.a)*. This prototype, a 10 gallon tank with a plant filter, used a method of aquaponics known as an ebb and flow[6] system. Re-entering a new semester, it became apparent through research that the larger an aquaculture system, the more stable and dependable it becomes - this is common knowledge in the fish rearing and aquaculture communities. Additionally the first prototype had shown a need for more water clarification, filtration, and oxygenation in order to provide a healthy aquatic environment for fish. A more technically enhanced prototype(v00.1) of the initial ebb and flow system created was proposed to cycle watering and create constant flow of water for aquatic life (*Figure 6.b*). In order to execute the prototype two pieces of hardware needed to be created, a control using solenoids to regulate flow to location, and a sump/filter (*Figure 6.c & 6.d)*. This filter used a bio filter[7], of sponges along with a substrate filter of rocks. , and Additionally the stand (*Figure 6.b*) was created to house the unit. (Note: The evaluation of this prototype will be addressed within the evaluative section below.)

The next prototype(v00.2) focuses on a realization that alternative technical solutions to cleaning and flowing water can also be solved within the scientific methods of Aquaculture. Rather than continuing to pursue a means of continuous water, flow through added electricity and programmed intelligence devised and implemented, proved to be an alternative solution to the ebb and flow model (*Figure 6.e)*. In order execute this model a new type of filtration was required. Including a new functional requirement known as a Clarifier[8] (*Figure 6.f)*. Finally in addition to this system, other elements were added to the growing environment for the plants, including a vertical grow bed[9] and a raft bed[10] (*Figure 6.g)*.

In the end the filter examinations provided a means to understand control of the science behind aquaponics. Rather than continually focus on technology as a digital or electronic based result, it is important to stay highly aware the technology can also take the form of scientific methods. In this case the prospective avenues shows promise to lower energy costs and provide increased nutrient absorption.

Evaluative

Approaching the Evaluative last allowed for reflection upon the entire semester, as well as an analysis of the work completed to date. This facilitated reflection upon the all the previous modules, including the filtration specific module. Additionally this section allowed for the integration of design principles as a guiding structure to gauge success, and evaluation of the project. Finally this section fostered the

6 A system where the plant grow-bed fills with water, until it reaches a cut off point of a syphon. Once the syphon is engaged all the water is pulled out of the grow bed. This cycle runs multiple times an hour.

establishment of a system for every eco-system built, to begin to understand their differences, strengths and weaknesses with acknowledgement to the projects evaluative framework. Past prototypes were then assessed within this evaluation guide, as a means to determine success and future direction.

Using the module framework provided within Professor Scott Pobiner's Thesis Studio proved quite useful. The constraints gave guidance to the process and in turn helped to provide direction and clarity. Approaching the evaluation of the work completed during the Fall Thesis Section, it became important to find other frameworks to support the project. Realizing that the projects main goals were to support sustainable economies and communities, it became evident that the Five Principles of Ecological Design written by Sim Van der Ryn and Stuart Cowen[11] would provide strong framing for the examination and its potential success.

The Principles of Ecological Design are outlined as follows:

1. Solutions grow from place
2. Ecological accounting informs design
3. Design with nature
4. Everyone is a designer
5. Make nature visible

Any prototypes or projects attempting to solve the Food Desert problem within New York, must fit within this framework to be deemed successful. Acknowledging this an evaluative system was created to analyze past and future prototypes. The system utilizes two overarching classifications for the evaluation of prototypes. The first area is the environment a constructed system lives in; thinking of the Ecological Design Principle 2 - *we must be aware of the environment we design within and its effects*. Each system must perform in unique areas, and accounting for fish and plant species correlates directly to these factors. The environment of the system is then analyzed by three sections, the micro, macro and social. The second area for evaluation is the prototype domains; it is important to recognize that there are a variety of domains merging within this project. By stating the purpose and use of each domain for each prototype it is clear to see what is overlapping, and then make distinctions as to what is successful and unsuccessful(*Figure 7.a*).

7 The area within a aquatic ecosystem where good bacteria grows. This bacteria feeds on harmful ammonia, created via fish waste, and created nitrites and nitrates, or plant food. This byproduct is then safely removed from the system by fertilizing the plants.

8 A piece of hardware which intakes water from a fish tank, the water is forced downward gently. The liquid is then forced to slowly rise in order to exit the device. During this process solids are settled out from the water, removing suspended solids, which cloud the water.

9 A hydroponic technique of growing plants vertically to save space. The plants are provided nutrient rich water to their roots, while in a soilless substrate container suspended in air.

10 A hydroponic technique where a plants roots sit directly in nutrient rich water that provides the roots nutrient rich water, using this method water must be extremely clean, continually moving and have a high oxygen content in order to maximize root intake and minimize root rot.

Looking at the document it is easy to see that the environment for each prototype is currently unchanging. This is due to the fact that new space has yet to be allocated, until now. This will be re-discussed within the Next Steps section. The prototype v00.0(*Figure 6.a*) failed in a few contexts, when examining the chart. Initially, the prototype lacked social interaction, a processing sketch without any outside access to data. In addition the placement of the system did not provide the appropriate amount of lights, which in turn limited growth and output. Prototype v00.1(*Figure 6.b*) also had a variety of failures which are important to point out. In this prototype organizational flaws and a push for the use of technology cause a drastic and dangerous prototype. Leaking water caught above solenoids prompted circuit malfunction. The prototype was eventually scrapped for an alternative direction in which filtration hardware could replace electrical hardware.

Prototype v00.2 (*Figure 6.g)* is a work in progress, while a new attempt at clarifiers is being rectified the system is running without it. A sudden drop in temperatures recently frosted an infant crop, rendering the plants dead. In evaluation of Prototype v00.2 the opportunity to analyze work in progress as well as self-evaluating the tool itself comes to light. While mapping out the projects (*Figure 7.a*) the chart visualizes the additions to prototypes. With v00.2 we can see how the micro environment of this current set-up is unstable. Potentially related to the time of year, however an important item to note for future progress. Additionally with this version an attempt to push an open data visualization as a means of providing data feedback to users is underway. This illustrates how the document for evaluation becomes a tool to facilitate project growth. Note the two prototypes with sub-par results, by illustrating the pattern a change in prototyping can be made. In doing so, progress can be captured in the lineage of the prototyping process. Additionally new features include hardware elements and features. The current clarifier and vertical filters in this space have been providing leaks, which may indicate that a shift back to an ebb and flow basin for this space may be necessary, due to the space constraints. Two small low powered LED grow lights have just been donated to the project, and will currently be under testing to sprout new crops, and then supplement the natural light for the budding ecosystem.

The evaluation document serves to showcase glaring flaws and potential directions for prototypes. As future prototypes are built they will be designed using successful elements while avoiding past pitfalls. This also provides opportunity for reflection and analysis in illustrating the components and advancements of the prototypes. Categorizing the sections serves as a checklist for each sequential examination for a greater understanding of choices, decisions and outcomes is fostered, as well as a concise metric for evaluation.

11 Edwards, Andres R. 2006. *The Sustainability Revolution: Portrait of a Paradigm Shift*. Philadelphia, Pa: New Society. 103-104

In closing, the prototyping which occurred Fall 2011 in Thesis Studio 1 proved quite fruitful. Although there were not a great deal of successes, the failures that happened created strong learning points and fostered ecological advancements on the road to synthesizing the solution. The Modules provided a strong initial framework to explore the design question, and in turn, create and execute the prototypes to shed light on questions proposed. After completing the modules a more clear vision of the project and its proposal emerges.

Proposal

In acknowledging the Social, Conceptual, Technical, Methodological and Evaluative portions of the aforementioned Design and Guiding Questions. There seems to be a potential solution to provide users better access to fresh affordable foods. In recognizing the research within the User Module of the Prototyping section an augmented consumer versus. producer model drastically changes the relationship to stores and markets within a neighborhood. With this model in mind it is apparent that methods for individual and community research, exploration and engagement within self-perpetuating, sustainable eco-systems must be designed as a foundation to empower neighborhoods to cultivate healthy self-sufficient local economies.

In order to actualize this solution, three key elements must be met: 1. Users must be provided with the ability to create and manage their own productive eco-systems via an interface to support users through data feedback; 2. Aesthetic solutions must be designed in order to effectively integrate eco-systems into everyday spaces, as a means for promotion, awareness and adoption; 3. Facilitated user implementations must be at scales which can be supported by resources available to participants, as well as ensure a viable cost to produce ratio. Each of these will be addressed to better understand the proposals rationale.

1. **Users must be provided with the ability to create and manage their own productive eco-systems via an interface to support users through data feedback.**

It is important to recognize that users need support and education in this emerging field. Instant results are crucial to fending off disaster, and ensuring healthy eco-systems.

> *"If knowledge from a distance is the goal of telerobotic devices, then epistemic immediacy should be the goal of interface design. This may be achieved by interfaces that allow the user to 'cope skillfully' in the remote environment - to interact instinctively and unreflectively with distant objects, rather than treating them as theoretical entities to be inferred from evidence on a video screen."* [12]

A robust and in-depth interface must be created to facilitate user engagement and the transfer of knowledge from this telerobotic device and its inquirer. In order to facilitate the most effective transfer of data a mapping of important data collection and dissemination points were outlined in a systems information diagram (*Figures 4.a & 4.b*). The way that the data will be delivered to the system gardener is outlined in a flow chart (*Figure 8.a*) describing what content will connect the various system messages, in an attempt to create a fluid interface between the user and eco-system.

2. Aesthetic solutions must be designed in order to effectively integrate eco-system into everyday spaces, as a means for promotion, awareness and adoption.

In order to promote the integration of these systems they must fluidly exist within our current environments. Be it rooftops, small apartments, backyards or any other unique location, these systems must seamlessly meld with their micro environment to adapt to the expectations of gardeners or onlookers. The aesthetic design of such a system is just as important as the eco-system and interactive design of the entity.

3. Facilitated user implementations must be at scales which can be supported by resources available to participants, as well as ensure a viable cost to produce ratio.

The data made apparent within the Abstract and Problem Identification sections of this paper, tells us that the world is growing more crowded and that current farming practices will not be enough to maintain our consumption. Additionally, within the United States, food deserts are prevalent throughout continental states. It is evident that the social economic landscape and physical climate are quite different across the nation. However, while prototyping and designing solutions, it is important to acknowledge the necessity of various scales. The principles of Ecological Design tell us that solutions come from place, and in using this framework it is important to focus current prototypes within the New York environment. With that understanding this solution must still recognize its potential to be transferable to other regions.

The purpose of this proposal is to outline how to create fluid and effective integration and communication between production eco-systems and the caretakers who must be aware of its current status. Checking that the three key elements of the proposal are met reaffirms that the methods, for individual and community research, exploration and engagement as related to high production agricultural systems remains open, affordable and adoptable. By maintaining these practices under open-source guidelines, users have the opportunity to participate without enormous overhead. Lowering the entry requirements positions the platform in a way that individuals and communities can easily begin to experiment, learn and adopt these previously foreign technological advancements.

12 .Goldberg, Ken. 2000. *The robot in the garden: telerobotics and telepistemology in the age of the Internet*. Cambridge, Mass: MIT Press pp. 19

Next Steps

- Finish and implement data sensor network
- Present - January 2012
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- Update and Fix Verticle Filter and other aspects of prototype v00.2
- Present - January 2012
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- Continue to talk with Hack Manhattan, and Harlem Community Garden
- Present - May 2012
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- Develop prototype v00.3 deployment in MFAdt 12th fl lab, with funding from AMT
- January - February 2012
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- Develop prototype v00.4 deployment outdoor backyard space, with funding from User
- February - May 2012
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- Document steps for successful hardware implementations, begin compiling instructions
- Present - May 2012

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Appendix

1. Journal Entries
2. IRB Submission(To Be Submitted)
3. AGRINDUSTRIAL DESIGN 2012 Extended Abstract