Revisiting Satya’s Vision and Challenges

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Nearly 15 years ago, M. Satyanarayanan published “Pervasive Computing: Vision and Challenges,” an article that helped inspire the creation of IEEE Pervasive Computing magazine, with Satyanarayanan as founding Editor in Chief. This critical article has received more than 2,500 citations and has been cited by articles that themselves have received hundreds of citations (https://scholar.google.com/citations). Given the article’s influence, I thought it would be interesting to revisit the vision and challenges Satyanarayanan presented to see how far we’ve come—or rather, how much farther we have yet to go.

**HOW MUCH PROGRESS HAVE WE MADE?**

As I reexamine the vision Satyanarayanan outlined and compare it to today’s reality, I see that we have made some progress. Parts of the two scenarios Satyanarayanan outlined (see the “Two Scenarios” sidebar) can be seen today. For example, we use cloud storage services that automatically sync our documents between devices—and we identify which documents to maintain on each of our devices. But many aspects of his scenarios remain a dream. For example, my smartphone has never told me to move to a different area to get better connectivity (apparently, it isn’t smart enough).

Satyanarayanan accurately predicted that the “early decades of the 21st century will be a period of excitement and ferment, as new hardware technologies converge with research progress on the many fundamental problems discussed in this paper.” However, although we are now well into the second decade of the 21st century, the nine challenges that Satyanarayanan laid out for us all remain significant in the field of pervasive computing. In fact, most of them are also important for the Internet of Things. Let’s consider a few of these challenges.

**User Intent**

We do a terrible job of capturing user intent; this problem is far from solved. Yet as we move forward in an IoT or pervasive world, we need systems to understand the user’s intent so that the automation provided by these systems in a smart environment supports, rather than impedes, the user’s goals.

**Cyber Foraging**

We see tablets in airports that patrons can use to stay connected, but they don’t provide support for the patron’s own device. Instead, the tablets are effectively public Web kiosks that let users check the status of their flight, read the news, or play a game. We do see surrogate devices in the wearable computing market. For example, the iWatch pairs to an iPhone to provide ease of notifications and access to information without users needing to get out their phones. These are a far distance from the vision Satyanarayanan outlines though. Cyber foraging will be an important feature for certain types of IoT scenarios.

**Context Awareness**

This is perhaps the most explored of the challenges outlined in Satyanarayanan’s article, and the one we understand most clearly, with extensive coverage in many publications. In fact, context awareness is discussed explicitly in one of our feature articles that examines affect sensing in mental health patients.

**IN THIS ISSUE**

In one of our feature articles, “The Personal Health Technology Design Space,” Jakob Bardram and Mads Frost propose a design space intended to help designers consider the many decisions that go into making a mobile app to support health and wellness. They consider four categories for design decisions. First, they look at the intervention model: Is the app intended to support a particular disease, and will it be used for personal or clinical use? Second, they examine the data processing: Is data collected automatically or via self-reporting, are patterns recognized using supervised or unsupervised
Two Scenarios

Following are the two scenarios M. Satyanarayanan outlined in his article, “Pervasive Computing: Vision and Challenges.” The first scenario he presented deals with a business traveller dealing with poor network connectivity at the airport:

Jane is at Gate 23 in the Pittsburgh airport, waiting for her connecting flight. She has edited many large documents, and would like to use her wireless connection to e-mail them. Unfortunately, bandwidth is miserable because many passengers at Gates 22 and 23 are surfing the web.

Aura observes that the current bandwidth Jane won’t be able to finish sending her documents before her flight departs. Consulting the airport’s network weather service and flight schedule service, Aura discovers that wireless bandwidth is excellent at Gate 15, and that there are no departing or arriving flights at nearby gates for half an hour. A dialog box pops up on Jane’s screen suggesting that she go to Gate 15, which is only three minutes away. It also asks her to prioritize her e-mail, so that the most critical messages are transmitted first. Jane accepts Aura’s advice and walks to Gate 15. She watches CNN on the TV there until Aura informs her that it is close to being done with her messages, and that she can start walking back. The last message is transmitted during her walk, and she is back at Gate 23 in time for her boarding call.

In the second scenario, a procrastinator takes advantage of the device flexibility offered by the pervasive computing vision to make final edits to his presentation as he walks over to the meeting room, where he will give his talk.

Fred is in his office, frantically preparing for a meeting at which he will give a presentation and a software demonstration. The meeting room is a ten-minute walk across campus. It is time to leave, but Fred is not quite ready. He grabs his PalmXXII wireless handheld computer and walks out of the door. Aura transfers the state of his work from his desktop to his handheld, and allows him to make his final edits using voice commands during his walk. Aura infers where Fred is going from his calendar and the campus location tracking service. It downloads the presentation and the demonstration software to the projection computer, and warms up the projector.

Fred finishes his edits just before he enters the meeting room. As he walks in, Aura transfers his final changes to the projection computer. As the presentation proceeds, Fred is about to display a slide with highly sensitive budget information. Aura senses that this might be a mistake: the room’s face detection and recognition capability indicates that there are some unfamiliar faces present. It therefore warns Fred. Realizing that Aura is right, Fred skips the slide. He moves on to other topics and ends on a high note, leaving the audience impressed by his polished presentation.

These scenarios highlight many aspects of pervasive computing. In the first example, the system proactively notices available bandwidth a short distance from its user’s current location, is aware that its user’s primary purpose is to catch a flight, and ensures that that user doesn’t miss her flight. In the second scenario, the system seamlessly moves its user’s work from a desktop computer to a handheld device to a projection computer. Not only that, but the system also figures out where its user is going and takes proactive steps to download the presentation onto the projection computer. It then realizes that not everyone in the room is authorized to see some of the material and takes proactive steps to keep its user from disclosing confidential information. Many features in these scenarios remain a challenge today.

Reference


Techniques, and is data analyzed for correlation or prediction? Third, they consider the feedback model, including aspects related to visualization, behavior intervention, and gamification. Finally, they bring regulatory issues to the forefront, including whether the system should be viewed as a medical device and examining which privacy model the system uses. This design space should prove a useful tool as readers working on personal health technologies consider new mobile applications.

Another feature article is “Opportunistic and Context-Aware Affect Sensing on Smartphones.” In this article, Rajib Rana, Margee Hume, John Reilly, Raja Jurdak, and Jeffrey Soar survey affect sensing on smartphones to monitor and inform mental health patients. They examine power efficiency, population size and type, elicitation method, context, accuracy and privacy, as well as the sensing type, affect mode, and whether the study considered facial or voice expression. Affect sensing is becoming a hot area of research, and this survey should help researchers understand what has been examined in the past and should also shed light on the gaps in our collective knowledge.

Our Smartphones department examines the trends in mobile visual computing systems and the impact of mobile GPUs. Consumer expectations for mobile capabilities continue to increase—users want everything from sophisticated photography options to phone-based virtual and augmented reality. These capabilities require new hardware and new software techniques. Kayvon Fatahalian provides a nice overview of current capabilities and expectations for the future.

The Notes from the Community department examines virtual reality and immersive technologies. I find the application of these technologies to the visually impaired particularly promising. The department also looks at wearable socks that automatically pause your video when you fall asleep—a particularly useful technology for me, because television seems to be a particularly good soporific. Furthermore, it examines some IoT technologies that have pretty serious security vulnerabilities. As professionals who understand how such oversights can affect the nontechnical population, we must be vocal about these shortcomings and advocate for the population’s privacy.
From the editor in chief

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Junehwa Song is a professor of the School of Computing and a KAIST-Chair professor at KAIST, Korea. He is also an affiliated professor of Web science and technology in the Department of Knowledge Service Engineering at KAIST. His research interests include mobile and pervasive computing systems, ubiquitous services, mobile context computing, social and culture computing, Internet systems, distributed systems, Internet news, and multimedia systems. Song received his PhD in computer science from University of Maryland at College Park. Contact him at junesong@nclab.kaist.ac.kr.

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rights. The final topic that caught my attention was a university in Oklahoma battling “Freshman 15” weight gain with fitness trackers. This is an interesting approach to teaching students how to take care of their health.

In our Pervasive Health department, “Creating Meaning in a World of Quantified Selves,” Matthew Bietz, Gillian Hayes, Margaret Morris, Heather Patterson, and Luke Stark discuss the unexpected risks that underlie the use of self-tracking technologies today. They point out that the data collected by these systems isn’t protected by legislation such as HIPAA or FERPA, that users often can’t determine what privacy rights they’re signing away when they click “I agree,” and that users don’t know which organizations receive the data nor how that data might be used in the future. They point out that self-tracking technology has triggered anxiety in at least one user who previously suffered from anorexia and in users who are trying to limit their total daily step count while recovering from surgery. This article brings up some issues that I had not previously considered.

In the Innovations in Ubicomp Products department, Albrecht Schmidt brings our attention to an initiative in the UK to bring ubiquitous computing to all middle-school students. Each child will be presented with a BBC microbit, a small device with some pretty powerful capabilities that is designed to give both students and teachers a low barrier to programming success. The goal isn’t to create a new generation of programmers, but instead to foster computer literacy among all students at a young age and to give them the satisfaction of building something new. I look forward to hearing more about this experiment in the years to come.

Finally, in our Conferences department, Brandon Amos, Ketan Bhardwaj, and Kiron Lebeck provide a summary of the HotMobile 2016 Workshop on Mobile Computing Systems and Applications. The keynote by Gregory Abowd sounded particularly interesting, with a vision of computational skin covering everyday objects. Other highlights include a paper discussing the challenges of circular displays and another on privacy leaks from wearable fitness trackers. If you weren’t able to attend the workshop, this Conferences department will help you find the papers of most interest to you.

Returning to my discussion of Satyanarayanan’s vision, and considering it in the context of this issue’s focus on domestic pervasive computing—although neither of his usage scenarios were located in a home environment, I’m certain he would agree that the home is a central place for applying pervasive computing technologies. Pervasive computing applied to the home environment might be one of the most difficult domains, because the home is central to human lives. Nowhere does the need for some of the challenges outlined by Satyanarayanan become more visible. For example, the technology supporting domestic pervasive applications must track user intent invisibly and accurately; it must be aware of the context of the home’s occupants (whether residents or guests); and it must be mindful of both privacy and security. Difficult challenges indeed!

REFERENCE


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