University of Ontario Institute of Technology

Leveraging key data to provide proactive patient care

Overview

The need

To better detect subtle warning signs of complications, clinicians need to gain greater insight into the moment-by-moment condition of patients.

The solution

A first-of-its-kind, stream-computing platform was developed to capture and analyze real-time data from medical monitors, alerting hospital staff to potential health problems before patients manifest clinical signs of infection or other issues.

What makes it smarter

Early warning gives caregivers the ability to proactively deal with potential complications—such as detecting infections in premature infants up to 24 hours before they exhibit symptoms.

The rapid advance of medical monitoring technology has done wonders to improve patient outcomes. Today, patients are routinely connected to equipment that continuously monitors vital signs such as blood pressure, heart rate and temperature. The equipment issues an alert when any vital sign goes out of the normal range, prompting hospital staff to take action immediately, but many life-threatening conditions do not reach critical level right away. Often, signs that something is wrong begin to appear long before the situation becomes serious, and even a skilled and experienced nurse or physician might not be able to spot and interpret these trends in time to avoid serious complications.

Unfortunately, the warning indicators are sometimes so hard to detect that it is nearly impossible to identify and understand their implications until it is too late. One example of such a hard-to-detect problem is nosocomial infection, which is contracted at the hospital and is life threatening to fragile patients such as premature infants.

According to physicians at the University of Virginia,[1] an examination of retrospective data reveals that, starting 12 to 24 hours before any overt sign of trouble, almost undetectable changes begin to appear in the vital signs of infants who have contracted this infection. The indication is a pulse that is within acceptable limits, but not varying as it should—heart rates normally rise and fall throughout the day. In a baby where infection has set in, this doesn't happen as much and the heart rate becomes too regular over time. So, while the information needed to detect the infection is present, the indication is very subtle; rather than being a single warning sign, it is a trend over time that can be difficult to spot, especially in the fast-paced environment of an intensive care unit.

Business benefits

- Holds the potential to give clinicians an unprecedented ability to interpret vast amounts of heterogeneous data in real time, enabling them to spot subtle trends
- Combines physician and nurse knowledge and experience with technology capabilities to yield more robust results than can be provided by monitoring devices alone
- Provides a flexible platform that can adapt to a wide variety of medical monitoring needs

The monitors continuously generate information that can give early warning signs of an infection, but the data is too large for the human mind to process in a timely manner. Consequently, the information that could prevent an infection from escalating to life-threatening status is often lost.

"The challenge we face is that there's too much data," says Dr. Andrew James, staff neonatologist at The Hospital for Sick Children (SickKids) in Toronto. "In the hectic environment of the neonatal intensive care unit, the ability to absorb and reflect upon everything presented is beyond human capacity, so the significance of trends is often lost."

Making better use of the data resource

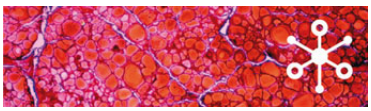
The significance of the data overload challenge was not lost on Dr. Carolyn McGregor, Canada Research Chair in Health Informatics at the University of Ontario Institute of Technology (UOIT). "As someone who has been doing a lot of work with data analysis and data warehousing, I was immediately struck by the plethora of devices providing information at high speeds—information that went unused," she says. "Information that's being provided at up to 1,000 readings per second is summarized into one reading every 30 to 60 minutes, and it typically goes no further. It's stored for up to 72 hours and is then discarded. I could see that there were enormous opportunities to capture, store and utilize this data in real time to improve the quality of care for neonatal babies."

With a shared interest in providing better patient care, Dr. McGregor and Dr. James partnered to find a way to make better use of the information produced by monitoring devices. Dr. McGregor visited researchers at the IBM T.J. Watson Research Center's Industry Solutions Lab (ISL), who were extending a new stream-computing

Smarter healthcare: Using streaming data to help clinicians spot infections

Instrumented

Patient's vital-sign data is captured by bedside monitoring devices up to 1,000 times per second.



Interconnected

Monitoring-device data and integrated clinician knowledge are brought together in real time for an automated analysis using a sophisticated, streamlined computing platform.

Intelligent

Detecting medically significant events even before patients exhibit symptoms will enable proactive treatment before the condition worsens, eventually increasing the success rate and potentially saving lives.

Solution components

Software

- IBM InfoSphere™ Streams
- IBM DB2®

Research

- IBM T.J. Watson Research Center

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—Dr. Carolyn McGregor, Canada Research Chair in Health Informatics, University of Ontario Institute of Technology

platform to support healthcare analytics. A three-way collaboration was established, with each group bringing a unique perspective—the hospital focus on patient care, the university's ideas for using the data stream, and IBM providing the advanced analysis software and information technology expertise needed to turn this vision into reality.

The result was Project Artemis, part of IBM's First-of-a-Kind program, which pairs IBM's scientists with clients to explore how emerging technologies can solve real-world business problems. Project Artemis is a highly flexible platform that aims to help physicians make better, faster decisions regarding patient care for a wide range of conditions. The earliest iteration of the project is focused on early detection of nosocomial infection by watching for reduced heart rate variability along with other indications. For safety reasons, in this development phase the information is being collected in parallel with established clinical practice and is not being made available to clinicians. The early indications of its efficacy are very promising.

Project Artemis is based on IBM InfoSphere™ Streams, a new information processing architecture that enables near-real-time decision support through the continuous analysis of streaming data using sophisticated, targeted algorithms. The IBM DB2® relational database provides the data management required to support future retrospective analyses of the collected data.

A different kind of research initiative

Because SickKids is a research institution, moving the project forward was not difficult. "The hospital sees itself as involved in the generation of new knowledge. There's an expectation that we'll do research. We have a research institute and a rigorous research ethics board, so the infrastructure was already there," Dr. James notes.

Project Artemis was a consequence of the unique and collaborative relationship between SickKids, UOIT and IBM. "To gain its support, we needed to do our homework very carefully and show that all the bases were covered. The hospital was cautious, but from the beginning we had its full support to proceed."

Even with the support of the hospital, there were challenges to be overcome. Because Project Artemis is more about information technology than about traditional clinical research, new issues had to be considered. For example, the hospital CIO became involved because the

system had to be integrated into the existing network without any impact. Regulatory and ethical concerns are part of any research at SickKids, and there were unique considerations here in terms of the protection and security of the data. The research team's goal was to exceed provincial and federal requirements for the privacy and security of personal health information—the data had to be safeguarded and restricted more carefully than usual because it was being transmitted to both the University of Ontario Institute of Technology and to the IBM T.J. Watson Research Center.

After the overarching concerns were dealt with, the initial tests could begin. Two infant beds were instrumented and connected to the system for data collection. To ensure safety and effectiveness, the project is being deployed slowly and carefully, notes Dr. James. "We have to be careful not to introduce new technologies just because they're available, but because they really do add value," says Dr. James. "It is a stepwise process that is still ongoing. It started with our best attempt at creating an algorithm. Now we're looking at its performance, and using that information to fine tune it. When we can quantify what various activities do to the data stream, we'll be able to filter them out and get a better reading." The ultimate goal is to create a robust, valid system fit to serve as the basis for a randomized clinical trial.

Merging human knowledge and technology

The initial test of the Project Artemis system captured the data stream from bedside monitors and processed it using algorithms designed to spot the telltale signs of nosocomial infection. The algorithm concept is the essential difference between the Artemis system and the existing alarms built into bedside monitors. Although the first test is focused on nosocomial infection, the system has the flexibility to handle any rule on any combination of behaviors across any number of data streams. "What we've built is a set of rules that reflects our best understanding of the condition. We can change and update them as we learn more, or to account for variations in individual patients. Artemis represents a whole new level of capability," Dr. James notes.

The truly significant aspect of the Project Artemis approach is how it brings human knowledge and expertise together with device-generated data to produce a better result. The system's outputs are based on algorithms developed as a collaboration between the clinicians themselves and programmers. This inclusion of the human element is critical,

because good patient care cannot be reduced to mere data points. Validation of these results by an experienced physician is vital since the interpretation of these results has to do with medical knowledge, judgment, skill and experience. As part of the project, the rules being used by Project Artemis are undergoing separate clinical research to support evidence-based practice.

Artemis also holds the potential to become much more sophisticated. For example, eventually it might integrate a variety of data inputs in addition to the streaming data from monitoring devices—from lab results to observational notes about the patient's condition to the physician's own methods for interpreting information. In this way, the knowledge, understanding and even intuition of physicians and nurses will become the basis of the system that enables them to do much more than they could on their own.

"In the early days, there was a lot of concern that computers would eventually 'replace' all health care providers," Dr. James says. "But now we understand that human beings cannot do everything, and it's quite helpful to develop tools that enhance and extend the physicians' and nurses' capabilities. I look to a future where I'm going to receive an alert that provides me with a comprehensive, real-time view of the patient, allowing me to make better decisions on the spot."

Broadening the impact of Artemis

The flexibility of the platform means that in the future, any condition that can be detected through subtle changes in the underlying data streams can be the target of the system's early-warning capabilities. Also, since it depends only on the availability of a data stream, it holds the potential for use outside the ICU and even outside the hospital. For example, the use of remote sensors and wireless connectivity would allow the system to monitor patients wherever they are, while still providing life-saving alerts in near-real time.

"I think the framework would also be applicable for any person who requires close monitoring—children with leukemia, for example," says Dr. James. "These kids are at home, going to school, participating in sports—they're mobile. It leads into the whole idea of sensors attached to or even implanted in the body and wireless connectivity. Theoretically, we could ultimately monitor these conditions from anywhere on the planet."

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[1] P. Griffin and R. Moorman, "Toward the early diagnosis of neonatal sepsis and sepsis-like illness using novel heart rate analysis," Pediatrics, vol. 107, no. 1, 2001.

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