An Internet of Things for Healthcare

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For the past few years, I've had a nagging pain in my right knee. I'm not sure if it originates from its severe impact with the pavement while playing street football when I was in high school or maybe even from a hard fall wrestling with my eldest son in my thirties. Of course, maybe I shouldn't still attempt to play basketball at my current age. Nonetheless, I finally did what any respectable Internet Computing scholar would do … I "googled it." After I probed the knee to identify the exact location of soreness, I googled images of the human knee's anatomy. Once I determined the location's official name, I googled that name with keyword variations, such as "pain when kneeling on …," "pain when climbing steps in the …," "problems with the …," and others. Then, I was able to determine the name of several ailments.

I used the name of the ailments to google even more health-related documents, magazines, and WebMD sites. Now, with my new foundational knowledge, it was time to start looking at the message boards and other social media. I was able to identify at least five other people with the same exact problem. In three cases, the individuals reported back to the message board their treatments and the corresponding success or lack thereof. With this new wealth of information, I finally, several weeks later, arrived at the doctor's office. I came *armed* with a very intricate history of the pain. The history was accompanied by my very own "decision tree," with respect to what the problem could be potentially. Associated with the decision tree was my self-generated list of suggestions for treatment. This story might resonate with you, because too many times, doctors just ask patients, "What did you read on the Internet?"

Google searches indeed play a major role in the current practice of self-diagnosis. The access to information, facilitated by Google, is perhaps the largest scale of human-enacted, case-based reasoning that occurs daily. It's only appropriate that this year marks the deadline for the challenge issued in 2003 by Andrew von Eschenbach, the director of the National Cancer Institute (NCI), "to eliminate the suffering and death from cancer" by 2015.[1] The solution wasn't specifically a cure, because many interventions were directed toward recording and sharing numerous images of cancer cases in varying stages. The increased number of cases would facilitate the doctors' ability to diagnose potentially terminal cancer in its infancy — basically, the Google approach.

However, in an era when our computational capabilities are more sophisticated than ever, there should be more automatic approaches to diagnosing problems than information retrieval. There are two technologies that might promote a more proactive approach to sharing health information, perhaps anonymously: mobile health technologies and the Internet of Things (IoT).

Increasingly, physicians promote the creation of digital health records. What if everyone had a memory device embedded in their body that maintained a history of their illnesses, injuries, and treatments? The device could also store images of ailments. Such a personalized record could also maintain a demographic user profile and a genetics profile. We could combine this access to historical information with the growing popularity of fitness activity bracelets and fitness monitoring software coupled with mobile devices.

IoT has largely been articulated as an approach that allows objects in the physical world to interact in a manner similar to the coordination between humans and information within the traditional Internet. Ultimately,

physical objects can become a meaningful aspect of the Internet. I could envision where the *things* in IoT could be modeled from humans in the context of their health. IoT for healthcare[2] has recently emerged as an approach for personalized healthcare, although the focus has been on telemedicine and promoting effective fitness and healthcare practices. What if we could monitor the human condition's full lifecycle by integrating digital health records, fitness tracking, and the Internet of Things? What are the possibilities? What are Internet computing's needs? Three things come to mind.

Human users could more easily search for individuals with similar injuries/ailments who also have a closely related profile. Search would have to be extended beyond static indexes of information. Search algorithms would be required to navigate dynamically generated indexes of humans and their corresponding health-related information.

Human users could be alerted proactively based on their fitness and historical medical or genetics history. While not everyone is going to want unsolicited medical recommendations, I might welcome a message that tells me that the manner in which I'm running led to injury in 30 other people with a relatively similar profile. To make this a reality, recommender systems and collaborative filtering techniques would have to become more dynamic. Researchers would need to integrate these approaches more effectively with IoT.

IoT techniques for promoting better health could interact with interfaces in the doctor's office and emergency room. Health Level Seven International (HL7; www.hl7.org) provides interface formats, but there's also a need for an expert system devised to facilitate the doctors' diagnosis when a patient arrives in the emergency room. To realize this vision, we'll need to enhance interfaces to support communication across healthcare IoT platforms and medical devices in medical facilities.

These are just a few possibilities. And this special issue on Continuous Digital Health demonstrates just how versatile the Internet can be in terms of supporting better health.

I would like to thank our guest editors, Aart van Halteren and Valérie Gay, as well as Maarten van Steen and our reviewers for leading the development of this issue. The articles in this special issue discuss Internet-enabled approaches for promoting better health habits, quality-of-life practices, and an overarching framework realizing the workflows for eHealth.

References

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