Designing for Doubt

Citizen Science and the Challenge of Change

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Abstract— **Vast quantities of data are collected about us and our world: credit card transactions, movements and traffic flows, social networks, disease outbreaks, bird migrations, and flowers blossoming. These datasets span a wide range of public and private information and contexts. However, it is the emergence of a host of mobile phone based citizen sensing platforms that is poised to become the dominant contributor to our datasets. In this paper we outline this important new shift in mobile phone usage – from communication tool to "networked mobile personal measurement instrument". We propose to explore how these new personal measurement instruments enable an entirely novel and empowering genre of mobile computing and research called citizen science. More importantly we highlight a set of challenges and focus specifically on the need for introducing design strategies for engaging these datasets that encourage doubt rather than promoting blind acceptance of fact as a path towards social change.**

Citizen science; sensors; sustainibility; ambiguity

I. INTRODUCTION

The concept of non-expert citizens collecting scientific data has existed for well over a hundred years [1]. However, a renewed manifestation of citizen science has emerged, invigorated by the recent introduction of open development platforms for sensor rich mobile phones, demonstrations of the power of crowd sourcing, and the cultural adoption of participatory practices to research, build, and study systems that allow everyday people to act as "citizen scientists" in collecting, sharing, educating, raising awareness, and solving problems across our landscapes and ecosystems. This new technologically enabled cultural practice often positions and refocuses urban landscapes as living laboratories where citizens play a new and active role in collecting, sharing, reporting, and interpreting, personally collected data to help facilitate scientific research. These efforts are aimed at exposing the dynamic interactions between people and the natural ecosystems and improving overall human health and well-being. This data collection practice departs from the traditional sampling and collection techniques used by scientist centered fixed sensing strategies, by introducing an important new actor, everyday non-expert citizens with sensor equipped mobile phones and the potential to radically change and expand the model of how scientific research is conducted.

However, a foundational element of science, the scientific method, is not typically imported into the framework. This is somewhat intentional in that these systems are designed to invite non-scientists to be active participants in collecting data and drawing conclusions. However this data will almost certainly be noisy; filled with inaccurate, un-calibrated and even intentionally malicious sensor readings. But representing the data using increasingly trustworthy tools of technology such as mobile phones, now a rather reliable source of location information on-the-go (*i.e.* where is a nearby bank machine?), or computers historically numerically accurate (*i.e.* help balance and track my finances), lends itself to a biasing of the perception of the data as more factual than it actually is. The inherent problem is that people want to *believe* more than they want to *doubt* with these citizen science technologies. We have seen elements of this problem before such as when interfaces are designed to refocus data to appear informal, unfinished, and more sketch-like [2]. These "sketchy" interfaces lend themselves toward broader user interpretation and questioning of designs by delaying any appearance of finality.

In this paper we frame important questions for engaging data within four core components of citizen science: collect, express, share, and change. We then highlight significant barriers to adoptions and a need for sensor legibility and the introduction of doubt within the design tools and interfaces for engaging these datasets.

II. CITIZEN SCIENCE

Citizen Science [3] builds upon a large body of related projects which enable citizens to act as agents of change. There is a long history of such movements from grassroots neighborhood watch campaigns to political revolutions. Some of the more well known movements are the National Audubon Society's Christmas Bird Count (CBC) where a census of birds in the Western Hemisphere is performed annually by citizens since 1900 [1]. More recently, the success of online approaches such as SETI@Home [4] and citizen sensing strategies such as "The Great World Wide Star Count" [5] an international event that encourages everyone to go outside, look skywards after dark, and report the count of stars they see (in effect measuring light pollution), and "Project BudBurst" [6] where people submit time stamped images of when flowers in their city bloom (in effect a phenology study of climate and pollen counts), point to an immense public interest in such collective movements.

Our research leverages Corburn's "street science" framework, which emphasizes local urban insights to improve scientific inquiry and environmental health policy and

decision-making. Corburn underscores the importance of local community knowledge as "the scripts, images, narratives, and understandings we use to make sense of the world in which we live" [7]. Even more emphatically he states that a community's "political power hinges in part on its ability to manipulate knowledge and to challenge evidence presented in support of particular policies" (p. 201). While such local knowledge and community-based practices are sometimes labeled as romantic or populist, Corburn insists that such views overlook the structural and global dimensions of problem solving for urban communities. Corburn believes that "street science" leverages community power imbalances, and can increase agency or decision maker understanding of a community's claims, thereby potentially increasing public trust. He insists that such local knowledge informs environmental health research and environmental policy making in four distinct ways: 1) by making a cognitive contribution by rectifying the tendency towards reductionism; 2) by fostering of a "hybridization" of professional discourse with local experience; 3) by pointing out low-cost and more effective interventions or remedies; and 4) by raising previously unacknowledged distributive justice concerns that disadvantaged communities far too often face.

III. Mobile Phone Based Citizen Science

Through the use of sensors paired with personal mobile phones, everyday people are invited to participate in collecting and sharing measurements of their everyday environment that matter to them and possibly other stakeholders such as urban planners and policy makers, community groups, local industry, computer sciences, engineers, social scientists, atmospheric chemists, environmental health organizations such as the EPA, urban planners, local and national governments, *etc*.

A. Sensor Rich Mobile Phones

We have already seen the early emergence of sensor rich personal mobile devices such as Apple's Nike+iPod Sport Kit (music player + pedometer), Apple's iPhone 3GS (mobile phone + proximity sensor + accelerometer, + compass), Nokia's 5500 (mobile phone + pedometer), Samsung's S310 (mobile phone + 6 axis accelerometer), LG Electronics LG-LP4100 (mobile phone + breathalyzer), t+ Diabetes (mobile phone + blood glucose sensor), and Samsung's planned body fat [8] and fertility monitoring phones [9]. Similarly, we have seen the "Web 2.0" phenomenon embrace an approach to generating and distributing web content characterized by open communication, decentralization of authority, freedom to share and re-use, and "the market as a conversation" [10] [11] [12]. This synergy of sensor rich mobile devices moving across our everyday landscapes coupled with the introduction of novel technologies enabling new models of citizen participation cannot be ignored by researchers and is certain to become a dominant paradigm in our evolving relationship with technology, our environment, and urban ecology [13-16].

B. Related work

Several research projects explore the role of mobile technology in promoting citizen science such as Equator's Ambient Wood Project [17] using PDAs for sampling the environment by children and White's LeafView mobile phone system for capturing, logging, and cataloging plants in the field by non-scientists [18]. More recently, UCLA's Center for Embedded Network Sensing has setup a research initiative called "Participatory Sensing" that is developing infrastructure and tools to enable individuals and groups to initiate their own public "campaigns" for others to participate in by using networked mobile devices [19]. Similarly, the MetroSense project outlines an exciting opportunistic "people-centric" approach to mobile phone sensing including several deployments with bicycles [20] and the Participate project in the UK where schoolchildren measure their environment with sensors and later offload the data for analysis [21]. Corporations have launched research into this area as well with various sensor data sharing initiatives such as Nokia's SensorPlanet [22], Microsoft's SenseWeb [23], SensorMap [24], and IBM's ManyEyes [25].

C. Sensing Air Quality

In our own research we have developed and studied a range of mobile phone based citizen sensing technologies [26-28] primarily focused on measuring air quality. Our research hypothesis is that this new usage model for mobile phones will lead to important contributions along four primary long-term research themes:

- Improve the science literacy of everyday citizens through active participation in basic scientific data collection and use of scientific principles [29; 30]
- Provide professional scientists and stakeholders with access to richer, finer-grain data sets for modeling, analyzing, and advancing both fundamental and applied knowledge regarding people and ecosystems [31; 32]
- Develop new usage models and user experiences for the mobile phone as a tool for promoting transparency and enabling grassroots participation in local community and civic government policy making
- Create a greater public awareness and understanding of the relationships between humans and the natural environment

Our research leverages the power of crowd sourcing, the recent open development platforms of mobile phones, and the cultural adoption of participatory practices to research, build, and study systems that allow everyday people to act as "citizen scientists" in collecting, sharing, educating, raising awareness, and solving problems across neighborhoods, cities, and nations. From our experience designing, building, deploying, and evaluating numerous such systems, we have formulated an operational framework for citizen science and outline a series of major research questions and challenges:

Collect – Why and how will people be motivated to participate in collecting data? How and what type of data will be collected? When will samples be taken? How will problems of sensor accuracy, drift, and calibration be addressed? What are the reasonable sets of sensors to use? Which sensors are best for individuals? Policy makers? Scientists? What environmental and human conditions make sense to measure? Where should the sensors be mounted and in what contexts and

positions are they best sampled? What sample frequency is best suited to each sensor, user, and context? How will novel hardware be integrated into mobile platforms by non-experts? What will be the overall user experience of collecting sensor data? To what degree is data collection automatic verses user controlled?

Express – How will issues of "sensor legibility" be expressed such as sensor range, accuracy, norms, drift, and calibration? How will the collected data be experienced? On an individual's personal mobile phone? In a public space or shared signage? In the home, office, public transit, or automobile? Which ranges of expressive techniques are best suited to individuals? Social groups? Neighborhoods? Cities? States? Nations? To what degree is the data scientifically expressed with numbers and raw values? Interpreted and abstracted? Viewed as ambient information? How are time, trends, gradients, and averages represented? Over what time ranges and resolutions? What are appropriate techniques to interact with the data and in which contexts? How do different expressive techniques (visual, tactile, audio, *etc*) inspire more persuasion, curiosity, awareness, education, sensor literacy, indifference, individual behavioral change, or the desire to act for societal level change [33]?

Share – How will collected data be shared? Which data standards, protocols and formats should be adopted and/or expanded? How will privacy be addressed? What techniques will be used to insure valid data? What practices of fair use, reuse, and individual ownership will be appropriate? How will data be archived, preserved, and authenticated? How can data best be shared with non-experts, community leaders, scientists, urban planers, health organizations, urban planners, civic government, decision and policy makers, local non-government organizations (NGOs), local industry, and activists groups?

Change – What tools and techniques will facilitate the most productive debate and ultimate positive social benefit? How will people use the data to argue for and against various hypotheses? How will data be compared? Can we "design for doubt" such that individuals interpreting the data realize and address the range of potential underlying possibilities for sensor failures and user errors both accidental and malicious in intent? What tools or frameworks best invite and encourage active participation and the development of real solutions to human and environmental problems using these novel citizen science datasets and the issues they reveal?

IV. DOUBT

While there is some support for designing citizen science tools to support the scientific method [34] of making an observation, asking a question, forming a hypothesis, testing the hypothesis, and then accepting or rejecting the hypothesis, such support is more the exception than the rule within citizen science technologies. It is also not clear to what degree we should embrace the scientific method and expose its methodology within the citizen science framework. What is clear is that we must design citizen science systems to instill elements of doubt when users engage with these datasets.

We have observed some evidence of user engagement with doubt with citizen sensors. In particular we have run numerous trials and workshops to evaluate various aspects of these systems. In nearly every case there are two phenomena that emerge.

First, users have an almost innate need to "set off" the sensor by exposing it to, in the case of our air quality sensors, horrific pollution. This typically takes the form of inserting the sensors into automobile tailpipes. This behavior is a common strategy users employ to collect direct personal evidence to validate that the sensor is indeed working and measuring air quality.

Secondly, when users are actively collecting air quality samples with a device, they take on and are granted a level of authority not unlike that observed by Milgram when an individual became an authority figure mainly through appearances such as donning a lab coat and holding a clipboard [35]. We have observed users, with no other visual appearance of authority except the possession of what appears to be a complex measurement instrument, to be granted unprecedented access to personal homes, businesses, and industrial sites.

A. Ethics and the Dark Side

While there a number of malicious citizen science scenarios, there are several that highlight fundamental problems such as data accuracy and human perception.

First, is it even possible to design a neutral sensor? By our very choice of sensors and problem framing we have setup a natural bias in the system. For example, in our own work we present the technology as "pollution sensors" or even "air quality sensors" – implying a good and bad scale. What if we instead called them "nutritious air sensors" and simply flipped the bias? Similarly, we may measure pollen where high counts are interpreted as bad since they often give rise to allergies and other adverse respiratory problems in humans. However, taken from nature's point of view, high pollen counts are indicative of improved pollination, healthy plants, available food sources for bees, and improved ecological life. We need to draw from ideas across this entire design space.

How will we deal with malicious use of data such as reporting poor air quality data from within a neighborhood to drive down housing prices? Even well intended data can be unwelcome. Take for example the event that inspired *Life Inc.: How the World Became a Corporation and How to Take It Back* [36] when the author, Rushkoff, posted details about a mugging in his neighborhood to warn others only to be attacked by the community for publicly logging location data about the event and potentially driving down their home values.

Are the tools we are developing for citizen science unintentionally creating a culture of fear? Are we providing individuals the proper levels and details to make rational decisions about measured pollution levels, water quality, and other impacts to human health? It is critical that the designs promote optimism and encourage the development of new solutions rather than instilling fear and panic. Nevertheless, this issue is a real concern. We have observed concern in previous studies we have performed where individuals become aware of new health concerns after their involvement in citizen science. While increased awareness is an encouraging result of

such persuasive interfaces for citizen science, we need to insure they are in check with reality and modulated by a larger picture of life, health, happiness, and well-being.

Another concern is that as citizen science tools become adopted into society they will increasingly be viewed as mechanisms to lodge complaints, gripe, and direct blame. Such systems will most certainly soon be ignored by those that can make change. We need to insure that our designs avoid finger pointing and make sure everyone has some "skin in the game". We need to design such systems to allow creative solutions that do not always accuse a single person or organization.

B. Looking Forward: 2010

2010 marks a major "measurement" in the United States – the decadal counting of citizens during the United States Census. It is inevitable that novel tools, techniques, and cultural practices that have emerged in the last ten years will play a new and critical role in this public event. As practitioners in this field, we have an obligation to develop tools, techniques, and infrastructure to help with this effort. It is also clear that this event presents an ideal landscape for conducting research.

V. CONCLUSION

We have presented a framework for citizen science and motivated it as a primary source of data for public engagement. We highlight a series of critical dilemmas within the research design space and outline potential solutions and a reframing of the challenges. We press on a fundamental concern of data perception and a need to design interfaces and experiences of these datasets with "doubt" as an important element. We are optimistic but acknowledge and raise critical concerns with the adoption of citizen science and the challenge of levering it for real social change as we desire.

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