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Sensory Triptych: Here, Near, Out There

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ABSTRACT

Sensory Triptych is a set of exploratory, interactive sensors designed for children that invite “new ways of seeing” our world from the perspective of the *here* (the earth, air, and water around us), *near* (things just out of sight), and *out there* (orbiting satellites and space junk) using familiar and novel interfaces, affordances, and narratives. We present a series of novel physical design prototypes that reframe sensing technologies for children that foster an early adoption of technology usage for exploring, understanding, communicating, sharing, and changing our world. Finally, we discuss how such designs expand the potential opportunities and landscapes for our future interactive systems and experiences within the UIST community.

Author Keywords

children, sensors, toys, education, citizen science, citizen exploration, critical design

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Sensory Triptych explores new form factors, interaction models, experiences, and sensing technologies for children that foster an early adoption of technology usage for exploring, understanding, communicating, sharing, and changing our world. Presenting technologies that promote curiosity, collaboration, and wonderment rather than computer games and mobile apps, Sensory Triptych operates across three themes. *Here* — By integrating soil sensors into common sandbox toys with light, vibration, sound, and e-ink displays for facial expressions, **Earth Explorers** encourage children to approach sensing and technology as tools for exploring, interrogating, and investigating their world in creative and playful ways. **Air Explorers** measure air quality with low-cost air particle sensors embedded into toy airplanes and skateboards while

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Figure 1. Examples of the three themes. *Here*: Earth Explorer, *Near*: Adventure Watch, and *Out There*: Overhead

Water Explorers embed flexible total dissolved solids (TDS) water sensors into toy boats to explore water quality in baths, sinks, lakes, streams, pools, and gutters. *Near* — **Adventure Watch** is a watch that provides real-time “nearness” for a narrow set of “interesting” kid specific places just beyond their field of view — parks with cool slides, junkyards, toy stores, skate parks, trains, earthquake fault-lines, etc. It invites a sense of adventure and discovery in seeking out and finding nearby places. As a car passenger, it encourages kids to imagine the world of adventures just beyond their vantage as it enables a “new way of seeing” the world around them. *Out There* — **Overhead** is a personal domestic object that continuously senses the world above us, outer-space, by tracking and reporting the flyovers of the more than 17,000 currently tracked orbiting objects as they pass overhead.

RELATED WORK

Over the past few years, researchers have developed a range of sensing systems to measure our local environment [1-10]. Personal, mobile devices coupled with novel sensors have empowered users to monitor factors such as air pollution, water flow in creeks [11], noise pollution [12], and metal content in soil [13]. Compelling visualizations of this citizen-collected data using graphs and maps have provided powerful tools for informing communities and expert analysis [12; 14; 15; 15]. Many of these phone based citizen science platforms have enabled a new practice of public participation around data collection and analysis [15]. Similarly, there has been a growing body of work into the interaction design of children’s toys and technologies [12; 16-21]. Finally, we have also seen a series of exciting projects exploring sensor legibility through critical design artifacts and ambiguity [22-24].

Our work leverages this impressive collection of important work to present a series of technologies that explore sensing, citizen science, sensor legibility, sensor

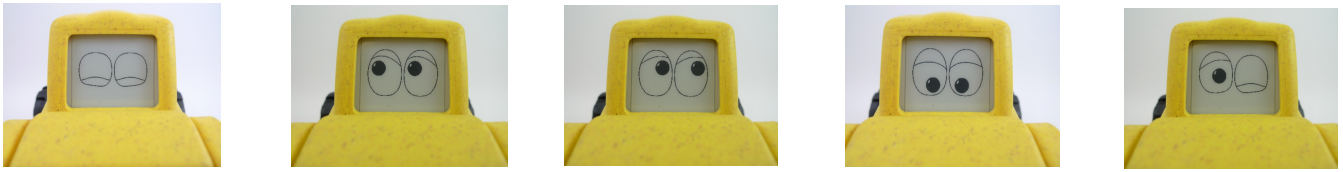


Figure 2. Examples of e-ink based facial expressions on the Earth Explorer: Sleeping, waking up, waiting for a sample, measuring a sample, and expressing a final result using a wink.

epistemology, and learning through novel form factors, contexts, and interactions.

FROM CITIZEN SCIENCE TO CITIZEN EXPLORATION

While citizen science has been an emerging and important theme in the research community, it may overly foreground a scientific agenda within the work [25]. We argue that the primary value of these projects is in rekindling a curiosity in our world by promoting and engaging individuals to look, feel, interact with, and explore the world around them. A more appropriate term is “Citizen Explorer” rather than Citizen Science. This paper explicitly focuses on foregrounding the design elements of such “exploratory” technologies through a series of physical prototypes and examples.

DESIGN MOTIVATION

The motivation for this work is at the conflux of childhood curiosity and citizen exploration technologies. From the latter, many of our technologies focus on providing universal interfaces to services and systems such as social media, email, online banking, weather, games, mapping, etc. While the ubiquity of our mobile tools makes them arguably strong candidates for embedding citizen exploration applications, we wanted to explore form factors and designs that avoided this interface overloading. To sufficiently vary the range of “seeing”, we used *proximity* as a sensing differentiator. This led to looking at sensing things that are very close (i.e. here), close by not visible (i.e. near), and very far (i.e. out there). One could imagine other ways to discretize this distance parameter. For us the main factor was to provide a design landscape that avoided solely focusing on most common type of sensing, here. This distance design constraint parameter worked well in showcasing alternative sensing approaches and opportunities.

The second motivation came through the authors’ observations and conversations with young elementary school children, boys and girls, aged 4-8. To be clear, we have not yet conducted user studies of these designs, and issues of usability, how well these objects promoted curiosity, and even gender issues have not yet been measured sufficiently to document in this paper. We can report that the children that have serendipitously encountered the technologies have expressed overwhelming excitement, enthusiasm, and desire to have one themselves. Similarly, we can describe the observations and interactions

with children that motivated this work. For example, when looking for design opportunities for environmental sensing, we studied and brainstormed starting with toys commonly played with by children outside. This led to the set of Earth Explorers designs. We also observed first hand examples of children questioning the visual “nearby” places that scrolled by peripherally on GPS car navigation systems. This childhood curiosity and in some cases genuine emotions of disappointment at missing out on seeing or visiting a nearby park or train track led to our more focused brainstorm that led to the Adventure Watch design. Finally, in discussions with children about far away things we found satellites, rockets, and planets to be a common theme. We intentionally ignored planets to avoid any overt “planet education” messaging and instead focused on the lesser explored experience of satellites. We were also drawn to satellites because, similar to other environmental issues such as air pollution and water quality, satellites are a product of and directly influenced by the actions of our industrialized society. However, to be clear the goal of these projects was not to produce a set of digital eco-toys. Rather, we wanted to explore new designs for seeing and exploring our world beyond mobile apps and overt sensing technologies.

HERE

The first theme within Sensory Triptych is *here* which is focused on developing new interfaces to sensing the immediate present place of play for children. We do this by integrating a range of sensing into familiar toys and playful affordances. The interaction design of these objects is not intended to deliver exact numerical values or signal ecological fear in children. Rather, these interactive environmental sensing toys provide signals to children about the soil, water, and air variations to promote curiosity and reflection. The feedback of the system through facial expressions, lights, sounds, and vibration, provide playful elements for children to develop into their own narrative. The *here* theme is manifest in three novel exploratory forms as described below.

Earth Explorers

We have integrated off the shelf soil moisture and pH sensors into a series of common sandbox toys such as a toy dump truck and bulldozer. Within each of these land based explorers are an array of sensors and output mechanisms such as lights, sounds, and vibration. The Earth Explorers also use e-ink for expressive facial output on these

technologies. While the measurements and outputs are accurate, the goal is not to output literal values but rather to develop experiences around the sensors that invite curiosity and child driven narrative into play.

Initially the Earth Explorer is asleep as represented by closed eyes on the e-ink display. Shaking the toy causes it to wake up and begin looking around curiously. When the bulldozer or dump truck is filled with dirt, as detected by a photodiode, the eyes on the toy look towards the loaded dirt and a light inside the cab of the toy flashes briefly to indicate a measurement has been taken. The sensed value, soil moisture for example, is mapped into four discrete ranges and output through a vibratory motor that can be felt when holding the toy. We combine high and low motor speeds with long and short pulse times to represent the four sensor value ranges.

Air Explorers

Similar architecturally to the Earth Explorers, Air Explorers integrate a newly designed laser particle sensor we have developed call *MyPart* to provide low-cost, low-power, air particle sensing into a toy airplane. Air Explorers express a similar range of output modalities including light, sound, and vibration for expressing measured air particle counts in real time which relates directly to air quality and health. The main difference in output modality from Earth Explores is that readings are taken continuously every few seconds rather than triggered by an event such as loading dirt. This means that as the toy airplane is being “flown” around several seconds of particle data are collected, mapped into four discrete ranges, and then output through vibrations similar to the Earth Explores.

Water Explorers

Integrating our recently developed low-cost, flexible total dissolved solids (TDS) water sensor called *MyWater* into a toy boat, Water Explorers invite children to explore water quality in their bath, sink, lakes, streams, pools, and gutters. The Water Explorers interaction functions similarly to the Air Explorer by taken readings every few seconds and outputting the results through a set of discrete vibration pulses.

Hardware and Sensor Details

All of the *here* theme artifacts (Earth, Air, and Water Explorers), leverage our existing body of work in citizen science, low-cost sensing, and critical design. As mentioned, we developed two low-cost, low-power sensors, namely *MyWater* and *MyPart*, that are integrated into the Sensory Triptych project and we describe them below.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid (in our case water). While TDS is not generally considered a primary pollutant, it is often used as an indication of chemical or other contaminates in drinking

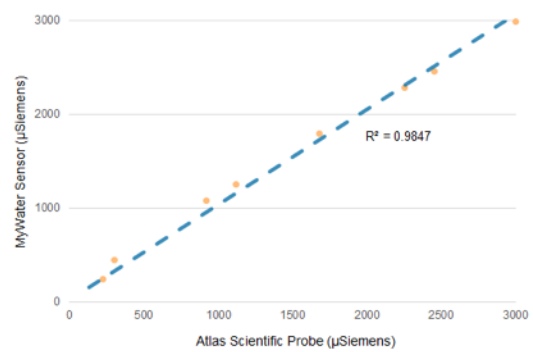


Figure 3. Data comparing our low-cost TDS sensor with a calibrated Atlas Scientific Conductivity Probe.

water. Using a small microprocessor, a handful of passive components, and nickel chromium wire, we have developed a low-cost, low-power, flexible TDS sensor for a fraction of the cost and size of off the shelf sensors that performs respectably against much more expensive scientific grade circuits and probes.

The *MyWater* sensor in the Water Explorers uses a TDS sensor we designed to measure the amount of total dissolved solids in water through electrical conductance. To detect changes in conductance, we used a standard Wheatstone bridge with the water of interest as the unknown resistor. The probes that contact the liquid are made of Nickel Chromium, a highly unreactive alloy. To prevent electroplating the probes, the direction of voltage through the Wheatstone bridge is alternated every second. The voltage between the two midpoints of the bridge is measured with a ten bit ADC onboard the AtTiny85 microcontroller. Tests were conducted against the Atlas Scientific Conductivity Probe (a \$150 sensor), and our sensor exhibited comparable performance across a range of 3000 microsiemens. The total cost of all components of our sensor was under \$10 (see Figure 3).

Laser Air Quality Particle Counter

Low-cost air quality sensing often consists of some form of gas sensor. These are typically a thermal conductivity based detector tuned to respond to carbon monoxide, ozone, nitrogen oxides, or other gases. However, these devices do a poor job of accurately measuring the actual gas concentrations due to sensor response selectivity and gas interaction problems. Furthermore, these gas sensors are high-power due to their thermal heating requirements. Most importantly, these gas sensors do not measure the primary air pollutant in regards to human health which is airborne particles. To address this problem, we have engineered a novel, functional, low-cost laser air particle counter. Our device demonstrates a signal response consistent with highly calibrated particle sensors in our lab. Again, because of the smaller, flexible form factor, and low-power usage, we are able to explore a wide variety of embedded applications, data logging, and wireless possibilities for this sensor.

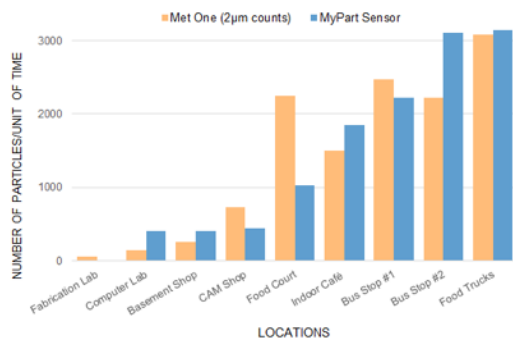


Figure 4. Data comparing our low-cost air particle sensor with a calibrated MET-ONE particle count sensor.

The *MyPart* sensor in the Air Explorers uses a laser and photodiode arranged orthogonally such that the focal point of the laser is located directly above the photodiode. Air is drawn through the system across the photodiode using a small computer fan. Particles in the air stream that intersect the path of the laser scatter light onto the photodiode, and the resulting voltage signal is amplified by an op-amp circuit and sampled by a microcontroller with a ten bit ADC. The data is analyzed for peaks, which indicate that a particle has been detected. Preliminary tests were conducted against a MET-ONE HPPC-6 (a highly calibrated \$2000 particle counter used in cleanroom applications) at different locations of varying ambient light intensity and air quality. The results show promising correlation between the *MyPart* sensor and the MET-ONE (see Figure 4).

NEAR

The *near* theme presents a new form of mapping constrained to near “places” just slightly out of sight. For example, while driving a car, adults focus on the the desired route and traffic as presented by most navigation GPS systems. However, for the backseat child, it is the objects “on screen” but just out of sight that draw their curiosity - the park on the next street over, the train tracks just beyond the visible trees, or the junkyard behind the adjacent buildings.

The Adventure Watch

The *near* theme delivers a highly constrained, curated experience of specifically chosen near places through a watch form factor. Tuned to only “slightly out of view”, nearby places, it foregrounds those sites of specific child fascination beyond 50 meters but within 500 meters. The watch uses GPS, a digital compass, and a small screen to signal when sites of childhood curiosity are nearby along with heading and distance information. The Adventure Watch is designed for a child but equally fascinating for sparking even a childhood curiosity in adults (Figure 5).

Unlike a traditional GSP units, the Adventure Watch is a GPS device that provides an abstracted proximity indication to an intentionally limited and selectable set of “places” of interest to children - parks with cool slides,



Figure 5. Adventure Watch indicating nearby train tracks.

junkyards full of a day’s adventure, toy stores, skate parks, etc. The Adventure Watch invites a sense of adventure and discovery as an exploratory tool for children to seek out and find nearby places of extreme personal interest and delight. When the child is a passenger is in a car or walking, the watch encourages them to reflect, imagine, and wonder about the world of adventures just beyond their vantage as it enables a “new way of seeing” the world around them. The directional heading and compass aid in the final navigation if the child sets of to actually discover the “landmark”.

OUT THERE

Finally, the *out there* theme provides a mechanism to sense objects permanently far away. So far away in fact that it is nearly impossible to travel to them or view them directly. In fact the sensed data must be believed at face value since direct measurements are often impossible.

Overhead

The *out there* theme of exploratory sensors is represented by Overhead (Figure 6) which presents a new level of curiosity and degree of trust reporting on the flyovers of overhead satellites and space junk in real-time with corresponding facts and data. It lives comfortably in a child’s bedroom. Overhead is a personal domestic object that senses the world above us, outer-space, by tracking and reporting the flyovers of Earth orbiting objects as they passes overhead. Decades of launches have left Earth surrounded by a halo of space junk with more than 17,000 trackable objects larger than a coffee cup and less than 7% of those as operational satellites. Based on its GPS location and orientation, Overhead uses real-time data to signal and report on each orbiting object — from the International Space Station to military spy satellites, discarded rocket engines, astronaut tools, and space junk. Overhead points out each orbiting object by swinging towards its actual position, projecting a small icon on the ceiling to track its transit in real-time, while it communicates data about the satellite through a set of three integrated clear screens embedded within each of its solar panels. Data includes, satellite name, country of origin, date launched, satellite type (i.e. communications, reconnaissance, weather, debris, etc), and a scrolling list of mission facts. An image of the satellite is also displayed with a human for scale.

This work is thematic with the Plane Tracker Project [26] which invites a similar curiosity around visible airplanes as they fly by. However, the work we present in the *out there* theme is specifically focused on exploring sensors that deliver information concerning mostly un-viewable objects. That is, while one can plan and observe a limited set of major satellites such as the International Space Station or Hubble Space Telescope near dawn and dusk, this represents only a tiny fraction of the over 17,000 tracked objects that orbit the earth and are invisible to the naked eye.

DISCUSSION

We present these prototypes as critical designs that demonstrate how reframing the landscape of sensing and interaction can afford new design opportunities for HCI practitioners. This Sensory Triptych demonstrates the value of designs that present sensor data in incomplete narratives or stripped of meta data and measured context. Instead these designs develop early childhood expectations of roles for technology away from the limited framings found in many of today's devices which often overemphasize a focus on improving efficiency, productivity, and accuracy.

Epistemology and Sensor Legibility

This series of objects reference epistemological issues around knowledge and truth in the manner in which it invites "new ways of seeing" our world. It questions ideas of "what is real" as it provides a mediated mapping of our world through digital sensing. It invites questions on the limits and consequences of sensors, values, and truth in what we see and cannot observe directly. It also draws out a separate debate around sensor legibility as it positions itself within a landscape of the literal and abstract. The project is a mix of juxtaposing narratives from the exactness, seriousness, and problem solving professionalism of overt sensing performed by experts to the embedding of casual sensors collaged within the playful curiosity of children and toys. It also inverts the idea of expert itself by framing children as the ultimate experts, storytellers, and explores of our world through their well developed craft of play, curiosity, and narrative. Finally, it argues for a children as activists and participants both within their own world and the larger context of Dewey's framing of the "public" [27].

Critical Design: Curious Toys and Curious Technologies

All of these objects critique current trend in technology and its adoption through critical design. There are several issues at play. First, the pervasive nature of electronics and technology embedded within children's toys have led to a series of distracting sounds, flashing lights, voices, and gyrating motions for toys. Worse, these toys often strive to complete narratives rather than encourage and foster the rich natural curiosity in children. Similarly, most current discussions of technologies for kids almost always gravitate towards mobile apps, computer games, and screen based experiences. But future innovation will come in a variety of



Figure 6. Overhead (illuminated and in darkness) communicating location by pan/tilt and displaying detailed satellite facts on its clear screens during each orbital flyover.

forms and experiences beyond today's touch screens. Getting dirty with crowd-sourced sandbox sensing, playground curiosities, and real-time orbiting satellites generates a narrative essential to this debate of technologies for children and our future devices.

Finally, this work focuses around reframing technologies to avoid the constant push to find friends, download hip music, and locate great restaurants and instead provide incomplete information, inviting individuals to engage more directly with the co-creation with technology and fostering of narratives and storytelling. How can our technologies celebrate these seams [28]? That is, rather than viewing the edges of technological limitations or lack of connectivity as problems, how can they be explored as opportunities for engagement, curiosity, and wonderment?

CONCLUSION

We have presented a set of exploratory, interactive devices that invite "new ways of seeing" our world from the perspective of the *here*, *near*, and *out there* through sensing technologies design for children that foster an early adoption of technology usage for exploring, understanding, communicating, sharing, and changing our world. We used this series of examples to identify and highlight how reframing the interface and experience away from expected standard practices can reveal a wealth of important and valuable potential interaction opportunities and new design landscapes.

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