Computing at the Margins

Report from NSF Sponsored Workshop

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Executive Summary

The last 50 years have demonstrated how investment in basic research and development has lead to Information and Communications Technologies (ICTs) that have transformed the way that some parts of society work, learn, live, and engage in democracy. The ability of society to leverage these ICTs is now considered crucial to the United States' and other nations' continued economic growth and social-civic participation. ICTs are also considered central to participation in global digital society.

However, while ICTs have transformed some societies, the continued existence of the *digital divide* argues that the benefits of scientific and technological innovation have not migrated into all sectors of domestic or international societies. Indeed, a majority of the world's population remains at the margins of these advancements, excluded from the digital society. One approach to closing the digital divide has focused on *access*: attempting to increase access to, and infrastructure support for, the same technologies found in more technologically saturated sectors of society. And yet, despite sustained investments in improving access, the divide resists closure, and it continues to limit the United States' ability to be a leader in a truly global digital society.

Recently, evidence from the scientific community has begun to suggest that a purely access-focused approach to bridging the digital divide is insufficient; instead, what is actually required is innovation predicated on the assumption that the digital divide represents technical and societal differences that must be accounted for in the research agendas of the broader Computing community. For example, networking research situated within the constraints posed by infrastructure-poor environments has driven scientific innovation by challenging the assumptions of the IP network architecture, leading to delay- and disruption- tolerant networking that are more innately suited to these environments. Other research has focused on the presence of unreliable power infrastructure as an opportunity to develop novel mobile messaging architectures. Human-Centered Computing researchers have designed new interfaces to support computer- and print-illiterate individuals in participating in digital society. In other words, evidence shows that moving away from approaches that focus on increased access to the same technologies, toward approaches that account for the unique socio-technical circumstances present in facets of our (and other) societies, can lead to fundamental and transformative Computing research and innovation. Further, evidence exists that solutions innovated in contexts such as these may have applicability beyond their initial design context. Innovations in delay- and disruption-tolerant networking, for example, have applications including interplanetary networking.

While each of these examples illustrates a point potential, widespread economic and societal gains cannot be fully realized until these individual explorations are brought together through the development of cohesive, end-to-end frameworks that guide research that currently spans multiple disciplines, within Computing and beyond. Specifically, if transformative basic research is to close the digital divides that exist both within the United States and internationally, then it will need to move from point solutions to a shared research agenda that pushes on multiple research fronts simultaneously.

To articulate this need, we brought together 24 researchers and leaders from universities and industry to discuss the scientific and technical challenges for this research agenda, which we call *Computing at the Margins*. Computing at the Margins has strong overlap with the field of Information and Communications Technologies for Development (ICT4D), also an emerging area of focus within Computing research community. However, Computing at the Margins also includes technologically underserved areas within Industrialized nations, which are typically out of scope in ICT4D research. The National Science Foundation sponsored this workshop. The GVU Center and the School of Interactive Computing hosted it. It also complements and continues discussions held at a previous workshop focused on ICT4D sponsored by the Computing Community Consortium (CCC), as well as a prior workshop held at Georgia Tech.

This report is a summary outcome of that three day meeting. We group the results of the discussions into three broad areas: access, empowerment, and innovation.

Access

In order for diverse sectors of the global population to reap the benefits of information technology, they must have basic access to it, and the necessary infrastructures to support it. We argue, however, that effective access is not simply a matter of overcoming the economic and logistic barriers to distributing current technology more broadly—not only have such approaches been demonstrated to be less than effective, they also ignore an opportunity for discovery and innovation. In this section, we outline a research agenda aimed at tackling the intellectual challenges of access in ways that account for the unique technical and societal contexts of the diverse global population.

Network and power. A fundamental access challenge is how to provide basic power and communications infrastructure. Existing, prevalent network architectures (most notably the Internet) make assumptions about the abundance and availability of such infrastructure—that devices are generally connected, have robust access to power, and so forth. Innovations in architectures that suspend these assumptions and instead reflect the constraints of a low-resourced environment will lead to new innovations in networking.

Nomadicity. Many sectors of the global population are increasingly nomadic—rural-to-urban movement, from migrants looking for better economic opportunities to those fleeing regional conflict, from religious pilgrims to transnational diasporas. Many technologies, however, are too often still rooted in assumptions of fixedness: that people—and hence their devices and information—remain largely stable over time. Information remains locked in silos, preventing ubiquitous access from any location; even as information moves to the cloud, intermittent connectivity may hamper access; a plethora of digital identity frameworks hampers access to information. Transformative technologies that are grounded in an empirical understanding of our increasingly nomadic lifestyles—and the implications of those for information access, information sharing, privacy and digital identity—are required to support access by mobile populations.

Interface. For end-users, access begins with their actions at the interface. Successes in interface design, such as the desktop metaphor, have led to transformative changes in access for many. But in other contexts—such as societies that do not use or value desks—what use is the desktop metaphor? The methods and mechanisms of user interface design and evaluation have been driven by a variety of values (for example, the idea that it is appropriate for a subject to critique the expert's design, a core value that drives iterative design), many of which break down as methods move from culture to culture, and across cultures (between researchers and users). In many contexts “users” do not even directly interact with technologies; they participate in a cycle of “intermediation” in which human mediators access, deploy, and interpret technologies outside the scope of a primary user’s reach or understanding. The “interface” then, does not belong to the device but to a person. Interface design and usability evaluation, not just in its products, but also in its processes, needs to be understood in new cultural contexts.

Green IT. Access also challenges the scientific community to examine global technology flows. While the materials mined, processed, and assembled into technologies which are then sold, resold, and ultimately disposed flow globally, they do not flow equitability. The costs of resource extraction and the emerging problem of e-waste disproportionally affect emerging nations. Can the Computing community build green technologies that redress this balance through local sourcing, reducing use, and making systems that are recyclable by end-users? Environmentally friendly technologies, such as low-power solutions or end-user modifiable machines may also most effectively leverage resource limited infrastructures. For example, what would a "Made in the USA" machine look like, who would it empower, could it be used to help people in rural and sporadically connected parts of the United States get online?

Access for all. Ownership of technology is sometimes used as a measure of access (for example, counts of the number of cellular handsets owned). But societal and cultural norms mediate the relationship between ownership and access. For example, societal expectations about the role of women may frame their ability to use certain types of technologies. Gender, as one example, presents an opportunity for questioning the designs of technologies and redesigning systems to make access for all more feasible within the societal and cultural constraints that often frame who, and how, human centered computing may occur.

Sustainability. For technology access to be empowering, it must come in the form of not just a momentary brush with transformative technologies, but rather sustained access that can impact individuals and societies more deeply. This mandate implies that we must build solutions in concern with regulatory, policy, and economic mechanisms that ensure that people have the sustained opportunity to experience the potentials of digital society, and learn through sustained participation.

Empowerment

People in the margins of digital life clearly need fuller access and richer environments in order to best create and innovate. But this alone is not enough to ensure that the digitally marginalized truly reap the benefits of these technologies. The silent majority needs *voice* but also needs *control*; indeed it is voice plus control that results in empowerment.

Consider dissident Iranian bloggers and tweeters from the 2009 elections. They have significant interest in controlling their audience (exactly who gains access to their communications), the means by which audiences understand these communications (how they are ontologically captured or how and when they may be translated or otherwise repurposed), to controlling their own identity and levels of privacy (exactly who knows who they are). With literally millions of tweets and blogs to date, these often marginalized Iranian voices have begun to change their nation and the world. But their inability to ensure privacy and anonymity has already had life and death consequences.

Locality. There is a tension between the profitability of technologies that are consumable worldwide and the meaningfulness of technologies that are deeply local. However this situation is not necessarily winner takes all. Take search for example. Search tools such as Google prioritize popular pages, frequently defined by the numbers of links to these pages. While this approach may work for certain types of search, it also contributes to majoritarinism: take, for example, the fact that the search term "Africa" does not yield any websites located in Africa on the first page of hits returned. Neither does the phrase "Democratic Republic of Congo." What is returned is a series of largely educational resources for people in the United States and Europe. A similar phenomenon occurs in the United States, where content is frequently more relevant to some cultural groups than others.

Algorithms that account for locality could help people find locally relevant content, which would in turn further encourage people to create more content, knowing that it could be found by others. Additionally, an area for exploration is community controlled search, where community members actively influence what can be searched and by whom.

Innovation in technical structures in addition to search algorithms is needed to enable locally meaningful technologies. For example, cultures categorize and taxonomize entities in different ways. A well-understood collision of ontologies is the prevalence of hierarchical information structures in the societies that have developed computing systems, which collides with cultures who use non-tree-like schemas to conceptualize "family trees". Support for fluid knowledge structures would enable, for example, communities to effectively represent knowledge internally while also conveying that information to outside audiences.

Civic empowerment. Our example of Iranian bloggers raises one of the most important forms of empowerment impacted by digital technologies, the relationships between citizens and their state. From free and fair elections to more transparent governance, new forms of digital technologies have the potential to transform the capacities of citizens to impact and shape the state. For instance rich environments for online participation can give strength to citizens as they petition their government. And new types of distributed data gathering can help ensure that polling places are fairly managed and votes are accurately tallied.

Peace and conflict. If one form of empowerment ensures that the state is responsive to the conditions and concerns of their people, another potential form of digital empowerment supports people in the *absence* of a government or when, for instance, the temptation for a state to employ the means of violence to engage in predation overwhelms their interests in safeguarding their citizenry. Advances in digital technologies in conflict and disaster settings can help reveal, geo-locate, and respond to urgent need. New approaches can also help countries in immediate post-conflict settings to reconcile and heal, for instance by offering broader participation in the national truth telling processes.

Self-determination. While it seems beyond argument to foreground issues such as civic empowerment and peace and conflict, ultimately marginalized communities and cultures must choose their own paths, identify their own issues, priorities, and preferences. Neither technology nor infrastructure should prevent that from happening, although now it often does. For example, people in homeless shelters are not allowed to use computers to play games, only to seek employment. They can borrow phones strictly for instrumental purposes such as contacting a social worker or medical practitioner, not, for example, to call a friend to chat. These regulative regimes entail serious ethical problems to which we must devote careful attention. We cannot assume "one person-one technology" as we can for more economically advantaged groups. With this critical shift comes a new moral landscape. Technologies accessed through NGOs, Internet cafes, libraries, more powerful or more educated members of a community, shelters, and so on, reorder relations we take for granted and must be investigated and assessed as C@M efforts develop.

Innovation

The third leg of our triad is to build on access and empowerment, to create new tools and technologies that allow a more widespread engagement with the process of innovation. Through such widespread engagement, we allow individuals, communities, and entire populations to move from being passive recipients of broad commercial interventions to being creators of locally-relevant technologies and information, which can in turn lead to economic empowerment.

There are many aspects to enabling innovation, ranging from tools and technologies that can be more easily appropriated by a wider range of people, to systems that support peer learning and knowledge exchange, to platforms and policies that allow innovators to deploy, disseminate, and gain economic advantage from their creations.

Enabling such widespread innovation engages with a broad spectrum of activities:

Broadening participation. Extending the process of innovation to individuals, communities, and populations who have largely been excluded will require new research aimed at uncovering how innovation currently occurs in such settings, what motivations and trajectories exist for innovation, and opportunities for engaging more people in the innovation process.

Content production. We must enable normal citizens, end-users, to act not only as passive *consumers* of content, but also *producers* of information that is relevant to them and their communities. Social networking sites, blogs, and other modes of content production are common and canonical examples today, but extending content production into new domains opens new possibilities for technology. For example, such tools may support citizen science or citizen journalism in settings where communities currently have little voice; new crowdsourcing technologies—perhaps leveraging the ubiquity of mobile devices worldwide—may allow widespread data collection and aggregation. Harnessing and extending the ideas that we see in socio-computational systems today, and making them truly global/universal, presents a rich set of opportunities to understand how people of different cultural, linguistic, technological backgrounds may create new forms innovation.

Reuse and learning. We know that many learn how to create new content and systems by exploring and reusing the work of others, much as the "View Source" option on web browsers has allowed many to learn how to create content for the web. Translating this common strategy into actionable systems to enable widespread innovation will require research into reusable technologies as well as frameworks for peer learning and the sharing of expertise.

Development environments. In addition to supporting learning through reuse, we need to create new technologies to allow end-users to develop innovative systems from scratch. Current technologies aimed at developers are difficult to use by those without sophisticated technical understandings. Lowering the barrier to engaging with, and creating, new types of technological systems will enable the creation of innovative systems by more people. Examples of technologies that may support such creation include programming by example, simple hardware prototyping tools, and FabLab-style development environments.

Platforms for dissemination. We need to develop and deploy new platforms for widespread dissemination of innovation. This focus may include, for example, technologies that allow individuals, collectives, or communities to publish (and potentially monetize) innovative applications or content. Imagine, for example, a distributed "app store" in sub-Saharan Africa that allows individuals to deploy and sell innovative, locally created applications without the requirement for a centralized approval authority, or fixed infrastructure. Special challenges here may include how to create distribution systems that can cross borders, and protect innovation and property rights, while eschewing onerous DRM-style restrictions.

Market Models. Understanding and creating new market models to enable widespread innovation. Such models should allow producers of innovation to monetize their creations, and provide a sustainable framework for ensuring the support and maintenance of any required infrastructures. These models may include ways for communities to pool their resources to be on likely successes, as well as share in the resultant benefits from those successes (e.g., the HoneyBee Network).

Research Enablers & Inhibitors

Advancing Computing at the Margins requires basic research in computer science, engineering, and the social sciences. While some results will focus on general principles and practices that are widely applicable, characteristics of this research agenda also required culturally and societally focused contributions. For example, while network architecture may be applicable in a variety of environments, the applications that it facilitates may be focused to the needs of a particular group, culture or society, respecting while empowering global and local cultural differences. Additionally, there is a need to incorporate the communities and cultures that have yet to experience the impacts of a digital society into the basic research that drives the next generation of technological innovation and societal transformation. Finally, interdisciplinary and transdisciplinary research is crucial to achieving success: enabling basic research that has sustained and transformational impact for the rest of the globe. Testbeds that support comparison will be an essential component for developing the science of Computing at the Margins.

Industries, seeking to understand technologically underserved markets, are also beginning to invest in this research area. However, government research support enables open technologies that enable a number of significant research trajectories. First, open technologies better allow researchers to share the results of their own work with others, and allow the community to build and refine each other's solutions. Second, they better support the participation of external communities, particularly in serving as a bridge to build international research partnerships. Third, open technologies may provide a variety of ways for end-users to engage, appropriate, and adapt the technologies created as part of this endeavor.

Many of the research thrusts in Computing at the Margins require solutions that empower end-users to create their own solutions, to be actively engaged and able to make, sustain and evolve their own digital futures. This mode of development requires a workforce capable of creating applications that scaffold and help end-users to be able to create computational media. It also suggests broad educational opportunities for end-users themselves, to teach a variety of literacies associated with digital media. Given the distribution of individuals, these educational opportunities are likely to require innovations in the modes of educational delivery and engagement.

Computing at the Margins has links to other national research agendas. Research in Green IT such as low power solutions represents significant opportunities for low-power resourced environments. Research focused on the role of technologies in improving the health and wellness of all Americans must account for those who live in underserved environments, because often they are also most prone to disease. While Computing at the Margins is not represented in its entirety by either of these other national agendas, it has strong synergies, which enables funders to get increased leverage from investment.

Importance of Government Investment

Across the disciplines that the NSF represents, research interest in this area continues to grow. It is piecemeal, however, and without significant and sustained government investment solutions will at best remain point solutions. But the digital divide is clearly a systemic problem; it has resisted point solution attempts to closure. The NSF is ideally suited to investing in closing this divide through sustained and substantial basic research investment because it is a funding agency that supports many of the disciplines relevant to Computing at the Margins including Computing, Engineering, Social Sciences, and Education. The NSF's relationships with other agencies such as NIH and USAID (suggesting foci around technology and policy for international development) further make the case.

In addition to sustained research funding, seeding community activities with funding would also help to strengthen the research. Shared repositories for scholarly and educational materials not only reinforce the importance of the research activities, but also allow the community to grow and learn from others' experiences. This will help train a generation of educators about the state of the art in Computing at the Margins, and through that reach out to a workforce educated in the methods and systems required to build systems that successfully cross the digital divide.

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Appendix I: Attendees and Affiliations

Workshop Attendees

1. Kentaro Toyama – School of Information, UC Berkeley
2. Ramesh Srinivasan – Information Studies, University of California, Los Angeles
3. Katie Siek – Department of Computer Science, University of Colorado at Boulder
4. Phoebe Sengers – Information Science and Science & Technology Studies, Cornell University
5. Tapan Parikh – School of Information, UC Berkeley
6. Bonnie Nardi – Information and Computer Sciences, University of California, Irvine
7. Beth Mynatt – Interactive Computing, Georgia Institute of Technology
8. David McDonald – National Science Foundation and School of Information, University of Washington
9. Scott Mainwaring – People and Practice Research (PaPR), Intel Laboratories
10. Colin Maclay – Berkman Center for Internet and Society, Harvard University
11. Cliff Lampe – Department of Telecommunication, Information Studies and Media, Michigan State University
12. Beth Kolko – Human-Centered Design and Engineering, University of Washington
13. Matthew Kam – Human-Computer Interaction Institute, Carnegie Mellon University
14. Steve Jackson – School of Information, University of Michigan
15. Julie Hersberger – Library and Information Studies, University of North Carolina, Greensboro
16. Beki Grinter – Interactive Computing, Georgia Institute of Technology
17. Irfan Essa– Interactive Computing, Georgia Institute of Technology
18. Keith Edwards – Interactive Computing, Georgia Institute of Technology
19. Ed Cutrell – Microsoft Research India
20. Chris Coward – School of Information, University of Washington
21. Jenna Burrell – School of Information, UC Berkeley
22. Gaetano Borriello – Department of Computer Science & Engineering, University of Washington
23. Aaron Bobick – Interactive Computing, Georgia Institute of Technology
24. Michael Best – International Affairs and Interactive Computing, Georgia Institute of Technology

Dinner Participants

1. Carl DiSalvo – Language Communication and Culture, Georgia Institute of Technology
2. Paul Baker – Center for Advanced Communications Policy Georgia Institute of Technology

Student Participants

1. Susan Wyche – Interactive Computing, Georgia Institute of Technology
2. Thomas Smyth – Interactive Computing, Georgia Institute of Technology
3. Chris Le Dantec – Interactive Computing, Georgia Institute of Technology
4. Jill Diamond – Interactive Computing, Georgia Institute of Technology
5. Marshini Chetty – Interactive Computing, Georgia Institute of Technology