Eric Paulos • Ian Smith • RJ Honicky

RE: REempower and REcycle

Abstract This paper briefly presents two concepts of "RE" (1) re-empowering individuals using personal mobile technology reconstructed as measurement instruments and (2) re-cycle as a design constraint for extending a product's usable lifetime. In the first example we demonstrate the integration of simple low-cost, low-power air quality sensors attached to a mobile phone. In the re-cycle case, we demonstrate the extended re-use of mobile phones using them as toolkits for new duties.

1 Super-powers and Super-senses

Our mobile devices are more than just personal communication tools. They are globally networked, speak the *lingua franca* of the city (SMS, Bluetooth, MMS), and are becoming the dominant urban processor. We need to shatter our understanding of them as phones and celebrate them in their new role as measurement instruments. Our desire is to provide our mobile devices with new "super-senses" and abilities by enabling a wide range of physical sensors to be easily attached and used by anyone, especially non-experts.

We argue there are two indisputable facts about our future mobile devices: (1) that they will be equipped with more sensing and processing capabilities and (2) that they will also be driven by an architecture of participation and democracy that encourages users to add value to their tools and applications as they use them.

We have already seen the early emergence of sensors on mobile devices such as Apple's Nike+iPod Sport Kit (music player + pedometer), Apple's iPhone (mobile phone + proximity sensor and accelerometer), Nokia's 5500 (mobile phone + pedometer), Samsung's S310 (mobile phone + 6 axis accelerometer), and LG Electronics LG-LP4100 (mobile phone + breathalyzer). 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".

What happens when individual mobile devices are augmented with novel sensing technologies such as noise pollution, air quality, UV levels, water quality, etc? We claim that it will shatter our understanding of these devices as simply communication tools (a.k.a. phones) and celebrates them in their new role as measurement instruments. We envision a wide range of novel physical sensors attached to mobile devices, empowering everyday non-experts with new "super-senses" and abilities. It radically alters the current models of civic government as sole data gatherer and decision maker by empowering everyday citizens to collectively participate in super-sampling their life, city, and environment.

These new mobile "sensing instruments" will promote everyday citizens to uncover and visualize unseen elements of their own everyday experiences. As networked devices, they repositions individuals as producers, consumers, and remixers of a vast openly shared public data set. By empowering others to easily create, report, and compare their own personal measurements, a new citizen driven model of civic government and technology needs can emerge out of these important new personal and community driven dialogues about our cities, neighborhoods, and mobile lifestyles.

The technological debate radically expands from beyond simply how to design a few functional mobile applications that satisfy the needs of thousands of people (such as a location service, a friend finder

Eric Paulos
Intel Research Berkeley

Ian Smith
Intel Research Seattle

RJ Honicky
UC Berkeley

social networking system, or a mapping overlay tool) to how thousands of mobile individuals can author, share, and remix publicly sampled data into a wide variety of more personally meaningful mobile experiences and tools.

Large scale services, while tremendously important, often suffer from lowest common denominator effects as they seek to make a single system satisfy the needs of everyone. We see our future urban technologies as a mixture of large scale systems and personally customized small tools. We are interested in exploring this new model of citizen authoring, public sharing, and personal remixing of urban life driven by personal experiences and measurements of the city. The result is an urban technological future that hopefully conveys personal meaning to citizens and a more informed and responsive civic government unburdened from its reliance on low resolution, generic, and filtered data driven solutions. By elevating everyday citizens into the role of data collector, commentator, and policy maker, we hope to directly empowering people to participate in the authorship of their emerging digital era Metapolis [1] with personally meaningful technological objects that matter.

2 Participatory Urbanism

In the spirit of Urban Computing, Participatory Urbanism is the open authoring, sharing, and remixing of new or existing urban technologies marked by, requiring, or involving participation, especially affording the opportunity for individual citizen participation, sharing, and voice. Participatory Urbanism promotes new styles and methods for individual citizens to become proactive in their involvement with their city, neighborhood, and urban self reflexivity. Examples of Participatory Urbanism include but are not limited to: providing mobile device centered hardware toolkits for non-experts to become authors of new everyday urban objects, generating individual and collective needs based dialogue tools around the desired usage of urban green spaces, or empowering citizens to collect and share air quality data measured with sensor enabled mobile devices.

Participatory Urbanism builds upon a large body of related projects where citizens act as agents of change. There is a long history of such movements from grassroot neighborhood watch campaigns to political revolutions. Our primary motivation from an urban standpoint comes from the insights of leading urban practitioners such as Jason Coburn, Jane Jacobs, and the sociologist Ulrich Beck.

Our work leverages Coburn's "street science" framework which emphasizes local urban insights to improve scientific inquiry and environmental health policy and decision making. Coburn 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" [2]. 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". While such local knowledge and community based practices are sometimes labeled as romantic or populist, Cobun insists that such views overlook the structural and global dimensions of problem solving for urban communities. Coburn 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 "hybridizing" of professional discourse with local experience; 3) 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.

We also draw from the work of German sociologist Ulrich Beck who postulates that as people become less constrained by social institutions, they are in a position to mold the process of modernization rather than remain passive observers of a system in which they hold no stake [3]. In Beck's world, individuals have the opportunity to become change agents by way of information – information is key to the (re)shaping of the social and political world. For us the creation, sharing, and remixing of urban information is a primary component of Participatory Urbanism.

Finally, in *The Death and Life of Great American Cities* Jane Jacobs writes that to understand cities we needed to "reason from the particulars to the general, rather than the reverse [and] to seek 'unaverage' clues involving very small quantities, which reveal the way larger and more 'average' quantities are operating" [4]. Jacobs continues, "Quantities of the 'unaverage', which are bound to be relatively small, are indispensable to vital cities". Participatory Urbanism attempts to elevate the local expertise of citizens and their personal, small, unusual, local, particular experiences across urban life.

The clear research initiative is to understand the roll that emerging *in situ* mobile technologies will play in this setting. We can find mobile technology as a new mechanism for citizen driven urban participation. Using only text and picture messaging, citizens have already initiated significant urban change.

» People Power 2: a four-day popular revolution that peacefully overthrew Philip-pine president Joseph Estrada in January 2001 where text messaging played a leading role

» Orange Revolution: a series of protests and political events coordinated using text messaging that took place in the Ukraine in 2004 that exposed massive corruption, voter intimidation, and direct electoral fraud between candidates Viktor Yushchenko and Viktor Yanukovych [5]

» TXTmob: a open source text messaging system used to coordinate protests during the United States Republican Presidential Convention in 2004 [6]

» Hollabacknyc.com: A blog where women “holla back” at harassers by taking their pictures with phonecams, then posting them online. Inspired by Thao Nguyen’s Flickr uploaded image of Dan Hoyt indecently exposing himself to her on a New York public subway in 2005 [7].

» Parkscan.org: a system setup in 2003 allowing people voice concerns on park maintenance by uploading information about public park conditions as text and pictures from mobile devices and the web [8].

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 setup their own public “campaigns” for others to participate in by using networked mobile devices and sensors [9]. As strong advocates of such participatory models, our work expands upon the understanding of this research space by 1) focusing on an initial capstone application of air quality, 2) emphasizing the author-share-remix metaphor for “on-the-go” participation, and 3) expanding the integration of new sensors for mobile devices. We have also seen exciting new work that addresses sensor data sharing (Microsoft’s SenseWeb [10], Nokia’s SensorPlanet [11], and Platial [12]) and remixing (SensorMap [13], Mappr [14], Swivel [15], and Preemptive Media’s AIR (Areas Immediate Reading) mobile device [16]).

3 Mobile ~~Phone~~ Measurement Instrument

Millions of us carry a mobile device such as a mobile phone with us everyday. For all of its computational power and sophistication it provides us very little insight into the actual conditions of the terrain we traverse with it. In fact the only real-time environmental data it renders is a narrow slice of the electromagnetic spectrum with a tiny readout of cell tower signal strength using a series of bars.

We believe that our personal devices should be measuring, collecting, sharing, and comparing a much wider range of environmental conditions. For example, the on-board microphone could detect noise pollution and sound levels, an onboard carbon monoxide sensor could report on automobile exhaust levels, or a pollen count sensor could warn of dangerous exposure levels for asthmatics. While the personally collected data is interesting, the real value is when many people collectively collect and share this data – geo-tagging it with GPS. Such sensor rich mobile devices usher in a compelling series of new mobile device usage models that place individuals in the position of influence and control over their urban life.

4 Measuring Air Quality

The World Health Organization estimates that 2 million deaths each year can be attributed to air pollution - that’s more deaths than those resulting from automobile accidents [17]. Direct causes of air pollution related deaths include aggravated asthma, bronchitis, emphysema, lung and heart diseases, and respiratory allergies. Historically there have been grassroot efforts by communities to address these issues, often when conditions become extreme. In 1998 The Toxic Avengers [18], a group of 15 young students, operating under the belief that people should have a right to live in a safe environment, successfully exposed to the community and in some cases shut down the myriad of risks inherent in having toxic industrial pollutants and the Navy Yard Incinerator in Brooklyn, NY in close proximity to residences and a school. However, in general the individual citizen has very little direct awareness of the air quality that they encounter daily and almost no public forum to debate strategies for change.

We have designed a system integrating air quality sensing into a technology already carried by people everyday. In this case, their mobile phone. We attached a custom sensor board with onboard carbon monoxide and temperature sensor onto a LG VX9800 CDMA mobile phone with assisted GPS (AGPS). The carbon monoxide sensor is a small scale, low power (< 350 microamps at 3 volts) micro fuel cell designed to be maintenance-free and stable for long periods. These fuel cells have a direct response to volume concentration of gas rather than partial pressure and

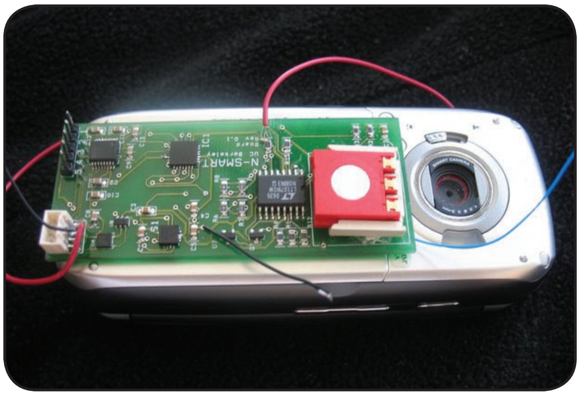

Figure 1 Sensor board with carbon monoxide sensor (red) attached to an LGVX9800 mobile phone

are ideally suited for integration into mobile devices. The sensor pack is powered by the phone's internal battery and communicates via RS-232 serial link with the phone (Figure 1).

The complete system geo-logs the sensor data at regular intervals with a bias towards taking measurements during voice calls and text messaging usage (insuring adequate exposure of the carbon monoxide sensor to ambient air samples). Collected data is sent using SMS. SMS was chosen over other data transport mechanisms because of its wide adoption and its use of the carrier's control channel rather than data channel, allowing data to be sent even during voice calls. The format of sampled sensor and corresponding metadata is in a standardized XML schema. This system demonstrates the successful integration of small form factor environmental sensors into a mobile phone sized platform. This system, show in Figure 1, is undergoing trial testing for upcoming user deployments. Earlier studies we conducted of air quality across Accra, Ghana resulted in various "heat maps" as shown in Figure 2 for one day of carbon monoxide from 10 people as they crossed the city.

5 RE-CYCLE

While manufactures offer incentives to recycle mobile phones, a European study finds that only 10% are actually recycled, 18% given to someone else to use, and 65% "placed in a drawer" [19]. The numbers are even more disconcerting in the United States where less than 1% of mobile phones are recycled [20]. Of course the question is why these "drawer bound phones" are never recycled. However, it also represents untapped potential for further use of the device beyond its originally intended purpose as a communication tool. This 65% is a significant quantity of phones that could be reproposed for further life.

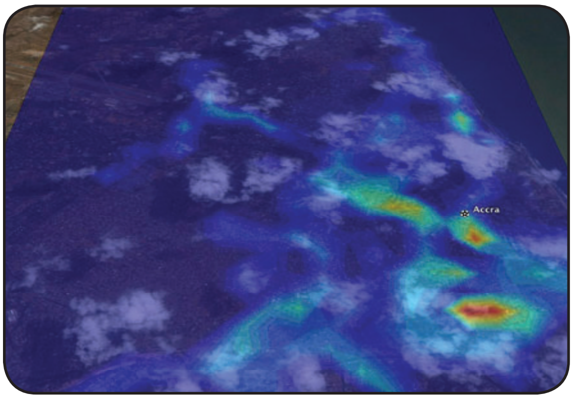

Figure 2 A heat-map visualization of Carbon Monoxide readings across Accra, Ghana. Colors represent individual the intensity reading of carbon monoxide during a single day across the capital city of Ghana. Note the variation across the city, within small neighborhoods, and on the approach to the international airport

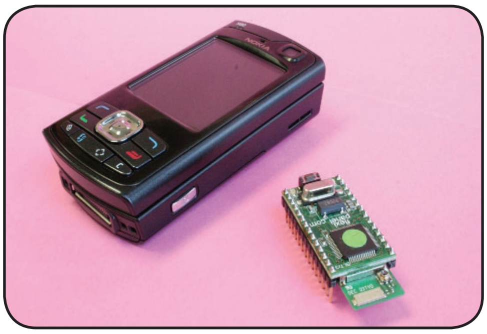

Figure 3 Objects of Wonderment Toolkit allowing End Of Life mobile phones to be re-purposed to provide new personal services and abilities beyond their previous role as primarily communication tools.

We have designed a system called *Objects of Wonderment* that allows easy re-purposing of mobile phones using simple visual programming to allow individuals to create new uses for these devices. Anything from monitoring moisture and sun in home and urban gardens, measuring skateboarding tricks, to creating new urban aural experiences. The purpose is to allow individuals to easily transform their "mobile phone as communication tool" into "generic urban processor" for personal uses. A picture of the system is in Figure 3.

6 Conclusion

As researchers it is our civic obligation to comment on and build systems to improve our lives and the lives of others. With environmental issues increasingly becoming a major problem in today's society we must lend our expertise and creative minds towards the development of tools, systems, and an overall re-thinking of the problem. In this paper we present two such systems that attempt to address these concerns.

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Author Biographies

Eric Paulos is a Senior Research Scientist at Intel in Berkeley, California where he is the founder and director of the Urban Atmospheres research group - challenged to employ innovative methods to explore urban life and the future fabric of emerging technologies across public urban landscapes. His areas of expertise span a deep body of research territory in urban computing, social telepresence, robotics, physical computing, interaction design, persuasive technologies, and intimate media. Eric received his PhD in Electrical Engineering and Computer Science from UC Berkeley.

Ian Smith hangs around the Intel Research Lab in Seattle; strangely, no one has told him to go away. His primary functions seem to be sitting in front of large radiation emitters, banging the home row keys, causing patterns of one and zeroes to be formed, and complaining loudly. This complaining is often related to the quality of coffee available to him, but more frequently is about the lack of an old school, shotgun wedding between software development processes and the needs of actual users. Before his current loitering at Intel, he ran the idle loop at PARC's Computer Science Lab and in the way distant past he annoyed people in the terminal rooms at Georgia Tech. Georgia Tech asked him to leave in 1998, PARC followed suit in 2003. He may, in fact, have no qualifications whatsoever.

R.J. Honicky is a Ph.D. student in the Computer Science department at UC Berkeley, and a member of the Technology and Infrastructure for Emerging Regions (TIER) research group. His dissertation work focuses on building a distributed scientific instrument by integrating environmental sensors into cell phones. He also studies various low cost wireless and networking technologies. He has worked at Intel Research, Tensilica, Microsoft Research, Network Appliance, Airtouch Cellular (now AT&T) and various startups. He has a Master of Science degree in Computer Science from UC Santa Cruz, and BA in English Literature from the University of Michigan.