Forensically-aware Insulin Pump Systems

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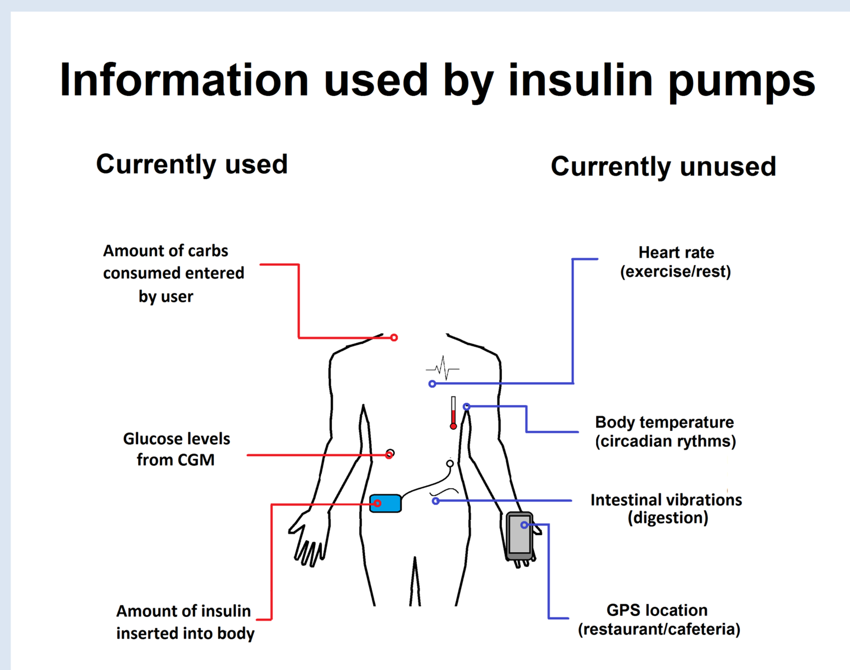
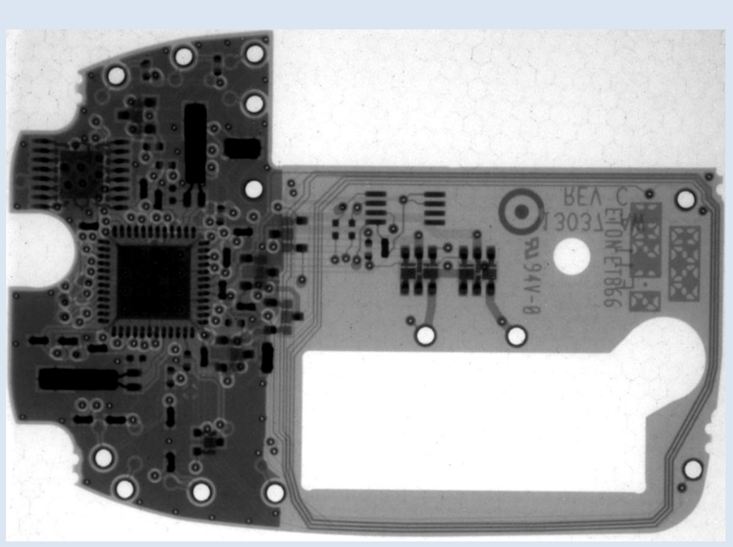
Patients are increasingly reliant on implantable medical device systems today. For patients with diabetes, an implantable insulin pump system can greatly improve their quality of life. As with any device, these devices can and do suffer from software and hardware issues, often reported as a safety event. For a forensic investigator, a safety event is indistinguishable from a security event. In this paper, we propose a new sensor system that can be transparently integrated into existing and future electronic diabetes therapy systems while providing additional forensic data to help distinguish between safety and security events.



Motivation

Halperin et al. first demonstrated unauthorized access to a medical device by partially reverse-engineering the communication protocol to an implantable cardioverter defibrillator [Halperin 2008]. They were then able to implement several methods that could compromise patient safety and privacy. Our goal is to improve system security by providing forensic information from the monitoring of bodily functions to prevent this type of unauthorized access.



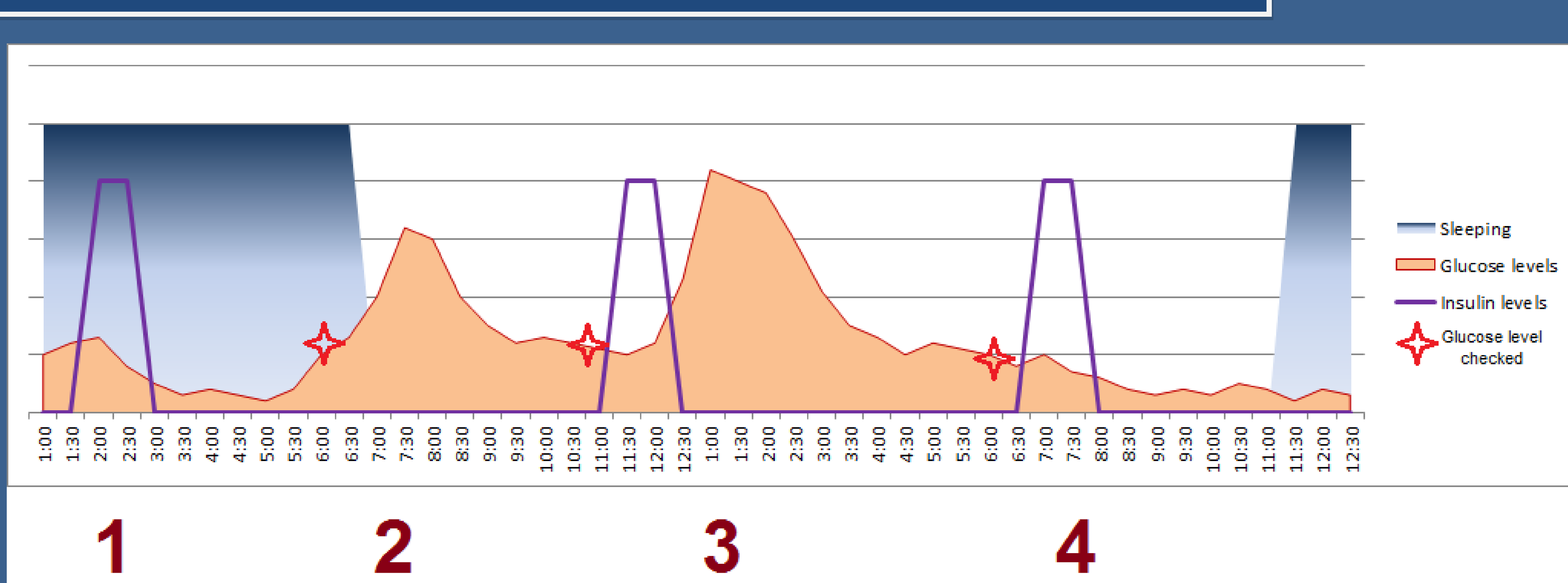
Goals

1) To determine what steps led to a negative patient event (e.g., miscounting of carbohydrates causes patient to issue high amount of insulin).

2) To determine what specifically caused a negative patient event (e.g., overdose of insulin caused hypoglycemia).

3) To take the steps that led to a negative patient event and the specific causes for that event and to determine the type of negative patient event. The event will either be a safety event or a security event.

Four cases for forensic information



Case 1: An unauthorized insulin bolus is given while the patient sleeps. A forensically-aware pump would be able to recognize when the patient sleeps and flag changes to critical device settings.

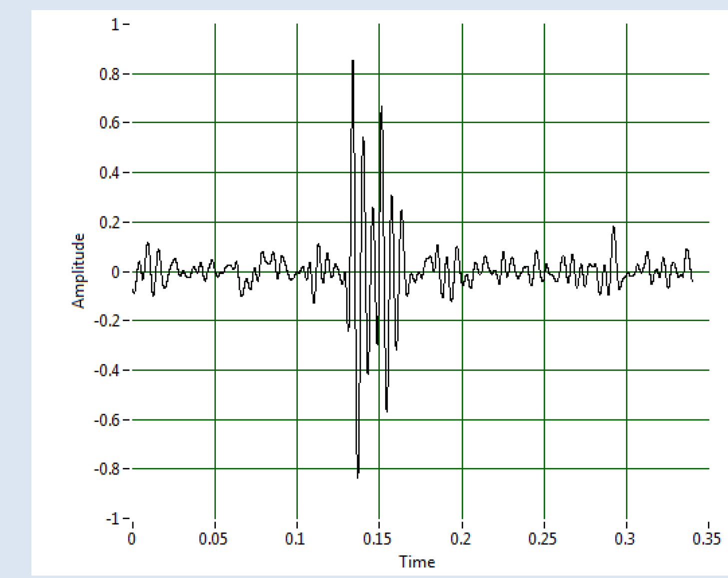
Case 2: The patient consumes a meal without issuing an insulin bolus. The absence of a bolus following the meal would direct the pump to record the missing bolus and the possible risk of hyperglycemia.

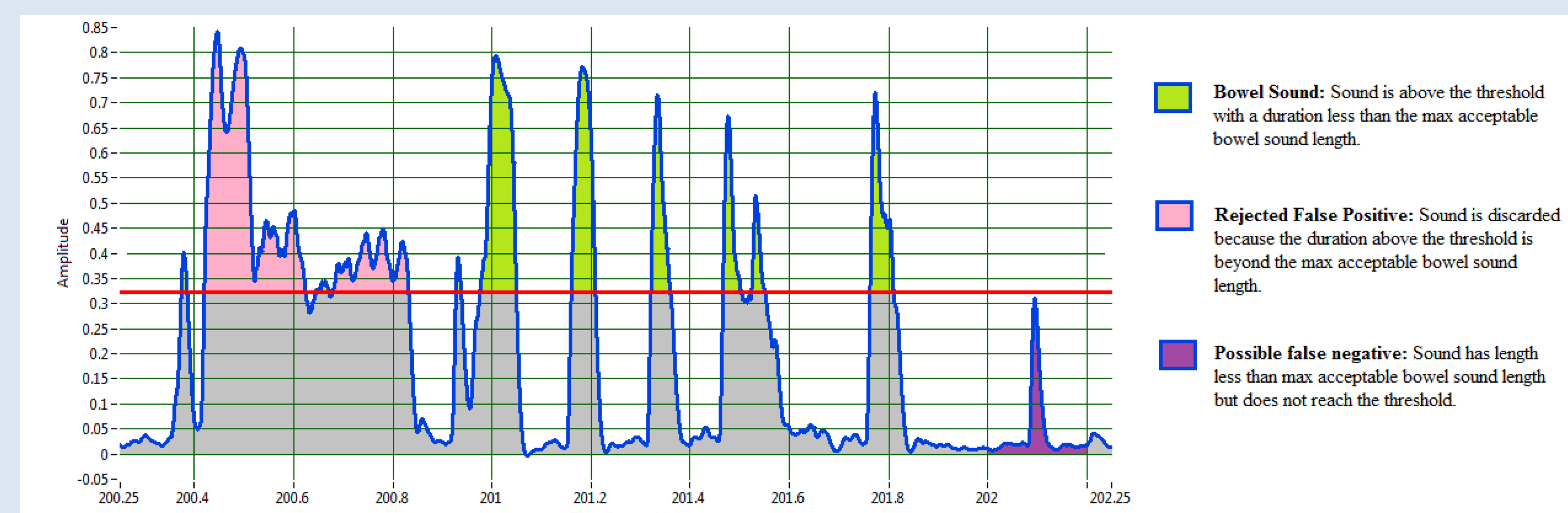
Case 3: The patient gives an insulin bolus and consumes a corresponding meal. By detecting the meal consumption, the pump would allow forensic investigators to discard this case when looking for security events.

Case 4: The patient takes an insulin bolus in anticipation of a meal but is unable to eat. With the absence of a consumed meal, the pump will record a case of possible hypoglycemia.

Methods

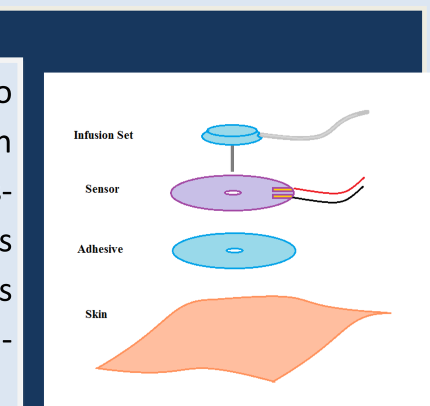
Capturing bowel sounds as a means of determining the state of the stomach and intestines is well understood [Cannon 1905]. Gastrointestinal activity detection is often used for diagnostics [Craine 1999, Campbell 1989]. We are using bowel sounds to improve medical device system security by detecting patient events and determining whether these events are safety or security events. Because eating is one of the primary ways a patient can change their blood glucose value, we use an electronic stethoscope to record bowel sounds before and after a meal.



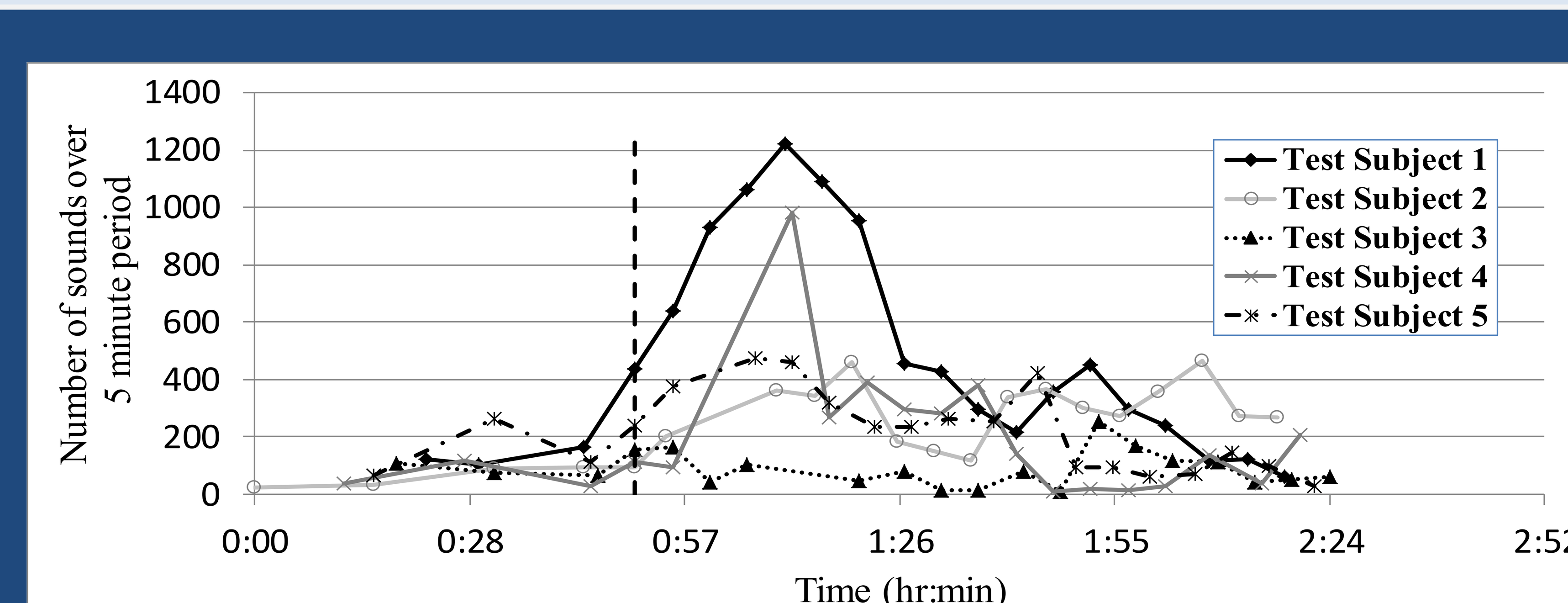


We processed the recorded raw data using a 25 Hz low-pass filter. Using the fasting data of each subject we created a unique threshold. When the filtered signal rose above this threshold we counted a bowel sound. In order to remove false negatives we computed a unique max acceptable bowel sound length for each subject and rejected bowel sounds that continued beyond this time period.

In the future we hope to integrate this system with current insulin pump system by combining sensors with components such as the infusion set or continuous glucose monitor



Results



This graph demonstrates our observed trends. While the amount of bowel sounds we detect varies from subject to subject, we note an approximate 1.5 increase in the amount of bowel sounds for each subject. Because of interference from other parts of the body, we are now addressing filtering out unwanted noises. A sensor can potentially use the gastrointestinal activity to detect meal periods, and an insulin pump can use this information to determine the appropriateness of insulin boluses.

Citations

[Campbell 1989] Campbell, F. C., et al. "Surface vibration analysis (SVA): a new non-invasive monitor of gastrointestinal activity." *Gut* 30.1 (1989): 39-45.

[Cannon 1905] Cannon WB. "Auscultation of the rhythmic sounds produced by the stomach and intestines." *Am J Physiol* 14.4 (1905): 339-353.

[Craine 1999] Craine, Brian L., Michael Silpa, and Cynthia J. O'Toole. "Computerized auscultation applied to irritable bowel syndrome." *Digestive diseases and sciences* 44.9 (1999): 1887-1892.

[Halperin 2008] Halperin D, Heydt-Benjamin TS, Ransford B, Clark SS, Defend B, Morgan W, Fu K, Kohno T, Maisel WH. "Pacemakers and Implantable Cardiac Defibrillators: Software Radio Attacks and Zero-Power Defenses." In *Proceedings of the 2008 IEEE Symposium on Security and Privacy*. (2008): 129-142.

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