

Camera for the Invisible: Toward a Toolkit for Urban Exploration

by
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B.S. Electrical Engineering,
Georgia Tech, 2002

M. Phil. Computer Speech, Text, and Internet Technology,
Cambridge University, 2003

Submitted to the
Program in Media Arts & Sciences,
School of Architecture & Planning

in partial fulfillment of the requirements of the degree of

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Abstract

We are *disconnected* from our environment. We can't reconnect because we can't even see the Nature within our urban surroundings. Inspired by urban explorers and Nature Awareness traditions, I will develop methodologies and design principles for coming into contact with the environment through direct observation of the previously unseen urban jungle. Building on the idea of revealing the imperceptible with a time-lapse camera, I will design both a new metaphor for sensors and a physical object: a synesthetic time-lapse "Camera for the Invisible" with implications for urban Nature Awareness, first person discovery/inquiry, environmental journalism, and "modernized poverty." Out of the struggle toward a toolkit for urban exploration, I will create a new categorization schema for perceptual scientific instruments, which will lead to a proposed new genre of tangible design called "skin2nature interfaces." I will write about the design process in a way that invokes intuition by engaging the reader in a semi-experiential process within the limits of this constrained medium. From my initial explorations, to the design and evaluation, I hope to engage myself, the users/explorers, and my readers in a process of *reconnection* with our respective local landscapes.

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I am very grateful to every living being. You have all helped me in some way. Some of you have helped me in more obvious ways, and I thank you so deeply for taking the time to work on these ideas that I consider so important. This thesis is a web of interconnected ideas that mostly aren't my ideas at all. I just spun the first few threads. Then people came along and spun some more threads. Then I added a few more, and I waited for all kinds of ideas to blow in and fly by. Now it's an idea party, thanks to collaboration from far and wide. Thank you all so much!

~ for the hope surfers and the makers of hope waves

~ to view the videos, sounds, and 3D CAD files in this document, download the multimedia version (this version doesn't contain any multimedia files)

~suggestions for reading my thesis:

If you are an academic first, skip straight to the intro and the conclusions

If you are a lover of adventure first, take a wild path through

If you are a lover of video first, start with the short film on page 26

if you are ...

...be

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Preface

Close Your Eyes: You're Reading It, So You Might As Well Try to Experience It

Hi, I'm Jay.



I want this thesis to be as experiential as possible. So if there's something you want to delve into more – well, go ahead. Or swing by my place and we'll take ourselves on an adventure... really, I mean it (my phone number's 321-bad-duck). I aim to be wrong almost as often as right to keep a bold balance between mapping familiar territory and discovering the dead ends and new paths not yet on the map. So please read critically, noting when I'm wandering off the path and whether you think it's headed somewhere wholesome. That experiential effect is going to be hard to get using paper sprinkled with a few videos, though I've tried my best to hack the traditional medium to allow for a smidgen of experience. So I'm going to have to ask you to get into it a little. Are you willing?

Start by turning off any music players or televisions. If you live in the future, no fair leaving on devices that I didn't know would be invented yet. Now close your eyes and see if you can hear your breath without forcing it. No, I said, "Close your eyes." Okay... now open them to read a little more. What else can you hear? (It might help to close your eyes.) If you are on a computer within a decade of 2008 you might hear the fan whirring. Maybe you can hear automobile engines or the rustling of leaves. What do you feel? Is your chair or the floor or the ground vibrating? What about when a truck drives by, then does it vibrate? What do you smell? Anything? Does the air have a smell to it? Musty, woody, polluted, fresh, moist, or do you think it's completely neutral? How did your shelter get to be where it is today? How did your food and water get to be here? Are you inside or outside...? Wait, I'm getting a feeling... inside!?

Okay... so for the rest of this document please try to get into it with me and feel free to stop and do your own explorations. You are also allowed to close your eyes any time you want to imagine or use your other senses. If you decide to do your own explorations, for goodness' sake, please email me about your experiences.

Life's Poem

A few years ago I performed this fable for the first time in a small crowded room with a single entrance/exit.

<Italicized text is/was performed through a lens which changes and exaggerates perception, both visual and audio>[1][2]

It was a rainy and serene night. A girl named life crawled behind a waterfall. She felt the smooth lip of the waterfall as she squatted and gave birth to a baby boy named poem. The girl held poem tight against her chest, skin to skin, as she watched the sunrise looking through the waterfall.

At that moment, poem knew that the entire universe was singing to him.

Poem climbed trees every day in his youth. Sometimes he would climb until he couldn't see the ground anymore. This was fun the first time he did it. But soon the bark all started to look the same, the tree would sway predictably, and what was once an adventure quickly became a routine. Poem went to his mother and asked why climbing the tree had become so boring. Life answered him, "if you love everything around you, nothing will be routine." the next day poem climbed the same tree he'd climbed many other times. At the top he felt the bark and really paid attention to it. He saw that there was an ant crawling around holding a leaf. Going over his mother's advice, he tried to love the ant.

He followed the ant all the way to the tip of a branch where the tree touched another tree. Poem kept following the ant onto the other tree and watched every step the ant took. a few hours went by and poem hadn't even noticed. "This is what life is all about," he thought to himself. "I never want to go back to the old way of looking at things. But, the next morning Poem had forgotten about his experience.

Poem grew to be a curious young man. He always wanted to know how things worked. He would watch the beavers build their dams, and he would try to imitate them with his axe. He became very skilled at stripping the trees of their bark. He learned to cure the timber under the water during the winter just like the beavers did. He reached the point where he could build dams bigger and faster than the beavers could. But he wasn't satisfied. He went to see his mother. Life told him that he should work side by side with the beavers and listen to their hearts beat. The next day, poem helped the beavers build their dam. As he was working with them, he had a vision.

He saw the pond they were damming. It started to attract animals to drink the water. The animals attracted other animals. The pond then started turning into wetlands and then a clearing and then a meadow. The meadow was home to a diverse population of animals. He saw the entire life cycle and felt that he was a part of it. He thought to himself, "I never want to forget the beauty of the world again. I want to hold on to this feeling forever. I feel as though I've already let it slip away from me once, though I can't remember when." The next morning, poem had forgotten about his revelation.

Poem was soon an adult and known throughout the land as the bravest and wildest cliff jumper there ever had been. He would climb the tallest cliff and dive into the shallowest water. On his way down he would pass waterfalls and ants crawling on trees, and he would land near the beaver dams. But he didn't

take much notice of these things. He would just climb back up and dive again. after he had jumped off the tallest cliff 100 times he went to his mother and asked, "why is it that even though I can jump off the highest cliff, I am still not satisfied?" life asked, "do you listen to the wind on the way down?" "No" he said. "Do you see the waterfalls you pass on the way?" "No." "What about the ants and the beavers?" "Well I see them sometimes, but how will that help me?" "Go to sleep tonight behind the waterfall and when you wake up you will know." reluctantly, poem looked out at the setting sun through the lip of a small waterfall. He started to notice how full of life he felt while sitting behind the falls. Looking through the water he looked out at the forest and saw everything in a new way. He vaguely remembered something about ants and something about beavers, but he wasn't sure what. He wasn't sure whether he was asleep or not, but he heard the waterfall whispering to him:

"Do you see how it feels to sit behind the waterfall?" "Yes, I am invigorated with a sense of what life is all about." "You are always behind a waterfall in life, you only have to remember that you are." when poem woke up in the morning he looked around slowly. Everything around him glowed. He could smell the sunrays and taste the stars. As he walked out onto the bed of pine needles with his bare feet he felt them as if for the first time. He remembered working side by side with the beavers. He remembered following the ant from tree to tree. He remembered the day that life had given birth to him behind the waterfall. For the first time he saw the connection between everything.

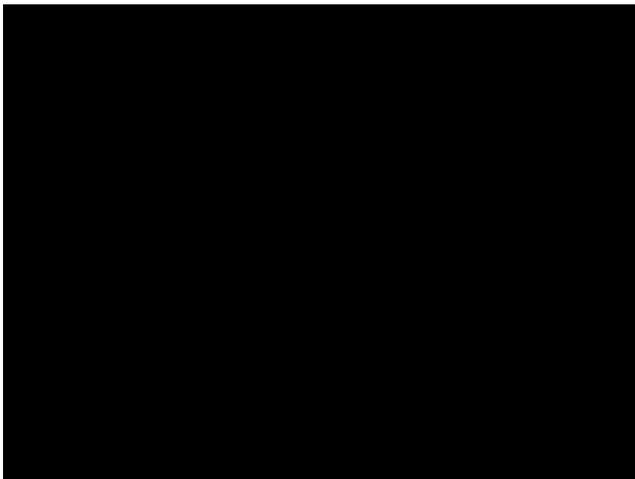
From that day on, poem always remembered that life is like being behind a waterfall. When poem had a baby, he told her this:

"Never doubt that you are behind a waterfall, because magic lies around every corner and in the heart of everything on earth. Even when you think there could never be a waterfall there, you must look harder."



**Embedded
Video**

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< The audience in the little room heard a swishing noise behind them, and they turned around to see that the only door to the room now had a waterfall over it. >

Chapter I. Welcome (an Introduction)

We are able in this day and age to build the tallest buildings and make 1 billion things [3] in a week. But the dreams and challenges of tomorrow cannot be met by our industrial revolutions and the corresponding mindsets. If the world's biggest challenge is how to get clean water, and our biggest dream is to live sustainably, we need tools and language that help us get there. We don't need to learn how to make things bigger, but to make things more interconnected... more synergistic. I see toolkits for all kinds of activities, but where are the toolkits for seeing interrelatedness? I dedicate this thesis to the idea that we are all interconnected and that we can all come to re-see it.

Once upon a time our distant ancestors ate what they could find and slept where Nature provided shelter. 150 thousand moons ago people started planting seeds. In many cities today, food comes from packages, and shelter comes from Craigslist. City dwellers rarely give a thought in a typical day to the hows and whys of their local habitat. Is the air I breathe while I sleep polluted? Which plants, animals, and humans live near my apartment, and how can we help each other? What's the connection between me, that tree, and that car? How was my city designed and built, and how does the layout interact with the sun, wind, and rain? Can I fix my problem myself with what I've got in my local landscape? What virtues can I learn from observing my land? I think it would be wonderful for people to discover questions like these and start investigating the answers...

One day, I started to wonder where my food came from, and how property rights got to be the way they are. This led to a series of three pairs of initial explorations, which I'll mention now and tell you all about in the next section. My initial explorations brought me from Boston to Virginia to India and back again.

The explorations started with an internship on a biodynamic farm and then some training in urban farming, both of which both taught me the importance of patient observation and trusting my own senses. My intuition began to awaken and I started to see my city as an urban jungle.

As I wondered how to make tools that could help other people awaken their own intuitions I studied inquiry with the author of the book *The Having of Wonderful Ideas* and visited a school in India with a "slow-learning" philosophy where I applied inquiry "on the streets." Both these experiences helped me learn the importance of taking the time to discover things for oneself, and how to foster this discovery process. At this point I knew I wanted to make a project out of urban exploration. With the urban farmers I had made a tool called the Urban Harvest Forecaster, and during my time in India I made a tool called the Curious Caterpillar (I'll describe both in the next section). The first was a utilitarian data logger, and the second was an instantaneously interactive gadget. I liked aspects of both of these, and I wanted to investigate how to combine the two ideas into a single tool for urban exploration.

I knew there must be some tradition to draw on, and this is where my last pair of explorations began. I first interviewed the people who have been studying Nature Awareness in the wilderness. Then I looked for the urban version of what the Nature Awareness people were doing. That was when I discovered a landscape architect who studies urban natural processes, and also teaches a class on studying urban Nature with a camera. This was as close to what I wanted to do as I could find, so I did an extensive case study on all of her previous students' projects, interviewing several of them to see how the process had

changed their everyday awareness. What the interviewees said showed me how useful a camera can be, as well as how extremely visual our society is.

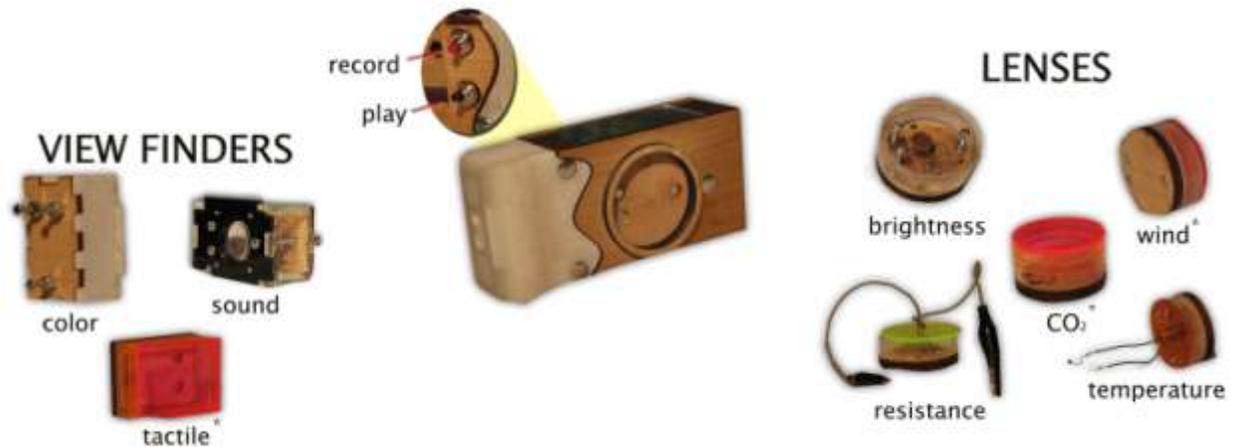
After taking a look at what other devices people had made, I started to design my own tools, all the while asking the question: “What would be a step toward a toolkit for urban exploration... a toolkit for re-seeing what’s all around me?” After my case study of the students studying urban Nature and during the beginning of the design process, I asked myself this:



*Note: The object on the bottom right is meant to represent a CO₂ molecule
I asked myself, “How can I accomplish what the camera did for the students of urban natural processes, but do so for nonvisual elements like temperature and CO₂? (Note: I recognize that CO₂ may be sensible to some people, but for the vast majority it’s sensed at the cardiovascular level without consciousness)*

I iterated on several designs, described later, which I started to refer to as “like a camera but for things you can’t see.” Then I tried making a camera literally (which I’ll describe in detail in the fifth section).

Camera for the Invisible



Camera for the Invisible

Camera for the Invisible lets you see temperature, hear CO₂, and feel brightness. It is synesthetic, which means it crosses senses. It's also a time-lapse camera, so if you record the wind overnight, you can play it back the next morning at high speed in one minute. It has many "lenses" that you can swap in and out on the front of the camera. Each lens lets you take pictures of a different natural phenomenon. It also has many "viewfinders" which you can swap out on the back of the camera, which lets you experience the lens inputs with the senses (fingers, eyes, ears, etc.). In this way, you can mix and match lenses and view finders for many input-output combinations depending on what you are investigating and what modality is easiest for you to understand at that time.

I hope that the Camera for the Invisible acts as a toolkit for exploring local urban environments, somewhat similar to how an electronics kit helps people explore circuits or an art kit helps people explore creative expression. Most agree that how we learn to interrelate with our environment is of the utmost importance:

"Climate change is a far greater threat to the world than international terrorism."
-the UK Government's chief scientific adviser [4]

Yet, I don't think the next biggest challenges or opportunities our world faces can be solved by a few genius environmentalists or scientists, but rather we need to redevelop a sense of common urban-ecological literacy. I think we need a population of people who understand how to work with their local landscapes to clarify our systems of air, water, energy, and respect for the interconnections of all living things. So I hope the Camera for the Invisible will facilitate the process of coming into contact with the

environment, but I also hope it acts as a metaphor and framework to help people think and talk about the unseen potential of urban Nature Awareness.

You might be able to see how a responsible and aware population can help the global environment with issues like global warming and wars over supposedly scarce resources. But even locally we can't keep going with just an elite group of a few environmentally informed. At a city scale, a handful of observant city planners know how to harness the forces of Nature to plan a city. They can align streets with wind flow to avoid pollution buildup in urban canyons, build water reservoirs in flood plains instead of low cost housing, and use alternatives to pavement to avoid the heat core problem [5]. But they have often been unsuccessful in gaining political clout for such planning since most people aren't aware of the importance of such "subtleties," and the decision makers, themselves often unaware, are left without a population to petition them. And yet few are lucky enough even to have an urban planner involved in their community plan at all. Mass migration to urban centers in more recently industrialized countries leaves a million new people every week to work out by themselves how their new environment should be set up [25].

"Environmental education must be radically reconceived ... We need programmes based on the identification and investigation of the problems by residents themselves..." [6]

These same practical city planning issues exist on a smaller hyper-local scale. One can control cooling and wind issues with carefully placed trees, and one can manipulate heating and lighting issues with attention to aligning windows with the sun. One can estimate or even measure the air or water quality of a city... or a house... and choose to do something about it, if one knows what to do.

"The land around your home is a vital piece of the urban forest and the watershed. How that land is managed - one lot at a time - can have a significant impact on your city's flood protection, water supply, air and water quality, waste management and economy." [24]

On a more human level, green spaces are inversely correlated with ADD/ADHD [19], and positively correlated with emotional, mental, and physical health. Studies in Louv's *Last Child in the Woods* show that in Nature play-space, children engage in imagination play, and the natural leaders are the creative children instead of the physically strongest leaders who dominate blacktops and AstroTurf. But are we aware of green spaces in our neighborhood, and do we know how to create them if we find them absent?

Louv argues that when one starts to see the Nature throughout the city, one also recognizes loose/available parts as elements in an ultimate toolkit. But we will need to have people see the Nature in the city for this meta-toolkit to manifest. As long as it remains invisible, so too does our ability to work with our land.

(Urban) Nature's toolkit is all around us... old junk lying around, energy-potential in the form of wind and sun, water that falls from the sky, buildings, plant matter that grows out of the ground, machines in the neighborhood, humans and animals (our neighbors)... but we don't see this meta-toolkit through the eyes of an urban Native, because few of us are Native to the city. So what happens if we don't know how to work with (urban) Nature's toolkit to get what we need while keeping it healthy? We become solely dependent on the market (professionals, stores, consumerism, etc.) to provide us with solutions. This dependence is what Illich calls "modernized poverty." [10] One symptom of modernized poverty Illich notes: "people are helpless to recognize evidence unless it has been certified by a professional." By

working through direct experience with the environment (as in first-person inquiry), one can gain confidence in one's own ability to understand the world – whether that means ignoring printed dates on food containers and using our own senses, or if that means improvising a fix for something that is broken instead of calling a professional, or maybe even looking out at a street and seeing... not nothing... not a coincidence... but a planned construction (perhaps poorly planned). Essentially, we could learn to see how our complex modern world fits together.

In a very simplified and literal example of seeing the invisible – I imagine that people can suddenly see the pesticides in their food or the pollution coming from cars into their lungs... both currently invisible. I wonder how that *nuevo*-visibility would change their interrelationship with eating and transporting? I imagine that people take the time to become aware once again about what their neighbors are up to and how they're doing, forming a social fabric between humans and across the landscape. Of course change is incremental, but if some of the catalysts for change aren't showing up in the eyes of the population we must find processes that bring the overlooked elements into focus.

I hope that people can use the camera to engage in a process of focusing their attention on their immediate urban landscape. By first exploring and then experimenting with the normally invisible parts of the local environment, I hope people will re-see what they take as common-place and gain an awareness of the invisible phenomena all around them. I see an inquiry into how our environments work and indeed our own selves too as a first step into disestablishing modernized poverty.

Chapter II. 3 Adventures, Traditional → Urban

Three pairs of inspirational people, three pairs of foundation-forming philosophies, and three pairs of informative explorations. In this section, I'll tell you about three separate pairs of adventures I had. During the first two explorations I had no idea that I wanted to make a larger toolkit, but I had a lot of questions to investigate... mostly about food. This is where I started to integrate my senses, awaken my intuition, and see how I could in fact work with the city to make my own (better) world. Through the process of the second two explorations I started to have a vision of a project that could facilitate exploring the urban environment. They showed me a viable, non-oppressive, educational model that I could draw from in designing a tool others might make use of. Finally, I knew I wanted to make a tool to encourage Nature Awareness, so I looked at how people facilitate Nature Awareness in the wilderness and then in the city.

Since this section is big I'll number it with letters and numbers to keep it organized.

I recognize that it's not necessarily typical in a thesis to relate foundational stories in such detail. However, I feel that the context in which I discovered the sensibilities which led to my thesis project are at least as important as the thesis project itself... no, in fact they are inextricably part of the thesis project. Please join me as I discover biodynamic farming, urban exploration, critical exploration, slow learning, Nature Awareness, and urban natural processes. The design criteria for the toolkit I eventually aim toward are mostly derived from these experiences. You may even be able to spot them before I did.

A) Biodynamic Farming → Urban Farming

From **Farmer Brad** and **Orian Welling** I learned how to farm **rural** and **urban** land in **Virginia** and **Boston**

1) Are the Plants Crying? Biodynamic Farming

While working with the urban harvesters, which I'll talk about more next, I started to wonder where my food came from *before* it went into the packages. To find out through experience, I went to Buckingham, Virginia and interned at "Om Grown Farm." On the farm they used some techniques developed by Rudolf Steiner called Biodynamics. And they used the same techniques many small organic farms use, though they don't have organic certification because it's too costly. They also develop lots of their own techniques and share local knowledge with other local farmers. That's because varieties of pests, weeds, and crops can be particular to certain locales, and some microclimates can differ even just a few steps apart. So it becomes necessary to have an intimate local expertise.

On the farm, I apprenticed with Farmer Brad.



Farmer Brad telling a story about a particular potato

Behind the potatoes was a field of Oregon blue garlic, and he said there were a few patches that were overwatered.



Oregon blue garlic... overwatered, but I couldn't see any signs

I asked him how he knew, and he explained that if I was patient and watchful I could find lots of signs. I spent many days at the farm touching, smelling, and tasting the landscape, not just once but over and over again to find differences over time and gradients over space. It took me a long time to get used to touching and really observing patiently. One day I noticed that the soil around one bulb of garlic was cooler than the soil around others (changes over space), and it had been that way on the previous day too (comparison over time). Thinking that the coolness could be a sign of extra water in the soil, I dug into the soil to feel if it was more moist than other nearby soil. I thought it was, but I wasn't sure. Then I looked at the leaves of that bulb, and here is what I saw:



A bead of water on the tip of a garlic leaf

Very small beads of water had formed at the tips of many of the leaves. It turns out that some plants cry in this way when they're overwatered. There wasn't really a good way to take a "picture" of the soil

temperature to share with you, but it was noticeably cooler to the touch. During my summer on the farm I learned more about the land. I was better able to care for the plants and understand what was going on. Most importantly I learned patience, respect, and stillness. It's easy to see why a farmer would want to have these skills, but what about city folk?

2) Create Your Own World: Urban Exploration and Urban Harvesting

I had already discovered the world of urban exploration before leaving the farm, but after returning I was looking for how to apply my new awareness of Nature and food to understanding my home, the city. I'll tell you how I first got into urban exploration and then how urban exploration first got into my research.

Accessing the Environment

How did a waterfall appear over the door at the end of Life's Poem? Right before the performance, I had installed a waterfall-door in place of the regular door. I initially made the waterfall door to investigate the nature of property rights. I had become very interested in inverting property rights as a way of inquiring into their validity.

"[Property] is a concept quite foreign to the original inhabitants of North America"

-From *Nature's School: Does the Land Have Rights?*

"All early societies in Africa and North America believed land could not be owned..."

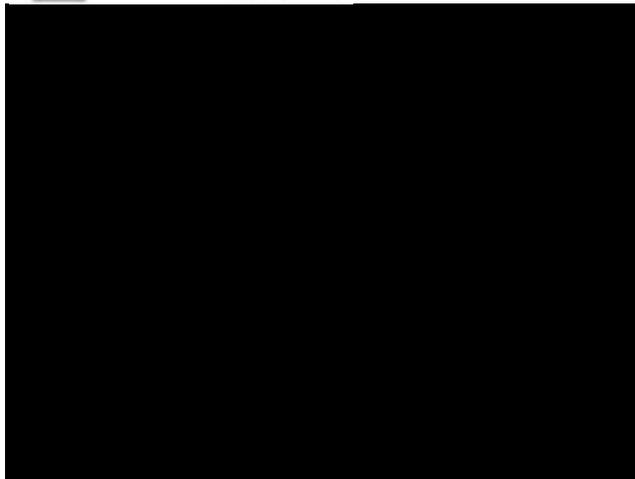
-From *Eve to Dawn: From Prehistory to the First Millennium, A History of Women in the World*

For example, I started with the question of whether kids have a right to non-adult spaces (the inverse of "no children allowed"), and if so what technology could enforce that right (a "grown-up filter")? In rural areas many answers to a kids-only space are handed down from generations: a tree fort, for example. But what is the urban equivalent? It's just possible that grandma and grandpa didn't grow up in your same urban environment, and they don't have the answer.

In studying property access I did a study of doors and ended up building this waterfall door [see appendix for a poster] (what I call a "BriefDoor" because it folds up into a briefcase and can briefly be moved, reinstalled, and reprogrammed). I started to investigate how we make use of our urban environment by installing the BriefDoor on apartment complexes and indoors setting up different *faux* borders with inverted property access rules (e.g. a *faux* U.S. / Mexico border).



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The theme of inversion as a technique for inquiry was useful as I continued in my later explorations: What don't we eat? Where can't we sleep? And in my final attempt towards a toolkit for urban exploration, the camera, What don't we see?

I installed this waterfall-door in place of many normal doors around the city to try to investigate a different point of view on property access. How we share resources is tied up in how we share land, and at the present property ownership seems to be very static. I imagine a world where property ownership is programmable and interactive, and as dynamic as the people who tend the property. That's why I made BriefDoor a playful and programmable gatekeeper for investigating property rights. As I started to investigate where people do and don't go, what is seen and unseen in the city's environment, I came into contact with a tradition called urban exploration:

Expanding Urban Exploration to create Urbonauts

Urban exploration: the examination of the normally unseen or off-limits parts of human civilization [Wikipedia, July 2008]

Though urban exploration has its roots in exploring abandoned buildings, for many it is a way of life, a way of looking at the urban land. Some urban harvesters (sometimes referred to as dumpster divers) find all of their food through urban exploration, and urban campers (sometimes called squatters) in similar ways find their shelter. So in a way, it's all about using your natural intuitions to live off the land in instinctually foreign environments that most people now live in: cities. At first I became fascinated with making use of what lay fallow. Then I wondered what else was unseen and untended in the city. For the rest of this section, I'll tell you about some tools I made for traditional urban explorers (urban harvesters & campers), and then talk about how I started to envision a broader set of urban explorers, of whom only a subset are the traditional urban explorers – maybe we could call the new, more prevalent, urban explorers... “urbonauts. “

Urban Harvest Forecaster

I was first introduced to urban harvesting by Orian Welling, a young transfer student to MIT, who had spent the previous year biking from Alaska to Argentina on a tight budget. During such an adventure, many questions arise about how the landscape can act as companion, food, shelter, and tool. During his first year at MIT, he brought me along on some modern day hunter-gathering runs, and through this action I learned many lessons. Orian put words to the tune I was feeling one night, "You can create your own world." Somehow, riding in a 1940's farm truck converted to run on reclaimed veggie oil, I saw what he meant. The world he was showing me had been hiding in nonexistence until he helped me create it. We wondered together what other worlds lie undiscovered all around us.

I wanted to contribute to the project, so I joined the community supported agriculture (CSA) group that fed twelve people every week from reclaimed crops. When an urban garden (such as a dumpster)



Urban garden outside of Boston

was bursting with crops, it was typical to feed 12 people for a week from a single 30-minute harvest.



A harvest from one food garden and one office supply garden

Through a community supported agriculture (CSA) model, the venture was modestly funded (truck repairs) before any food was ever harvested -- then the harvest was split between all the members of the CSA, regardless of how much was brought back... everyone got a milk crate full of food for their \$4.

As I pulled truckload after truckload of fresh juice, office supplies, vegetables, and many other things commonly on my shopping list, I started to ponder how America could waste 50% of its food [7], and yet still eat more than a healthy amount?

Short Film

Where Does My Food Come From?

Creating Your Own World



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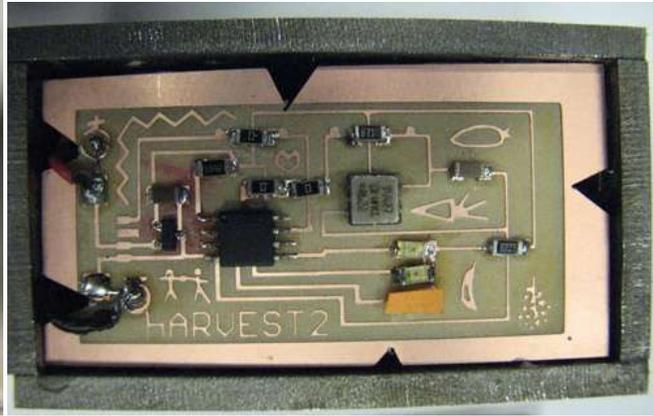
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I had learned from Farmer Brad that traditional farmers have used moon charts to predict when to harvest their crops in harmony with the land. So working with Orian and his team, I started developing a tool to help forecast good times to harvest in the urban environment. The Urban Harvest Forecaster senses when people throw food into the urban gardens (dumpsters) and when competing harvesters (dump trucks) empty out the garden.



Urban Harvest Forecaster, heavy steel like a farm tool



Under the hood, the sensor embodies its meaning internally with circuit art: carrot, banana, people holding hands, etc.

The urban harvest forecaster helps pick a bountiful season for harvest by sensing when the dumpster is tipped over and when the lid is opened and closed.



Orian says

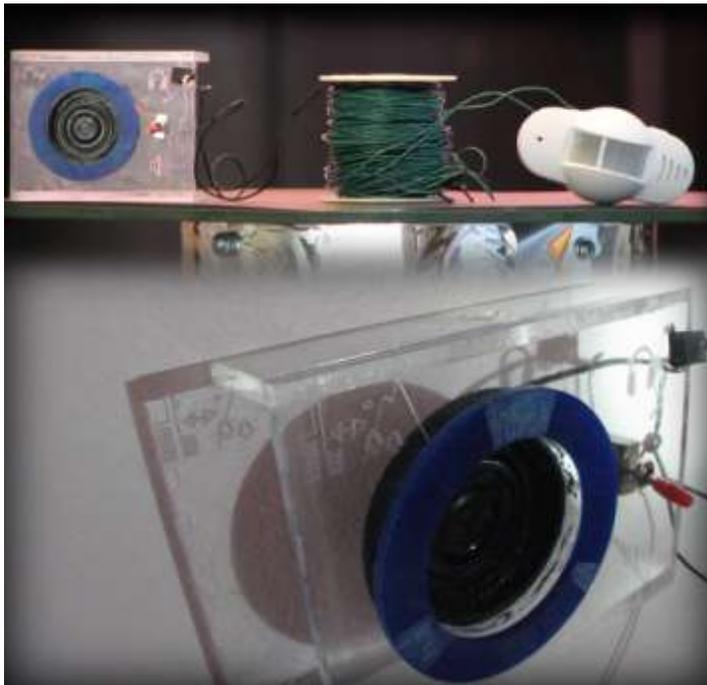
“Having an urban sensor is like knowing what season it is. Out [there] in the wild that’s easy, since in the winter it’s cold, in the summer it’s hot, in the fall the leaves fall off, etc. In the urban jungle it’s a little more difficult. Everything’s all computer-like already, so the only way to know what season it is, is to have a computer (sensor) to tell you. Without it, it can take years to figure out the seasons of any particular city ... in order to determine the best time to harvest. It took me 1.5 years to settle on the best time for the Boston area.

Some critics have said that cities are different from Nature, and that it’s not helpful to invoke metaphors like “seasons” and “gardens” when talking about collecting food from dumpsters. But, by developing (and borrowing) a language that is evocative of spaces where our intuition works, I hope to invoke our intuition – one major motivation of this thesis. As I worked with a landscape architect (described later) I started to invoke even more natural language to refer to the city.

Some aspects of the Urban Harvest Forecaster sensors have been problematic to learn and experiment with because there is no playful exploratory mode, only a data gathering “time-lapse” mode. A system of two sensors is “food-ouflaged” near other rotten food at the bottom of a dumpster and the other is “plast-ouflaged” on the lid of the dumpster [21]. Months later we pick the sensors up. That’s a long time between testing cycles, making it hard to get a feel for how the sensors work, though it is appropriate for the situation.

Covert Alert

As people started to hear about our sensing work with urban harvesting, other urban explorers started to think how they might be helped by extending their senses. Some urban campers requested a tool for knowing when someone was approaching their area while they were asleep. So the next tool I made was really just a reorganization of a tool I found at Radio Shack. I rewired a motion chime that makes a doorbell sound when someone enters your store. I wired it to act as a Covert Alert that people can hear in their headphones when someone is approaching their camping area.



Covert Alert allows you to choose whether to play the alarm sound loud through the speaker or quietly through your headphones, so that you can know someone is coming without letting anyone know you are there. It was good that I was able to take an existing solution and repurpose it, because it allowed me to send out the product a few days after the initial request, which was important since the urban campers needed a solution right away to be safe.

"Finally I could sleep, knowing that ... I would be woken (by sensors detecting the motion and then alerting me discreetly through the headphones which would waken me as I slept upstairs) giving me enough time to exit through the roof avoiding arrest or attack."

- Emily, an Urban Explorer

But also, since the door chime is readily available in many places, it means anyone can copy the method to make their own. This is sometimes called viral replicability, and is an important design criteria for things that will never be mass produced.

Through the process of making tools for urban exploration, I started to notice some inspiring processes at the heart of urban exploration:

- Observing the environment carefully and patiently to see patterns
- Studying the immediate neighborhood over time to become a local expert with Native knowledge
- Challenging conventions to make new discoveries, while being respectful of people, animals, and land in the process
- awakening all the senses to invoke a healthy intuition

After making tools for two traditional types of urban explorers, I felt that there was a whole area of urban exploration outside exploring buildings and dumpster diving. I wanted to make tools that could make us see the reality and the value in our (urban) surroundings that goes unnoticed, encouraging the exploration of seemingly mundane things like the front yard. I imagined a whole new generation of NASA-like urbanonauts who explore their home towns, making fascinating discoveries that spin off local civilian knowledge much more useful than Velcro. But what is the appropriate way to start learning about one's own city? In my next story, I'll tell you about critical explorations, which is a methodology for making people's thought processes more visible and placing importance on the thoughts. This method of first person inquiry helped me to see that in order to facilitate awareness of something like urban Nature, one just needs to focus attention on it and make it visible.

B) Practicing Inquiry in General → Applying it on the Streets of Bangalore

From Eleanor Duckworth and Geetha Narayanan I learned how to use inquiry in general and in particular in Boston and Bangalore

1) What Do You Know? Inquiry-Based Education

I took a class from Eleanor Duckworth, a professor at Harvard School of Education and student of Piaget and Inhelder, which was all about *The Having of Wonderful Ideas* [8]. I learned to watch people think through situations and ask them about their thought process without looking for a right answer.

For example, on the first day, during an activity called "going to the movies," we had to show all the ways that four people could sit in four chairs. Note, we didn't have to find out *how many* ways they could sit, rather we had to *show all the ways*. I quickly solved the problem as I'd been shown before in my math classes and waited for others to finish. We were using beans and noodles and little trinkets to represent the four people, and we would arrange them in rows of four to show all the ways people



could sit. What was a big surprise for me was that everyone in the class thought about the solution to the problem a different way. But isn't this such a boring and "already-solved" problem? Yet the way each person thought about it was really interesting and unique. Even when people came to the same solution, each person's path and reasoning was different and sometimes shocking (especially when it ended up working and I thought it wouldn't). I found myself becoming fascinated with how people think about even the most mundane of questions.

As we conducted other, more interesting explorations with people, we learned to ask all about the person's thought process. We would just inquire, "What makes you do that?" or "Tell me more." (which is also the title of one of her books, *Tell Me More*). These inquiries helped me learn to appreciate people's thoughts and at the same time place value on the thoughts by taking an interest in the thoughts. Does it seem like I just said the same thing three times?

I asked people to tell me more

Their answers were interesting, which made me start to value their thoughts

When someone values your thoughts, it suggests that you might want to value your thoughts

When you value your thoughts, you start to explain them more

Oh my we've just entered a positive feedback loop

This process is referred to as a critical exploration.

One of the first questions we typically ask in a critical exploration is, “What do you notice?” This is a low floor question, also often used in art critique, and a good strategy for getting people started thinking... not about what they previously knew, but what they “knowtice” right now. I later learned that this is a type of inquiry-based learning which has a large tradition [9].

In that class we also worked on solving “old” problems ourselves through direct observation and manipulation. For example, we were to watch the moon and keep a journal to try to figure out what the moon was doing. Two of the many questions people were wondering about were, “What path does the moon follow in the sky?” And, “Does the shape of the moon change as it moves across the sky?”

I wasn’t getting very far with keeping a journal, so I decided to take some pictures. At first I experimented, just taking photos and looking at how they turned out instantly on the digital camera screen. Then I started small time-lapse experiments consisting of several pictures.

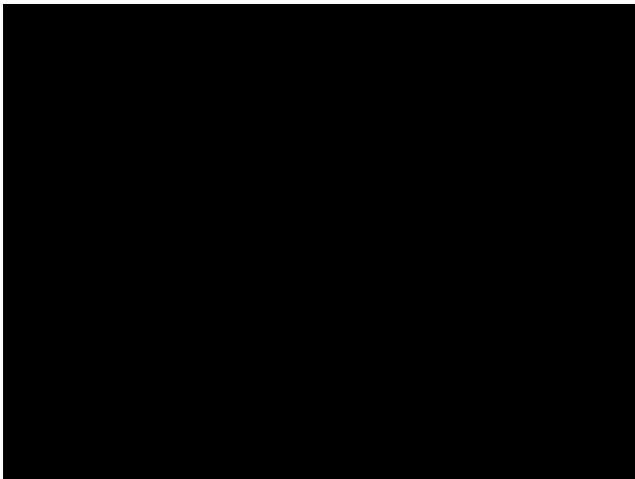


Time-lapse of the moon taken at 30 minute intervals



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During my first experiments, I didn’t get the exposure right to see the shape of the moon. Also, I picked a night where the moon’s path was obstructed by clouds. But the instantaneous feedback of the digital camera let me experiment with all this until I was mature enough to set up a satisfactory experiment. One clear night on the Harvard Bridge, I took a series of photos that ended up spurring lots of discussion

in the class, especially because the photos gave us a concrete way to think about the two questions from above.



Each taken 24 minutes apart and superimposed

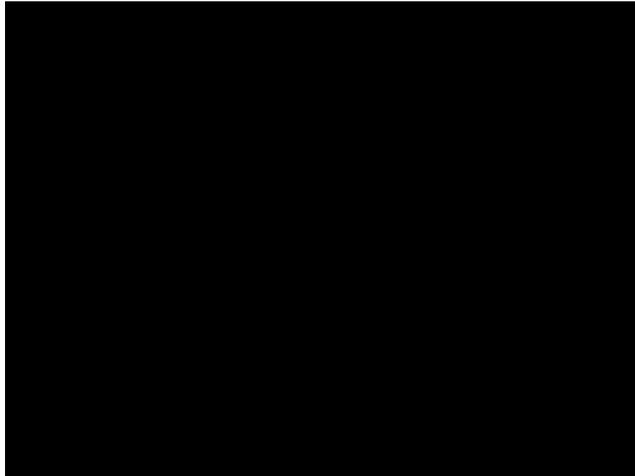


Same picture with a straight line drawn for reference



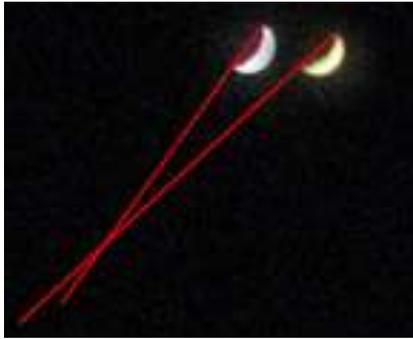
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We projected the moon-lapse onto a whiteboard and put dots along the center of the moon's path. We weren't quite sure if the dots were on a straight line or not, but we started to guess. Later I created these composite pictures (above). Based on the picture above on the right, I would say that the moon doesn't travel in a straight line as viewed from Boston. I can say that without reference to any expert, but by trusting my own observation and thinking.

Then I took two of the photos of the moon which were separated by 96 minutes, put them right next to each other in space, and drew lines showing the orientation of the sun's light reflecting off the moon as perceived from Boston. This is what I got:



First and last moons put next to each other with orientation lines superimposed. The orientations aren't the same.

So I would say that the moon's lighted portion as seen from Earth does rotate as the moon moves through the sky, because the orientation lines are at different angles from each other.

I was able to see processes that were otherwise invisible. Others were really interested in seeing the photos since they were actual photos taken in Boston by someone they knew, not a theory out of a book. That is, first person perspective was involved. The whole class was hotly involved in analyzing and debating the meaning of the photos.

Months later, a professor told me that the moon's curved path might be due to the 35mm lens distortion. I wondered if he was right, so I went out and took another picture of a distant building with a "straight" edge and superimposed a straight line over it. The two lines were parallel to the eye, meaning that my camera lens doesn't bend straight lines to the point where it's visibly obvious. So I decided that distortion of the lens wasn't a factor in my moon results. But it was an important point – bigger than the fact that a lens is curved. The point is about measurement, perspective, and understanding that any scientific instrument is a system with limitations.

I started to realize that what I was using was in fact a scientific instrument. Not just any scientific instrument but a low-cost, battery-powered, mobile, ubiquitous, easy-to-use, data logging, scientific instrument. Furthermore it was instantly usable and playful with a single button push and continuous instant feedback, but ultimately allowed me to do scientific experiments that lasted hours. These factors eventually played a big role in my decision to use a camera as the basis for my toolkit design.

As of 2008, time-lapse cameras are still hard to get a hold of. Cameras with this feature still aren't very deployable and are expensive. A redesign of time-lapse for urban exploration would need to be deployable into the urban jungle. This means it must be low power, cheap, weatherproof, and camouflageable. One would hope that regular digital cameras will meet many of those criteria soon, and it seems that they are well suited to explore the urban environment, except that they are a little weak on helping you see things you can't already see. As I learned on the farm, you can't see everything with a traditional camera, like the temperature difference I felt in the soil that led to my discovery.

In a way, I had started to build up a trajectory, though I wasn't aware of it until looking back and it wasn't a straight trajectory. I wanted to think like a farmer, but in the city like an urban explorer, and I wanted to harness the methodology behind critical explorations to lend weight to people's awareness of the environment. What was missing? Perhaps the final piece was a woman with a striking vision who was working with a population so vibrant that my designs brought them back to mind again and again.

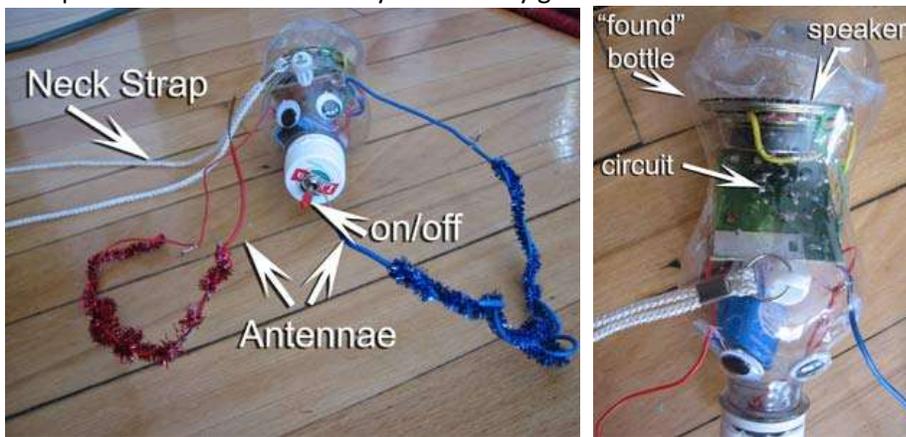
2) Lab in a Bag: Slow Learning

In Bangalore, India, for three weeks in summer of 2007, I found myself at Drishya, a “not-school” in the slums of Bangalore, which adheres to tenets of the slow learning movement [21]. Slow learning is a dangerous redesign of the idea of schooling with a shift to *slowness and wholeness* as opposed to *acceleration and industrio-specialization*. Dangerous simply put because a “challenge the dominant paradigms of the time and can be described as heretic.” [10] To give an example of what is meant by slowness, 1/3 of the day is typically spent in healing activities like breathing, which is necessitated by the extreme conditions of the children’s daily lives outside of Drishya.

I was working with the founder, Geetha Narayanan, on a project called “lab in a bag”. I was inspired by her vision of a mobile lab in a bag. At the same time playful and useful. At the same time cheap and rugged. In this context, I am motivated to work toward a toolkit for urban exploration that is also a step toward a lab in a bag. It was also in this context that I accidentally created my first spontaneously playful tool for urban exploration:

Focused on the theme of water, and inspired by the PicoCricket’s musical banana (an instantiation of Pico Crickets for playing sound based on the resistance of a banana). A PicoCricket is an invention toolkit created by LifeLong Kindergarten, the group in which I am currently a seeker [22]. I’ll explain more about PicoCrickets in the Related Projects section of chapter III.

I created a dedicated resistance-to-sound synesthetic pair (a circuit whose sole purpose was to convert electrical resistance into a sound pitch). Since the main things in the environment that conduct electricity contain either water or metal, one way to think of it is as a probe that makes sounds when it touches objects that contain water or metal. I packaged it in a plastic bottle and formed it into a caterpillar like the ones in Drishya’s butterfly garden.



Curious Caterpillar – front view

top view

The children touched the caterpillar’s antennae to everything in their environment that they



Testing a plant stalk



Testing the soil collaboratively



Testing rock, fruit, bikes, plastic, each other...

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Right before the video starts they ask "Can we go outside?" In the first half of the video the Curious Caterpillar is made from Pico Crickets. In the second half, it is a standalone circuit.

could find and listened to the results. They didn't need prompting. They just erupted into activity. The neck strap was helpful in the final design so that the hands could be free, but also tended to make it less collaborative since it was attached to one person – perhaps suggesting a double neck strap design (though maybe not literally)? The water bottle was a compelling case since it is familiar and can be found in the local environment. The circuits were made in collaboration with the facilitators. The cook and one of the children was so interested that he stayed late into the night to help.



Making a curious caterpillar circuit with facilitators. Intermittently the power would go out and we'd work by candle light.

All the parts were bought locally on the grey market. If the circuit had had memory, we might have been able to do some interesting things by leaving it places overnight. But the continuous and instantaneous feedback proved playful and provocative for initial exploring and getting the idea quickly. However, they were probing the environment with wires, and not necessarily (though they did sometimes) touching the environment with their hands. Also, there was not much control over how the tool worked. I was compelled to continue looking into these types of exploratory sensors by the overwhelming enthusiasm of the children at Drishya and the strong vision provided by Geetha. As I designed I often had the children from Drishya in the back of my mind.

C) Blindfolds → Urban Jungles... or Nature Awareness → Urban Nature Awareness

From Tom Brown Jr. and Anne Spirn I learned about Nature Awareness in the wilderness and in the city in New Jersey and Boston (but I didn't visit New Jersey, just read and interviewed about it).

A Note About Theses

The thesis process is interesting, because at a certain time you have to make a proposal for a project, whether or not you think you're ready. It's hard to untangle my readiness from the starting point of the thesis project since they happen at the same time, which in the story line is now, or right after I got back from India.

Curious Caterpillar + Urban Harvest Forecaster = ?

At this point in time I start to have a vision of wanting to make something that is as spontaneous as the Curious Caterpillar, but as useful as the Urban Harvest Forecaster.

$$\begin{array}{l}
 \text{Curious Caterpillar} \\
 + \quad \text{Urban Harvest Forecaster} \\
 \hline
 \text{????????????????????}
 \end{array}$$

I want it to be for exploring the urban jungle, but I just don't have enough of an idea what the history of Nature Awareness is and how you get people to inquire into their urban habitat. So I start to look into Nature Awareness authors. Then, I interview disciples of the most compelling authors or study with the authors when possible.

1) Nature Awareness Traditions

My First Brush with Nature Awareness

Years back, on a Nature walk in Western Massachusetts our Nature guide asked us to look forward and hold still while holding our arms straight out in front of us (go ahead and try!). Then we were to wiggle our thumbs and move our arms out from the center of our field of view to the left and right edges, all the while wiggling our thumbs and keeping our eyes straight ahead. At some point the left thumb disappears off the left side of your vision, and the right thumb disappears off the right side. Those are the limits of your field of vision. Almost 180 degrees. But we have been trained by screens and other parts of modern life to have tunnel vision.

Blindfold 'Em

My biggest finding in the Nature Awareness tradition was that people overemphasize their visual system. It's not as simple as that actually. They don't even use their full visual system; they tend to look straight ahead. So in order to give people the experience of using their other senses, I was very interested to find that a common tradition in Nature Awareness is to first take people out into the wilderness and blindfold them. According to my interviews with people at the Tom Brown Jr. Tracker School, this is the first thing they do with people. They say that people are so focused on their vision, and even then only the central part of their gaze, that they aren't open to the intuitive understanding of Nature gained when integrating all the senses. Joseph Cornell also uses this same technique with an opening activity where people partner up and find objects in the wilderness to hand to their blindfolded partner who must then guess what it is without looking.

Tom Brown Jr.'s The Tracker

In the book *The Tracker*, Tom Brown Jr. hints at many of the things that have eventually become part of my design criteria for Camera for the Invisible. He says: "[Birds] leave their track in the air most of the time and I don't have the nose to follow it." Even as a lifelong tracker, he can't smell the history of a bird's motion through the air, making that type of bird track essentially invisible to him. To me this means it could be helpful to use sensors to make this type of track visible.

When speaking of the greatest lessons he learned from Stalking Wolf (his Native American mentor) he says, "He taught me to see invisible things from the trail that all action leaves around itself." He points to the fact that some invisible things are possible to learn to "see" given the right state of awareness, foreshadowing an important consideration when making toolkits to facilitate Nature exploration: to what degree will the person transcend the tool? Or restated for myself as a designer of such tools: how do we get the tools to facilitate the explorer's transcendence?

Tom says, "He taught me how to teach myself the mystery of the track." Here, I think Tom is talking about first person inquiry. He is referring to that mystical school lesson that everyone wishes was taught, the lesson about how to learn and how to be curious. Of course there is no such lesson literally,

but Stalking Wolf still managed to “teach” it. And Tom Brown Jr. learned it to the point that he says “I do not believe I am in any danger of running out of discoveries.” This is an attitude which I think is fostered by first person inquiry, and leaving behind the fear of replicating someone else’s discovery, because of course the process of the discovery is original every time. This, of course, is also the focus of Eleanor Duckworth’s class (discussed earlier in this chapter).

A Walk in the Woods and Joseph Cornell

Erik and Vesna Plakanis are followers of Joseph Cornell. They run “A Walk in the Woods” Nature guide service. I interviewed Erik, and he told me one story in particular that helps me remember to focus on experiential learning styles with, if necessary, one person at a time:



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“You can read about it, you can see it on TV, you can hear about it, you can be lectured about it. But when you can take a stethoscope in the spring, and put it on the outer bark of a tree and you can hear the pulse of that sap being pulled up, water being pulled up from the ground. That sap, pumping up rhythmically, up into the branches until the buds unfold... Just taking one person at a time and getting them to experience that.”

This next paragraph isn’t a misprint, go ahead and read it again:

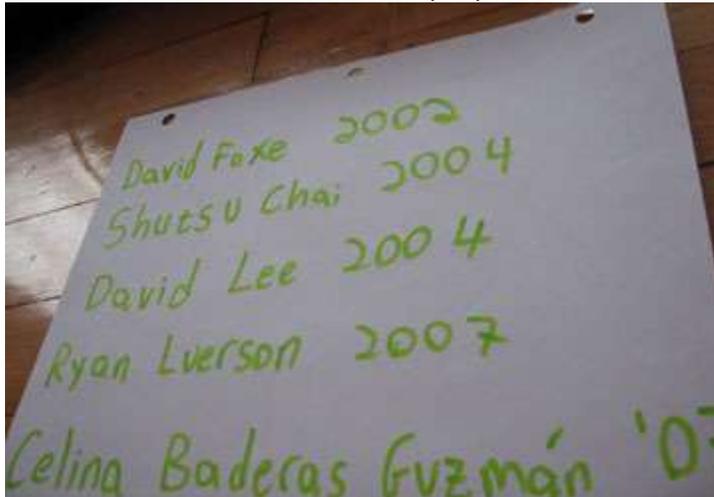
“You can read about it, you can see it on TV, you can hear about it, you can be lectured about it. But when you can take a stethoscope in the spring, and put it on the outer bark of a tree and you can hear the pulse of that sap being pulled up, water being pulled up from the ground. That sap, pumping up rhythmically, up into the branches until the buds unfold... Just taking one person at a time and getting them to experience that.”

2) Urban Natural Processes: A Case Study Using Cameras



Boston from a bird's point of view with some terrestrial biomes labeled. Photo from cover of [Granite Garden](#) (11)
Annotation added by me, but in the spirit of the book.

It was from Anne Spirn's talks on the urban natural processes that I could fully see the extent to which we live in an urban jungle. Anne has an entire class dedicated to observing urban natural processes using a camera. The class is called "The Once and Future City." Everyone in the class chooses a separate 5-block area of the city to explore. They come to observe that area over and over again for a 3 month period. They are especially looking for urban natural processes. When I found this class, it was the closest neighbor to the type of methodology I was interested in. She had all the reports from previous classes online [11]. I decided to do an in-depth case study on what effect this class had on the several dozen people who had gone through it over the last six years. I read all their reports online and set up interviews with them. I interviewed people who took Anne's class spanning from 2002 to 2007.



Class Webpages: [David F.](#), [Shutsu](#), [David L.](#), [Ryan](#), [Celina](#). Each person put a webpage up detailing their explorations.

Having gone through the experience of exploring the city for a few months, they understood quite well what type of tool I was trying to make, even though I didn't know yet. David Lee said:

"I think the most profound statement of the class and Anne (Whiston Spirn)'s book was that the city is not the 'anti-nature'; rather, natural processes pervade the urban environment and have

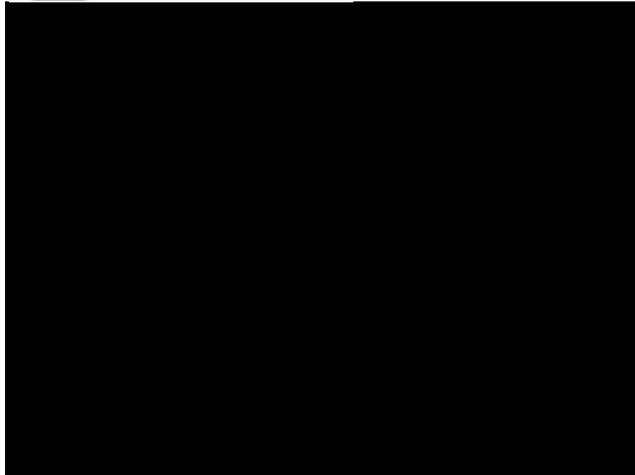
a huge impact on our quality of life. I would add to that the reminder that human behavior and the way people walk through and use sites is natural as well. Our bodies respond to stimuli in instinctual ways that planners often ignore when designing public places. The job of urban designers is to create places that engage people in positive ways. It seems like you are approaching this from the opposite end: giving individuals the tools to experience any place more vividly. I think this sort of thing works best when a person has first become familiar with a place on their own, without cameras or maps or guides or historical knowledge. Discovering something unexpected about a place you are already familiar with is, to me, a particularly delightful feeling. So, save the tools for the second or third visit!"

I started to realize just how informative these interviews were going to be. I started to view these experiments as the predecessors to my own experiments, on top of which I would build. I decided to interview a "man on the street" to see what his view of urban Nature was:



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He focused on the visual, and further, the apparent. But he didn't seem unthoughtful or ignorant of Nature at all. As he says, "I think I appreciate them if they strike my consciousness; I'm not sure I look for them." I imagine many people react this way to their landscape. "React" being the point. If something "strikes" them. What I wonder is, what process can you offer people so that they can engage more actively in looking... indeed, "seeing" with their whole bodies? I proceeded to interview more students from "The City" (the nickname for the class) to see how the process they had gone through influenced their ways of "seeing."

David took The City class in 2002. He's a really interesting case because he's such an insider to his area, Bow and Arrow Street. He recently moved onto the area which he studied 5 years earlier. He is also a professional architect. So he really knows the area inside and out. His insider knowledge helped him to perceive totally different concepts in the area from anyone else.

During our interview, he summed up Anne's main point: "The point of *The Granite Garden*, much of Anne's work, and the work that came after it, was to reconnect the idea that there is nature in the city."

As David walks by the architecture bookstore he is thinking of the map that he had included in his case study (above). He takes me into the bookstore and shows me that one of the books in the store has a map from the 1930's of this very location on its cover... It's from the fire insurance records.



Map of Bow and Arrow St. from 1930 of a book in the bookstore



The same map... David shows me it's on the cover of a book in the bookstore

Minutes earlier, in looking for natural processes in the same location -- out in front of the bookstore -- I don't imagine any maps at all. In fact, I don't even see the bookstore; its sign isn't very prominent. I see what happens to food if you throw it on the ground. Birds come to harvest the food.

This empty lot was in David's report. They had moved a house that had been here. David brings me by the new house and shows me the address: 11 and 1/2... because it was placed between two other houses.



Vacant Lot from David's Case Study

Now there's a theater there. David explains a little about the new theater:

“The big thing that has changed is that the parking lot that was the center piece of all this was here, and it was just sort of this gravel mishmash for at least ten of those years... From a Nature Awareness thing... the weathering of materials... the copper trim, depending on how it's treated... this will turn statue of liberty but not for a while.”



A closeup shot of the new theater weathering

He was so precise about everything. But more importantly, when he looks at the new theater, he sees 15 years of empty lots, moved houses, and weathering copper. When I saw my friend perform in the new theater, all I saw was the performance.

As with the theater, David had taken another picture back in 2002 which I took a picture of in 2007:



In front of the [National Lampoon](#) office on Mt. Auburn St. in 2002



The same location in 2007 with a "ceremonial bench"

I was amazed at how simple it was to compare an observation he had made 5 years earlier with one I made now.

David says:

"This entire island wasn't there... this was all asphalt from here across. It's unusual that these [benches] are long enough that someone can sleep on them. Because of the scale of everything else here that they didn't make, this is big enough that it deserves, not just 'a bench,' but a sort of ceremonial-like 'let's observe the Lampoon' bench (the bench is pointed directly at the interesting National Lampoon building)."

David sees things in his environment that are many levels above what I'm even looking for. I started to understand that he was literally an insider when he first swiped his key card to get us into one of the

buildings. This is the most concrete moment where what used to look like a brick wall now looks like a courtyard or painted hallways. He says "If you can know mentally that there's a space on the other side of a gate or the other side of a wall..." The rest was implied: What if you can know, mentally, that the invisible is there? It could totally change how you perceive a brick wall.



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How can I learn to do this without moving into an area and becoming an architect?

I asked a couple of the other students to spontaneously make observations about urban Natural processes as I took them for a walk outside. They didn't know ahead of time I would ask them, yet they were ready to think on their feet. Ryan says:



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“People look at trees a lot, but people don’t really look at trees, they’re like oh that tree’s got leaves on it, but not all the time. I’d be lying if I said I do this all the time, but quite often I’ll look up and be like oh that tree has no leaves on it, but these ones do, and maybe that one down there has green leaves and these are more orange, it’s probably just the type of tree... It seems like it might be a species difference, but sometimes you’ll notice the trees on one side of the street are all leafless and on the other side they all have leaves. Maybe it’s really windy on one side of the street and it blows all the leaves off, because of the way the buildings were arranged way down the end of the street, thus having an effect on the leaves way down here.”

I was amazed how Ryan was aware of so many factors playing together. I also noticed that his initial cues, like trees having leaves or the colors of the leaves, were all visual.

I asked Shutsu to think on her feet too:



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Shutsu: “I noticed in the past those columns change colors... the interesting part is that some of those columns are farther into the building. At first I thought it was because the first time I walked past it it was a rainy day, but I then I was actually kind of perplexed because it was darker on the side away from the outside and even more back there because they’re not even wet... So I ultimately decided that it was because the sun comes down really strongly and then moves over, and it was probably just washed out by the UV rays.”

Me: “And you’ve looked at that before?”

Shutsu: “Yeah, I noticed it, like, one night when I was walking by.”

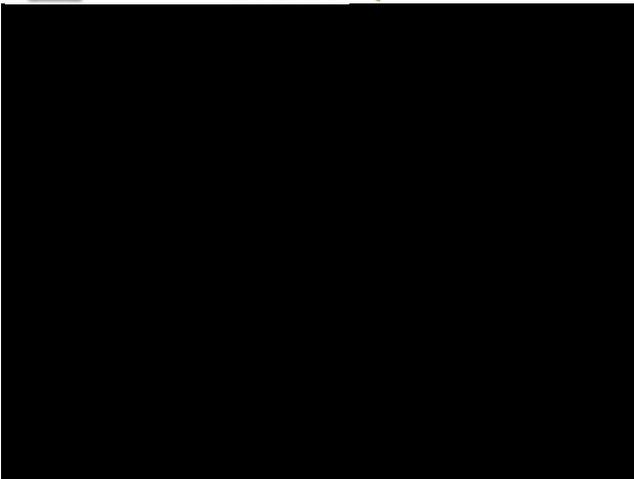
I’m watching to see how they react spontaneously, but I’m also curious to see what clues they reveal about how they normally think about their landscape on a daily basis. Here Shutsu reveals that she is looking for cues like this long after the class was over and far out of her chosen area of study. And it’s obvious that she didn’t just think of this on the spot: she says she noticed it one day. To me this shows

how going through the process they went through can raise your awareness level on an everyday basis. I had many other experiences that pointed to the same conclusion when talking to these students. Coming back to the visual cues, again all Shutsu's cues were visual, though she showed awareness of the invisible mitigating factors. To me, this implies that her months-long studies of urban natural processes had helped her to see the unseen, but the camera had trained her to point to cues that the camera could capture.

The power of first person learning also came out in these interviews. Ryan says:



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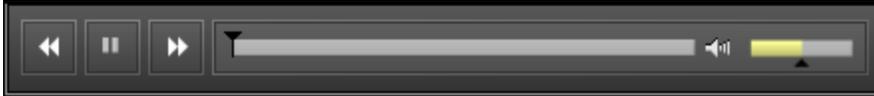


“[Anne] was very big on first person observation. She wanted us to go out into the site, take pictures, write things down... I still know everything that I found out because I found it out myself, that's not to say that it was right, but it certainly wasn't wrong, and these are things I can go to any city now and look at it's not like I read a text book on the history of Kenmore square and I know all about it but I don't know anything about this place here. It's not like that. I discovered things about it... now when I look at this place I might be able to say something, or the next city I move to, actually I haven't been home since that class, when I go home even I'll probably notice things I didn't notice before even though I've lived there for seventeen years.”

It was also surprising how much doubt and fear I found in first person learning. There is a hint of it in Ryan's statement. But one student I interviewed said, “A lot of that stuff [I learned first person] it's probably true, it's not necessarily like false but...”

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This was an anonymous student at MIT who was unable to trust his own observations because they might not be 100% true. This brings up a potential problem with using scientific instruments so often to view things: instruments augment our senses, but it's problematic if they trump them.

One student who I didn't get to interview was able to come up with innovative ways of seeing the invisible using his own breath. He would blow into the cold air and watch which way the wind was blowing. He did this in several spots and mapped out the wind in this urban cave:



Map of air flow by watching breath in cold air Pile of debris left in the middle of the air vortex

The "X" in the middle of the map corresponds to the pile of debris sitting next to the car in the picture on the right. It was interesting to me that Grant was able to invent this "warm breath in the cool air" technique during the process of his exploration in the class, which is a nice case of someone learning to "see" the invisible.

But it was also telling that he didn't use his tactile or auditory senses to make the measurements. Only when the wind became visible did it become measurable – one more subtle example of needing something to be literally visible before it becomes real. Shutsu talks about her experience with the camera guiding her through the North End. Ryan and Shutsu both talk about invisible processes, but when it comes to substantiating their concepts with observations, they point to visual cues of what they see. In these explorations, as is often the case with science (and politics, etc.), if you can't measure it you can't report it. Since everyone is walking around with cameras, and because everyone is visually oriented, things that aren't visible (or can't be made visible) are simply left out of the story. If a court transcript doesn't talk about the mood in the room, or the facial expressions on the witnesses, judge, lawyers, or defendants, then those factors become irrelevant inasmuch as the transcript need stand as a

representation of what happened. Wikipedia states, “the technical term *landscape* comprises the visible features of an area of land” [July 2008]. Anne Spirn has named one of her books *The Language of Landscape*. Landscape is undoubtedly important, but how can we break the mantra, “I have to see it to believe it,” or at least expand the idea of “see.” All this was happening at the same time that I was iterating on my preliminary designs (chapter III)... The decision to make a Camera for the Invisible coincided with finishing the writeup for this case study.

I was noticing that the students didn't touch or smell anything. I wondered how the process would differ if there were a camera-like tool that could help frame the nonvisual aspects of the landscape? If a camera is for the visual, what device would capture other sensory data like temperature? Ryan was able to talk about relative average temperature over the course of days through the presence or absence of snow on one side of the street vs. the other. What would Ryan do if he could sense temperature more directly and take a "picture" of some sort to help tell his story? What about the things in the environment that we can't sense at all, like CO₂? Could we take pictures of that? These questions led me to make this graphic, which I presented earlier in the introduction.



Note: The object on the bottom right is meant to represent a CO₂ molecule

I do think the process these students underwent helped them to become more aware on a daily basis after the class was over. They have become urban explorers and know how to look for nature processes in an urban landscape. The process of returning to their site many times and observing for long periods of time helped them to become more intimate with the landscape and even motivated their observations further through piquing their interest. The use of a camera helped tremendously in communicating the students' observations to the world on their websites. However, it's not totally clear that the cameras helped them to observe per se. Shutsu says the camera helped her decide what to observe next (how to focus her attention), and I definitely think that a camera helps you focus on making an observation by narrowing the field of what can be observed. This narrowing is a sort of scaffolding that's useful to get people going. But in framing it also encourages people to leave things out

of the frame. The people in the class focused on visual cues almost exclusively, with sound being the commonest exception. It would be nice to have a suite of tools to scaffold or narrow the first-person observation activities in a variety of ways.

Since a 5-block area has a lot of activity in a city, too much to master, I'd also like to see what happens in a hyperlocal space smaller than a block. While there is some richness in allowing for the breadth of natural processes in a larger space, I do wonder what happens when a space is constrained. Do people develop more patience and watch for longer periods, pushing themselves into observations that span time as often as space? Do people push their methods of observation beyond those handed to them rather than apply the observations to more area? I think they might, and when I conduct my explorations of urban nature I'd like to try limiting people to "their favorite spot" or "a set of a few _____'s" such as park benches (actually I don't end up having enough time to try coming back to the same place again and again, but we do end up keeping the explorations on one property). I'll leave you with a few thoughts of what the students learned.

Shutsu says:



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Video**

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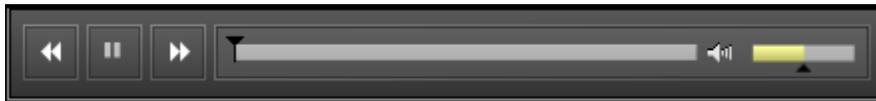


“One thing that Anne’s class did for me is it caused me to look up while I walk rather than just you know forwards and where I was going.”

Perhaps you, yes you the reader, would like to take this moment to look up and see what’s going on in the environment? Can you sense anything invisible?

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“I realized that when I would look at a street there was actually no mental process happening. Like there really wasn’t. I was just looking at a street and it seemed so normal, that’s the thing, like you take for granted that a street looks a certain way... I just realized that I wasn’t asking why or how it got to be that way. It was just a realization of what I wasn’t doing.”

Chapter III. Preliminary Designs

The goal of this section is to unravel the design process that led to the choice of Camera for the Invisible. It starts wide with a survey of the tools that are closest to the type of tool I thought I wanted. Then I go on to extract design criteria that I think my tool should embody. I mine these design criteria from my previous adventures (in II) and from looking at the other similar products. Then I give a general framework for how my tool might work at an abstract flow-chart’y level. I try to imagine what it would be like if the tool existed by telling a story about a girl who uses the tool. Then I start coming up with designs to make the tool a reality. I iterate several times, coming closer and closer to an inspirational form factor.

Currently Available Tools

I feel it’s important to get a sense not just of what the tools’ capabilities are, but also about how they market themselves. So I’ll let them describe themselves from their websites:

Educational Data Logging Sensors – Pasco

The product line they carry that is closest to what I want to do is the SPARK Science Learning System. I find them uninspirational, heavily focused on prepackaged experiments and not on play or exploration.

From the website <http://www.pasco.com>:

The SPARK Science Learning System is a revolutionary all-in-one mobile device that seamlessly integrates the power of probeware with inquiry-based content and assessment.

- Ideal for discovery-based K-12 science
- More than 60 free guided-inquiry labs pre-installed
- Completely integrates science content with data collection, analysis and assessment
- Finger-touch navigation and completely intuitive data collection and analysis capabilities
- Use with any PASPORT Sensors

SPARK completely redefines the concept of easy-to-use--so the focus remains on the learning of science.

Hobo – A Data Logging Tool for Climatologists

There are sensors that overlap with this work as well: The Hobo is a tool for climatologists. It's so named because you could throw it on a train and it will take temperature readings across the country for you. But it requires the use of a computer and it isn't playful or simple to get started.

From the Website:

HOBO U12 Family of Data Loggers

12 Bit Loggers with USB interface

The U12 series of data loggers offers models with internal sensors and / or models with external channel(s) that accept a wide range of sensors / input cables.

HOBO U12 loggers provide 12-bit resolution for detecting greater variability in recorded data, direct USB connectivity for convenient, high-speed data offload, and a 43K measurement capacity. The [HOBO U12 family of loggers](#) allows users to affordably monitor temperature, humidity, light intensity, and other measurements required for indoor energy, HVAC/R, and industrial projects.

PicoCrickets

Pico Crickets [23] are playful, and can be used to see many things in the urban environment.

From the website <http://www.picocricket.com>:

A PicoCricket is a tiny computer that can make things spin, light up, and play music.

You can plug lights, motors, sensors, and other devices into a PicoCricket, then program them to react, interact, and communicate. [Meet the PicoCricket](#). For example, you can make a cat and program it to purr when someone pets it. Or you can make a birthday cake and program it to play a song when someone blows out the candles. See the [PicoCricket in action](#). The PicoCricket Kit is similar to the LEGO® MINDSTORMS™ robotics kits. MINDSTORMS is designed especially for making robots, while the

PicoCricket Kit is designed for making artistic creations with lights, sound, music, and motion. [Who's using the PicoCricket?](#)

Traditional Tools Are as Useful as Always

Magnifying Glasses, stethoscopes, etc. as Eleanor Duckworth points out, could be just as useful as a new gadget for some parts of this study. I don't think these tools require a description

Extracting Design Criteria

While I never formally organized any guidelines or features that I must include in the design, during the design process I was always thinking back to my previous experiences in India, on the farm, etc. In this section I'm going to try to summarize some of the guidelines I was using informally throughout the design process.

Process Features

Process Features: the nature of the process, or behavior, you'd like to see arise as a result of bringing together a person, a tool, and a methodology.

Processes are a function of methodology, the tool design, and many contributing factors. But in designing a tool, it is worth distinguishing "process features" from "tool features." Process features can't be easily tested and can't be "tacked on" so in a way, they'd normally be posed as a question: "does the tool allow the user to _____?" By posing them as features of the process rather than causations of the tool, a space is created for the designer to consider designing for process rather than designing tools. Like Duckworth's trick to place value on the thought processes of explorers, process features are a trick to help designers place importance on how people will use the tool. I'll list tool features next, and I'll even pose some questions for evaluation at the end. Here are some of the processes I hope a toolkit for urban exploration could facilitate:

Environmental Contact: People should be physically touching the environment, possibly also tasting, smelling, and listening to it. This is like the time on the farm when I felt the coolness of the dirt.

Patient observation: Whether it's to collect evidence, show a friend, or just to see how things change over time, it could be nice to see people coming back to the same place at different times, or watching the same place over time. I tried a bit of this when learning the patterns of the urban gardens.

Rediscovery: Because the discovery process is new each time, rediscovering an old idea is actually a brand new event. Most astronomers already know how the moon moves around the earth, so my rediscovery isn't about the new knowledge so much as it is about the path. Even the same person can rediscover the same knowledge twice and have the path be new. The more viewpoints you take, the more comprehensive your understanding (usually).

Exploring: People should move around the environment and take a second look at things they think they know, which I would say is at the heart of the urban exploration movement. Both Tom Brown Jr. and Joseph Cornell recommend exploring to re-see in the Nature Awareness tradition.

Investigating: After something of interest happens or is discovered, the explorer looks more closely at the situation. No explanation or hypothesis is formed, but intuitive hunches create curiosity that requires investigation. I noticed this stage in my own explorations. It was a stage between exploring and experimenting, where I knew I was onto something but didn't know what. Like when I started inverting property rights to investigate them, but I hadn't yet discovered that urban explorers examine "the normally unseen or off limits parts" [reference same Wikipedia quote again] of the city.

Experimenting: Sometimes after investigating the explorer notices something of particular interest and starts coming up with an explanation for it. Then the explorer puts the idea to the test. This is only one description of experimenting. In my own thesis, I'd say I turned from investigating to experimenting at the point when I wrote my thesis proposal. It's telling to see that I didn't choose to settle down and experiment until pressured.

Tool Features

Time-lapse: The tool should let you compress observations taken over lots of time into small amounts of time, to "fast-forward" through the experience, because it allows slower patterns to emerge at a scale humans can understand. I found this useful when observing the moon.

Space-lapse: You might call this contextual graphing or mapping, but I think there's something to pointing out the similarity this has to a graph. When I was on the farm, I made a discovery by feeling the temperature of the ground in different places. It would be nice to be able to compare different places at the same time, in some form like a graph embedded in the landscape.

Instantaneous interactivity: Getting immediate feedback is playful and helps people get started tinkering and doing tiny experiments to see how things work. The curious caterpillar showed me how great it is for people to start off with something that is immediately interactive.

Deployable: By deployable I mean many things... waterproof, long battery life, small, camouflageable... Deployability makes it possible to do many concurrent experiments (or one experiment) over long timeframes by leaving sensors embedded in the environment. This was especially noticeable with the urban harvest forecaster. Deployable is a near neighbor of durable. The Hobo aims to be deployable. Most electronics are very bad at weathering the storm.

Viral Replicability: If you believe people construct their own understandings, than an industrially stamped out solution can only bring a new mindset so far. When possible, it's nice to have a tool that's virally replicable so that scaling becomes a question of usefulness, and tools spread at the same time as mindsets, evolving as they spread. Each time a tool is virally replicated, a new person accepts the idea of having a use for the tool and adapts the tool to the materials and needs that they have. That doesn't mean industrial replicability is unimportant. In fact industrial replicability, especially in small runs, is one of my goals.

Questions for Iterative Evaluation While Designing

Does the tool help people see the invisible? Since urban exploration theory and Nature Awareness theory continually bring up the point of the invisible, this could be a crucial point of the tool. It's also where a tool can help most legitimately over just using the senses alone. I think this point has come up in all my initial explorations.

Does the tool facilitate people noticing things? It's worth making the point that just because something is theoretically visible doesn't mean people notice it.

In which ways does the tool bring people into physical contact with the environment?

What kind of floor, ceiling, walls, and furniture does the tool have? A low floor means people can get started using it right away without much help. This is important for the democratization of the tool which is crucial. The ceiling refers to how far people can go with the tool, which is important for novices who stay with the tool for a while and for experts or professionals. The question of wide walls asks whether the tool can be used in many contexts for diverse interests. Furniture refers to helpful scaffolding that constrains the way the tool is used in such a way that people are able to get certain kinds of results.

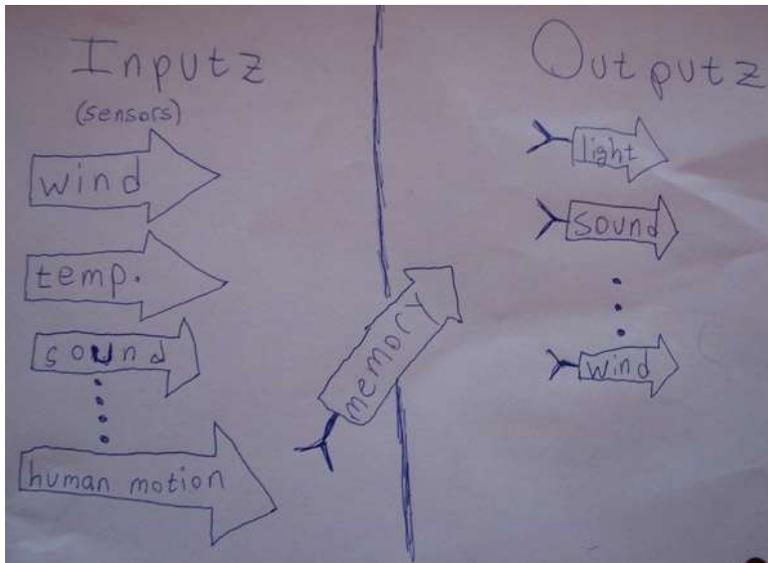
Does the tool have the potential to serve the population democratically? To make real change we will need more than the landscape architects and climatologists to understand and be empowered. One aspect of serving everyone in the population is the ability to afford and/or access a tool. It can be easier to access a tool if it can be made or repurposed from local materials. Another less industrial idea of access is whether people are able to leverage their current knowledge and intuition to make use of the tool when they finally do come into contact with it. This type of access might also be called a low floor.

Does the tool generate language and metaphor that could help bring about a new mindset? A tool can be useful to people far beyond its apparent primary function. Some tools give people a new way to think and talk about a situation, sometimes even for people who haven't even used the tool themselves.

Hopefully, the design should also take into account the toolkit's own transcendence as the ultimate goal, with contact and experience with urban-nature as the immediate goal. I thought the baseline kit should start with one compelling input and output pair, and should grow iteratively with explorers in the loop. All the while, I had some of these questions and design features in mind, while others came up during the process.

General Framework – Space, Time, and Perception

I started to imagine wanting to be able to capture many types of observations across time and space: temperature, pollution, human/animal motion, and much more. I also imagined wanting to play them back in different mediums like sound, light, wind, etc. so that they would become experiential. So at the outset of this thesis I conceived of a toolkit that was a set of inputs and outputs which can be mixed and matched.



Example of input-output pairs in the urban jungle time-lapse toolkit. The diagram was drawn at the beginning of the proposal.

In this toolkit, you would take one “block” (where the physical form of a “block” is not yet known) from the input category and “plug” it (I wasn’t yet sure what I meant by “plug”) into one block from the output category to create a synesthetic pair like “temperature-to-light”. [12] This would allow for instant exploration of the landscape. The memory block is a special case that acts first as an output block, storing output for use later. Then, the memory can be used as an input block for “playback” with the option to speed up time. I imagined having many block-pairs next to each other, embedded in the environment, to give a view of the landscape over space, and I hoped that the memory module could provide high speed playback of events for a time-lapse effect. As I moved forward in my design, I always kept this framework in mind. The question became how to realize such a framework in a way that leveraged people’s previous intuitions, and combined some of the design criteria while making appropriate tradeoffs to find a nice point in the design space.

Imagine If This Tool Existed...

What if someone had a tool in their hands that met most of the design criteria and implemented the ideas represented in the inputs/outputz graph? Then what would they do with it? There are many ways to imagine how it might work, so I’ll just paint one image... an optimistic, somewhat technocentric, but imaginable image.

Car Wind

Imagine a girl, maybe with asthma, who lives along a busy street. As she plays with the toolkit she notices that when cars drive by they blow wind at her. She starts measuring the wind of cars as they drive by. Then she leaves it out overnight recording and comes back out in the morning and as she plays it back she sees that fewer cars come by in the middle of the night, then a lot at rush hour right before she normally wakes up. Then she puts a few wind sensors stretched from the road to her house, and when a car drives by she watches the ripple effect as the wind blows all the way to her front steps in a wave. Next, she connects the CO₂ sensor. At first she blows on it with her breath and watches it change. Then, accidentally, she sees the CO₂ go up when the wind blows. But other times when the wind blows

the CO₂ stays the same or goes down. Eventually she connects that the CO₂ only goes up from the wind of a car that drives by. This happens every time. A few days later she is telling her friend that she discovered that “car wind” contains CO₂. Her friend asks her to show him, so they get out the toolkit, this time placing several CO₂ sensors all around the front yard and the sidewalk. They watch how the CO₂ gradient fades into the front yard when a car drives by, but that it is much lower behind a row of bushes and trees. That night they bring the kit inside but forget to turn it off. At bedtime mom asks, “Why is the toolkit glowing?” And the girl just says, “I forgot to turn it off, but it’s glowing because a car just drove by and the CO₂ comes all the way into the house because the house is so close to the road.”

From here I can imagine many things being possible. In a highly optimistic case, the girl could use what she’s learned to cure her asthma. Maybe she’d remember that there was less pollution behind trees and bushes, and then she would use her sensors to find the right conditions to grow the same trees and bushes in front of her window. That’s kind of cheesy, but totally awesome. In a less highly optimistic case she may just link the idea of car pollution to her asthma after talking to some people about it and start to “see” the invisible gradients of things like air and temperature in her everyday life. At the least she would know that cars give off CO₂ and know that she discovered it herself. Of course all this is assuming that she made any interesting discovery with it in the first place. In any case, I like to think that the types of discoveries people are likely to make with these types of sensors are ones that help them to see the invisible urban natural processes in their daily lives.

Iterating Towards a Toolkit for Exploring the Urban Jungle

First Design Iteration – A Software Simulation

I wanted to imagine the toolkit more concretely, but I didn’t want to build a full prototype yet. Within a few hours, I was able to use the computer programming language, Scratch [13], to create a simulation of what it might be like to have several of these input-output pairs hooked up at the same time.

You have **2 messages**

urban explor demo



Download this project!



Download "**urban explor demo**" (22 sprites and 80 scripts) and open it in [Scratch](#)

Project Notes

this is an alpha version of a virtual demo of my thesis project. i will build this in physical hardware next month. You can read more about it here http://media.mit.edu/~silver/thesis/proposal_jay.pdf

INSTRUCTIONS

Drag out and connect inputs (W, S, H, L) to outputs (colored light, music). This makes a sensor that can sense sound, human motion, light or wind, and convert it to light or sound

Note: the "w" represents a wind sensor, the "h" represents a human motion sensor, and the "L" represents a light sensor. The triangles represent color outputs, and the radios represent sound outputs. A Scratch Simulation of a tool for urban exploration. Available to interact with at: <http://scratch.mit.edu/projects/jay/64637#>

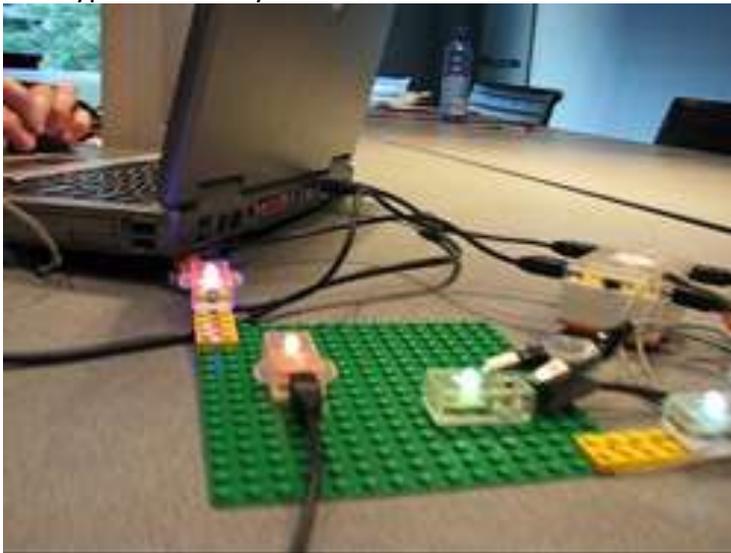
In this prototype everything only exists in software, so all the sensors and outputs are virtual (much like a video game). In this frame-grab of the Scratch program, there are two colored lights hooked up, one to a human motion sensor and one to a wind sensor. There are also two sound outputs hooked up, one to a light sensor and one to a wind sensor. Then there are representations of "wind", "light", and "human motion" as physical objects. So for example, as wind gets nearer to the colored light (hooked to the wind sensor) it turns more red; farther away it turns blue. As light gets closer to the sound output (hooked to the light sensor) it outputs a higher pitched sound; farther is a lower pitched sound. This really is best illustrated by trying the demo.

In this way it's possible to imagine a street with wind/color pair that shows the wind gusts as they blow across the streets. You might also imagine a CO₂/color pair that shows how the CO₂ gets swept out by the wind and replaced by the cars. On the other hand, maybe you'd rather listen to these phenomena as sound. Either way you can now walk through the street (or on the side of the street if there are lots of cars) and experience the graph of these invisible (or in the case of wind, non-visual, but sensible) phenomena by moving through the landscape.

Second Design Iteration – Rapid Physical Prototype

In the early prototyping stages I put together a team of undergraduate researchers: one main person to help with electronics, one to help with case design, and one artist to help us prototype at the speed of graphite. So when I say “we” in the design process I’m talking about me and one or more undergraduate researchers.

The first physical thing we did was hook up a microcontroller, a temperature sensor, and a red/blue LED to convert temperature to a color. While it worked nicely, we learned that more than a day of building was too long to spend to test one design idea. So I used Pico Crickets (as discussed in “currently available tools”) to iterate every 20 minutes until we had an early prototype like what you see below.



Four temperature sensors next to a laptop

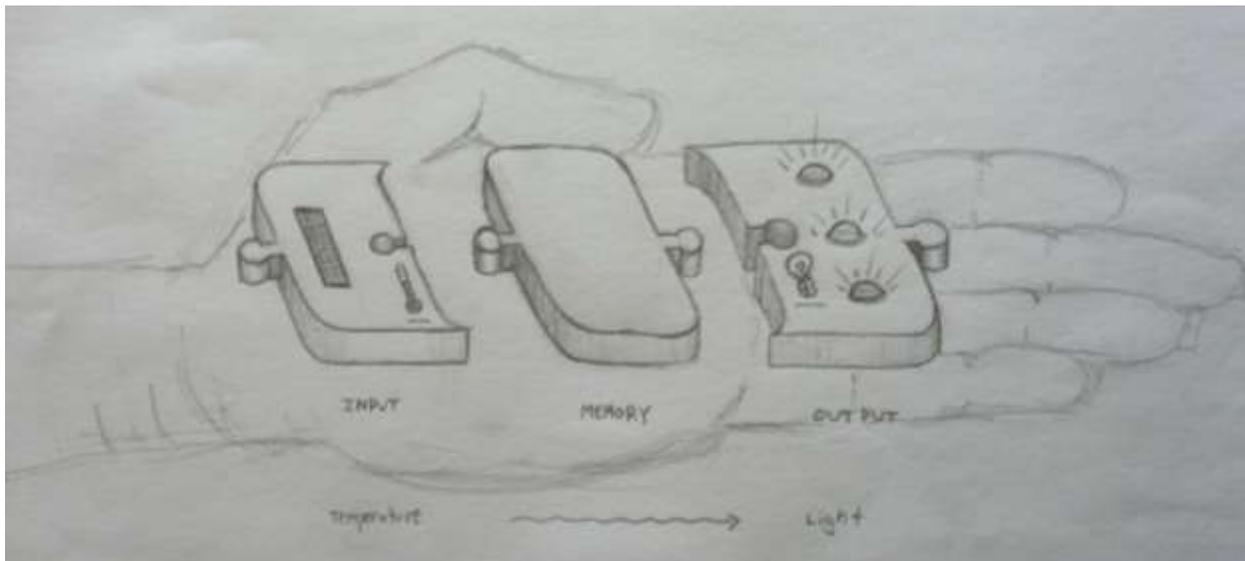
In this example, this quick prototype is a set of 4 temperature sensors that show temperature interactively as it changes. We tweaked the temperature ranges to be near room temperature. Here, the four temperature sensors are each outputting light: red for hot, blue for cold and orange and green in between. When placed next to a laptop, they make visible the temperature gradient emanated across the laptop’s environment (laptops are hot!). In this first rapid prototype there was no memory, and thus no time-lapse. I thought it was powerful that these sensors functioned with instantaneous feedback just as the modern digital camera always shows what the lens sees on the viewfinder even without taking a picture. Another thing to notice is that the colored-light “graph” of the information is embedded in the landscape in an intuitive way, not abstracted out onto an x-y axis on a black and white page. To make this into a time-lapse, imagine taking the temperature sensors and deploying them into the environment for 24 hours. Then later you could play them back as, for example, colored light. But you could play them back at high speed to watch the process of temperature change over condensed time. If the sensors had been dispersed geographically over a large space, they could later be condensed into a representative arrangement of that space, yet small enough to see all the temperature data at once.

In testing this design informally with people we found that the wires were alienating, but that the instant feedback and synesthetic representation of temperature were playful and intuitive. We also found that the temperature range had to be reset depending on the environment, which was easy enough for us to do, but posed a problem of consistency between environments.

Third Design Iteration - Drawings

At this point I started to meet regularly with the design team, formally composed of five undergraduates, though I have always had help from many people informally. We were now convinced (by imagining and trying the prototypes) of the type of function we wanted from the toolkit. But the question now was, what form should it take? What's out there that we can build on? What will people understand? What will generate models, metaphors, and language that are useful?

We started to think in terms of cartridges to get rid of wires. I suppose I had always thought that to connect two parts together you needed a wire, but then again, the part itself can be the wire if it is a cartridge. We came up with several concept sketches quickly that embodied the design principles in different ways. For example, a puzzle piece design, drawing on wooden railroad blocks:



A drawing of a puzzle piece version of the kit with temperature input, memory in the middle, and colored light as an output. There are no literal wires, rather the electrical connection can be made by the puzzle pieces directly.

We thought it would be nice if the tool could fit in one hand, leaving the other hand free to come into contact with the environment. But a professor pointed out that the hand is drawn very long, perhaps because we really wanted the pieces to fit into the hand, and perhaps they can't.

Engineer 1: "What's that fella's? The new product won't fit in the people's hands? Well we're just going to have to lengthen their hands!"

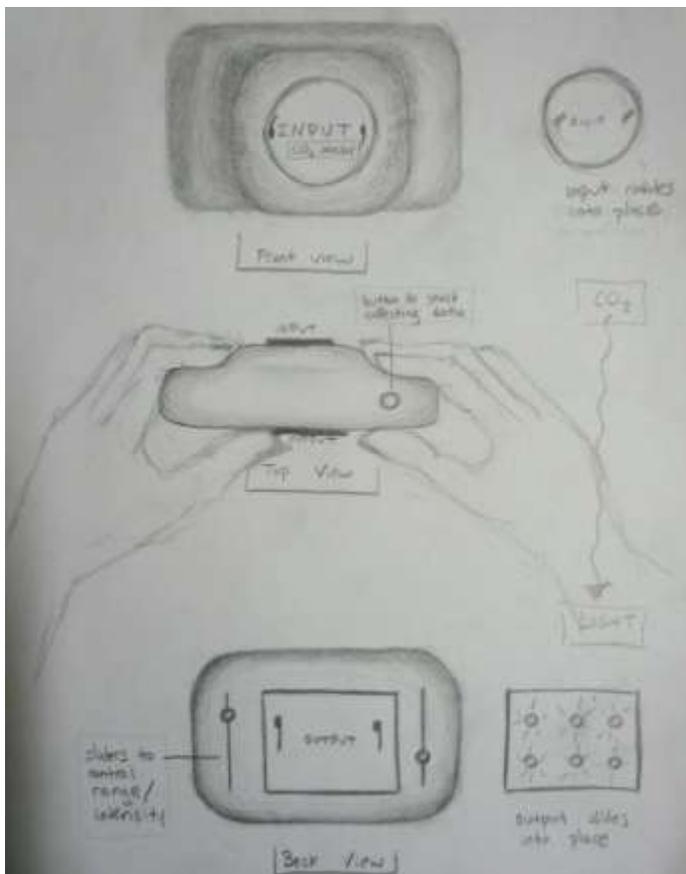
Engineer 2: "Yes, yes, something's definitely wrong here, who designed this hand?"

The puzzle pieces do seem to build on people's intuitions of how to put them together, but the most important part isn't how they're put together. The important part is what the process of exploring will look like. So the puzzle pieces do leverage intuitions but not in the most important direction. How do the puzzle pieces create meaning and metaphors that help people think in new ways? New ways of mixing and matching yes, so that's good, but not new ways of re-seeing and understanding, which is more important. The architecture of the puzzle pieces asks, "How should I be put together?" We started to look for something with architecture that asks, "What do you want to investigate?" Hopefully, we could keep the tangible feel of snapping together a puzzle in the process...

Fourth Major Design – A Camera, Lenses, and Viewfinders

If you look at the puzzle pieces and imagine them popping up a bit to be taller, they do almost seem like a camera. Actually at this point we were saying, "like a camera but for taking pictures of invisible things," quite a lot. So, almost joking, we thought, "Could the tool actually itself be a camera?"

No one was quite sure if that made sense, so we drew a picture of what that could be like.



The first visual representation of the Camera for the Invisible. CO₂ comes in the front through a lens and gets converted to a colored light on the back.

At the first moment, we hadn't yet thought about how a camera also can have memory built into it. The way we were brainstorming when the idea of "literally a camera" came up was:

- we would come up with some crazy idea for a form factor using intuition
- then talk about that form factor to see how it does or doesn't meet our goals
- then move on (until we thought of "camera")

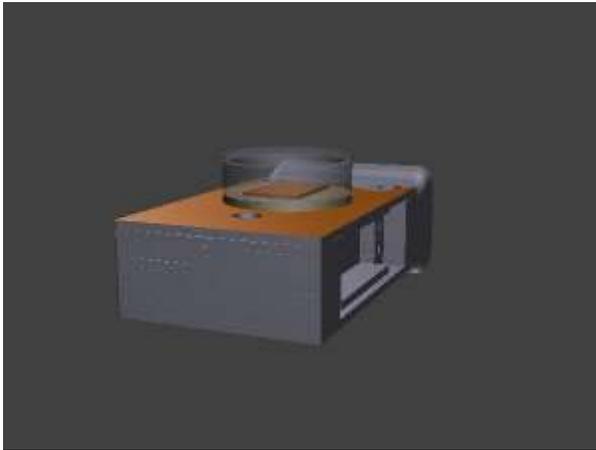
When camera hit it felt natural but I was mistrusting of it at first. We soon realized that memory fits nicely with a camera. It was a few weeks before we realized that choosing a "camera" would effectively eliminate the reality of having many of these sensors deployed throughout the environment. At first we imagined there could be many cameras, but in the end people don't tend to use many cameras at the same time. It started to sink in that this choice of implementation had many powerful constructs and leveraged intuition in many ways... some helpful to our goals and some hurtful.

Chapter IV. Camera for the Invisible



Right before the final evaluation of the camera, work on the camera itself froze. Though in many ways I see it as unfinished, it is at a stable point worth freezing and talking about. For the purposes of keeping the discussion consistent, I'll refer to the camera as it exists in its current resting point.

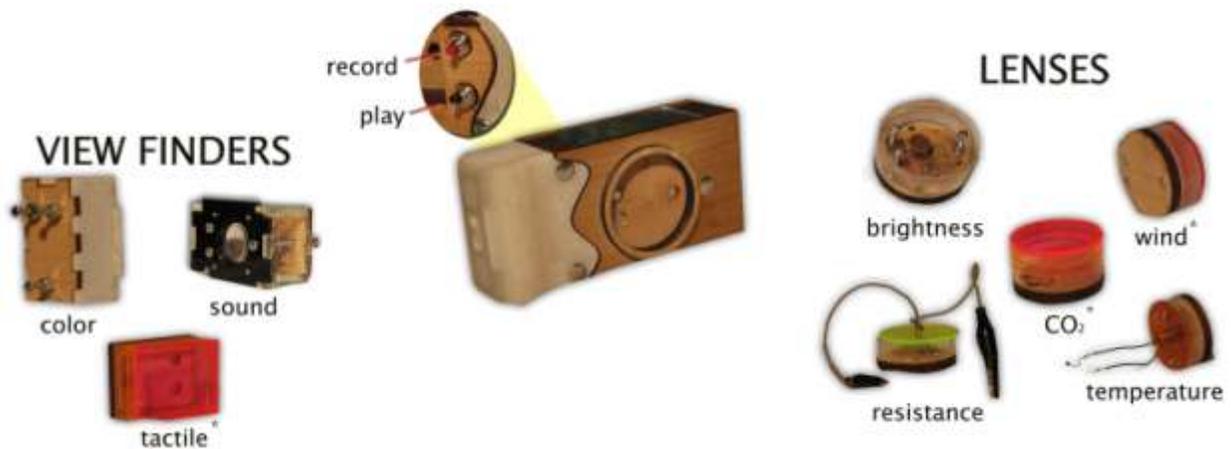
The version of this thesis that you are reading does not include 3D CAD files. To see a 3D model of the camera, download the multimedia version of this document.



The Camera

At this time, the camera has two fully functioning viewfinders (color and sound) and three working lenses (temperature, resistance, and CO₂). The camera has internal memory, but no removable memory. The camera has two traditional exploratory tools integrated: a magnifying glass and a mirror. The physical body is made of wood and acrylic held together by three screws, with an on/off switch, a record button, and a play button. It has the ability to record in time-lapse mode and play back at regular or fast-forward speed. A neck strap for hands free operation is attached to the handle.

Camera for the Invisible



*The main parts of Camera for the Invisible.
These parts not working at time of evaluation

Exploratory Mode

The basic premise is that you mix and match a lens and a viewfinder to create a synesthetic pair, then explore your environment. By default as long as the camera is on it is in exploratory mode -- transforming the lens input into a sensible output on the viewfinder. The normal mode of interaction is one of continuous and instantaneous feedback.

Lenses and Viewfinders

The camera is essentially all about lenses and viewfinders, and the lenses and viewfinders are analogous to the inputz and outputz respectively in the figure.



Lenses

The lenses snap into the front of the camera, fastened magnetically. There are three magnets inset into the wood, and three screws protruding from the lens that are aligned with the magnets. Around the lens hole there's an outset ring. Every lens takes some range of input and converts it to 0-5 analog voltage output, and each viewfinder takes 0-5 volts in and converts it into something humans can sense. We made it a priority to implement at least one lens from each of the following categories: possibly visible, but often ignored so arguably invisible; sensible but not visually so; and not sensible to most normal human beings.

Brightness

The brightness lens converts brightness from the range of full sun exposure to near-complete darkness. The brightness lens is used by pointing the camera in the direction of the brightness in question, very closely to how a normal camera lens is pointed.

Temperature

On the other hand, the temperature lens must touch the subject of experimentation to find the temperature of that part of the object. It can also be used to measure ambient temperature just by walking around with the lens pointed forward or in the air. The temperature lens responds to temperatures from 20 degrees Fahrenheit to 110 degrees Fahrenheit.

Resistance

The resistance lens has two alligator clips sticking out of it. You must connect those two clips to the subject of measurement, then it will measure only the path of least resistance between the two clips, which is often called the “electrical resistance of the object,” but it depends how the clips are hooked up. The resistance lens can read from zero ohms to 100 Mohms.

Viewfinders

The viewfinders are placed into the back of the camera, into a deeply inset rectangle, which leaves the viewfinder almost flush with the back panel, but sticking out slightly.

Color

The color viewfinders use colored light to visually display what the lens is sensing. We considered many possible ways of using color to convey quantities, such as low and high temperature. At first we displayed the whole hue spectrum continuously, but we found people couldn’t tell the difference between small changes. In the end we chose eight colors from low to high in this order: purple, aqua blue, bright green, yellow, orange, red, and hot pink. In this way it was easy to tell if something changed from blue to green, for example. But what about within the blue range? We decided to denote changes within a color range by blinking slower for lower values and blinking faster for higher values -- somewhat like a Geiger counter.

Sound

The sound viewfinder maps low inputs to low frequency sounds and high inputs to high frequency sounds. So, for example, if used with the temperature lens, hot things would sound like a flute and cold things would sound like a tuba.

Taking Pictures... Doing Experiments

The camera works in many ways like a modern digital camera. For example, it always shows what the lens sees in the viewfinder so long as it’s switched on. This provides for instantaneous interactivity. When someone decides to record something there are two buttons: one red and one black. While experiments can be done in exploratory mode, one might think of taking pictures as the experimental mode, in the sense that experiments can be recorded and documented. There’s no hard line between exploring and experimenting, but as one starts to get an idea and wants to test it, often taking pictures becomes helpful, and then it starts to feel more experimental.



Recording

Normal mode

The red button starts a recording when pushed and stops a recording when pushed again. During recording a red LED glows through the acrylic handle. These recordings are like video recordings in the sense that they are recordings through time. With only internal memory, continuous recordings can be taken for 1.5 minutes. If you stop recording and start again the two recordings will be back-to-back. This can be good for comparing two different places or situations.

Time-lapse mode

If you hold down the red button, the camera goes into time-lapse mode, recording 100 times slower than it normally would, which is 1 sample every 10 seconds, instead of the usual 10 samples every second (the red LED blinks correspondingly every 10 seconds). This is especially useful for hours long recordings.

Playback

Normal Playback

When the play button is pushed, the viewfinder shuts off input from the lens and starts playing from internal memory. By default it plays back at regular speed.

Fast Forward Playback

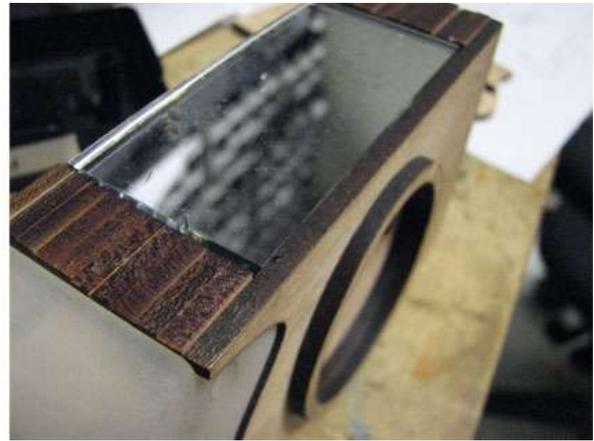
If you push the play button again during playback the playback speed doubles. Each time the play button is pushed the speed doubles again. This allows you to see recordings at many different time scales.

Removable Memory

There is a slot on the side of the camera for an SD card. This function doesn't work yet, but was intended as part of the design. The SD card could be removed and placed in a computer to download recordings and make programmatic representations of the data. Also, different SD cards could be used for different recordings to give some tangible, physical significance to each separate recording. SD cards also follow the trend of building on people's current understandings of how a camera works, because SD is the current standard.

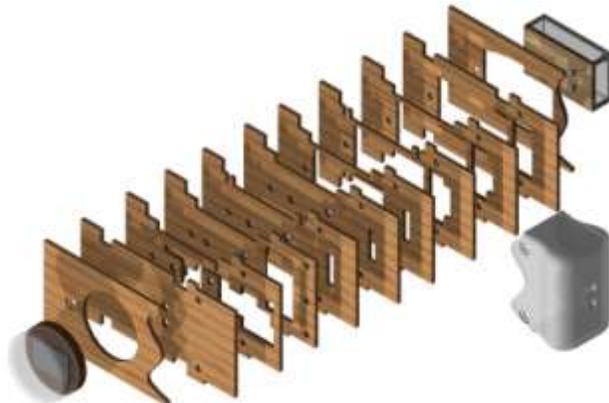
Integration of Traditional Exploration Tools

A removable magnifying glass and mirror were integrated into the body of the camera as battery covers. When someone goes to change the battery cover they are likely to take off the magnifying glass and maybe start exploring with it. On the other hand, someone may be hesitant to take the battery cover off just to explore. The mirror is a classic tool that Duckworth uses to explore, and a magnifying glass is a classic component of many environmental kits and Nature Awareness activities. A stethoscope was considered as a neck strap, but I couldn't find a practical way to integrate the stethoscope and still have it function elegantly by the time the project was frozen. With the addition of these peripherals the camera starts to feel a little like a Swiss Army Knife, but for observing rather than for acting on the environment. The magnifying glass and the mirror can also both interact with the lenses, most notably the brightness lens.



Technical Notes: an Overview

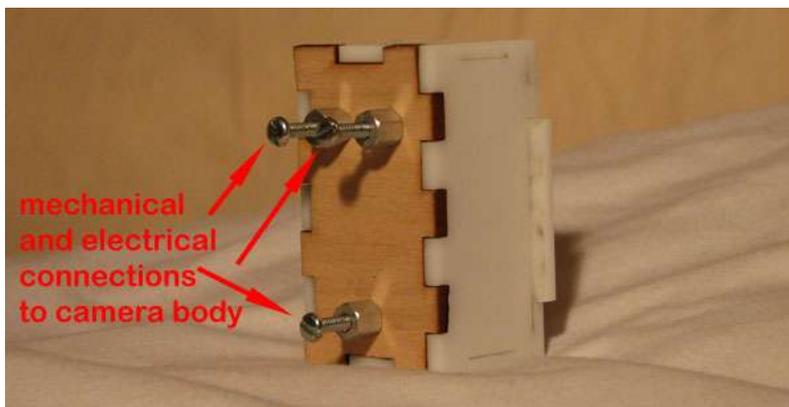
The body of the camera was drawn in solid works.



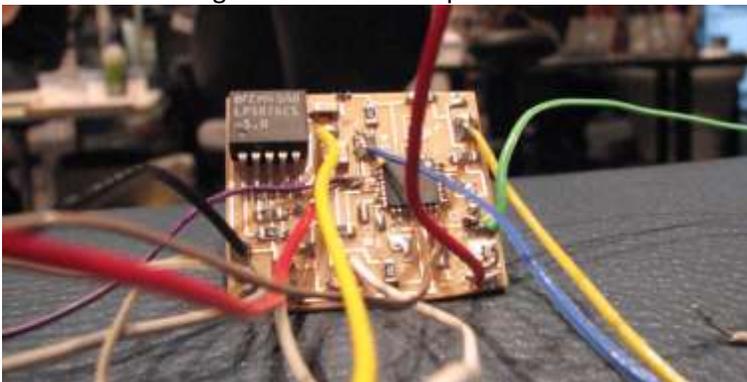
The wood part was laser cut in $\frac{1}{4}$ " layers and wood glued into four separate layers.



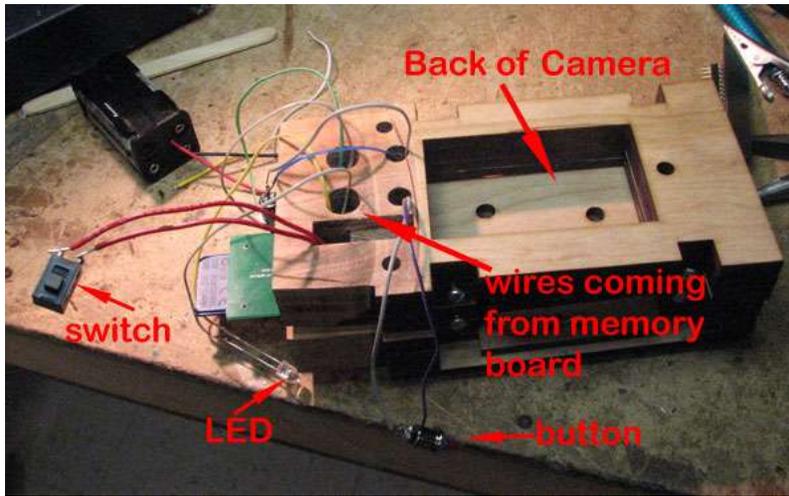
The plastic handle was 3D printed and press fits over the four body layers. The power is completely located inside the camera body with 4 AAA battermaies. A low voltage dropout regulator then distributes power to the memory board inside the camera as well as to the lens and viewfinder. The lens and viewfinder each have three electrical connections, which double as magnetic mechanical connections.



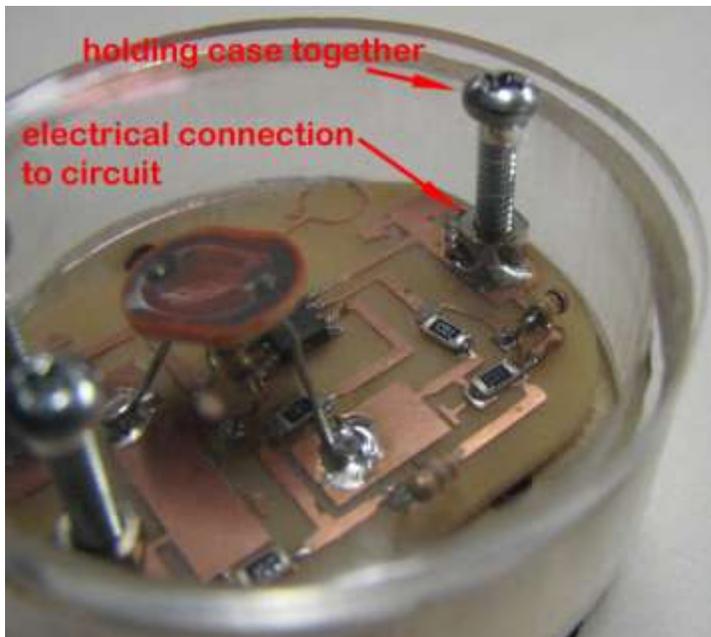
One is for ground, one for power, and one for analog data. Inside the camera, there's space for an SD card socket (not hooked up) and a memory circuit board. The memory board currently uses the internal SRAM of an ATmega 168 to store samples.



All communication goes through the memory board, which samples (in normal mode) at 10 samples per second. The memory board is not only wired to the lens input magnets and the viewfinder output magnets, but also to the LEDs and buttons.



The lenses all use resistance based sensors with op amps to scale the output from 0-5V. The viewfinders have ATtiny 45's to convert 0-5V inputs to the appropriate sound and color. The cases for the lenses and viewfinders are held together with three screws which simultaneously act as the magnetic mechanical attachment to the camera, the electrical connection to the camera, the electrical connection to the circuit board, and the mechanical holding together of the case.



The circuit boards were all milled from copper coated FR4 on a Modella mill and were drawn in Eagle.

Some Informal Exploring to Show the Camera Features

I asked my wife Jodi to explore with the camera around our dorm on MIT's campus. I hadn't planned on sharing the exploration in my thesis, but it now occurs to me that it serves the purpose of speculating about what would be possible with the camera, only more realistic. But because we collaborate so closely on these ideas it's not at all the same as trying it out with any other person; the purpose is to show a few realistic possibilities with the parts that are working. I mostly used the color viewfinder in the pictures. I think it's interesting that I normally prefer the sound viewfinder, but when we decided to take photographs of the exploration that influenced our decision of which viewfinder to use most.

Exploring the Bumps on the Cover of a Sewer



A



B



C



D



E

In A, take in the whole situation with soft eyes. Widening your gaze can help you blur out the details and see the whole picture. In B, the temperature lens is shown with the temperature probe touching the sewer cover in a valley between two bumps on the sewer cover. The viewfinder isn't showing but it's pink and blinking quickly. In C the temperature probe is above the sewer, and is blinking more slowly than in B. In fact, as the probe gets farther and farther away from the sewer cover, the viewfinder was blinking slower and slower until it eventually turned red (the next color down on the rainbow scale). In D, after the viewfinder turned red a few inches above the sewer cover, Jodi touched the sensor with her fingers to see if her fingers were hotter than the air above the cover, but surprisingly it stayed red and

blinked slower (her fingers were colder?). In E Jodi continues to explore the valleys and bumps on the sewer cover, finding that valleys are hotter than bumps, but only by a little.

Light Pollution Outside a Bedroom Window



Jodi doesn't like to have light coming in the window when she sleeps. As she moves closer to the light, the color turns from purple to blue to green to yellow. If she has the sound viewfinder in, the sound goes from a low pitch like a tuba, to a higher pitch. Interestingly, when she did this exploration, she lived on the other side of the building. Now she's moving to a new room on this side of the building, and she is starting to think back to her explorations with light pollution and what the many sources are and the effects.

Electrical Connection Between Two Plants



Taking recordings and sharing discoveries, Jodi and Layla played with different electrical paths through the two bushes and noticed small changes in the blinking rate of the viewfinder when the path between the two bushes was changed. If she pours water into the soil between the two bushes, the electrical path slowly becomes more conductive, giving insight into how the water continues to be wicked through the soil long after it's been dumped on the ground. She was recording the increase in conductance on the camera. After a while, the conductance seemed to level off (the blinking rate held steady). She stopped the recording and played it back at high speed. At high speed the conductance seemed to go down at the end just a bit (the fast playback helped her notice the perceptual difference of a slow, gradual change). Maybe it's because of evaporation? Maybe it's because of the water spreading out further in the soil? Maybe it's a chemical reaction that we haven't yet learned about? Maybe it's because the plant changes its internal structure by starting or preparing to drink up some of the water?

Or, did the alligator clips move slightly? The cause isn't clear to us yet, and more experimentation is needed.

Chapter V. Evaluation

In making the camera I have prioritized audiences like the first generation learners at Drishya and the novices of the world. That is why my main hands-on trial was with a teen, and I asked for critiques from the facilitators at Drishya, the slow-learning not-school in India which I had visited and been inspired by. I would have very much liked to try the camera with the children at Drishya, but it was just too far away to visit at that time.

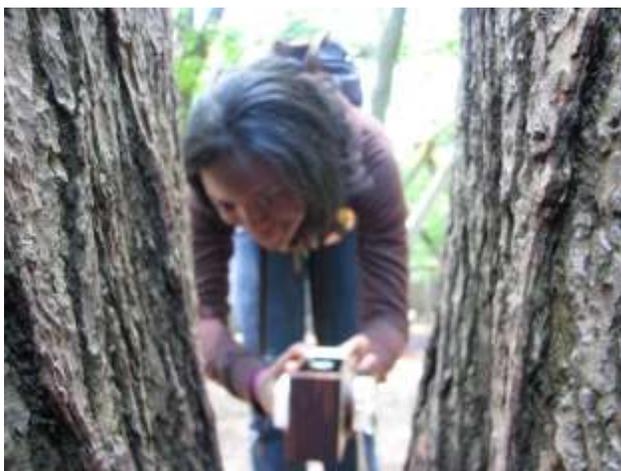
Camera as a Tool for Urban Exploration with Urbonauts

The main hands-on trial was with a 15-year-old female. But in early, informal studies I tried camera prototypes with several people. They were all able to easily understand the interface and the point of the camera. There weren't usability problems to do with, "What is this for?" or "How do I attach this?" People took surprisingly easily to the idea that this thing worked like a camera, and that they ought to wander around and take "pictures." In one of these informal studies, one boy organized the things in the neighborhood by how well they conducted electricity using the resistance sensor. He put things that might seem disparate from some points of view in the same category: Fences with fire hydrants, dirt with plants, sidewalks with telephone poles. I didn't ask him to do this, I just asked him to show me around the neighborhood and try out the Camera for the Invisible. Afterward, I asked him to tell me what he discovered so that I could report back to others who were interested. He said he discovered a new way of grouping things, which is when he elaborated the groups. As it turns out, the things he put in the same group have similar electrical resistances.

Now I'll tell you about the one main empirical study that I had planned with a 15-year-old female named Song. I set it up in a preschool where there was plenty of indoor space, outdoor street space, and a big playground. Song is 15, but her mother works at the preschool, and it seemed like it would be in the spirit of the urbonauts to go where she has gone many times before to try to re-see what she already knows. She knows the site so well because she went to preschool there and returns often because of her mother.



The goal was to see what types of behaviors and thoughts would be invoked by bringing out the camera and simply saying what type of sensory information each lens and viewfinder was for. My intervention was mostly of the “What makes you say that?” type (here I’m applying the techniques and skills I learned in Duckworth’s class directly), so as to encourage more thinking out loud and to lend weight to the importance of her thought process.



A picture of Song on the playground

Song is going to be a freshman in high school after this summer. She lives with her mom, her dad, and her sister, Ode, (who also ended up participating in the study), and she has two older brothers. Outside

school her favorite thing to do is dance, and she told me she is going to be a dancer. In middle school her favorite subject was humanities.

I feel like I need to disclaim that during the experiment I sometimes felt that since Song knew I was testing out a new device that I, myself, had made, she often tried to show me that she liked the camera.

I started in the backroom (site 1) preparing the Camera for the Invisible and my own camera to take videos. I was taken by surprise when Song came into the room before I was ready because she was excited to get started, so I asked her to put new batteries in the camera and attach the neck strap. Before I could introduce the lenses and viewfinders, she already snapped in the brightness lens and the color viewfinder with no cue from me. Her sister, a couple years younger, started joining in. Sometimes Song's sister would join in and sometimes she would do her own thing, though I noticed that some of the most interesting things happened when the two sisters were together (You'll see that in the video I show later in this section). I also noticed that Song led most of the explorations, though her sister would sometimes take control. Song would usually take control back quickly. That's probably because I started the exploration with just Song, and I think I may have asked Song more questions. Also, because I had it in my mind that I was starting the evaluation with one person, I think I did a bad job of facilitating cooperation. I'm sometimes confused about how to write up this exploration because one participant is vocal and present throughout and the other participant is less vocal and comes in and out. In writing up the document, I feel I don't know how to properly articulate Ode's participation. Part of the reason for that is because Ode would make comments to her sister which I couldn't always hear. If this situation came up again, I would want to ask Ode what she was saying and do a better job of encouraging participation. But, like I said, because I was thinking I would be doing a one-person study, it became difficult for me to reconfigure my understanding of the process. I also feel that the fact that Song held the camera most of the time influenced where I pointed my own camera and my own attention (in my Conclusions I briefly address cameras and cooperation). So please note that in most of the situations I describe Ode is a quiet but active participant. I feel it's important to mention all this since I am in part of a learning process, and because others may learn from some of my mistakes. I feel it's important to say this up front before you read what happened to help you interpret what's going on. I've also learned that the evaluation process should be more iterative and should have more time dedicated to it. Now I'll go on to describe what happened in the evaluation.

After a few minutes, Song was pointing the camera at the window and then at the floor and saying, "Light... dark," as the viewfinder changed from blue to purple. She then switched out the color viewfinder for the sound viewfinder, and she soon noticed the same pattern. She made an interesting synesthetic statement as she pointed the camera at the window and the floor with the sound viewfinder, "This sound is blue, and this is purple."

She switched to the resistance sensor and asked me what it was for. I told her, "electrical conductance." Song and Ode started probing the room for electricity as though the two alligator clips were a divining rod for electricity, which made sense based on what I had explained. This shows me how different resistance is from brightness, temperature, wind, and CO₂. It really isn't very ambient the way an electric field would be. But instead of re-explaining myself I watched out of curiosity to see what they would do. Song knocked on walls, turned on light switches, and made photocopies with the resistance leads inside the photocopier. This process suggests to me how interesting an electric field sensor actually would be.

Song touched the alligator clips to her Ode's face and got a reliably consistent response. She said, "Maybe it's from the heat... Let me see we could really test it like this," then she moved on to test things that didn't have "heat."

Song led us outside to site 2. She had the brightness/color pair connected, and she started exploring the different brightnesses along the street: her shadow, the sun, the sidewalk, the asphalt, under a tree, out in the open... She was able to tell that the different colors represented different amounts of brightness, and even which order the colors went in, though she never understood why the colors were blinking, so I didn't see her express that brightness could be considered to be on a continuous scale.

Song changed out the lens to temperature and tested the rocks, leaves, me, but found that they didn't differ in temperature that much, only changing between yellow and orange. Unfortunately on a hot day the rocks, leaves and human bodies are about the same temperature when viewed on a scale from 20 degrees to 110 degrees. So she switched back to the brightness sensor, because it was the most reliably responsive.

(site 3)

(note: Ode is present)

Song started making recordings, so I told her about the play button, and she made recordings and played them back without a problem. We went onto the playground, and clouds started passing overhead. Song and Ode made a discovery. They noticed that during a recording without moving the camera at all the viewfinder changed from orange to yellow. Song played it back for me, then I asked her to narrate what just happened.

Song: "Basically, we were outside, I was standing right here, and it was yellow, the shadow I guess like (pause) the sun (pause) the cloud moved, because the sun is still in the same place, but I guess the cloud moved, and the (sun comes out again) like how it's brightening up back now, you see how it's slowly brightening back, before a cloud went over.... Yep, you see, look, see."

Me: "What am I looking for, what should I look for?"

...

(sun goes behind the clouds)

Song: "There's not light you know how there was light before."

Ode: "It's yellow."

Song: "You know how it was shining?"

Me: "I did see how light was shining through before."

Song: "And now there's no light at all, and there's gonna be, like I'm just saying I think it's the clouds"

Me: "Okay."

Ode: "Look at this one."

Me: "Can we test your theory somehow?"

Song: "Uhhhhm, Yeah, we can test right here."

Ode: "It's orange."

Song: "Right here is orange, (sun comes out again) SEE how it's light again!"

Me: "I see."

Ode: "It's orange."

Song: "Yeah, it's orange right here, okay let's go to a shadow. It's yellow."

Me: "Uh huh."

Song: "So a shadow is yellow, well, it wasn't as light as it is now,"

Me: "Uh huh."

Song: "That's why this is still a shadow, technically this is still like light, but it's more like a shadow... (She takes a recording) Right now it's orange, right here is really orange, okay, yellow... right here, yellow, but green, so I think it all depends where it is in the light, because we are outside, so there could be a little bit of light shining anywhere..."

Then she pops off the magnifying glass and starts looking around with it. She pops off the mirror too and starts using them in conjunction. After a few minutes looking around, she looks at her finger and says:

(Note: Ode is not present even peripherally during this conversation)

Song: "I could see my hand, I can see any kind of dirt on my hand that I didn't know I had."

Me: "Really?"

Song: "I could see my fingerprint!"

Me: "Huh look at that, I see your fingerprint too."

...

Song: "I could see them like it's popping out, and I could almost feel them now."

Me: "Really?"

...

Song: "Look at your finger print."

Me: "Wait now what are you showing me?"

Song: "Your finger print."

Me: "Okay, I do see it."

Song: "Now you're more aware of what you have, so if you're more aware of your finger print you can feel the ruffles... You see?"

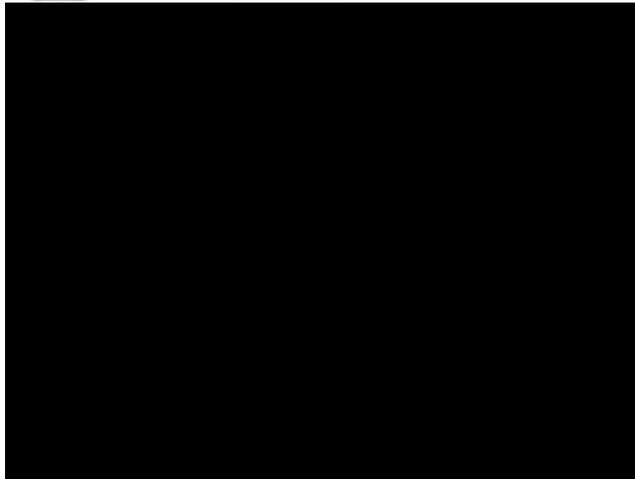
Me: "I do feel the ruffles, but you're saying you never felt the ruffles of your finger print before?"

Song: "No... It seems more scratchy. I could actually feel it. It's making me see things I didn't know I had, well I knew I had a fingerprint, but I just didn't know I could feel them like this. This is cool."



**Embedded
Video**

The version of this thesis that you are reading does not include videos. To see the video, download the multimedia version of this document.



Remarks

Looking back, I realize that by telling her less about how the camera worked she ended up putting more effort on exploring the camera itself. If I had told her all about how the camera worked from the beginning, I think she could have spent more time exploring the environment. So next time I do this I will explain all about how the camera works.

I also found that we dropped lots of lenses and after being dropped we spent a lot of time wiggling them and hoping they worked. So these things really have to be more drop-proof.

The temperature sensor really wasn't that responsive, because it was on a universal scale that spanned the entirety of possible temperature ranges, but we were only experiencing a small slice of temperature ranges. This showed me how important it is to have responsiveness if people are to figure out how something works on their own, and I would now say that despite the troubles it could cause, it would be worth making the camera work on a relative scale instead of just one universal scale. That is, perhaps the camera could zero in to the current temperature if a button was pushed, then the variation would be around the starting temperature.

I think the camera was very useful in focusing attention on the environment and promoting the process of walking around and exploring different parts of the environment with more senses than just the visual. But the technical problems of the lenses not working reliably, and the sound viewfinder making

terrible sounds after being knocked around, were limiting enough that I'd like to try this again after making the components more reliable.

One study with one pair of sisters on one day just wasn't enough. So any results are suggestive without being conclusive. But what it did reveal (in combination with early informal studies) is that people understand the idea of mixing and matching inputs and outputs when they're in the form of lenses and viewfinders on a camera. People then understand what to do with the camera if you tell them what each lens or viewfinder is for, like, "temperature" or "color." I had always planned to add icons to the lenses and viewfinders, but didn't. There is pretty much no indication of what the lens does right now, and that is strange even for real camera lenses, which have markings describing the lens' properties. It was also surprising how natural it was for people to start moving around to different parts of the environment and make observations and take measurements. I have a lot to learn about evaluations, and I think they're much more complicated than I had previously thought from listening to people discuss them.

Song was able to explore and to investigate. She also came up with many experiments on her own, but unfortunately some of them were focused on how the camera itself worked. Like when she supposed heat influenced the resistance sensor. But she also came up with her own experiments that weren't too conclusive, like when she thought there might be electric wires in certain parts of the walls but unfortunately the sensor she had wasn't capable of testing that. Then, in one of her final experiments, I pushed her to form the experiment by asking, "Can we test your theory somehow?"

Here's a short list of some of the things for which I saw direct evidence that the camera can facilitate:

- Focusing attention on the environment
- Focusing attention on itself
- Promoting walking around and exploring
- Coming up with theories
- Playing with functional mapping and making connection between sensory modalities
- Rediscovering and re-seeing known territory

Critique of Camera as part of Drishya's "Lab in a Bag"

I visited with three researchers currently working in Drishya on the "Lab in a Bag" project: Padmini Nagaraj, Dipti Sonawane, Palash Mukhopadhyay. Padmini is a former teacher in India, now a researcher at Drishya. Dipti and Palash are recent graduates from Srishti School of Art, Design, and Technology, who have been working on the Lab in a Bag project for a year now. I held critique sessions with them, and excerpted a couple of statements from them which help feed back into my design. For the critique, I demonstrated the camera briefly indoors, which isn't ideal, but we didn't have much time. Then I asked them for feedback especially relative to the children at Drishya and the work they do with Lab in a Bag.

Padmini: "If you have an input in here and you have a sensor over here and I just aim and shoot kind of a thing and record, and my sensor senses let's say various temperature, but I don't see

numbers for temperatures – I see colors. I can see colors with my five senses. The children interact very well with their senses: smell, vision, sounds, touch, taste. If there could be something that could be changing in sound, or something that is changing in smell or odor, or something that is changing in color of light, or intensity of light, or intensity of sound, or frequency of sound, then they can immediately say ‘Ahhh! So this is changing, so what is it that’s changing around me that’s making this change?’ So, if my camera does it that’s enough. I don’t need a Pasco (sensor) in that case to show me numbers...” Right now for a 7-year-old I don’t see why numbers should [something I couldn’t hear because I was laughing]. It’s okay if he says ‘Ahhh it’s becoming warmer and how do I relate warmth to colors?’ So I would say probably, ‘Blue is cool... Red says it’s warm when I look at the sun I look at red and yellow and orange and I know it’s warm.’”

...

Padmini: “And in the night as the sky turns blue, purple, and then black I know it’s cool so when I look at it I can relate to it so it makes sense for me to just have something like that to tell me about temperature or heat, and that’s enough for a 6-year-old or a 7-year-old.”

Padmini: “The other thing I was thinking of is: Can this become waterproof?”

...

Palash: Long term, I can even see this as becoming a recording device for a kind of performance.

Dipti: That’s what I was going to say. We were thinking about the butterflies, and we were trying to get how the butterflies are coldblooded and what happens in the night, how can we trace these behaviors to form some kind of a maybe an installation or some kind of a performance, so I think if it changes in colors and becomes suddenly brighter you know...

Palash: it could be another part of a toolkit for expressing using digital media because you could record a situation and then play it back and perform with it.

Dipti: Yes.

Palash: So you know record the brightness of sound and then maybe dance to the sound, or record sound as brightness and then perform a play with the brightness changing. So there could be various possibilities beyond just the device...

Remarks

Two things were especially interesting to me about the comments from the Drishya facilitators/researchers. One was that Padmini concurred that numbers would be much less meaningful to the Drishya students than colors and sounds would be. I expected that to be true, but wasn’t sure. The comment that really surprised me was the idea that the camera could be used for dramatic performance. I hadn’t designed it for that, but I like the idea of it, and even though normal cameras aren’t used for drama in the way they were describing, videos are being used in that way. Their major

concern about the camera in its current state was whether it could be dropped, submerged in water (on purpose or accidentally), and generally whether it could survive. I think this is important too.

Overall I felt they were very enthusiastic about the use of Camera for the Invisible in situations like Drishya.

Chapter VI. Conclusions and The Future

In this final chapter, I'm going to harvest some crops. I invite you to taste them and help me decide what's ripe.

I'll critique the Camera for the Invisible using the design criteria set out earlier and by comparing it to other possibilities. Because the camera doesn't achieve everything I wanted it to, I'll propose a new schema and some new vocabulary to help conceptualize a toolkit for modern urban explorers. Then I'll propose a pragmatic path for designing some of the tools for the urbonauts of the near future.

My Own Critiques

Taking the Camera Road

By choosing a "camera" model over the other options in the design iteration process, I closed off some opportunities and opened up others. Since I only have one camera, I can't say for sure, but it seems that a camera pushes away the idea of being embedded in the landscape – though it is true that time-lapse cameras are sometimes left in the landscape for a while.

Suppose we didn't choose the camera road, but rather completed some other version of the original inputz/outputz diagram. The truth is that to make something intuitively usable there will always be feature compromises. But let's imagine that we made something usable and more like the original plan of a smattering of sensor pairs that could be hooked together in pairs many at a time. Then we could spread sensors all over the environment, like Christmas ornaments. Maybe a temperature sensor and a color output, for example. It would create an embedded contextual graph. The process of exploration is not the same as with a camera. I imagine one first walks around the environment and decides where to leave the sensor pairs. Then, one walks around the environment looking at the different colors and watching the patterns, making inferences about the environment. In a way, previously invisible information is hacked into the environment, and in a way the environment becomes decorated. The hands are free and the awareness is spread wide. The recording process is more complicated than with the camera. If it were possible to design it elegantly, a kit with multiple input/output pairs could subsume the camera by choosing sometimes to only use one pair at a time.

The process is different in the camera form factor. In order to explore space, the camera requests from people that they walk around the space, focusing their awareness on one thing at a time. One hand is usually full holding the camera. The environment is bare, with sensory conversion happening on the way to the senses instead of being embodied in the environment. The camera separates the explorer from the environment. Recordings are simple to initiate and can happen on the fly. Rearranging the lens/viewfinder pairing can happen more spontaneously.

On the other hand, if a single sensor pair is used at any one time, it might be possible to use the kit as one would use a camera. So it could be possible to imagine the original inputz/outputz subsuming the camera at least technically, though perhaps the architecture wouldn't speak as elegantly.

A Quick Comparison with a Traditional Camera

In a way, the Camera for the Invisible is just like a normal modern digital camera. A modern digital camera has more features, and the Camera for the Invisible is simpler, with just two buttons and an on/off switch. A modern digital camera usually doesn't have a time-lapse mode as of this writing, and Camera for the Invisible does. Modern digital cameras don't have traditional exploration devices built in, and of course they don't transform sensory information: they frame and represent it. But they both take recordings through time into memory and play them back. They both have interchangeable lenses. And, they both have a camera form factor.

Collaboration

Collaboration isn't something I talk about much in this thesis. But cameras and many other scientific instruments (as well as mice and keyboards) do a really bad job of facilitating collaboration. They are all too often designed for a single explorer. I mentioned a two-neck-strap design when discussing the Curious Caterpillar, which I now see as a panicked attempt to remedy the problem at the end. What I did see with the Curious Caterpillar was people sharing the two antennae to collaboratively explore. Later in this section, I'll introduce Puddle Jumper, which attempts a legitimately collaborative interface, not just collaboration tacked on at the end.

Brief Comparison to Other Products

Now that the camera is finished it starts to seem less and less like the other products I originally compared my project to.

Hobo

The Hobo seemed similar to the original design kit, but completely different from the camera. The most important difference that comes to mind is the low, low floor of the camera that gets you started immediately. Tied up in this difference is the way the Hobo is marketed and designed, and thus the way the Hobo is perceived by novices: namely, not for them.

Pasco

The Pasco sensors technically function in many ways similar to the camera: no computer is necessary, data can be collected with different sensors, etc. But the huge difference in playfulness and the camera metaphor makes the resemblance to the Pasco mostly a technical resemblance. Even so, there are so many technical differences, like ease of extension and use of color and sound for output.

"You know, that project that uses sensors to map pollution"

Over the time I've been working on this project many people have said something like, "Oh it's like all those projects where people map air quality collectively?" I really think it's different from that genre in so many ways. The most important difference is that those sensors come with a narrowly predefined purpose that isn't likely to build on the explorer's own interests. Simply put, the walls are narrow, and the potential range of activities is limited. For most of these projects, I find the suggestion that "*walking around with an air pollution sensor strapped on that will contribute to a map in a predefined way*" is leveraging the collective input of people somewhat insulting to the idea of those people's autonomous contributions. That said, there is the advantage of working collectively to make such a map (and then

reflecting on the map), and there is some learning and new thinking that goes into contributing a sample to a larger network of fellow humans.

PicoCrickets

PicoCrickets are really an invention toolkit, not an exploration toolkit, though I now find them to be my closest neighbor, even closer than educational data logging tools. In some way that's not too surprising since my group (LifeLong Kindergarten) is the one that created the kit. But I still find them more different than I thought when I started out on my quest. The camera has way more furniture than the PicoCrickets, meaning that it has a much more specific purpose: to explore the urban environment. In some ways the camera is a subset of what's theoretically possible with the PicoCricket since you can partially build the camera (with a limited set of software-swappable (not tangibly swappable) lenses and viewfinders) out of the PicoCrickets. Indeed I built my first physical design iteration (remember the laptop giving off heat?) from PicoCrickets and a few extra sensors that don't come in the kit. But the form factor and extended capabilities have a lot of features that make it substantially different and suggest a whole different activity/process. The camera accentuates exploration, while the PicoCricket accentuates creation. However, the PicoCricket has been used for exploration before, and there is one famous and inspirational case that stands out: "The Chocolate Walk." I'll give a very brief description here. In The Chocolate Walk, a group of Girl Scouts walked to a donut shop with PicoCrickets hooked up by the facilitators to be temperature recorders. They explored with the sensors along the way, then in unison they touched their temperature sensors to hot chocolate they got at the donut shop. Finally, they returned and looked at the graphs on the computer to find interesting features including a big spike in the graph when they touched the hot chocolate.

The Design Criteria Applied Briefly

I used the design criteria in guiding the design iterations and then again when building up the camera features. So it's natural to expect that, since I chose the criteria, the camera will meet many of them. But I find it's a good exercise for me to go over the design criteria that the camera doesn't address as well. The design process necessitated tradeoffs which forced prioritizing some criteria over others. Some didn't fit with the idea of a "camera." Some features I would have liked to add on, but there wasn't enough time. Some are too complicated or expensive. After going into some of the design criteria that weren't met in some aspects, I'll briefly mention the design criteria that are more nearly met.

Environmental Contact

The camera definitely provides a setting and opportunity for people to come into contact with the environment. In some cases, as with the resistance sensor, it even requires coming within an inch of the environment. But nothing about the camera necessitates touching the environment. And while it may subtly suggest smelling or tasting, there's nothing explicit that pushes in those sensory directions.

Patient observation

The camera definitely models patient observation such as in time-lapse mode. But so far I haven't seen anyone using the camera to really sit patiently to watch how things unfold, though no one has actually tried the camera for long periods of time.

Experimenting

Though exploring and investigating abounded, experimentation was more rare.

Space-lapse

While the camera can be used to see changes over space, it only takes in a single pixel of information at any one time. So to see changes over space one has to move the camera through the environment. This could be an advantage since it promotes exploring and moving around in the environment.

Viral Replicability

This is an interesting one to me. I definitely think the idea of a camera form factor as a multi-cross-sensory exploratory tool is virally replicable. The parts themselves can be replicated to varying degrees. All the circuitry was made with cheap, readily available parts, and are all on single layer circuit boards which means they could be made ad-hoc on a protoboard quite easily. When I was in Bangalore, I could find all the parts that went into the functional parts of the camera within a single block of an electronics market. But I don't think that's the camera's strong point. And I should mention that the camera case itself used rapid prototyping machines like a 3D Printer and a Laser Cutter, which aren't readily available to most people. What I think is exciting about the replicability of the camera is the lens and viewfinder interface. The early models of the camera were just a box with magnets embedded in it so that the lens and viewfinders could snap onto the box. The box had batteries inside and was literally made of four wooden rectangles. The lenses themselves are made of wooden circles (though the circle isn't what's important) with three screws driven through the wood. The sensor is then gives analog output through one of the screws and gets power through the other two screws. This is a very simple model for others to build... in some ways simpler than using a "standard connector" because screws are more widely and cheaply available than connectors and it doesn't matter what size screw you use (within reason). The viewfinders are connected the same way, taking analog data in through one screw and power through the other two, and being held onto the camera body through magnetic force. This means it's pretty easy and cheap to make extra lenses and viewfinders, and the camera body can be as fancy or simple as you want it to be. So while I recognize that it's not the most virally replicable model, I still think the idea and many of the materials lend themselves to being reproduced by others, especially when compared with other possible models for datalogging sensors.

Design Criteria that are Met

Throughout the design process and during evaluation, I have already discussed many of the ways the camera does a good job of meeting the other design criteria. But I'll summarize some aspects very briefly now. It encourages people to notice things, explore, investigate, rediscover things, and see the invisible. The camera is instantaneously responsive, can do time-lapse, and has a lower floor than any other data logger or sensor kit that I'm aware of, which is an important step towards serving the earth's population democratically (access being the other major hurdle). What I am most excited about, perhaps, is that I was able to meet many of these somewhat more functional goals while generating language and metaphor that could help bring about a new mindset. Whether or not the camera invites people to transcend itself is open to time and debate.

Transcending PIE and Merging the Person with the Environment – A New Relational Schema for Instrumentation

I'd like to introduce what I believe to be a new way of looking at scientific perception instruments, in the spirit of transcending instruments and merging the human with the environment. The simplest possible summary of this section is stated here:

Instruments often come between a person and their environment. Can we redesign instruments to move out of the way and let the person come into contact with or be immersed in the environment?

The Unfortunate PIE Instrumentation Model

The story starts by looking at how cameras are used. If there's a spectacle worth experiencing, do you have to decide between experiencing it and taking a picture of it? Sometimes you can do both, but many things happen fleetingly, and I've heard many times, "I missed the experience by trying to photograph it." The fact is that cameras are typically used in such a way that literally orient them between you and your environment.

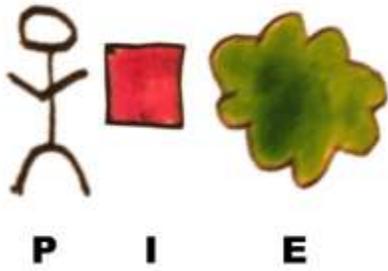
Instrument in the Way

Note: I'll be using photographs, cartoons, and textual acronyms throughout this section to help communicate the relationships between some of the agents in the exploration process. As the relationships become more abstract I'll use less photographs.

As a photographic representation



As a cartoon representation



As textual acronym: P I E

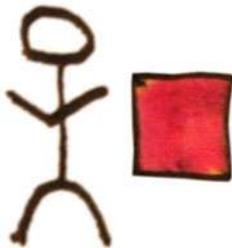
To be clear: the photographer is the person, the camera is the instrument, and the subject worth photographing is called the environment. When I say environment, I mean anything in the presence of the instrument, from a manmade object to a forest.

The reason I start with a camera is because I've been working with Camera for the Invisible for months now, and so it is in this context that I have grown to appreciate many aspects of "camera," while also growing the following simple critique: "It gets in the way of the experience." I have seen people studying the camera while ignoring the environment. But this problem isn't limited to cameras. The PIE model is quite common, and is the same for all lenses I can think of, historic and modern. Sometimes with a telescope, the moon is far and the instrument is closer to the person

As a photograph:

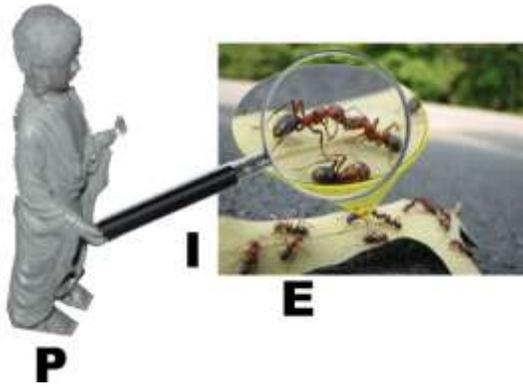


As a cartoon:



Textual acronym: P I E

And sometimes (e.g. with a magnifying glass and a bug) the instrument might be closer to the environment



As a cartoon:

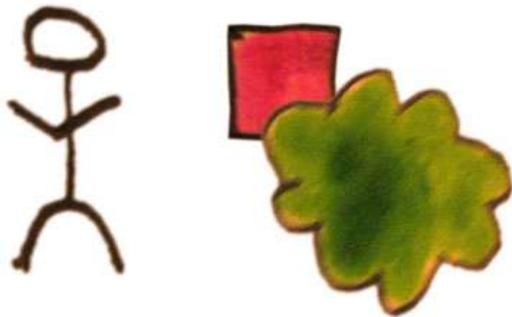


Textual acronym: P I E

Electromagnetic spectra, including light, travel quite freely and ambiently through air, as do sound waves. But many measurement instruments don't take ambient readings from phenomena that travel on the air the way lenses do. Many instruments measure by probing the environment: temperature probes, voltage/current probes, or any other sensor that needs to make physical contact with the environment in order to measure.



As a cartoon:



Textual acronym: P IE

Note: There is no space between the "I" and the "E" because they are physically enmeshed, not just near or touching.

So many, many scientific instruments that are intended for perceiving or measuring the environment follow some variation of the PIE (with more or less space between the "P," "I," and "E") model. PIE isn't the only model, and I'll proceed to talk more about other existing models, but I'd argue it's the most common by far.

A Simple Instrumentation Model that Brings the Person and the Environment Together

As I've said before, in designing instruments for exploring, my ultimate goal is to interconnect the person and the environment, transcending the instrument altogether.

Instrumentation Transcendence



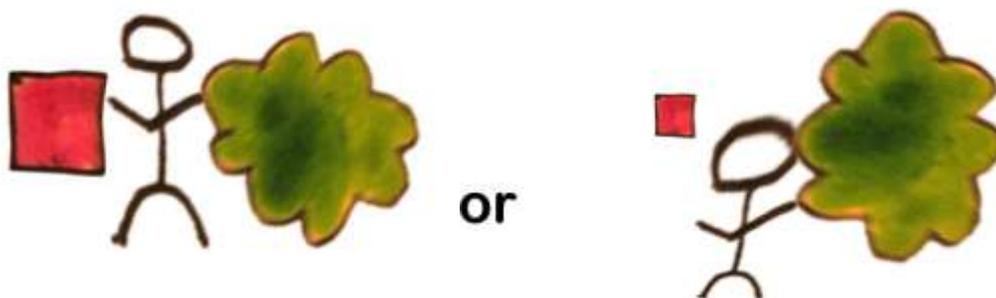
Textual acronym: PE

The person and the environment are brought together

Some would argue that, if this is the goal, why make a tool at all? The answer is that I see the ability of tools to influence people’s exploration process (or lack thereof). When you have a hammer, everything looks like a nail, even after you put down the hammer. So what variation of a hammer would make everything look like something worth touching? What variation of a hammer would make the environment itself seem like a set of connectable parts? What variation of a hammer would make it so that the nail becomes an object, not just for hitting, but for contemplation? And, if it’s true that everything looks a little more like a nail even after you put the hammer down, what interesting types of lasting effects could be produced if a tool that answers the previous questions was realized?

I’d like to propose a rearrangement of “PIE” that would help the person connect to the environment. Later I’ll propose an immersion model, but let’s start with what I think is the simplest possible rearrangement. Let’s put the instrument behind the person and put the person as much in contact with the environment as possible:

Environmental Contact



Textual acronym: IPE

Instrument in the background or “behind” with the person and the environment coming into contact.

The IPE model aims to somehow design the instrument into the background while, ideally, encouraging a visceral interaction between the person and the environment. I will introduce a technologically simple design called “Puddle Jumper” in the “Future Designs” section of this chapter that I claim accomplishes an IPE model. In the images above one just places the instrument linearly behind the person, while the other places the three equally almost like the corners of a triangle. Either representation gets across the

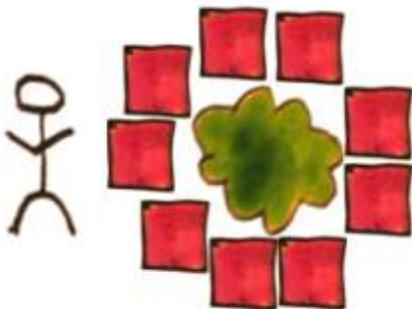
idea that the instrument should move out of the way; let's move out of the PIE model and into a model more like IPE.

Classifying Other non-PIE Instruments

What about other non-PIE instruments?

Environmental Isolation

Let's look at a paint color analyzer like the ones they have at a hardware store to match the color of the paint on your walls. You bring in a paint chip, they enclose the paint chip in a machine, and the machine reports the exact color back to you. Taking a close look at what's happening, you are actually breaking off a piece of the environment, inserting it into the instrument and then the instrument reports back to you. So the environment becomes completely encased inside the instrument and isolated from the person by the instrument.



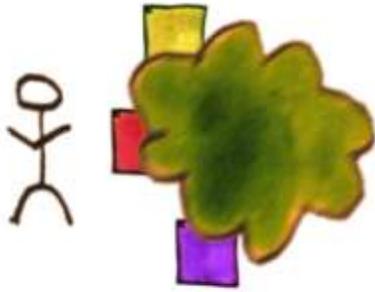
Textual Acronym: PIIIEIII

Don't worry too much about the exact textual acronym, just that it's a shorthand for the cartoon, which itself is a shorthand for a complicated interaction

Another good example of environmental isolation is a blood sugar level meter. Many instruments in scientific laboratories follow this model of collecting a sample and bringing it back to the lab. This can allow for some immersion in the environment while collecting the sample. But, it has the disadvantage that there is no instantaneous interaction and the tool itself emphasizes sampling the environment as opposed to contacting or connecting to the environment. This is a good time to mention again that different tool models are good for different purposes, and I'm specifically hunting for a model that helps the person come into contact with, or immerse in, the environment.

Object Embedded Instruments

Some manmade objects have sensor(s) or instrument(s) embedded in them, which can't be detached, like a stereo with a graphics equalizer that shows the different frequencies the stereo is playing, or a car that comes with many meters embedded in the dashboard:



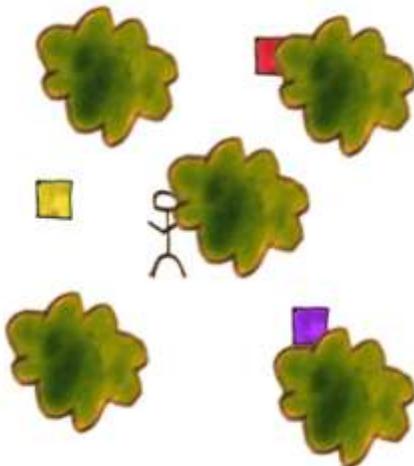
Textual Acronym: PIIE

This could be confusing because it could be strange to think of a car as “the environment.” But I’m taking manmade objects as part of the environment, and single objects are a special case.

These instruments are only intended to be used in one way with the object they are connected to. You aren’t meant to use the gas meter on the car to measure how much gas is in a bucket, and you aren’t meant to use a stereo’s graphics equalizer to measure the frequency of the audio coming out of your mouth. (Of course, there’s always room for creativity...)

Environmental Immersion

In designing scientific perceptual instrumentation that intends to immerse the person in the environment, it’s useful to have a smattering of instruments (like a car has in its dashboard) but to have them available for dispersing into the environment freely. This was the original design proposed with the inputz/outputz diagram in Chapter III. Now if you attach this collection of sensors all to one object, like a wall outside your house, you can watch how things in the environment influence that one object, which has the same momentary effect as PIIE (above), but is more flexible since you can embed the sensors how you like and you can move them to a new object. But, what I’m really interested in is placing the sensors throughout an environment in which you can move about. This was best exemplified in the Car Wind story from Chapter III.



Textual acronym: IEPEI

In this model the person is free to move about throughout the environment. The set of instruments encourages looking around the environment, embedding the instruments in the environment, and then moving about with hands free observing what is essentially a graph embodied completely within the environment. I am holding up immersion as a high goal, and I think it is, but it may be worth mentioning that it could be important to be able to step out of immersion and then back in – not simply being immersed in perpetuity without the ability to take multiple perspectives.

It is in the IPE model and the IEPEI model that I see the most hope for designing instruments that encourage contact with the environment and immersion in the environment, respectively.

Where is PIE Going?

I think there is a subtle but important distinction between putting the instrument behind the person (IPE) and putting the instrument inside of the person:

Human Embedded Instruments



Textual Acronym: PIP E

I mention this model because I see that some people dream of merging the person with the scientific instrument. Take, for example, this possible progression from the following three PIE models to the possibility of a Human Embedded Instrument (PIPE) model:

- 1) magnifying glass – P I E
to
- 2) eye glasses – PI E
to
- 3) contact lens – PI E (the instrument is starting to merge with the person here)
to
- 4) instrument inside the eye to record and play back optical data – PIP E

“When a wearable computer functions in a successful embodiment of ‘Human Intelligence’, the computer uses the human’s mind and body as one of its peripherals, just as the human uses the computer as a peripheral. This reciprocal relationship is at the heart of ‘Human Intelligence’.” [Mann 1998, Proc. IEEE]

I would propose a different sequence of instrumentary evolution for the purpose of encouraging environmental contact:

- 1) magnifying glass
to
- 2) eye glasses
to
- 3) contact lens
to
- 4) instrument behind the human (IPE)

What is hoped for by putting the instrument behind the human is to allow the environment to be intimately pressed up against the human. I'll talk about Puddle Jumper in the Future Designs section ahead as a concrete example of an IPE tool that literally requires the person to touch the environment in playful, exploratory ways.

Person Out of the Loop

I don't want to go into too much detail on this model because it's potentially complicated. But I think it's worth mentioning that, while PIE is the most apparent model, especially historically, the most prevalent model today may not have the person involved at all. Computers have thermostats in them that report the temperature to the CPU. Most people never see the result of that report, but if the CPU gets too hot the computer will automatically shut down to avoid overheating. The same thing goes for some cars, ovens, climate control devices, etc. There are countless machines around most of us that have sensory instruments embedded in them or communicating to them about the environment without any people being involved in the perception or action. There are many ways to conceive of this model, perhaps even explicitly mentioning a new player which we might call a machine.

Textual Acronym: MIE

In the near future, it's likely to become ever more common for instruments and machines to communicate to each other in a decentralized network of sensors and machines perceiving the environment.

Textual Acronym: MMIIE

It is important to note that while PIE may be the most influential mental model or even the most common model encountered by people, it may not be the most widely deployed. Thus, it could be debatable whether the IE model or the PIE model actually has more influence, though I would still argue PIE affects our lives and thoughts more as of 2008. Since MMIIE is yet one more possible evolution of PIE, it's important to watch where it's headed to help us propose alternate, more humanistic alternatives.

Summary of the New Relational Schema for Instruments

There is probably no limit to the number of ways to think about rearranging the dominant instrumentation model of our time (PIE). In this section I've named some of the most common arrangements. The purpose of looking at instruments relationally as I have in this section is to help guide design choices that promote certain instrumental interactions. In my case I chose to focus on how instruments relate to people and the environment. It's possible to choose other relational agents to optimize instrumentation design with respect to other purposes. But the main purpose of developing this particular schema was to see how different instrumentation models do or don't help bring the person and the environment together.

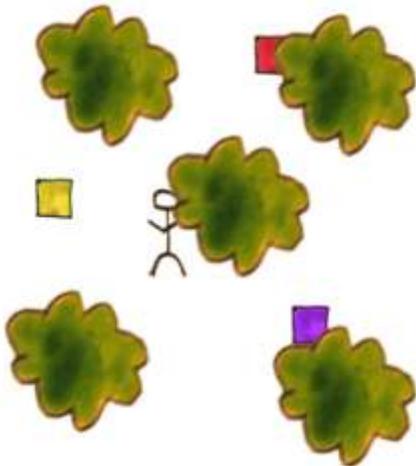
The prevalence of the camera has brought about many terms to accompany it. A couple of those terms are “shoot” and “capture” which refer to what the person is supposed to do with his subject or his environment. There are many other words inspired by cameras, but the fact that cameras inspire vocabulary that is so similar to vocabulary used in weaponry is a topic worth pondering, and is documented dramatically in some scenes of the award-winning Antonioni movie *Blow Up* from the 1960’s.

Vocabulary Toward a Toolkit for Urban Exploration

In this section I will develop a handful of new terms that I think are useful for facilitating thinking and discussion about new exploration tools. I’ll introduce new ideas and reiterate ideas I discussed previously, giving names to the ideas. In choosing the concepts worth naming I tried to select for ideas that are most relevant to designing for human-environment interrelatedness and that most desperately need a name so that we can have language to encourage their use.

Embodied Contextual Graphing

The concept of embodied contextual graphing is most vividly exemplified in the Car Wind story, and has been discussed throughout the thesis. It follows an



EIPEI model, and allows the person to walk around in the environment while getting readings from instruments embedded in the environment. Some such systems already exist. One that comes to mind is a set of windmills installed in an outdoors location that convert wind to light along the intensity dimension. Few are mobile and easily distributable by novices. This way of “walking around in a graph” is in my opinion the closest example to experiencing graph concepts and is also a model for exploring the environment which allows the person to be tangled up in an intimate relationship with the environment.

(Mixable) Synesthetic Dyads

While many scientific instruments convert something you can't sense (like voltage) into something you can sense (typically a number or a graphic), none (that I know of) allow people to mix and match sensory inputs and outputs. Even without mixability, few tool designs take enough advantage of the very simple idea of designing with synesthetic dyads. As discussed throughout the thesis, it's useful to compose your own synesthetic dyads combined with your own exploration in your unique hyperlocal space. Furthermore, building on the idea of multiple intelligences and specifically learners who do well with particular modalities, mixing synesthetic dyads allows people to interpret the invisible aspects of the environment in a way that works best for them.

Urbonauts

As introduced in Chapter II, urbonauts are to the local environment what astronauts are to the frontier of space. Astronauts turn outward boldly going where no man has gone before. Urbonauts turn to the immediate, boldly re-seeing what every man and woman already has seen. Urbonauts have the spirit of traditional urban explorers but work within much wider walls than abandoned buildings or dumpsters. Urbonauts are to their front yard and local community as traditional urban explorers are to abandoned buildings.

Star Simpson, a 20-year-old woman and an avid traditional urban explorer who is also an inspirational model for an urbonaut, said to me in an interview:

"I think exploration has a lot to do with wonder and playfulness. Constantly asking, 'I wonder what's in there?' makes you ask other 'I wonder...' questions. You realize that everything that's built is built upon a huge, vast amount of human choices. Also, wondering, 'Why is this here?' 'Why did the designer make these choices?' leads you to more playfully consider your own choices. When you're constantly asking 'I wonder..?' and 'Why?' you begin to see that the way things are is not carved in stone, even if it's cast in concrete."

Human-Imitable Outputs

I don't yet know what the significance of this idea is yet, but in one informal study someone had the sound viewfinder in and was exploring the temperature of a sewer cover and a glass of lemonade. As she went back and forth the temperature went up and down. The sound viewfinder would change pitches up and down. She later imitated the sound of the viewfinder to me, and I realized that what she was doing was actually vocalizing what would normally be represented as a graph or a series of numbers. I started thinking about my color viewfinder and realized that people can't imitate the colors at all, though they could imitate the flashing in some way. Then I thought that the color viewfinder could have been a different kind of visual viewfinder; it could have instead had a picture of a hand with two fingers moving closer together and farther apart. The fingers would be acting like a column representing a quantity through time, which is something many people have recommended I include as a viewfinder (the column/row of LEDs/bar graph). This would normally seem silly and unnecessary to me, but after listening to the girl repeat the sounds of the audio view finder, I started thinking about the value of suggesting to people that they can in fact act out various quantitative series through time using their voices and perhaps bodies too. So if one of the viewfinders pictured a thumb and pointer finger moving up and down (kind of like when you look at someone far away through your thumb and pointer finger and pretend to squish them), then it would be very suggestive that you can imitate the viewfinder. This is when I realized that it could be interesting to think of viewfinders that are human-imitable.

Most people's ability to memorize long sequences of numbers is limited; however their ability to remember sequences of notes is much greater. Human-imitable output is really about humanly communicable results. Does the tool facilitate informal discussion of results, or does its discussion require long charts and tables to understand? Which brings us to Intuitive Data Processing.

Intuitive Data Processing and Situational Instrumentation

I can't believe nobody said, "Why the hell are you converting sensory information to sounds and colors?" While in some ways I would have been happy to have a real-time graphing viewfinder or even a numeric viewfinder, I also wanted to see what would happen if I didn't have any way to look at the data from a traditional perspective. I think it's amazing that these types of outputs are rarely used in tool design, yet they are useful, playful, and quite usable for many purposes.

I would have liked to have removable SD memory, so that the data could be "visualized" in arbitrary ways in a program like Scratch. But I didn't get it working this time, so the only way to "view" data was as a color or a sound on the camera. You could watch it fast or slow, and you could swap different representations, but you couldn't ever know what "number" the electrical resistance was or see a traditional graph of the temperature over time. You could only experience the equivalent of that graph by listening over time or watching the colors change.

Experiential graphs don't have to be limited to sound and color. We can get elaborate and be as ridiculous as we want: we could ride an experiential graph in a rollercoaster. If we work some more with the idea of experiential graphing, I think it could give rise to a way of thinking about signals through images, sound, and bodily senses that could be called intuitive data processing. Further, an instrument that is prepared for intuitive data processing might take advantage of how you're trying to think, what you're trying to study, and where you are located to become a situational instrument. For example, if you're using your eyes to examine an environment, then an instrument shouldn't use visual feedback (which almost all instruments do). A metal detector is a good example of a properly designed situational instrument (it beeps while you scan visually with your eyes).

So why don't data loggers have a simple mode for alternate sensory output? I'd say they should if they're meant to be explored with.

For centuries now, science has privileged thinking and seeing over intuition and other senses, and unofficially but fairly explicitly communicates which is more important. [14]

Re-Seeing "Connected"

I'll leave you with a thought that has little to do with journalism, but hits home with me, and spurred me to think about reclaiming the word "connected."

"What's interesting about technology is that all the little devices that people carry around these days seem to close people off from their surroundings. Listening to your iPod while taking a walk closes your

ears off from say the birds calling or a river flowing. Your Blackberry allows you to be reached, all of the time. You are always connected...”

Reading this comment makes me think of reclaiming the word “connected” from the cell phones and iPods of the world and using it again for being connected to what’s going on around us. That doesn’t have to mean unplugging our new i-Whatever; it just means the designers of the new i-Whatever have to be more humble and become aware that what we’re coming into contact with matters at least as much as the music being streamed live from another location [2].

The next day I was out on the street, and I ran into a man wearing a backpack full of electronics with an electronics shirt talking on a cell phone. I interrupted him to ask if I could take a picture of his shirt which said, “I’M VERY WELL CONNECTED.”



He agreed using gestures and let me take his picture while he continued to talk on the phone. I don’t mean to say that he should have gotten off the phone for a stranger to take his picture. This isn’t a criticism of his behavior. What I do mean to say is that the word connected is being used in a very specific way. He is connected to people in other parts of the world through machine interfaces. This is a trend in speaking about connectedness in terms of human-machine connection or at best human-machine-human connection.

So here I have described one possible future direction for Camera for the Invisible. Now I’ll stop introducing new vocabulary, and start talking about specific new designs that implement the concepts wrapped in the vocabulary. It is my hope that these new designs

Future Designs

I’ll start by talking about an incremental extension of Camera for the Invisible for the purpose of Environmental Journalism (either civic or professional). Then I’ll propose three other non-incremental paths that address three of the biggest disadvantages of the camera:

- Not fully virally replicable
- No embodied contextual graphing
- Stuck in the PIE model
- Not collaborative

The three specific paths are

- Hacking Cameras
- Embodied Sensors
- Puddle Jumper

I hope these other, more radical, directions help us think more broadly and paradigmatically about the idea of a toolkit for urbonauts. These three alternate paths have the advantage that they will be technically much easier to make than the camera was (though they may be less versatile in some respects). Therefore, they provide a practical path for quickly moving forward and testing ideas. Transitioning from the third future design path, “Fingers as Sensors,” I’ll talk about a new area of design which has grown out of my thinking for this thesis: skin2nature interfaces.

Environmental Journalism

Let me start with what I think is an incremental direction (though possibly a decremental if professionalism ended up influencing the design negatively) that the camera could be taken.

With a few changes to the camera, I imagine journalists could want to use it to add nonvisual information about the scene to their photos in reports. I had originally imagined citizen environmental journalism, but thought it could be interesting to see what people who are thinking about environmental journalism from a professional standpoint would say about the camera.

Would they say:

“We already use professional data loggers so we don’t need a toy like this.”

Or

“Why do I need to record carbon dioxide levels, I’m just a reporter not a scientist.”

Or

“A camera like this would help me communicate some of my findings about the environment to people in a way they could understand.”

I really didn’t have any idea where they would stand on the issue. But I didn’t think the camera was ready for a realistic test of its journalistic capabilities. So I sent a short paper [15] about the camera and a poster to Dave Poulsen who is the Associate Director of the Knight Foundation for Environmental Journalism. In my interview with Dave, he was strongly in favor of the camera being used for environmental journalism, though he agrees it needs to be developed further before it would be ready.

“I teach my students that science is not owned by scientists. Journalists – particularly environmental reporters – can do their own research instead of merely reporting what experts say. Professional reporters have organized air quality studies, searched for and discovered species once thought to be extinct, sampled human hair for mercury, checked water for bacterial contamination. A device such as the Camera for the Invisible provides a suite of tools allowing them to make yet more direct observations. Climate change is sure to be the hottest environmental story going for years. An ability to measure carbon emissions and report them could well lead to public pressure to reduce those emissions.”

He also talks about the “where” of a place that environmental journalists need so badly. It’s not just about geography; he says the where is about the environmental situation. I ask Dave “Why not use an existing solution (there are many, for example a simple data logging meter of the appropriate sensor type)?” He responds:

“Maybe journalists should do that. I think that they don’t simply because they are unaware of them. Or if they are aware of them, they are intimidated by them or believe they need to be trained to use them. Or they haven’t really thought of them as journalistic devices. As designed, the Camera for the Invisible is an accessible device. It has the comforting look and feel of a traditional camera. I think users will be less intimidated by it than they might be by other equipment. It also appears extremely compact. It’s one device with multiple uses. Portability is a huge consideration for journalists.”

Dave also engages nine of his environmental journalism students in a written critique, which I won’t include in its entirety.

Overall, I think the director of the environmental journalism center thought the camera could be used for journalism, while his students thought it was useful, but more so for educational purposes.

Hacking Cameras

One direction I’d consider taking Camera for the Invisible is to start with a product that already exists, such as any camera. This could allow for the viral replicability discussed in the Covert Alert section, except with much more potential for evolution and adaptation than Covert Alert has. One way to hack a camera to see the invisible is to devise a mechanical trigger that turns any normal camera into a time-lapse camera, and I have seen this done by several hackers on instructables.com. Surprisingly, few consumer-level cameras include time-lapse or intervalometer mode. But essentially no cameras exist to take pictures of interchangeable invisible phenomenon. So how can we make a set of interchangeable lenses that strap on to a normal camera?

One way would be to make lenses that can fit over the existing lens of a camera. These lenses, like the lenses for Camera for the Invisible, could sense any arbitrary phenomenon that is possible, like CO₂ concentration. Then they could transform that information into an amount of brightness which would then shine on the lens of the camera. This basically turns a multi-mega-pixel camera into a one-pixel camera (or perhaps a handful of pixels). But the functionality for recording, reviewing, and downloading is already built into the camera, and in the case of a camera phone (and some camera models), the output could be programmatically transformed to be sound, color, graphical, etc. There will be difficulties with automatic gain adjustment and nonlinear scaling, and the additional lens will probably need to be self powered, but it’s one way of trying to turn any camera into a Camera for the Invisible. Further, the overwhelming prevalence of the digital camera in modern society would allow for the evolving process bootstrapped by viral replicability (if it can reach the right effort-to-meaning ratio).

Reclaimable Sensor Throwies

As discussed previously in the “Transcending PIE” section, there is a common problem in scientific instrumentation and in using cameras in general: there is something between you and your subject, and

some of the experience is missed out on. I'll propose two specific projects that could start to transcend PIE through environmental immersion. Let's begin by talking about Throwies and Chirpies, which follow an IEPEI model. This model is desirable, as previously discussed in the "Embodied Contextual Graphing" section.

A throwy is:

"A small LED attached to a coin battery and a rare earth magnet (usually with conductive epoxy or electrical tape), used for the purpose of creating non-destructive graffiti and light displays."
[Wikipedia, August 2008]

A chirpy is the same thing except replacing the LED with a sound maker. They were first invented in 2006.

A few changes would have to be made to make Throwies into Reclaimable Sensor Throwies. The most obvious change is that you would need to add a small sensor to a Throwie. Then, instead of using them in the graffiti sense to display a message by dispersing them in the environment, they could be an environmental color-map of some aspect of the landscape. This is akin to the original set of inputz and outputz I proposed at the beginning of the design process. Whereas Throwies are sometimes considered to be disposable, which could wreak havoc on the environment, Sensor Throwies should be thought of as reclaimable, more like Christmas ornaments and less like confetti. While these could have memory or mixability, let's suppose we make them without memory and maybe even without the ability to be interchanged. This will make them much simpler to prototype, but still have the advantage of showing what it is like to be able to embody a contextual graph in the landscape. Suppose you hang 20 of them on a fence, in the snow, and on a bare tree in winter. They transform, for example, temperature to color, and you look while moving through the landscape. You have real live pixels of information embedded in the landscape. This is a graph. In many cases we can already see wind in this way rippling across a field of grass or the leaves of trees. We can hear temperature very accurately by listening to the way crickets chirp. But in the city, the grass is paved over with asphalt and the urban children don't know what crickets sound like (not only do I notice that crickets don't live in the city, but my wife said that the kids at her urban preschool don't know what a cricket is). And as you may remember from the Car Wind story, many of the new important elements of our urban environments, like pollution, aren't sensible. So while there are some natural equivalents to Reclaimable Sensor Throwies, they will rarely do the job in the typical urban environment.

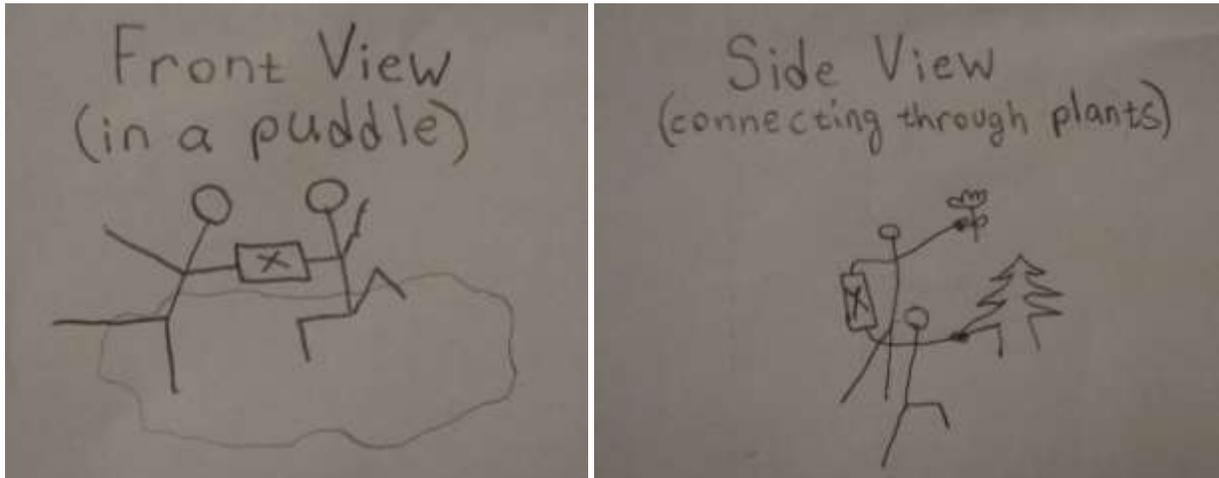
Technically, it's a sort of intensity graph across 3D space, which is four dimensions of information. 4D information is sometimes exemplified as a sphere with hotspots in the sphere. But by embedding Sensor Throwies in the landscape you can "walk around in the sphere." This was one of the original goals of the project which was lost when choosing a camera. This is also a simple path for creating an Embodied Contextual Graph.

Fingers as Sensors with Puddle Jumper

A Virally Replicable IPE Instrument with a Collaborative and Skin2Naure Interface

In some ways the title of this section is tongue in cheek. Fingers are sensors! Yay! We can reclaim them. But in the traditional (at least traditional by modern standards) model of a scientific measuring instrument the instrument goes between the experimenter and the environment, PIE, as explained in

“Transcending PIE.” Puddle Jumper tries to put the instrument in the back and gets the people to touch (literally) the environment.



Puddle Jumper is so named because it allows you to compose music by jumping in a puddle with your friend. The way you put it on is by holding hands with your friend inside of a sock-like-cloth-tube. In the sketches the “sock” is marked with an “x.” Puddle Jumper takes advantage of a nonmixable synesthetic dyad: electrical resistance converted to audio pitch. Technologically, Puddle Jumper is an extension of Curious Caterpillar with a person hooked to each of the antennas. But from a design and process feature perspective it’s a huge leap ahead.

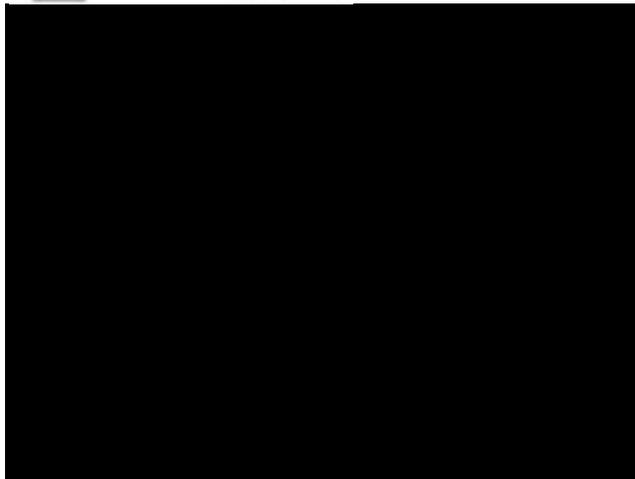
In the front view (above), two friends playfully compose music by standing and dancing in different places in the puddle. By touching the puddle with their feet, they’re functionally using their feet as sensor probes to measure the resistance of portions of the puddle. In the side view, they’re composing music by touching a tree and a plant at the same time that are electrically connected through the soil. The two friends can effectively roam the urban environment and compose music on anything with non-infinite electrical resistance, simply by touching the city with their fingers. This is an example of what I call a skin2nature interface, which I’ll describe in the next section.

This is also a legitimate two-person tool for urban exploration. Unlike the 2-neck-strap design, it not only requires, but facilitates the cooperation of two friends in the sense that each person has a free hand and equal “control” over the device. The reason I say one free hand is because the people are holding hands with their other hand in order to activate the device and ensure simultaneous navigation. That free arm (and in fact the entire mass of skin on the person’s body) becomes the probe to the environment. I won’t explain why here, but it takes two to measure the resistance of something, and it is done by each person touching the same object.

Here is a video taken today (literally the day that I am writing the last words of my thesis, 8/6/2008) by some workshop participants who were given many exploratory tools (magnifying glasses, PicoCrickets, etc.). One of the tools was a bare bones Puddle Jumper (just the circuit). Their initial assignment was to explore outside with the tools before building on top of them. I did not go outside with them, nor did I tell them the tool was called Puddle Jumper, but it did happen to be a rainy day:



The version of this thesis that you are reading does not include videos. To see the video, download the multimedia version of this document.



The reason I show this video is just to show the preliminary suggestion that the design of this tool can lead to people jumping in puddles and otherwise touching the environment without the presence of a facilitator, though a facilitator was there for the indoors introduction and this is only one example.

In exploring with the circuit that goes into Puddle Jumper, I've seen that there are a huge number of ways to configure and embody the two leads (previously the caterpillar antennae) that are inputs to the circuit. The two leads have been embodied in a pencil [16], a jacket [17], and many other objects that coordinate and interact with people and the environment in various ways. Today I ran a workshop (mentioned in the previous paragraph) with some teens which starts with the bare circuit and allows the teens to embody and connect the circuit in any configuration they can come up with. That idea, combined with the fact that the circuit is cheap, simple to build, and reliable, makes it a decent candidate for viral replicability that truly allows for evolution and adaptation. Many people have already replicated the circuit for various purposes (from students at Srithi to anonymous people on the internet), and Jean Baptiste has made what he calls a Drawdio-Bot [18] using the circuit, which was the most unexpected evolution yet.

It's not as tool-kitty as the camera was with swappable parts, but what's important is that it puts the person and the environment together with the instrument behind (IPE), it has a legitimately collaborative interface, and it is truly a skin-to-nature design.

The Puddle Jumper actually requires that the explorers come into physical contact with parts of the environment in order to make measurements of them. This model of putting the instrument more and more out of the way, and actually having the interface require physical contact between the body of the person and the subject, is what leads to the idea of the skin2nature interface.

Skin2nature Interfaces

This line of research opens up a whole school of skin2nature interfaces. The Puddle Jumper is essentially already a continuous 1D tangible controller that uses almost anything you touch as a potential 1D input to a system such as a computer. Let me elaborate. Right now the Puddle Jumper is controlling the frequency of a pitch on a continuous 1D scale. But, instead of hooking up the input to a noise maker, it

could be hooked up to an arbitrary machine that is expecting a 1D input. While Puddle Jumper isn't displayed to work this way in its diagram, if one finds any continuous "resistor" (the easiest to find is a puddle or dish of water), sliding ones finger along this resistor produces a continuous 1D sweep of analog voltage which could be provided to any arbitrary machine. Building on top of that idea, I also prototyped a 2D controller in a dish of water, which can also works in oil-impregnated cloth. You can throw water on any surface and it becomes a 2D controller. You can embed water or oil in cloth to make the cloth a 2D controller, and then you can wrap that cloth onto arbitrary convex shapes such as a sphere and control (for example) a globe on a screen.

Flower Petter and Skin2nature On-Switches

Using skin2nature interface design I have already created a shoe I call "Flower Petter." A Flower Petter design is any design that knows when you're in contact with Nature by testing the connection between your skin and the ground. It turns out that trees, flowers, plants, the dirt, humans with bare feet, and animals all literally share a common ground, and are therefore electrically connected. It should be noted that this isn't "artificially intelligent" and doesn't exclusively test whether something is part of Nature. Anything else that also shares a common ground, like a fence, will also be detected the same way a flower is. But the simplicity of the function is an advantage: the circuit components can be purchased for cents and consist of no more than a battery, a resistor, a transistor, connecting wire, and an actuator of choice (like an LED). This is an example of a binary skin2nature interface: touching Nature is effectively an on-switch.

Ok2touch

Considering the human as part of Nature, human touch becomes a skin2nature on-switch with the proper design. I've prototyped this in a jacket I recently designed and exhibited called "ok2touch." Ok2touch encourages people to playfully compose music by touching the wearer of the jacket's skin, by holding hands, bumping noses, or tapping on a forehead. There is plenty of talk in this day and age about why we shouldn't touch inappropriately, which is important. But human skin-to-skin contact is widely known to be extremely important to the way we interrelate.

Human-Human-Contact and Human-Environment-Contact Aware Machines

I think skin2nature design is a new type of human computer interaction which defies the trend to touch petroleum products and allows machines to be aware of our contact with Nature and each other as humans.

Goodbye

I started by thinking with my feet and my body. My experiences farming, hands in the dirt or hauling and sorting bags of food, were visceral. I learned how to think through others by watching learners with Duckworth and watching the children explore in Bangalore. I learned that I could think through generations past by interviewing gurus and students of Nature Awareness. I thought with my hands when building a camera prototype. I thought with the help of new friends when I evaluated the prototype. I thought about how I could contribute ideas towards a toolkit for urban exploration. "I'm thinking and breathing with my eyes closed right now."

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