Editor: Cecilia Mascolo • cecilia.mascolo@cl.cam.ac.uk

Engaging the Masses in Pervasive Computing

A Missed Opportunity?

Christine Julien • *University of Texas at Austin*

Jamie Payton • *University of North Carolina at Charlotte*

Pervasive computing research is often couched in socially relevant applications, yet we've largely failed to leverage its potential to excite and engage the public. By focusing research efforts on engaging everyday users as an essential part of research, design, and evaluation processes, the pervasive computing community can interest the masses while also increasing the quality and impact of research.

As female students studying computing in the late '90s and early '00s, we were often aware that we were different from those surrounding us in classrooms and labs. Social researchers noticed the same thing and initiated research projects to discover reasons for the disparity and find solutions that would effectively increase participation by traditionally underrepresented groups in academic computing programs and careers. Specifically, this research suggested that couching computing in terms of socially relevant problems can attract women and minorities to the field.

Studies have found that women, in particular, have a strong desire to connect their education in computer science to social concerns related to enhancing and supporting others' lives. This potential to attract underrepresented groups to study STEM (science, technology, engineering, and mathematics) subjects is shown qualitatively through longitudinal studies of women, their capabilities, and their choice of educational goals and careers, and quantitatively with numerical statistics on enrollment in educational programs. Take graduate programs: women's enrollment in the "traditional" biological sciences — which have a strong and readily apparent social connection — has typically rivaled (if not exceeded) men's enrollment in the same disciplines. Similarly, biomedical engineering has successfully attracted women, with graduate enrollment in the US increasing from 33 percent female in 2000 to 37 percent female in 2009.

Yet in this same time period, when the question of how to engage women in computing was at the forefront of social science research, women's enrollment in graduate computer science programs actually dropped from 30 to 26 percent of total enrollment (see www.nsf.gov/statistics/nsf12300/). Today, as professors in US higher-learning institutions, we observe this evidence every day as we look around our classrooms and the conferences we attend and see that the situation of women in computing hasn't changed since we were students more than a decade ago.

Here, we look at pervasive computing and its potential to engage the masses in research and development. By focusing research to better include the human users of our products and projects, we can potentially involve them in solving problems that are socially relevant and, by extension, draw more minority groups to the field.

Published by the IEEE Computer Society

1089-7801/12/$31.00 © 2012 IEEE

The Promise for Broadening Participation

Pervasive computing is socially relevant, by definition; over the past 20 years, the field has aimed to seamlessly integrate technology into objects that people use, unthinkingly, on a daily basis. As technology has evolved, and the sophistication of our solutions has increased, pervasive computing researchers have paid increased attention to socially relevant problems such as aging in place, smart homes and buildings, and green computing. Peruse any journal or conference proceedings, and you'll find that almost every pervasive computing article has its motivation presented via some problem of societal interest. Yet attend one of these very same conferences, and you will hear frustrations among researchers about whether and how their results are having any real and measurable impact on users. Such an obvious disconnect between the research process and results and real social problems helps neither the product itself nor the effort to attract and retain members of traditionally underrepresented groups.

Consider, in contrast, participatory sensing, in which ordinary users serve as sensors through simple interactions using their commodity computing devices (usually smartphones). Although participatory sensing doesn't encompass pervasive computing, the two fields are highly related. Some might argue that participatory sensing doesn't fit Mark Weiser's original vision of disappearing computing:

> The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.[1]

However, participatory sensing research quickly became integrated with the mainstream because the approaches were immediately and directly implemented on devices that users are familiar with and carry every day. For better or worse (a topic for an entirely different column), such devices have intimately woven themselves into users' everyday lives. Furthermore, from an application perspective, participatory sensing has addressed issues that broad swaths of people genuinely care about — from environmental monitoring issues such as local ground water quality and the propagation of invasive plant species to commuting issues such as access to public transportation and bike sharing. Although wireless sensor networks have also addressed similar issues of broad appeal, the applications that result in the wireless sensor network domain aren't usually accessible to everyday users.

Having such a broad user base for participatory sensing applications enables the development and evaluation of fundamental research, including energy-efficient device and user localization, security and privacy models for participatory applications, and network and infrastructure planning and allocation. Moreover, participatory sensing projects (such as Mobilize; www.mobilizingcs.org) are already helping to engage underrepresented women and minorities in the research process, showing strong initial results.

How can pervasive computing in general have similar successes, and how can we better integrate social relevance to increase participation of traditionally underrepresented groups (in the research process, most especially)? Specifically, we must better engage the masses; the same techniques that engage the masses will draw in the much-needed participation of underrepresented groups. We must directly connect the research process and product to users through issues and applications these users care about and can employ. We must also try harder to use results from pervasive computing research to attract young researchers to the field.

It isn't necessarily the case that what we're doing to engage prospective researchers is wrong; it's that these steps aren't enough. Small yet fundamental changes to research and outreach processes can increase the impact of pervasive computing research while increasing the participation of traditionally underrepresented groups. A first question with respect to the research process is whether our efforts ever even reach real users in a way similar to what participatory sensing has achieved.

The Reality

In the most recent proceedings of the IEEE International Conference on Pervasive Computing and Communications,[2] more than half the papers (15 of 28) included evaluation using human subjects. None of these efforts, however, involved the anticipated users of pervasive computing algorithms, services, or applications in the design process; instead, users aided in data collection to support an experiment or evaluate a fully implemented pervasive computing application. Most of the studies relied on only a few users, and only two studies had more than 10 participants.

Furthermore, demographically, participants often included students, staff, and visitors within the research lab rather than the everyday users that our pervasive computing systems claim to target. This evidence demonstrates how pervasive computing researchers tend to integrate users into the research process: we generally view users as an evaluation tool from which we can draw qualitative and quantitative results that substantiate our

conclusions (primarily to justify publications on our research products). Less commonly, we use real users to justify the inception of a research project, usually by surveying their habits or perceived desires. Only rarely (if at all) do we fully integrate users into the process or integrate a result into users' real lives. Even when we perform decent-size studies, we most often draw users from our own or related research groups or, in a handful of cases, from a general university population. These populations don't represent a broad sweep of everyday users.

When it comes to engaging traditionally underrepresented groups, we believe the failing is at least partially in perceiving such activities as a "community service" rather than part of the fundamental research process. Integrating engagement and research not only benefits the future of the field but could also improve result quality. Separate from our research efforts, we develop curricula targeted at youth, but these curricula aren't often focused on either the social issues that can attract underrepresented groups or on our actual cutting-edge research projects.

We can see this disconnect in the fact that separate venues exist for publishing outreach work, and those findings aren't widely read by the broader pervasive computing research community. Consequently, the lessons learned in such research don't often carry over (at a large scale) to more traditional research projects, except when we try to use education and outreach as yet another motivating scenario in which we can employ pervasive computing. This indicates the need for two fundamental shifts: first, outreach programs that are themselves part of the research arm of pervasive computing and exploit the input that program participants can provide to the research process (as well as product evaluation) and, second, outreach programs that embody both an updated perspective on Weiser's vision of disappearing computing and a focus on socially relevant application concerns.

Metrics, Design, and Engaged Evaluation

So, where do we go from here? The frustrations arising from the lack of real, measurable research impact and research's disconnect from real users should motivate us to explore new metrics that target these issues. Given Weiser's original definition, our metrics have often targeted "user distraction," with a positive goal being to decrease it. However, user engagement seems, at some level, to be at odds with metrics for distraction. Even with a participatory-sensing-like perspective on the notion of disappearing computing, our research needs guidance on how to measure engagement, properly target real user populations, and at least aid in transitioning our results to real pervasive computing practice.

Toward engaging the masses, integrating efforts such as participatory design with pervasive computing research can give "customers" (that is, real users) a stake in the entire research process in much the same way that participatory sensing gives users a stake in the application. Such techniques can also provide a natural way to blur the boundary between research and outreach, where outreach participants can truly contribute to the process by experimenting with, suggesting, and even helping to design and develop fundamentally new research. Even existing outreach efforts that engage underrepresented groups (such as Mobilize) are still quite distinct from the research process. They tend to focus on the application instead of on still-open essential research questions such as energy-awareness, efficient communication, human computer interaction, social network integration, and privacy-aware localization.

Finally, we believe that we're missing an opportunity with respect to melding our engagement efforts with the evaluation of our research contributions. Our perspectives on both are shortsighted: we view engagement efforts as community service, while our evaluation efforts typically view users as just another "tool" in the process. We need a study of best practices in recruiting participants for evaluation (and participatory design) that goes far beyond the standard solicitation within the CS university community. In addition, we need an evolution in our publication and proposal review processes that places an increased value on truly engaged evaluations (in much the same way that, for example, the sensor network community has placed an increased value on actual implementations and deployments). In conjunction with a participatory design process, evaluation through engagement can provide better results (both quantitatively and qualitatively) that connect with an avenue for deployment and impact.

Everyone would benefit from engaging the masses in pervasive computing. Adopting this new perspective benefits the research community by enabling higher-quality research with a demonstrably higher impact. Pervasive computing (and computer science more generally) would benefit from increased participation of the masses and, by extension, traditionally underrepresented groups. And the public at large would benefit from a greater awareness of pervasive computing and how fundamental research in this field can provide significant gains in socially relevant applications. Of all computing

disciplines, pervasive computing has one of the highest potentials to engage directly with everyday users and applications. Research in this field should, by definition, have a direct impact on users; engaging these users in fundamental ways is an opportunity that we must not overlook.

References

1. M. Weiser, "The Computer for the 21st Century," *Scientific Am. Special Issue on Communications, Computers, and Networks*, 1991.
2. *Proc. 2012 IEEE Int'l Conf. Pervasive Computing and Communications* (PerCom 12), IEEE CS Press, 2012.

Christine Julien is an associate professor in electrical and computer engineering at the University of Texas at Austin, where she's the director of the Mobile and Pervasive Computing Laboratory and the codirector of the Pharos Mobile Computing Testbed. Her research focuses on innovative approaches to collecting, assessing, understanding, and sharing data and context in dynamic pervasive computing environments. Julien has a DSc in computer science from Washington University in Saint Louis. Contact her at c.julien@mail.utexas.edu; www.ece.utexas.edu/~julien.

Jamie Payton is an assistant professor of computer science at the University of North Carolina at Charlotte, and the codirector of the Networking Research Lab. She leads research projects that aim to promote the development of robust, quality-of-information-aware applications for pervasive computing environments. Payton has a DSc in computer science from Washington University in St. Louis. Contact her at payton@uncc.edu; www.cs.uncc.edu/~payton.