Researchers working toward automating sedation in intensive care units

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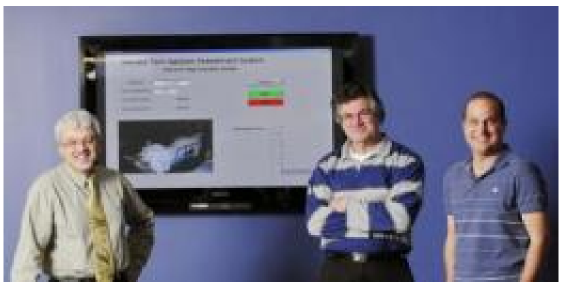

Georgia Tech researchers Wassim Haddad, Allen Tannenbaum and Behnood Gholami (left-right) and Northeast Georgia Medical Center chief medical informatics officer James Bailey have developed control algorithms to automate sedation in hospital intensive care units. Their algorithms use clinical data to accurately determine a patient's level of sedation and can notify medical staff if there is a change in the level. Credit: Georgia Tech/Gary Meek

Researchers at the Georgia Institute of Technology and the Northeast Georgia Medical Center are one step closer to their goal of automating the management of sedation in hospital intensive care units (ICUs). They have developed control algorithms that use clinical data to accurately determine a patient's level of sedation and can notify medical staff if there is a change in the level.

"ICU nurses have one of the most task-laden jobs in medicine and typically take care of multiple patients at the same time, so if we can use control system technology to automate the task of sedation, patient safety will be enhanced and drug delivery will improve in the ICU," said James Bailey, the chief medical informatics officer at the Northeast Georgia Medical Center in Gainesville, Ga. Bailey is also a certified anesthesiologist and intensive care specialist.

During a presentation at the IEEE Conference on Decision and Control, the researchers reported on their analysis of more than 15,000 clinical measurements from 366 ICU patients they classified as "agitated" or "not agitated." Agitation is a measure of the level of patient sedation. The algorithm returned the same results as the assessment by hospital staff 92 percent of the time.

"Manual sedation control can be tedious, imprecise, time-consuming and sometimes of poor quality, depending on the skills and judgment of the ICU nurse," said Wassim Haddad, a professor in the Georgia Tech School of Aerospace Engineering. "Ultimately, we envision an automated system in which the ICU nurse evaluates the ICU patient, enters the patient's sedation level into a controller, which then adjusts the sedative dosing regimen to maintain sedation at the desired level by continuously collecting and analyzing quantitative clinical data on the patient."

This project is supported in part by the U.S. Army. On the battlefield, military physicians sometimes face demanding critical care situations and the use of advanced control technologies is essential for extending the capabilities of the health care system to handle large numbers of injured soldiers.

Working with Haddad and Bailey on this project are Allen Tannenbaum and Behnood Gholami. Tannenbaum holds a joint appointment as the Julian Hightower Chair in the Georgia Tech School of Electrical and Computer Engineering and the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, while

Gholami is currently a postdoctoral fellow in the Georgia Tech School of Electrical and Computer Engineering.

This research builds on Haddad and Bailey's previous work automating anesthesia in hospital operating rooms. The adaptive control algorithms developed by Haddad and Bailey control the infusion of an anesthetic drug agent in order to maintain a desired constant level of depth of anesthesia during surgery in the operating room. Clinical trial results that will be published in the March issue of the journal IEEE Transactions on Control Systems Technology demonstrate excellent regulation of unconsciousness allowing for a safe and effective administration of an anesthetic agent.

Critically ill patients in the ICU frequently require invasive monitoring and other support that can lead to anxiety, agitation and pain. Sedation is essential for the comfort and safety of these patients.

"The challenge in developing closed-loop control systems for sedating critically ill patients is finding the appropriate performance variable or variables that measure the level of sedation of a patient, in turn allowing an automated controller to provide adequate sedation without oversedation," said Gholami.

In the ICU, the researchers used information detailing each patient's facial expression, gross motor movement, response to a potentially noxious stimulus, heart rate and blood pressure stability, noncardiac sympathetic stability, and nonverbal pain scale to determine a level of sedation.

The researchers classified the clinical data for each variable into categories. For example, a patient's facial expression was categorized as "relaxed," "grimacing and moaning," or "grimacing and crying." A patient's noncardiac sympathetic stability was classified as "warm and dry skin," "flushed and sweaty," or "pale and sweaty."

They also recorded each patient's score on the motor activity and assessment scale (MAAS), which is used by clinicians to evaluate level of sedation on a scale of zero to six. In the MAAS system, a score of zero represents an "unresponsive patient," three represents a "calm and cooperative patient," and six represents a "dangerously agitated patient." The MAAS score is subjective and can result in inconsistencies and variability in sedation administration.

Using a Bayesian network, the researchers used the clinical data to compute the probability that a patient was agitated. Twelve-thousand measurements collected from patients admitted to the ICU at the Northeast Georgia Medical Center between during a one-year period were used to train the Bayesian network and the remaining 3,000 were used to test it.

In 18 percent of the test cases, the computer classified a patient as "agitated" but the MAAS score described the same patient as "not agitated." In five percent of the test cases, the computer classified a patient as "not agitated," whereas the MAAS score indicated "agitated." These probabilities signify an 18 percent false-positive rate and a five percent false-negative rate.

"This level of performance would allow a significant reduction in the workload of the intensive care unit nurse, but it would in no way replace the nurse as the ultimate judge of the adequacy of sedation," said Bailey. "However, by relieving the nurse of some of the work associated with titration of sedation, it would allow the nurse to better focus on other aspects of his or her demanding job."

The researchers' next step toward closed-loop control of sedation in the ICU will be to continuously collect clinical data from ICU patients in real time. Future work will involve the development of objective techniques for assessing ICU sedation using movement, facial expression and responsiveness to stimuli.

Digital imaging will be used to assess a patient's facial expression and also gross motor movement. In a study published in the June 2010 issue of the journal IEEE Transactions on Biomedical Engineering, the researchers showed that machine learning methods could be used to assess the level of pain in patients using facial expressions.

"We will explore the relationship between the data we can extract from these multiple sensors and the subjective clinical MAAS score," said Haddad. "We will then use the knowledge we have gained in developing feedback control algorithms for anesthesia dosage levels in the operating room to develop an expert system to automate drug dosage in the ICU."

Provided by Georgia Institute of Technology

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