Pervasive healthcare at scale

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1 Background and experience

Professional biography. David Kotz is a Professor of Computer Science, and Associate Dean of the Faculty for the Sciences, at Dartmouth College in Hanover NH. During the 2008-09 academic year he was a Visiting Professor at the Indian Institute of Science, in Bangalore India, and a Fulbright Research Scholar to India. At Dartmouth, he was the Executive Director of the Institute for Security Technology Studies from 2004-07. His research interests include security and privacy, pervasive computing for healthcare, and wireless networks. He has published over 100 refereed journal and conference papers. He is an IEEE Fellow, a Senior Member of the ACM, a member of the USENIX Association, and a member of Phi Beta Kappa.

Experience. I recall reading Marc Weiser's article when my issue of *Scientific American* arrived in 1991, and have been conducting research in pervasive computing, and teaching courses on the topic, since the mid-1990s. Over the past fifteen years I have conducted large research programs on the topics of middleware for pervasive computing (the SOLAR system, 14 refereed papers 2000–2008), mobile agents (the D'Agents system, 20 refereed papers 1994–2002), security for context-aware computing (4 refereed papers 2002–2008), and large-scale anonymous opportunistic sensing (the AnonySense system, 8 refereed papers 2006-2009). I have also been actively involved in related fields of wireless networks (including enterprise networks, mesh networks, and ad hoc networks) and mobility modeling, with an eye toward understanding how the users of mobile-pervasive systems use the network in hopes of better designing networks to support current and future pervasive systems (about 16 refereed papers). I co-founded the Community Resource for Archiving Wireless Data At Dartmouth (CRAWDAD.org), which has over 2,500 users worldwide and which has helped the research community produce over 280 papers spanning a range of topics.

Currently, my core research is in mHealth security and privacy – more on that below – in which my team has so far produced 6 refereed papers. I am leading the Trustworthy Information Systems for Healthcare (TISH) project (NSF Trustworthy Computing award 0910842) and co-leading the Strategic Healthcare IT Advanced Research Project on Security (SHARPS) project (HHS ONC award 90TR0003-01). See `http://www.ists.dartmouth.edu/projects/tish.html`

2 Vision

My vision is to leverage pervasive computing, communication, and sensing technology to improve the health of individuals worldwide.

Recently, improvements in mobile computing and developments in miniature medical sensors have enabled mobile health (mHealth) sensing, promising new opportunities. In an *mHealth* sensing system, patients wear or carry one or more sensing devices, and their mobile phone acts as a gateway between the sensors and a repository that makes the data accessible to patients or their caregivers. An mHealth sensing system can deliver continuous health monitoring to patients throughout their daily activities with the potential to simultaneously reduce the cost and improve the quality of healthcare [SHG+10]. An mHealth system can provide timely reports about the patients' medical condition, close monitoring by healthcare providers, and reduced re-hospitalizations [CSL+10]. Applications include long-term care for patients with chronic diseases [ZYA+10, AL10] or risk management for people in rehabilitation [WSF+10]. There are many non-clinical applications for mHealth sensing, as well, including elder care [AGS+10], lifestyle coaching for people seeking to change unhealthy behavior [BC10], and fitness monitoring for athletes [CBLBD10]. The UN Foundation recently formed the *mHealth Alliance* specifically to explore and promote the value of mobile computing technologies in improving healthcare in developing nations [UNF09].

Evolving mHealth technology will empower individuals to better monitor and manage their own health, encouraging them to live healthier lifestyles and prevent many health problems before they begin. In concert with the healthcare system, mHealth technology can help professional caregivers to better monitor their patients, detect problems earlier, and reduce the need for hospital visits that are expensive to payers and inconvenient to patients. Finally, mHealth technology will also empower public-health officials to better monitor the health of entire populations, at the local, regional, and continental scale, detecting outbreaks and tracking epidemics, and correlating health with environmental factors such as urban design, pollution, and climate change. These opportunities are equally important and challenging in both the developed and the developing world.

Many recognize the opportunity posed by mHealth technology, and many share the core vision to use mHealth worldwide. The mHealth summit in Washington DC this October – organized by the mHealth Alliance, which has a global-health focus – was attended by several thousand attendees from around the world, including academics, industry developers, and public-health professionals. They passionately believe in this vision... but many technical challenges remain.

3 Advances

To achieve the vision above will require us, as scientists, to tackle intellectually exciting challenges that will also lead to socially important impacts. Specifically, how do we develop mHealth technology that is *safe* (not harming health), *effective* (having demonstrated impact on personal or public health), *accessible* (usable by individuals of varied educational levels, physical handicaps, cognitive abilities, or native language), *economical* (affordable by most individuals, especially in the developing world), *interoperable* (able to compose systems from multiple vendors), *secure* (not vulnerable to malicious attack by those who wish to cause physical or economic harm), *confidential* (not exposing the user's private information, including health status), *lasting* (usable for years despite the rapid evolution of mobile technology), and *scalable* (deployable to millions of individuals without excessive technical or social infrastructure costs).

A concerted effort to solve these challenges, especially at scale, will lead to fundamental advances in mobile sensing and computing devices, secure systems design, body-area networks, human-computer interfaces, accessible computing, public-health monitoring, electronic health records, privacy in medical databases, and medical informatics. Evidence for the likelihood of such advances is beginning to appear in the top-tier conferences and journals (both in CS and medicine) as early work on these challenges has led to exciting new ideas [HHBR+08, for example].

This work will require a strong interdisciplinary approach, involving social scientists, public-health professionals, and medical experts, as well as technologists, to ensure the development of effective technology. NSF should be encouraged to support cross-cutting programs in this area.