Non-Invasive Sensing of Bladder Volume with Multiple Source-Detector Pairs

Introduction

• According to the Urology Care Foundation, 33 million in the U.S. suffer from bladder incontinence, especially for those patients who suffer from spinal cord injuries. They can’t control or sense their bladders.

• Accidental leakage of urine is embarrassing and troublesome. It’s not time but volume that determines when is the bladder going to leak.

We believe NIRS with multiple source-detector pairs can provide a non-invasive, wearable solution to this problem.

Theory

Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of electromagnetic spectrum.

According to the absorbing plot, there is a peak at 975nm wavelength for water. As bladder is full of water when it is full, this characteristic make it very useful to use NIRS in detecting the volume of urine.

![Bladder diagram](image)

By placing light source and photodiodes at the same side and measuring the intensity changes of light at the detectors, we can get an estimation on the volume of the bladder.

![Bladder measurement diagram](image)

• Ultrasonic method was carried out by lots of researchers, but it is too expensive for most patients.

• Previous work on NIRS proved it could detect the bladder[1], but their solution was not stable and hard to implement on different people with only 1 source-detector pair. There’s no practical solution on market currently.

We plan to use multiple source-detector pairs and machine learning algorithms to improve the device.

Method

We implemented simulation of the model and circuit design at the same time this summer.

Simulation Part:

To simulate the reaction of photons after we emit them into human body, we choose Monte Carlo simulation. Considering five different human tissue layers, including abdominal wall muscle, parietal peritoneum, colon mucosa, colon submucosa, urine, we build two bladder models for an empty bladder and a full bladder respectively. The Monte Carlo Simulation Model combines the shape of each tissue and their optical characteristics. We hope to find the difference on light intensity in these two models.

Circuit Part:

Based on the previous work of another project, we made an improvement from 1 Source-Detector pairs to 8 Source-Detector pairs on the booster-pack. We are using CC3200 and AFE4490, both of which were developed by Texas Instrument, as major control. A decoder and a switch were added to control those LEDs and photodiodes flexibly.

![Circuit diagram](image)

Results

![Photons' time-varying distribution in the full bladder model](image)

The simulation results include both the number of photons in each tissue and photons’ time-varying distribution. We can see clearly from simulation that the empty bladder model shows a quite different characteristics compared with the full bladder model. This can be used to match the experiment results and help to explain what is happening inside human bodies using NIRS.

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Reference