Urban Integration of Plants and Technology

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A thesis exhibition presented to
OCAD University
in partial fulfillment of the requirements
for the degree of
Master of Fine Arts
in
Digital Futures
49 McCaul street,
Toronto, Ontario, Canada,
April, 2014

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Urban Integration of Plants and Technology
2014 Ontario College of Art and Design University
Digital Futures. Master of Fine Arts

Abstract

How can we use technology to help integrate plants within our urban environments?

This thesis investigates the process of integrating plants seamlessly into our modern urban code/space(Kitchin & Dodge, 2007). Firstly, I explore how humans interact with our own physical space and how this correlates to our digital space. These factors set the groundwork for an exploration of the possibilities of integrating additional entities currently perceived as external to our urban landscape, such as plants, into the posthuman future imagined by Katherine Hayles(1999) and Donna Haraway (1991). By viewing plant intelligence as data, we can begin to draw parallels between the behaviour of our existing technology and plant behaviour. The examination of plant consciousness as vastly different from our own outlines the difficulties in this data exchange. However, by analyzing the similarities that already exist between plants and current technology, we can see how an exchange is already occurring in our code/space. Our coevolutionary past helps contextualize this integration, and facilitates the exploration of past human/plant information transfer. My exhibit explores the mimesis (Adorno, 1997) of technology to plants' reactive intelligence. This illustrates humanity's influence on plants, and the unused space in our urban environment they could inhabit. This paper and accompanying exhibit proposes a future where plants and technology coexist, where our coevolutionary pattern continues as an integral part of a proposed posthuman future.

Acknowledgements

I would to thank my advisors Simone Jones and Judith Doyle at OCAD University for their dedication and support, as well as Tom Barker, Nick Puckett, and Emma Westecott. I would like to thank Hilary Predko, Lauren Archer, Alex Leitch, Erin Rodgers, Seth Hardy, Brett Hagman, and my other loving friends at Site 3 for helping solder, code, and talk my way out of problems along the way. Great thanks to my DFI Support Team, Ruzette Tanyag, Mitzi Martinez, Andrew Forbes, Maz Ghaderi, Dushan Milic, and Umar Amanullah. Additionally, my home and remote support from Glenn Mills, Raph T-M, Gaby Harvey, Tyler Campbell, Cynthia Piskopos-Hébert, my parents and family.

So, I can just write anything here and you'll publish it?
Dedicated to infinite possibilities.

Index:

List of Figures

Part 1: Context

Introduction - Integration

Katherine Hayles (1999) imagines a posthuman future where information transfer between human and machine is seamless. Through this lens, I explore a future where plants can take part in this single system of data sharing. This requires plants to be integrated architecturally as well as digitally within an environment that has been deliberately calibrated for our needs as humans, and not those of plants. As we continue to expand our urban spaces, we must accommodate the needs of plants within the city. Our decreased daily interactions with plants has built a gap between us.

By analyzing how we have coevolved throughout history, and understanding how we situate plants within our existing space, I hope to provide some insight into how we can relate to plants within our code/space (Kitchin & Dodge, 2007). How can we integrate plants within our technological, and architectural structures? Parallels between plant intelligence and our existing digital landscape provide a framework for fluid data transfer, communication and integration of plants and humans. As we

Fig 1: Plants and technology

move into a posthumanist future, technology and plants may be used as a prosthetic to enhance our environment and maintain the coevolutionary dependance created between humans and plants.

Relating To Our Space

Understanding how we relate to our urban environment is a key component to designing an effective method of plant/human communication. Although physical dependence on plants is a direct result of a coevolutionary relationship (Jackson, 1996), there is little room for plants to exist within our urban setting without being strictly controlled by both social/cultural preferences and physical limitations due to urban architecture.

I would like to explore how we relate to our own space, in order to propose an idea of how to consciously incorporate other entities. Casey begins this discussion of integration in “Between Geography and Philosophy: What Does it Mean to be in the Place-World?. Casey contests Locke`s (1689) theory that the self and place are separate, suggesting there are many things that tie our notion of self to the places we inhabit. The objects within our spaces tie the self and place together. The tools that belong to a worker are an example of this:

> “Places are intimately interlinked in the world of concrete work. not only are tools “instruments that have functional purpose of their own … … but they create work or products that allude to the person who makes use of them.” (Casey, 2001)

Objects help situate us within our space, and link us to the habits we form within them. Plants have held this function in our lives for thousands of years.(Jackson, 1996) Beyond food and medicine, plants enrich our environment and tie us to the places we are in. From letting early humans know which areas might lead to water, to the use of domestic greenery in offices to decrease depression (Lohr, 1996), plants have played an important role in enriching the spaces we live in. “[objects help] us to grasp the particular place we are in the particular person that we are objects and things help places feel lived [..] rigger and substance that thickly lived places” (Casey, 2001) Casey explains that objects help link us to places we inhabit. Objects accumulate in spaces we are often in, which he calls “thickly lived places”. These objects reference the activities and connection we have to this space.

Plants in our urban spaces serve as objects to link us to our places, and as curated elements of our environment, no longer hold their coevolutionary natural properties. Plants in our environment are deliberately chosen and placed in spaces that are convenient for our needs, and not necessarily for those of the plant. For example, (Lohr, 1996) plants in office spaces have been proven to make workers happier. These plants are selected for this explicit purpose, and placed strategically within the working environment to accomplish this goal. We do not allow them to behave naturally, and have decontextualized them from an environment where they can comfortably acquire what they need within, however they are confined to the physical locations we have placed them in. Outside the urban landscape, plants can expand their roots to search for what they need, and through the cycle of nature their seeds get spread to the surrounding area where they may have a better chance at life. Within our city, plants are forced into very specific areas, be it within pots or garden plots. Unwanted plants are often removed from the environment. Because of this, plants rely heavily on us to provide for them, everything from water, to sunlight, to adequate physical space to grow. In this way, plants have become dependant on us to survive, and must abide by the conditions we set upon them.

Heidegger's (1971) concept of how we construct our urban environments centres around how we form a connection to the spaces we inhabit. He suggests we construct spaces that allow us to identify with the function of that physical location beyond a purely utilitarian perspective. It is the essence and our relation to the spaces we dwell within that make them meaningful. In order to establish a meaningful relation to a space, and thus truly inhabit it, Heidegger suggests this can be done through forming habits and routines within these spaces, allowing us to form a connection beyond the physical. Forming habits and relationships with a space allow us to truly inhabit it.

> "Yet space is not something that faces man. It is neither an external object or an inner experience. It is not that there are men, and over and above them space. [...]if all of us now think from where we are right here, of the bridge in Heidelberg, this thinking towards that location is not a mere experience inside the persons present here; rather, it belongs to the nature of our thinking of that bridge that in itself thinking gets through, persists through, the distance to that location. From this spot here, we are there at the bridge, we are by no means are some representational content in our consciousness. From right here we may even be much nearer to that bridge and to what it makes room for than someone who uses it daily as an indifferent river crossing. " - Heidegger, 1971

Forming relationships and bonds with our space can be facilitated by exploring the pre-existing by-products of our coevolutionary experience with plants. By allowing plants to exist in a natural state that does not co-depend on us, rather co-exist, we can utilize the relationships that have been forged through thousands of years of coevolution. Rethinking our physical space to allow for a more natural integration of plants can have benefits that range from air purification, to food, to creating deeper bonds with the physical spaces we inhabit within our city.

Our Digital Environment

We are surrounded by technology that gives the spaces we live in a necessary layer of functionality. Kitchin and Dodge (2011) describe this layer over our environment as Code/Space. Our city can be viewed as a code space. Without the technology that enhances our environment, the space would cease to exist with the same functionality we have come to expect. We are dependant on code, and it is thickly woven within our physical space.

Although plants exist physically within our world, they are unable to use our urban environment in the same ways we can. Down to the physical architecture of our city, this space is designed to accommodate the layer of software and technology we have access to. The fabric of our social interactions is dependant on the use of software. Daily interpersonal communication revolves largely around notifications, text messages, phone calls or other digitally assisted communication. Our social structure is set up so that the majority of our communication does not need to take place face to face, and can occur in our own time, in our own space. One can choose to check messages or take a call when it is convenient. Of course there are still conventional conversations, however the context interactions are influenced by our code/space. The information we choose to share is impacted by the fact that we can choose to “email the details”, or “set a reminder”, in this way “our relation to physical and virtual space can overlap and influence each other” (Casey, 2001).

These crucial interactions are driven by layers of software that are based on logical and binary operators. Plants share similar on a very basic level. As discussed later, reactive intelligence and binary indicators drive plant behaviours. It has taken years for the majority of the urban population to be comfortable using technology for daily life, both as a result of cultural acceptance and need for an intuitive interface. These binary decisions are not displayed blatantly, but are masked by layers of user experience and design concepts. My exhibit examines this basic layer of similarities between plants and technology. There is no layer of veiled user experience, simply technology responding to basic stimuli as plants do. This serves as a departure point for integrating plants into our code/space.

There are those who have taken an active interest in plants, as they require very dedicated and specific knowledge. To know what a plant needs, and how to make it grow requires knowledge on how to read the needs of a plant, and how that particular variety needs to be treated. A similar concept applies to those with a strong interest in technology, however there is a layer of our code/space that is so integrated into our social context that anyone can interact with it on a basic level.

Plants and Posthumanism

"If my nightmare is a culture inhabited by posthumans who regard their bodies as fashion accessories rather than the ground of being, my dream is a version of the posthuman that embraces the possibilities of information technologies without being seduced by fantasies of unlimited power and disembodied immortality, that recognizes and celebrates finitude as a condition of human being, and that understands human life is embedded in a material world of great complexity, one on which we depend for our continued survival." Katherine Hayles

Katherine Hayles discusses the idea that changes leave us on the verge of becoming posthumans. Information transfer between the machines that we use and ourselves is becoming increasingly seamless. As Hayles explains it, "[...] it [is] a small step to think of information as a kind of bodiless fluid that could flow between different substrates without loss of meaning or form." If we view intelligence purely as information or data, we can begin to see how these transmissions can be possible. Hayles views the body as a prosthetic for the mind, although they are extremely closely linked and dependant upon each other for survival. The transfer of information between mind and body is a seamless result of a symbiotic relationship, and the seamless connection we strive for with the tools that we use.

"Communications sciences and biology are constructions of natural-technical objects of knowledge in which the difference between machine and organism is thoroughly blurred; mind, body, and tool are on very intimate terms." - Donna Haraway, 1991

Hayles questions the prospect of physically severing the connection between mind and body: "how could anyone think that consciousness in an entirely different medium would remain unchanged, as if it had no connection with embodiment (Hayles, 1999)" as we are so intertwined. The mind and body have reached a co-dependant state with each other, one cannot exist in its current essence without the other. Connections such as these are forming between our environment and tools. Our technology is created to monitor, notify and assist us much in the same fashion as our bodies do. For example, the body notifies the mind it needs food through the feeling of hunger.

Thinking of information transfer as a simulation of consciousness is clarified by Hayles through the use of the Turing Test, and further the Moravec test. If humans are unable to perceive a difference between computed thought and human consciousness, there is functionally no reason to distinguish them as two different entities.

> "Whereas the Turing test was designed to show that machines can perform the thinking previously considered to be an exclusive capacity of the human mind, the Moravec test was designed to show that machines can become the repository of human consciousness-that machines can, for all practical purposes, become human beings. You are the cyborg, and the cyborg is you. " - Hayles, 1999

The environment and code/space we inhabit is rich with the flow of information. Our phones and computers communicate and share information.

Smart buildings and environments can now sense our presence or needs and adapt. This responsiveness can be interpreted as a form of data based articulation, or an intelligence not so different from our own. The data is being processed and information articulated, the fundamental differences in the correlation between our body and mind versus that of the smart building and its sensors is a pivotal factor. “Rather, embodiment makes clear that thought is a much broader cognitive function depending for its specificities on the embodied form enacting it.” The smart [object] does not have the same presence and embodiment as a human, however, its articulation of data may allow it to function indistinguishably from a human consciousness deciding whether or not to turn on the heat. What then, is the practical purpose of differentiating between a computational consciousness with the instructions:

```
IF ( (bodies are present) AND  ( temperature is below X degrees) {
     Turn on the heat
}
```

-- and a human consciousness acting upon these same conditions? If the boundaries are broken down, and the transfer of information can occur without loss of data between human and machine, we can begin to become one with our environment, tools, and coevolutionary counterparts.

“ Central to the construction of the cyborg are informational pathways connecting the organic body to its prosthetic extensions. This presumes a conception of information as a (disembodied) entity that can flow between carbon-based organic components and silicon-based electronic components to make protein and silicon operate as a Single system. “ - Donna Haraway, 1991

In Actor-Network Theory, Bruno Latour (2005) examines a theory of a heterogenous network, which views all interacting objects as equal participants in an interaction. People, objects, animals and plants, all interact in equal parts which are dependant upon one another within the network. Humans and plants are all part of this network system, playing both important and equal roles.

Elements in our environment and the tools we use to navigate our urban space and code/space are in the process of melding together to become a Single System, reading data from one another and sharing their information. Plants gather and share data very similarly to computational systems, and this data is shared with other plants in the nearby vicinity through chemical means similar to a network. Through the use of technology we can begin to integrate plants and technology within our urban environment. The coevolutionary benefits humans get from plants inhabiting our space can be used to their fullest. These prosthetic connections to our environment can create feedback loops, where both elements of the system are intertwined and dependant upon another, “ feedback loops can flow not only within the subject but also between the subject and the environment (Hayles, 1999)”

By using plants as a technological base, these systems can begin to exchange data between plants and humans even before we can achieve seamless information transfer. This integration will facilitate us finding a spot for plants within our code/space. Our coevolutionary dependancies in combination with increasing urban environments, may be leading us to a direction where this is necessary.

Intelligence and Consciousness

My installation examines the parallels between low level, binary technologies and plant intelligence. The fundamental binary operators that allow plants to have reactive intelligence share many parallels with technology. The speed with which the sculptures react to light stimuli allows the viewer to experience the decisions plants are making in a timeline that we can relate to. As plants are living creatures, the question of whether plants are consciously making these decisions or whether it is a simple response to a stimulus is raised. Understanding this intelligence and consciousness can help integrate plants into our code/space.

What does it mean to be conscious ?

Consciousness is both difficult to describe and define. Chalmers describes these issues as the “Problems of Consciousness” and divides them into two simple categories: the “hard” and “easy” problems of consciousness.The “easy” problems of consciousness consist largely of the cognitive function required to have a conscious being. Chalmers lists them as:

- the ability to discriminate, categorize, and react to environmental stimuli;
- the integration of information by a cognitive system;
- the repeatability of mental states;
- the ability of a system to access its own internal states;
- the focus of attention;

- the deliberate control of behaviour;
- the difference between wakefulness and sleep.

These criteria are all cognitively measurable. It is possible to tell whether an organism is experiencing these phenomena. The “hard” problems of conscienceless is what is called “Qualia”. “ There is something it is like to see a vivid green, to feel a sharp pain, to visualize the Eiffel Tower, to feel a deep regret, and to think that one is late. (Chalmers, 2001)“ Nagel (1974) describes the sensation as there is “something it is like to be” a conscious organism. This is the subjective feeling of existing as that entity. Not only is consciousness subject to experience of type of being (human, animal, computer, ect.) but also the nature of the specific organism itself. What is it to be a human? Further, what is it to be -you- as a human? There is no scientific method to detect this state, as all of the criteria are compatible with its absence. Nagel (1974) describes this as the subjective and objective experiences of “what it is to be” that entity.

“This subjective aspect is experience. When we see, for example, we experience visual sensations: the felt quality of redness, the experience of dark and light, the quality of depth in a visual field. Other experiences go along with perception in different modalities: the sound of a clarinet, the smell of mothballs. Then there are bodily sensations, from pains to orgasms; mental images that are conjured up internally; the felt quality of emotion, and the experience of a stream of conscious thought. What unites all of these states is that there is something it is like to be in them. All of them are states of experience.” - Chalmers 2001

To simplify, awareness is often a word used to replace they very loaded term of consciousness. It is possible that other organisms experience awareness of themselves as they exist, and their environment, however with less of a profound awareness of their existence within the scope of space and limited time as humans do.

In his 1974 paper “What It Is To Be A Bat”, Thomas Nagel explores the implications of a profoundly different consciousness than our own. Bats use echolocation as their primary perception of the world. This is a sense so far removed from anything we can experience, it is difficult to know where to begin to imagine it.

> ” I cannot perform it either by imagining additions to my present experience, or by imagining segments gradually subtracted from it, or by imagining some combination of additions, subtractions, and modifications.” (Nagel 1974)

There is no drastic body modification we can perform, or alteration of our state of mind we can obtain that will bring the human consciousness nearer to that of a bat. Even if one were to be slowly transformed into a bat, there would be no way to fully perceive or analyze the past or future states of that metamorphosis. Furthermore, if one were to be instantly transformed into a bat, the experience would be that of a being newly transformed into a bat without the lifetime experience as that entity. It is then, not possible to articulate this experience back to a way we, as humans, can comprehend as these sensations and experiences are completely foreign to us.

What is Intelligence ?

Intelligence can be measured and defined in many different ways, and in various forms that are vastly different from human intelligence. For example, crows and parrots can solve some sorts of problems easier than humans can (Trewavas, 2005). Wang breaks intelligence down into three complementary concepts that embody this phenomenon: Information, Knowledge, and Behaviour. The interplay between these three elements is what constitutes intelligence. Gather information, process it and render outputs, or as Wang puts it, “the ability to know and to do.” This extends beyond what we perceive as human intelligence, and can take many forms. Machaelle Wright, author of “The Perelandra Garden Workbook” puts this nicely:

> “The biggest hurdle for humans in understanding nature intelligence is their habit of using human intelligence as the defining yardstick for different intelligences in the rest of reality. Human intelligence is but one expression of intelligence. It is defined by the human form through which human intelligence generally functions” - Machaelle Wright (2012).

Wang outlines four forms of intelligence that meet these criteria with various levels of intricacy (fig 1). Entities ranging from human beings, classified as Natural Intelligence, to software systems that exist solely in the digital realm. (Details on other types of intelligence can be found in Appendix D.)

No.	Form of intelligence	Embodying Means	Paradigms
1	Natural intelligence (NI)	Naturally grown biological and physiological organisms	Human brains and brains of other well developed species
2	Artificial intelligence (AI)	Cognitively-inspired artificial models and man-made systems	Intelligent systems, knowledge systems, decision-making systems, and distributed agent systems
3	Machinable intelligence (MI)	Complex machine and wired systems	Computers, robots, autonomic circuits, neural networks, and autonomic mechanical machines
4	Computational intelligence (CoI)	Computational methodologies and software systems	Expert systems, fuzzy systems, autonomous computing, intelligent agent systems, genetic/evolutionary systems, and autonomous learning systems

The intelligence exhibited and displayed in my installation is reactive intelligence. Plants have the ability to gather data as knowledge, form conclusions based on this and perform a behaviour. These actions are only taken in response to direct stimuli in their environment.

“ No doubt it occurs in countless forms totally unimaginable to us “ Nagel 1974

Although plants possess many of the “easy” attributes associated with consciousness, there remains an ever present ambiguity of whether or not there is an essence of what it is like to be a plant, or sense of Qualia. As Nagel (1974) proposes, there are likely many forms of consciousness that we simply lack the ability to perceive or begin to understand. Thus, it is important that we do not personify plants. If there is something it is like to be a plant, it is something so unlike our own existence, there is no logical reason to correlate it to human consciousness. As consciousness is an abstract concept, for the purpose of this thesis I will state that plants are not conscious in any way we can perceive, due largely to their non-centralized analytical neurological system, though they may be conscious in some other capacity. If one were to agree consciousness exists within plants, and the principals of their behaviour are mirrored in technology, this pushes us much closer to a world with a singular system.

Plants can perceive input and provide output and behaviours based on their environment. Plants behave similarly to colonies of insects, Trewavas explains, in the way that their decision making tools are not centralized to one location. This is reflected in our code/space and technology as the layers of libraries, code, and system that make up our digital landscape (See Appendix E). Combinations of these connectors on a large scale allow choices to be made based on a massive array of factors and stimuli. These similarities provide a platform for integrating plants as technology into our digital environment.

“information flow can diverge, branch converge adapt, synergies and integrate through cross talk. learning from accelerated rate of information flow through selected pathways just as it does in simple brains. Either the amount of the consistent proteins or chemical neurones is increased, or the affinity between information is increased using phosphorylation” (Trewavas, 2005)

The Behaviour of Plants

As plants have a vastly different method of intelligence and perception, and if there is any consciousness, it is vastly different from our own, it may be difficult for us to recognize that plants are very active organisms. However, they do not walk or physically move through space (though some species of Droseraceae (Karban, 2010) do make rapid movements, and pollen release has been clocked as the fastest motion observed in Biology) plants are constantly sensing and reacting to stimuli from the world around them.

Karban (2010) has noted thirteen primary types of stimuli that may cause plants to react: contact, light, gravity, nutrients, water, cues from favourable hosts, environmental conditions, stress, resources, floral damage, temperature, microbes and interactions with herbivores. These stimuli can cause reactions not only in plants' leaves, stems and shoots, but even in their seed count and reproductive tissues. My installation reacts directly to light stimuli.

Plants forage for food similarly to animals, through their root systems. Based on the nutrients in the soil plants make decisions which direction to grow. The same concept applies to the petals and flowers of plants, which are designed to minimize self-shading (Trewavas). By using a phytochrome sensor to detect red radiation generated by other nearby green plants, leaves can sense unshaded locations before they grow(Karban, 2010). Plants are also able to sense their surroundings and the volume of the space they are in. Experiments where plants are grown with the same amount of nutrients and sunlight show that plants in larger pots grow bigger. Additionally, plants are able to sense occupied soil and grow their roots in another direction. “Plants assess and respond to local opportunities that will in the future benefit the whole plant” (Trewavas 2005).

Plants have the ability to communicate with each other through the release of chemicals called Volatiles, as well as anticipate future dangers (See appendix C). These behaviours are built from binary logical gates, layered upon each other similarly to libraries in code (See appendix E). These same concepts are visible in integrated circuit (IC) circuitry through transistors. Radio and network signals mirror volatile communication, sending stimuli from one location to another. The light in my installation utilizes a mixture between volatile and technological communication. The light of each sculpture affects the actions of nearby sculptures. My sculptures, like plants are more likely to move towards what they require. If the needs of the sculptures are met, they will glow brighter and communicate which direction the others should face through light.

Coevolution of Plants and Humans

Human survival has always been contingent on successful interactions between other animals and plants (Jackson, 1996) Humans are bicultural creatures, which means there are elements of human biology, and human cultures that are linked very closely. This can take many forms as Jackson(1996) outlines in his paper "The Coevolutionary Relationship Between Humans and Domesticated Plants". This is a result of the coevolution of humans and many other organisms, in this instance I focus on the close evolutionary relationship between humans and plants.

Our interactions with plants around us has physically and cognitively shaped our evolution. The plants surrounding our environment have also influenced our culture. The line between food and medicine has become blurry, as our bodies have evolved to take in the healing elements of plants in our ecosystem, and neutralize the harmful ones. Beyond food and medicine, Jackson outlines other uses humans have used plants for for thousands of years. The plants in our predecessors' immediate ecological environment were used as tools. Plants can be indicative of nearby water or fertile soil. In our modern cities, these are no longer functions we require from plants, and so we have grown somewhat apart culturally.

The plant-like technological systems we have moulded into what can be perceived as the code/space that enables our urban lifestyle, which can lead to a next stop in this coevolution. Integration of plants and technology would allow us to bridge the gap that has been socially and physically created between humans and plants in our city. The next stop in this coevolutionary process may be where we, for our benefit, employ plant-like behaviours through the vessel of technology as an aid in preserving the existence of plants within our expanding cities.

Integration in our Spaces

"a plant whose virtues have not yet been discovered"
Ralph Waldo Emerson

In urban settings, plants are curated to our specific needs, be it aesthetic or functional. These purposes are determined with our needs in mind, and not the desires of plants. We allow plants to exist under our conditions within an urban context, in a pot, in a garden, in some predetermined context. Further exploration through case studies can be found in Appendix B. Stray plants are actively removed from our space, and instead are placed into designated areas, cut out of our urban environment.

Our urban landscape does not allow for plants to get what they need. In a pot, a plant cannot forage for water or nutrients in soil in the same way they do in nature outside of an urban context. They become reliant on us to place them in a sunny area, water them regularly, and ensure they have space to grow. Plants in our urban environment are effectively at our mercy, yet we depend on the oxygen they create for our survival.

A combination of software and code structures make up the world we navigate. Everything from our devices to architecture is tailored to the way we are able to function. The way we are developing the ever-growing urban landscape does not allow plants to navigate, forage, or grow. Water is located in a specific place, plants are removed if they are not in the place that we want them and indoor plants are limited to the sunlight we provide them.

In “Weeds: In Defence of Nature’s Most Unloved Plants” , Richard Mabey discusses how we make decisions on curation of greenery in our spaces. Certain plants are labeled as “weeds”, or undesirable to have in a given context. There are many factors related to what can be considered a “weed”, some are cultural, contextual or practical and are often subject to change over time. In a study of junior high school students, Han (2006) explored the benefits of greenery in classrooms. The presence of leafy green plants has been shown to increase happiness and promote desired behaviour among students. Plants with cultural significance are also seen as beneficial. Mabey gives the example of English Bluebell plants, seen as a “forest plant” that spreads widely, while the Spanish Bluebell is seen as a garden plant and removed when seen growing outside of a garden.

Part 2: Exploration

Methodology:

The original inspiration for this work began with the exploration of free and accessible food resources. I began to consider how we integrate food into our lives, cities, and interactions. The growing cityscapes prompted an analysis on how we can integrate a system that produce free and accessible food, not only into our physical environment, but within the digital space we have created for ourselves as well.

My research began in exploring the technical aspect of building networked gardens. Plants have no longer become a part of our everyday lives, they are a curated element of our existence, and have become somewhat fetishized and idealized. Those who dedicate their lives to plants, and there are those who feel responsible for their death. We take ownership of plants, and they become our responsibility. We have removed them from the environment they have evolved to grow within, and thrown them into a dependant state.

This realization set me to thinking about reopening the path of communication between humans and plants. What would this look like, if we were to allow plants to communicate with us, within the context of our own environment? If we integrated plants within our physical and digital world, we could begin to share information with them in the same way that we share information with each other. Further, as we progress on the same path of technology, the transfer of information has the potential to become increasingly seamless between human and machine, and further, to human and plants.

I began to build prototypes that ranged from talking plants to wearable technology notification devices in order to communicate with plants. These assist human plant interaction, notifying the inhabitants of the space what the plants needed, or if they were “happy” in a sense that only we, as humans, could understand. After some time with these prototypes, I began to see where the break in communication was. The mere existence of plants is so vastly different from our own. What is it to be a plant? (Nagel I1974). This is where I began to explore the idea of plant intelligence. Understanding this can help bring us closer to creating a meaningful dialogue, and a coevolutionary relationship that makes sense.

It is also important to consider the role technology plays in evolution. Understanding the way plants work and how that relates to our technology (programming, specifically) could be the next step in the evolutionary process. We cannot consider ourselves above, or outside nature. There must be a new place for these organisms, and that may mean helping them find one within our new environment. Can expanding the consciousness of plants to our own be the first step? Or will there be a piece of technology that allows us to coexist, in a mutually beneficial state?

Phase 1: Networked Gardens

Context:

This project began as an attempt to facilitate interactions between plants and humans. My original approach was to give the knowledge needed to take care of plants to the average person. By integrating plants into our existing urban environment and code/space in a way that is already understood in contemporary Western society, it was my hope to cultivate grass roots communities that can provide sustainable food.

As it stands, gardens largely exist as segregated areas of the city, carved out of spaces designated for plant growth. As urban areas on our planet increase, both the need for food and space to grow it traditionally are inversely correlated. The physical design of urban gardens must integrate with architecture, and not simply sit within, on top, or around it. There are vast amounts of unused vertical space in the city, walls, posts, and roofs. Additionally, the city leaks resources. Power outlets, internet signals, heat and exhaust emanate from our daily activities and often go unused. Harnessing these elements we passively produce can help create free and accessible food in the urban setting.

One of my research goals was to explore how the power of knowledge and grassroots movements, food can become a free and accessible resource for urban populations. Simple technology platforms that make electronics accessible (such as Arduino, RepRap, Processing and Lasersaur) can allow communities to produce gardens that self-monitor, maintain, and ease the communication barriers that have risen between humans and plants.

Networking websites and mobile apps could provide community members with the tools to maintain these gardens as well as find the food the require. These tools are already integrated within our everyday environment, and their methods of communication we are familiar with.

The original work was intended to bring together these elements in a community driven urban gardening project that provided free and accessible food, integrated within the city in such a way that the community could build additional gardens as their needs expanded. The physical plans as well as programming infrastructure would be available through an Open Source distribution platform such as GitHub. Community members would be able to add new ways to integrate gardens in urban settings and make these plans publicly available as well.

In 1950, Detroit was one of the largest cities in the United states ("Detroit historical Society, 2014). The auto industry was responsible for a massive city growth. The city was expected to continue to expand for years to come, as citizens came to Detroit to live the American Dream of middle class life. From 1950 to 2010, the population dropped by 1,135,971 (Granzo, 2014), making it one of the fastest shrinking cities in the United States. Today, Detroit is mostly a ghost city. There are abandoned buildings on every block, and even those that remain are in such dilapidated state that it is hard to tell what is still in use. In the past 10 years, there has been a movement called the “Greening of Detroit”. This movement aims to bring gardens and life to the urban wasteland that occupies much of the 1773 square mile area of the city. There have been many parks and green areas set up around the city centre. Some of these contain raised beds full of food, and others are decorative or green recreational areas.

In October 2013, I visited Detroit to see how this greening project was impacting the community, and integrating with the cityscape. Detroit is in a unique situation, as many of the buildings are in a state that is beyond repair, they must be rebuilt in order to be in use again. This gives the city a chance to integrate gardens into the structures themselves. As it stands most of the gardens that I encountered occupied plots of land that once held abandoned homes. It can cost as low as $2,000 to get a single plot of land within the city of Detroit; additionally, many residents squat on unused land and convert it into gardens.

The majority of the gardens I saw were located in empty plot flat land. These are simple to set up, and with the amount of excess space Detroit offers they are quite effective at producing large amounts of food within the city limits. However there are drawbacks to this setup. Areas of soil where buildings have been removed may contain toxic remains, and thus produce toxic vegetables. If these are not regulated and the soil is not checked properly, this can lead to illness in the population consuming the food. Several raised bed gardens have been set up within the city, however these are vastly more costly and much less space efficient, and generally not an option to build without funding. Because these gardens are built through a community or funded organization, the raised bed gardens tend to be sectioned off from the public. They are only accessible to the community.

This presents a unique opportunity for a city to reform around these new ideas. It is difficult to vastly change the infrastructure of an existing, functional city. There are already protocols in place not only physically such as buildings and transfer of goods and services, but also socially. Cities that are comfortable in their ways, may not feel the need to radically change their way of life, even if it is for a long term goal. Cities such as Detroit have been plunged into a state of near anarchy at the time of my visit, October 2013.

The successful movements in the city stem from grassroots communities and revolve around ideas of free and accessible food. Any available surface can be converted into a way of growing food. The lack of enforcement of traditional building structures allows for unique designs to take hold, and exploration of new ways to grow food. New generations growing up in Detroit aren't affected by the modern concepts of the Western food economy. The attitude of food as a right, and not as a privilege is much more common, and communities work to feed each other.

I see this as a potential seed for something great. There is no resource here for any technology implementation at this point, however the ideas are there for the foundation. Architecture can start to integrate with the needs of the city, and as it is rebuilt, these ideas can be reflected in that image.

Phase 1 Prototypes

Fig 2: Plant Sensors

My first prototype has two main sections. The first, is a physical circuit that monitors the plants' status. Humidity, moisture, temperature and light were monitored for each individual garden box. These prototypes were constructed from acrylic cubes. Each box was connected to an Arduino Pro Micro, and daisy chained together to a Arduino Uno with a Ethernet shield. The boxes also had RGB LED indicator lights.

Each Pro Micro within a garden box was assigned an individual ID, which was hard coded. Each Arduino Uno was assigned a hard coded ID as well, which identified each cluster of Pro Micro units as a garden. These IDs allowed the gardens to be uniquely identified over the internet. Individual garden boxes can also be calibrated for the type of plant they grow which is fed by a database. The garden units were given descriptive information such as location, name of garden and creator.

Fig 3: Plant Lights

Initial prototyping was done in an acrylic cube, however the enclosures for each of these units was intended to fit within our urban landscape. Early cardboard pre-prototypes included garden units fitting on lights, walls, and within furniture. These designs would be publicly available through a web interface for users to observe, create or modify.

The second aspect of these prototypes was the web/networking aspects. The prototype aggregated all of the data received by the Pro Micros in the Uno and sent them through the ethernet shield as an HTTP request. The data was logged in a MySQL database.

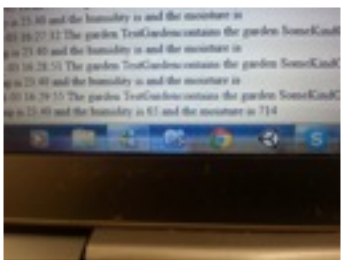

Fig 4: Web Interface

A front-end web interface displayed the data as gardens, which could be inspected as individual boxes as well. Each garden and box had a data visualization of the status of the garden. The goal was for the user to be able to search by location or availability of food.

In creating the Phase 1 prototypes, the barrier I kept running into was the communication between humans and plants. As vastly different beings, we communicate on unique levels. Additionally, the use of technology has further removed us from the ways we historically communicated with plants. We are no longer tuned to understand the subtle ways in which plants communicate. This was proving to be a barrier in truly creating seamless integration of nature within the city. Before we can begin this task, we must create a seamless understanding, or transfer of information between humans and plants. In "Aboriginal People And Their Plants", Clarke discusses how connections were formed culturally with plants and humans. "Apart from its physical aspects, the cultural landscape is also an expression of how people engage with their world and it involves the way people view their concepts and experiences of their surroundings " (Clarke, 2007). Through oral tradition and social teaching, aboriginal societies taught future generations the importance of human plant communication and interactions.

Phase 2: Human-Plant Communication

These prototypes aim to examine how plants exist within the space we have created. Our urban landscape does not take into account the needs of plants as their own entity BUTrather how we can use them to benefit us. BY examining different methods of integration within our environment, we can create a seamless transfer of information between humans and plants, creating a form of posthuman prosthetic.

Prototypes:

I created several prototypes to explore the interaction between humans and plants in our city. Some involved trying to bridge the communication gap, and others enableD plants to move within our space and gather the elements they need from our environment.

Several experiments were conducted in order to assist plants in communicating with humans. These experiments took three main forms: extending the ability of the plant to maintain its own state, helping the plant transmit its message to a human audience, and helping the human tune into the plant's needs. These methods outline ways in which this crucial communication can be facilitated. The expected outcome is to provide plants with a platform on which to transmit their message, and a method for us to listen. The primary questions addressed in these works of art are issues of where, why, and how this path is best reached.

Experiment 1: Mechanical Plants

Context:

The plants within our urban environment are a result of a human-curated selection, rather than naturally growing from their environment. In this experiment, plants are given the ability to provide themselves with water and sunlight as they need it within a space they are not naturally familiar. We give plants a pot or bed to exist within, inside our environment, where they have no real hope of finding anything beyond what we give them. In this experiment I give plants the ability to receive what they want, and to find what they need outside of their predetermined environment.

In this experiment, I explored the idea of plants as robotic or transhuman beings. Plant intelligence can be translated to something similar to what we call desires, or needs. By using roots and growth patterns, plants seek out desirable conditions. We have built our environment in a way that accommodates our ability to physically move throughout space to satisfy our needs. Enabling plants to move freely through our spaces could drastically alter the way we perceive their actions, or take notice of their desires.

First test: Self-Watering

The first prototype created to explore this idea was a self-watering plant. This plant uses its environment to get what it needs, and request what it lacks. As plants are often in states where they are dependant on human involvement in our urban environment, this plant breaks that dynamic by being able to maintain itself temporarily, and notify humans in a way they can understand when it requires further aid.

The piece is powered by an Arduino Uno and a moisture sensor. When the moisture sensor detects the plant’s need for more water, a servo motor activates a watering mechanism. If the plant is still not watered, it calls for help. The plant is equipped with a bike bell which it rings until the watering can is full again.


Fig 5: Watering plants

In this way, the plant is able to take some agency for its own existence. It can request help in a way that speaks to human interaction, while also taking partial responsibility for its own health, as we have previously not allowed it to do so by putting it in a pot.

Second Test: Spider Robot

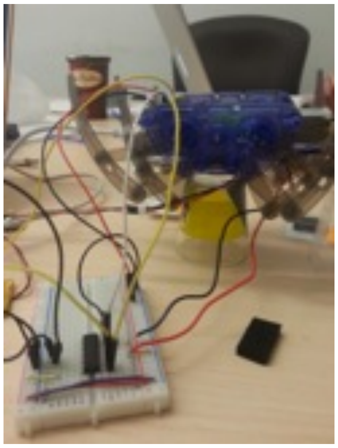

Fig 6: Spider

Taking this concept to the next level, I made a robot that can physically navigate our urban space. This robot's goal was to stay in sunlight. It is powered by an Arduino Pro Micro, a DC motor, an H-bridge circuit and 2 photocells.

Aesthetically, the spider bot is designed to bridge the gap between what we view as natural and what we view as mechanical. The legs and motion are reminiscent of spiders, however the mechanical noise and nature of their movement is very mechanical.

The logic that drives this creature is similar to that of a plant. Firstly, it can only move in two directions, as it is only intended to follow the sun. Its best location is on a windowsill or somewhere with repetitive sun motion. As a simple machine, accomplishing directly what it needs to. The single DC motor is driven by an H-bridge circuit that inverts the polarity of the motor, causing it to go backwards. Two photocells monitor the sun. If they are both within light, the plant stays where it is, If one begins to fade out of light, the plant walks in the direction of the light until both sensors are within the light again. If the light begins to fade, the plant returns to its original position, and reaches a state of equilibrium.

Experiment 2: Notification Plants

Context:

Plants used in this section of the experiment were meant to integrate into our existing code space. Social networking and many of our social interactions are based on a system of notifications. This act of an event interrupting your day to day activities to deliver information is something that the majority of plants are not capable of. Does this help increase the gulf of communication between us and plants ? Is there simply no space within our code space for beings that cannot send notifications?

First Experiment:

This prototype is a wristband notification system. It is a wearable piece that consists of an Arduino lilypad, and 2 XBee radios. The first radio is attached to the plant and a monitoring system, collecting data about temperature, moisture, and sunlight. If any of these areas is in need, the XBee Radio sends out a signal. The second radio is attached to a wristband and vibration motor. When the wearer is in range of the radio, and the plant is in need, the wrist band vibrates.

Fig 7: Notifications

The user is only given notifications when it is possible for them to react and fix the situation. Notifications are directly tied to the environment that they are in, as opposed to notifications through a phone, email or other digital devices where a notification can be received when the user is anywhere.

Second Experiment:

Fig 8: Talking plants

The second iteration of notification plants was a talking plant. This prototype was equipped with an Arduino, speaker, and proximity sensor. Once again, the Arduino was monitoring the status of the plant (moisture, temp, and light). When the plant was in need, a voice recording would play. Proximity sensors influenced which recording, letting the user know the plant "knew" there was someone available to help. As the plant became more dehydrated for example, it would get angrier if no one watered it.

This would not only allow users to identify with the plant in a way they could understand well, but to perhaps empathize with its needs as they became more urgent. Additionally, the user would only receive feedback if they were nearby.

While programming the moving plant, I began to draw parallels between programming and plant behaviour. This became increasingly important to me as I tried to bridge the human/plant information transfer gap. Programming is already a very specific skill, which requires a particular way of thinking. Plants do not have a single consciousness, but are made up many logical reactions to stimuli that work together to achieve a collective goal, to keep the plant alive. Each element has a function it acts on individually, however when they are brought together these individual functions create a singular result.

Continuing in this track, I felt it was more important to discover how plants are actually working and explore their methods of communication between each other before we decide to mould them into a prosthetic. How can we enable seamless transfer of information between us and organisms we cannot fully understand?

These pieces are intended to provide insight into how plants behave and work. They allow humans to explore the logic of a plant, and by doing so, we begin to understand why they are so vastly different from ourselves.

Phase 3: Exploring Plant Intelligence

Context:

Based on the concepts of plants in our environment previously discussed in this thesis, my installation examines the parallel between technology and extending plants as a posthuman prosthetic.

Plant life operates on a drastically different interpretation of the world than our own. We have built up our own urban environment to reflect the way we perceive the world, and enhance our experience within it. Our architecture, in both a physical and digital sense, allow us to navigate the urban landscape in a way that is intuitive to us. Social interactions, and daily activities are facilitated by the spaces we inhabit.

As a result of this extreme tailoring to our needs as humans, we have created an additional barrier to communicate with the vastly different consciousness of plants. Spaces plants take around us are cut out from our environment. Gardens, pots, planter boxes, are all objects that exist on top of our space and are not integrated within. Further, plants are restricted to these locations. Curated areas of our environment place plants in a state where they are completely reliant on us for their survival. Urban settings are so suited to our needs, they do not account for those of others.

Understanding the needs of plants has become a science of its own. Botany, ecology, biology, are all different approaches to decoding the existence of plants. During the earlier phases of plant-human coevolution, it was a much more common occurrence for the average human to have some knowledge of the status of plants in their environment. At this point, human daily existence in a modern urban city does not involve interactions with plants as it once did.

As our cities continue to expand, our need for food and space with which to grow it are inversely correlated. In order to sustain our lifestyle we must find ways to grow food within our cities. Objects and information that have been successfully integrated into our daily lives use methods of information transfer that are familiar to us. These interactions must be easy to understand for the average user of technology. The goal is for information transfer to be seamless. This means that we do not have to interpret information between us and the object, in this case the plant, and that no essence of the information is lost from plant to human. This seamless transfer of information would allow the object to essentially become a prosthetic. The data that constitutes our consciousness, and the data being transferred from the plant, would functionally be the same.

Plants act through a form of reactive intelligence. They respond to stimuli in a predictable way. These “if”, “and” and “or” responses come together within a single plant to create a unified reaction, although they are not centrally connected. Although we do not yet have seamless transfer of information in our lives, we are certainly on the way. Technology uses these same constructs to transfer data between human and machine through code. “If” statements are not initiative for seamless transfer of data on their own, but when packaged in the form of a mobile application, web interface, or physical interaction, they become much easier for us to understand.

Technology in our environment runs off the same type programatic of logic constructs as plants do. From software, which is directly made up of logical statements, to simple hardware such as a transistor, the building blocks of all modern hardware, which functions essentially as a binary switch. Massive amounts of layers of logic make up both our physical and digital urban landscapes.

We are constantly working towards building better user interfaces, better transfer of information, and more intuitive objects. By including plants in this loop of free information transfer, they can once again become a part of our intuitive daily interactions. Extending this network of information transfer may allow plants to integrate into our devices and code/space.

With the lack of traditional space to grow as they once did, and their continued need for our aid within our urban environment, I consider what it means for the future of plant evolution. Plants must be able to continue to thrive within our world, as we are dependant on them for oxygen. Can technology be the next step in the human/plant coevolution? As we continue to destroy their natural habitat, we can create a new one for them within the world we have constructed.

This project frames plants as a form of intelligence we are already familiar with in the form of technology, and evolution, but have become alienated from due to our modern urban environment.

My installation draws parallels between the behaviour of plants and its similarities with technology. The behaviours exhibited in the sculptures are the same as many plants. Each object rdesires sunlight, and is influenced slightly by others. Every sensing element of the sculpture is wired individually. This piece is an exploration of intelligence: simple loops and circuits working together, dependant on each other, not centrally linked but their actions are correlated.

The sculptures use simple technology to mimic the behaviour of plants. In “Forget Heidegger”, Neil Leach (2006) explores the concept of mimicry as creative exploration. Leach argues against Plato’s examination of imitation, and instead, for Adorno and Heidegger’s notion of creative engagement with the object through mimesis.

> “To understand the meaning of mimesis in Adorno we must recognize its origin in the process of modelling, of ‘making a copy of’. In essence it refers to an interpretative process that relates not just to the creation of a model, but also to the engagement with that model. Mimesis may operate both transitively and reflexively. It comes into operation both in the making of an object and in making oneself like an object. Mimesis is therefore a

> form of imitation that may be evoked both by the artist who makes a work of art, and also by the person who views it. Yet mimesis is richer than straight imitation. In mimesis imagination is at work, and serves to reconcile the subject with the object." (Leach, 2006)

Understanding this line between plants and technology can allow us to use plants as a form of technology integrated into our urban architecture and code/space, eventually as a prosthetic extension of our own consciousness. " The subject creatively identifies with the object, so that the object, even if it is a technical object — a piece of machinery, a car, a plane, a bridge, whatever — becomes invested with some symbolic significance, and is appropriated as part of the symbolic background through which individuals constitute their identity" (Leach, 2006)

These pieces are intended to explore how plants exist within our world. The paradigms they operate under, revolve around reactive intelligence and stimuli. Individual systems work together to create one living organism with no central nervous system like our own.

Installation:

Fig 9: Installation

My installation represents the parallels between plants and technology through 10 hanging sculptures as “Systems Art“ (Shanken, 2013). The aesthetic of these sculptures intentionally draws from organic and mechanical forms. The primary material is acrylic plastic, though the forms created reference forms found in nature. The LED light on the sculptures mirrors the indicator colours of leaves on plants, showing the “health” of the sculpture.

The installation generates noises from the motors based on the health of each piece. Each piece communicates with each other not directly through wires, but through light, much as plants communicate with each other through chemicals. Each searches for light (with some degree of random movement), and the health of the surrounding plants helps guide it towards the source.

Fig 10: Installation 2

The viewer can interact by turning a light switch on and off.. This change of the environment illustrates the reactive intelligence of plants. Allowing the user to directly interact with the work lets them see the changes they are making reflected directly in the piece. Reactions in plants are often not as easy to observe. By creating sculptures with faster responses, the viewer can explore reactive intelligence and plant behaviour in a way they can directly experience.

The sculptures begin to search more frantically in the dark for light, and calm down when they have what they need. This exploration allows viewers to experience and interact with the rules that control plant behaviour in a way they can relate to. Parallels between plants and technology can be seen here, as technological devices mimic plant behaviours. Each motor and light unit has autonomy, however their behaviour is dependant on each other. When in a group their behaviour is different. The light and health from each plant alters the behaviour of others, they feed and help each other.

W. Grey Walter was a neurophysiologist and roboticist who's work explored how small amounts of brain cells could create complex actions. He created robots that exhibited these behaviours. His tortoise robot, CORA, used simple Phototaxis (movement of an organism towards light stimuli) to reach targets.Explorations of simple reactive intelligence mechanisms have played a large role in many systems art pieces. The contemporary work of the Canadian architect and visual artist, Philip Beesley, heavily influenced my approach to my installation. Beesley's works, such as Hylozoic Ground (2010) and Hylozoic Soil (2010) explore similar concepts of reactive intelligence by creating an immersive and responsive mechanical forest. Although Beesley's work is not explicitly interactive, his sculptural installations highlight the parallels that exist between reactive plant behaviour and simple technological systems.

Fig 11: Hylozoic Soil http://philipbeesleyarchitect.com

This piece allows the viewer to experience reactive intelligence, similar to plants' response to stimuli. The interactive elements and direct responses to user interaction facilitate the exploration. Before creating gardens that can be integrated into our spaces, it is important to understand the entity we are trying to accommodate. I see this installation as a prequel to creating a sustainable garden within our code/space.

Humans And Nature - Conclusion

In "Extracting Humans From Nature", Redford and Sanderson (2000) examine the impact humanity has on nature, and attempt to justify a balance between conservation and expansion. In doing this, they found the general consensus among conservationists is that regardless of the form our inhabitants takes, it is impossible to completely negate the effect humans have on forest environments. Although rural dwellings are preferable to urban ones, it is impossible for us to exist on the planet without affecting our environment.

As discussed, coevolution has left us in a state where we are dependent on plants for our survival. It is unavoidable that we will continue to drastically alter the environment, destroying forests, and expanding through rural and urban spaces as to population increases. It is necessary for humans and plants to either find a way to coexist, or for us to find another way to get the benefits plants give us. Human/plant coevolution is a complex web of interchanging features, and as their natural environment dwindles we must find a way to reach a balance.

The theory of a posthumanist future as Katherine Hayles and Donna Haraway define it is a distinct possibility if we remain on our current trajectory. Our digital environment is currently thickly woven with our physical architecture, and the search for methods of seamless transfer of information is well underway.

Our population has begun to near the point of expansion where our cities occupy such a dense and large portion of the planet that our rural areas will soon be unable to supply enough food. This problem brings questions of plants in our society and urban space to light again, as these things must be dealt with within our environment.

The same laws of reactive intelligence and reactions to direct stimuli that govern the behaviour of plants can be paralleled in the most basic levels of our technology such as transistors and simple programmatic logic. These paradigms of simple intelligence are layered to create technological interfaces we can easily understand, with the goal of fluid conveyance of information between humans and machine. Parallels between plant and machine intelligence set the groundwork for integrating plants within our environment in a similar way as technology.

In beginning this project, I had intended to bring free and accessible food to an urban environment. I had focused on how we can maintain plants to serve our needs. In my research, I came to understand that we need a deeper relationship to plants, beyond just their physical needs in order to establish a functional interaction. It is not enough to display information, we must create a meaningful connection, which can only come through understanding plants.

Perhaps the next step in our coevolutionary relationship with plants is one where we actively assist plants to exist within the environment we have created, or enhance their ability to navigate our space. Their basic needs and desires can be translated to an interface similar to those already integrated within contemporary Western urban culture. By understanding plants and encouraging data exchange between humans, our current model of urban environments and digital landscapes can be adapted facilitate plant integration.

Glossary

Arduino: An open-source microcontroller for small electronic projects.

RepRap: An open-source 3D printer.

Lasersaur: An open-source laser cutter design.

Fibonacci Sequence: A sequence of numbers frequently found in nature.

Fermat Spiral: A spiral made up of Fibonacci sequences

PHP: PHP Hypertext Protocol. A server-side web programming language

Hard Coded: Values that are written as numbers and not variables in a computer program.

Arduino Pro Micro: A small Arduino based microcontroller

Arduino Uno: A large Arduino based microcontroller

ATTiny85: Small micro controller chip

Photocell: A light sensitive variable resistor

HTTP request: A protocol for requesting information from a web server

LED: A light emitting diode.

Ethernet Shield: An Arduino attachment for connecting to the internet through an Ethernet cable.

MySQL: A server-side web programming language for database data entry, organization and retrieval.

Front-end Web interface: The portion of the internet that the user interacts with. Mostly HTML, CSS, and JavaScript.

Servo Motor: A 180 degree motor that can be controlled very specifically.

DC motor: A small motor powered by direct current

Wearable (technology): A piece of technology that is integrated with clothing or made to be worn on the body.

XBee Radio: A radio used for short-range simple communication.

Transistor: A binary switch used in all most basic forms of modern technology.

Library[code]: Pieces of code that can be widely applicable to facilitate tasks.

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Appendix:

Appendix A: Code -

```
#include <SoftwareServo.h>
SoftwareServo myservo;
float RGB1[] = { 0, 0, 0};
float INC[3];
int red, green, blue, curr;
int bestPos = 0;
int highValue = 1023;
int pos = 0;
int redLED = 3;
int blueLED = 5;
int greenLED = 11;
void setup() {
  myservo.attach(6);    scan(20);
    myservo.write(bestPos);
    howVal(highValue);
    delay(4000);
}
void loop(){
  if(analogRead(0) > highValue + 50){
    scan(20);
    myservo.write(bestPos);
    howVal(highValue);
    delay(8000);  }
  if(analogRead(0) < highValue - 50){
    scan(20);
    myservo.write(bestPos);
    howVal(highValue);
    delay(8000);  }
}
void scan(int speedVal){
  change(10, 0, 0, 5);
  highValue = 1023;
  for(pos = 0; pos < 180; pos += 1){
    myservo.write(pos);
    curr = analogRead(0);
      if(curr < highValue) {
        delay(100);
        highValue = curr;
        bestPos = pos;
      }
  delay(speedVal);
```

```
  }
}
void change(int newRed, int newGreen, int newBlue, int speedVar) {
    INC[0] = (RGB1[0] - newBlue) / 256;
    INC[1] = (RGB1[1] - newGreen) / 256;
    INC[2] = (RGB1[2] - newRed) / 256;
  for (int x=0; x<256; x++) {
    red = int(RGB1[0]);
    green = int(RGB1[1]);
    blue = int(RGB1[2]);
    analogWrite (redLED, red);
    analogWrite (greenLED, green);
    analogWrite (blueLED, blue);
    delay(speedVar);
    for (int x=0; x<3; x++) {
         RGB1[x] -= INC[x];}
  }
}
void howVal(int thatVal) {
  thatVal = map(thatVal, 0, 1023, 255, 0);
  if (thatVal > 200) {
    change(30, 255, 0, 10);
  } else if (thatVal > 150) {
    change(70, 200, 0, 10);
  } else if(thatVal < 75) {
    change(100, 0, 50, 100);
  } else if (thatVal > 50) {
    change(30, 0, 100, 10);
  } else if (thatVal < 50)  {
     change( 0, 50,255, 10);
  }
}
```

Appendix B: Case Study: NYC Gardens

The ways in which we have attempted to integrate gardens in our city are not effective. Urban community gardens often occupy rooftops or plots of land. With choosing to occupy space like this there are many pros and cons. Schmelzkopf, a professor of geography at Monmouth University did a study on urban community gardens in a small corner of New York CIty called Loisaida(1996). The majority of these lots are 15x50 foot spaces which are fenced off and maintained by selected members of the community. Although these gardens are able to grow a significant amount of food, they require exclusive access as well as funding to start. By law, they are required to be fenced in, and are thus not accessible to the public. Further, the initial garden requires significant setup, including building planter boxes and raised beds, which require funding. There are several gardens in Loisaida that are “squatter' gardens. These are open to the public, however there is some controversy on whether it is safe to plant vegetables in these, as the soil may contain lead or other heavy metals from demolished buildings.

These gardens do not fit fluidly within the city. They are locations that are cut out of the city and curated. They must be built and accommodated. Those who maintain them require a specific set of knowledge. How to maintain each type of plant, when to harvest them. The signs must be read by direct communication, understanding the plants needs externally. This is not intuitive for the average person. It is not reasonable to expect the average citizen to be able to make these connections with plants without some kind of facilitator, aide, or prosthetic.

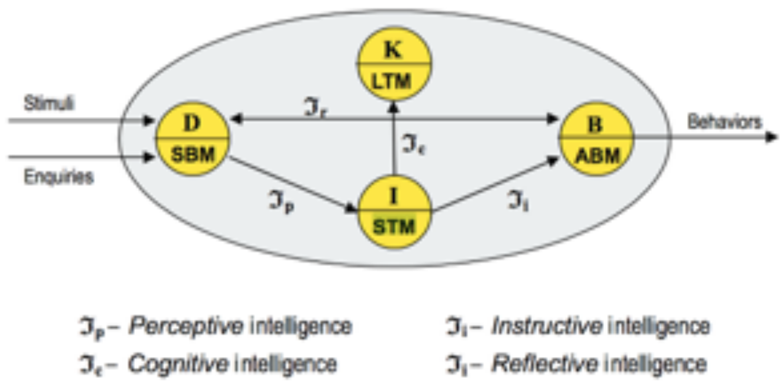
Appendix C: Volatile Communication:

Volatiles are an organic compound (VOCs) emitted by damaged or distressed plants. These compounds contain a combination of chemicals that can warn nearby plants of dangers, attract predators or repel herbivores (Heil and Beuno 2006) (Blande, 2010) Karban (2010) gives several examples of how these can be effective. “Plants emit different blends of volatile chemicals in response to attack by closely related caterpillars (De Moraes et al 1998) these cues provide detailed information that allows species specific parasitoid wasps to locate their particular hosts “ Sagebrush also increases its level of resistant chemicals after a neighbouring plant has been attacked. (Karban, 2010). These volatile chemicals not only communicate with other plants, but prompt other species to change their behaviour.

Although it is not through cognition, plants have a way of appearing to anticipate the future. This is in response to stimuli that can be indicative of a future event. A prominent example of this is deciduous plants shedding their leaves in the winter. The shortening of the photoperiod triggers this reaction in plants, in anticipation for the colder season. Another example is the growth of a clover branch, which is dependant on not only the plants currently surrounding it, but the ones that had been neighbours previously. Additionally, some plant responses to light are dependant on the previous pattern of exposure. (Kaban, 2010).

Appendix D: Forms of Intelligence:

Wang outlines 4 forms of intelligence that meet these criteria with various levels of intricacy (fig 1). Entities ranging from human beings, classified as Natural Intelligence, to software systems that exist solely in the digital realm. The GAIM model (Wang, 2009) breaks down Natural Intelligence into 4 basic types based on their use of data (D), Knowledge (K), Behaviour (B), and information (I). Natural intelligence is complex and doesn't need to touch all of these categories as long as it is responsive to a stimulus.



Appendix E: Code/space

As explored in Kitchen & Dodge (2011) and Wendy Chun (2011) explore how code is layered upon its self within our code space. Libraries are used to support new libraries, and even the most advanced programmer has no way of knowing every action the machine is actually taking, down to the individual manipulation of binary bits. It becomes impossible to know "good" code, because practices have become diluted. No one is able to have an objective opinion on the "goodness" of code, or its efficiency, as no single person can know the implications of every line or function.