n a laboratory within the University of Colorado Boulder’s Department of Computer Science, machine learning algorithms analyze input from a robot’s sensors and guide it smoothly through a complex obstacle course. Fifty miles away in Greeley, farmers analyze data from thousands of tiny, wireless temperature monitors residing within the reticula of their herd of dairy cows. Meanwhile, a father in Pueblo makes a midnight drive to the emergency room, too worried over his young daughter’s worsening cough and spiking fever to wait for tomorrow’s appointment with her pediatrician.

The common thread between these scenarios may not be immediately obvious, but, in fact, each plays a part in an emerging story about companies in Colorado that are applying big data and big software engineering solutions to solve big problems in human health.
Discovering clinically important relationships

Steve Moulton, M.D., is the director of pediatric trauma and burn programs at Children’s Hospital Colorado, a professor of surgery at the University of Colorado School of Medicine, and also the founding chief medical officer of Flashback Technologies in Boulder. He joined the university in 2007 with experience from a previous startup, and an idea nagging at the back of his mind.

“Electronic medical records were just starting to gain traction, and I had this thought that if we could store continuous vital sign waveform data in EMRs, and then analyze them against other clinical data, we could begin to discover new, clinically important relationships. Being a surgeon, I was most interested in better methods for the detection and management of acute blood loss.”

Moulton knew of an ongoing research program at the U.S. Army Institute of Surgical Research (USAISR) at Fort Sam Houston, near San Antonio, Texas, that had developed an experimental model capable of simulating acute volume loss associated with traumatic injury or rapid dehydration in humans. Overseen by Victor Convertino, PhD, tactical combat casualty care research task area program manager at the USAISR, the program sought to discover patterns in noninvasively collected vital signs data, such as those generated by pulse oximetry, that could accurately predict impending hemodynamic collapse. However, the datasets being collected were enormous, complex and impossible to analyze using conventional methods.

A call to the Department of Computer Science at CU-Boulder connected Moulton with Assistant Professor Greg Grudic, PhD, and Research Assistant Professor Jane Mulligan, Ph.D. Together, Grudic and Mulligan had studied machine learning in the context of autonomous robotic navigation for more than 20 years. Through a cooperative research and development agreement (CRADA) with the university, the USAISR was able to provide datasets from its volume-loss model for the team to analyze.

“We got the data and Greg and Jane fed it into their integrated feature extraction and machine learning algorithms,” says Moulton. “The software was able to determine which features of the waveforms were important, and literally within four to six weeks the team had built initial models for continuous, beat-to-beat analysis of vital signs as they trended from normovolemia to hemodynamic collapse.”

The resulting technology has led to the creation of a new physiological parameter called the compensatory reserve index (CRI). The CRI is being developed by Flashback Technologies and is now in early-stage clinical trials, funded by the U.S. Army.

Gathering body temperature data to predict disease

The inspiration that led to the founding of Prima-Temp, also located in Boulder, seems similarly serendipitous. The company’s clinical founder and chief medical officer, Wade Webster, M.D., had been practicing as an emergency room physician in Kirkland, Washington, and had become interested in the potentially enormous clinical utility of collecting and analyzing continuous body temperature data.

“While poring through old textbooks and studies published many years ago, Wade was fascinated to learn that specific patterns in body temperature fluctuation can be predictive of certain infections and diseases well before other symptoms manifest,” says Lauren Costantini, Ph.D., the company’s CEO. “These practices went by the wayside with the advent of biomarkers and more advanced molecular diagnostics, but he thought they could have enormous utility if we had an easy, reliable way to capture and analyze continuous temperature data.”

Costantini says that the problem Webster had to solve was how to get at those data when the current standard of care for monitoring patient temperature in the hospital is to measure it with a thermometer about once per nursing shift. “It’s antiquated, really, and Wade realized that there is so much more we could do in early detection of infectious disease, hospital-acquired infections, and other diagnostic areas if we had more robust temperature data to work with.”
It so happens that Webster was raised in Greeley, and was involved in development of a wireless internal temperature sensing technology used by the dairy industry there and developed by Boulder-based Phase IV Engineering. Webster and Phase IV adapted the sensor and wireless transmission technology for human use, and Prima-Temp was born.

“Essentially Phase IV asked me, ‘what do you need it to look like?’ and together we began collaborating on several application-dependent form factors that now make up our product pipeline,” says Costantini. While Prima-Temp continues to pursue its long-term goal of developing external sensors for continuous, in-hospital temperature monitoring, the first product they anticipate bringing to market is the Ovu-Ring, which is directed at the reproductive health and assisted fertility market. This device continually measures a woman’s core body temperature to help identify fertility cycles and predict optimal timing for conception.

Connecting people with health information: There’s an app for that
iTriage of Denver, which was founded five years ago and is now a part of Aetna, was also started by emergency room physicians. They had practiced for 20 years and collectively seen tens of thousands of patients, and were determined to find a solution to a problem they saw over and over—patients who understood very little about medical information and about how to efficiently access the healthcare system.

“When they get sick or hurt, patients want to know what they have, how serious it is, and where they should go to get the appropriate level of help,” says Peter Hudson, M.D., a co-founder and the CEO of iTriage. “Our goal was to develop a mobile app to help people navigate and connect with the U.S. healthcare system.”

They have been successful with that focus, developing a mobile app that helps users learn about health problems, compare symptoms, decide whether urgent care is needed, find doctors, make appointments and track health information. Hudson says iTriage’s free app has been downloaded more than 11 million times, and hosted more than 50 million sessions last year. The company claims 20 percent of the U.S. hospital market as customers, and their acquisition by Aetna in 2011 has given them access to a huge amount of network- and member-specific data to analyze, and turn into integrated products for the mutual benefit of patients and member providers.

“Right now a lot of hospital systems are trying to integrate with physicians to create a strong network of allied providers, but they have a hard time reaching customers,” says Hudson. “iTriage gives providers tools to help them connect with and educate people on the mobile devices they use every day.”

The relatively sudden rise of the mobile health industry and companies like Flashback, Prima-Temp, and iTriage owes itself to developments in computing science that didn’t exist a decade ago. For example, as Hudson points out, “The miniaturization of powerful computing technology into portable, smart mobile devices with a slick user interface, their rapid and widespread adoption, and mechanisms for easy distribution of software apps were necessary precursors to the development of mobile health applications.”

Moulton adds that recent advances in analytics have been critical to mobile health. “A lot of this has been dependent on having these machine learning technologies and feature-extraction algorithms similar to those that Google and Facebook are now using to scour huge consumer behavior datasets,” he says. “The difference is, we’re using them to scour datasets representing literally terabytes of individual-specific health data.”

Costantini notes an overall trend favoring greater collaboration between medical and engineering sciences. “It used to be rare, but now you can get experts in engineering, information technology, analytics and medicine together in a room, and each outlines the problems they’re trying to solve. The others speak up to say ‘I can do that,’ and before you know it, you have a mobile health product in development.”
If it’s any indication of how significant the potential in this space is, computing industry giants Google and Apple have clearly taken notice, with recent acquisitions of intellectual property and talent, and meetings with the FDA, that send strong signals about their intent to get into the sector.

The hurdles, on the other hand, are not trivial. Although the FDA recently issued much-welcomed guidance for the mobile health industry, the regulation of healthcare products that combine software and devices is still evolving, and pioneers in this space face the risks of forging an untested regulatory path. Defining target markets and educating audiences about the uses and limits of the technology also present tough new challenges.

Moreover, while the potential benefits of mobile health are enormous, it remains to be seen whether mobile health and the associated trend known as the “quantified self” will prove to be a temporary trend with its principal value in consumer entertainment, or a durable movement toward improving clinical outcomes.

“Some will take it seriously as a way to achieve an optimal level of health and performance,” says Moulton. “Some will routinely check their personal data to stay loosely within norms, and there will be others who couldn’t care less.”

“The real question,” adds Hudson, “is whether people are self-quantifying when they’re already fit and healthy just to confirm what they already know, or are people who really need this health knowledge using it to get better? Will those people use it long-term to achieve the health results they’re hoping for?”

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Nevertheless, for pioneers in the mobile health space, the opportunities enabled by this convergence of data analytics and medicine are too exciting to pass up. Says Costantini, “We as humans are constantly radiating data, and finally we’re in a position to capture those data and do something with them. The quantifiable self will lead to the optimized self.”

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