Wearable NIR Sensors for Hand Gesture Detection

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Abstract

Photoplethysmography (PPG) is a non-invasive technology where a source emits light onto a tissue and a photodiode (PD) measures changes of blood volume from the reflected light. Using near-infrared (NIR) light emitting diodes (LED), light shined onto the skin can penetrate through the subcutaneous layer of fat to deeper parts of the body, such as to the muscles[1] and blood vessels. When the targeted muscles change in shape, motion artifacts (MA) caused by those movements are created and have large amplitudes in the PPG signal[2]. These artifacts arise mainly as a result of attenuation, which is unique for different muscular density profiles. As such, MA caused by bodily movements can be traced back via a machine learned algorithm to accurately identify which targeted muscles are being engaged. Here, we explore a wearable device that utilizes NIR LEDs and PDs placed over the digitorum muscles of the hand to monitor real-time PPG motion artifacts for gesture detection.

Methods

In-Lab Manufacturing Procedure

The circuit prototype was digitally designed and laser engraved onto a sheet of 2-layer pyralux material (see **Figure 1**). Ferric chloride was used to etch away copper excluding the circuit trace. Components were soldered onto the board and an insulating layer was added over the circuit trace.

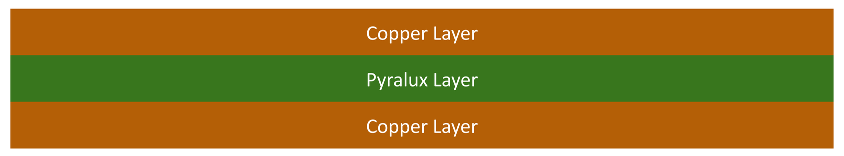

Figure 1. Visualization of 2-layer, pyralux material used for flexible circuit board manufacturing

Data Collection

The design was connected to input channels of a DAQ to record data from the PDs. The data was saved for post-processing.

Design

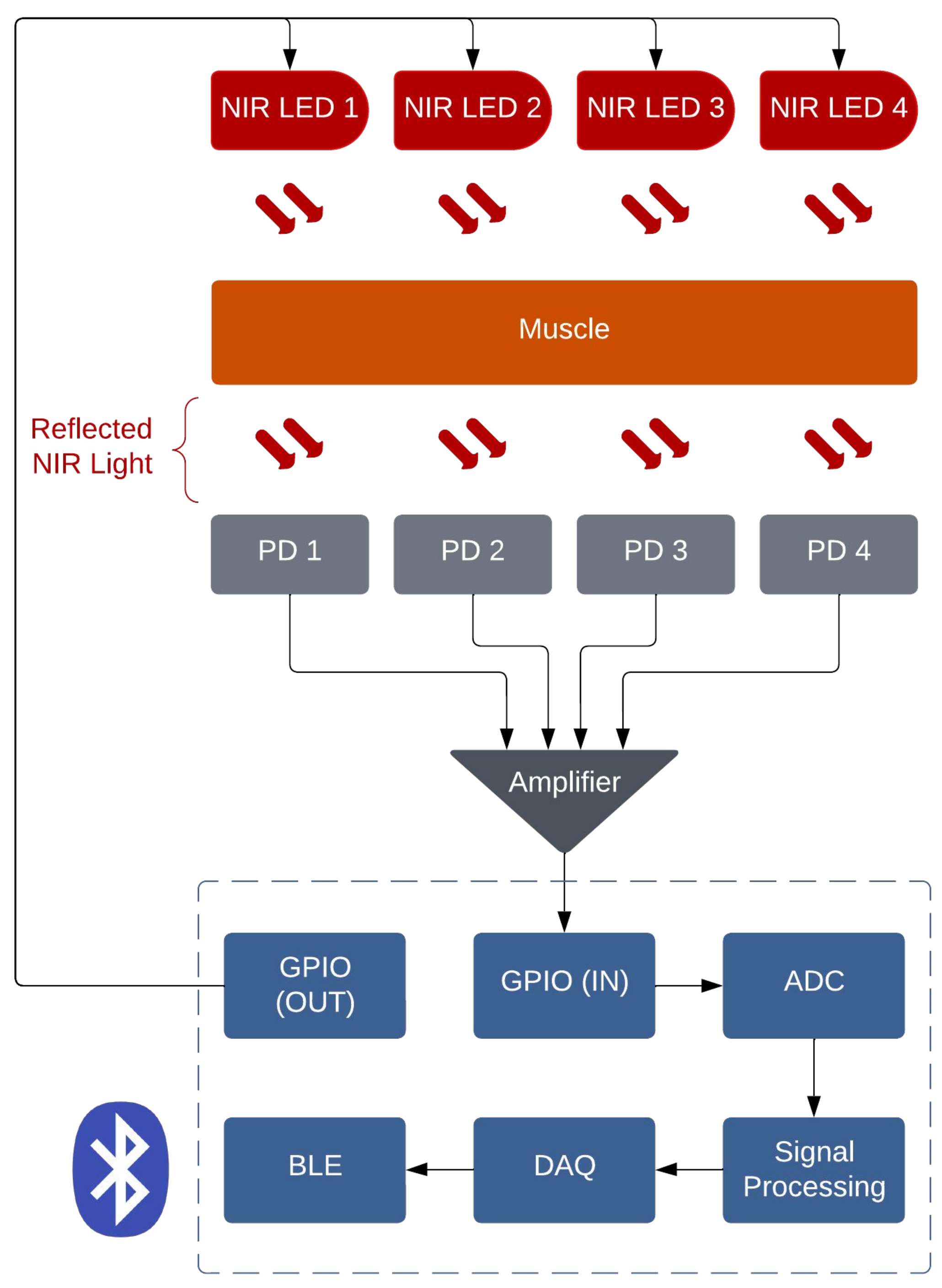

Figure 2. Flowchart of the reported device. The PDs records reflected light from the muscle and produce a photocurrent that transforms to a photovoltage from the amplifier. Analog data is digitized to be analyzed for gesture detection.

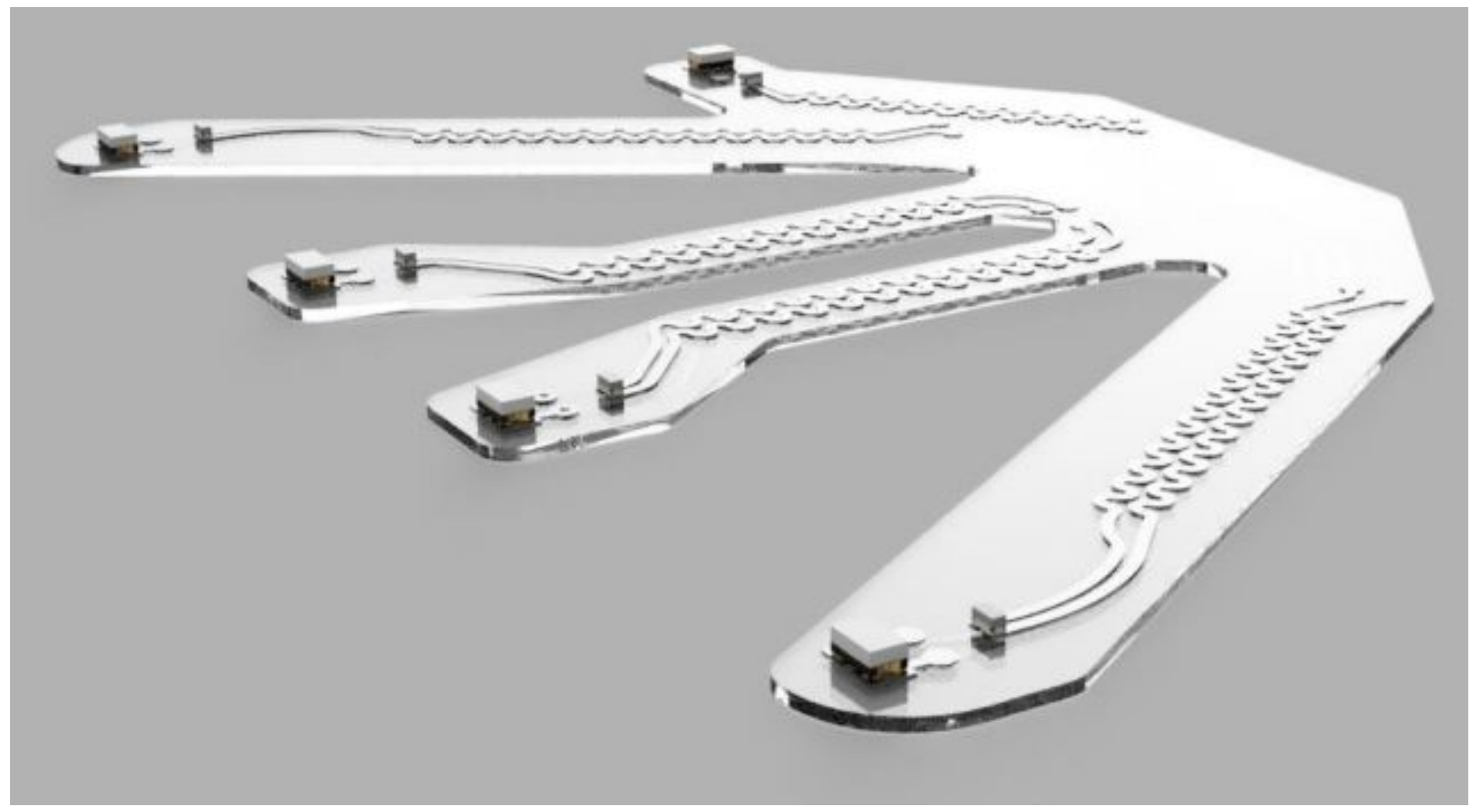

Figure 3. Display of the 2-layer flexible PCB of the gesture detection system. The model contains 5 PDs (distal), 5 NIR LEDs (proximal), and a serpentine wire design.

Acknowledgments

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Results & Discussion

Using the reported prototype, the device was able to capture and record changes in voltage recorded from the photodiodes. Each of the 4 channels produces unique values for a single change in finger flexion, as seen in **Figure 4**.

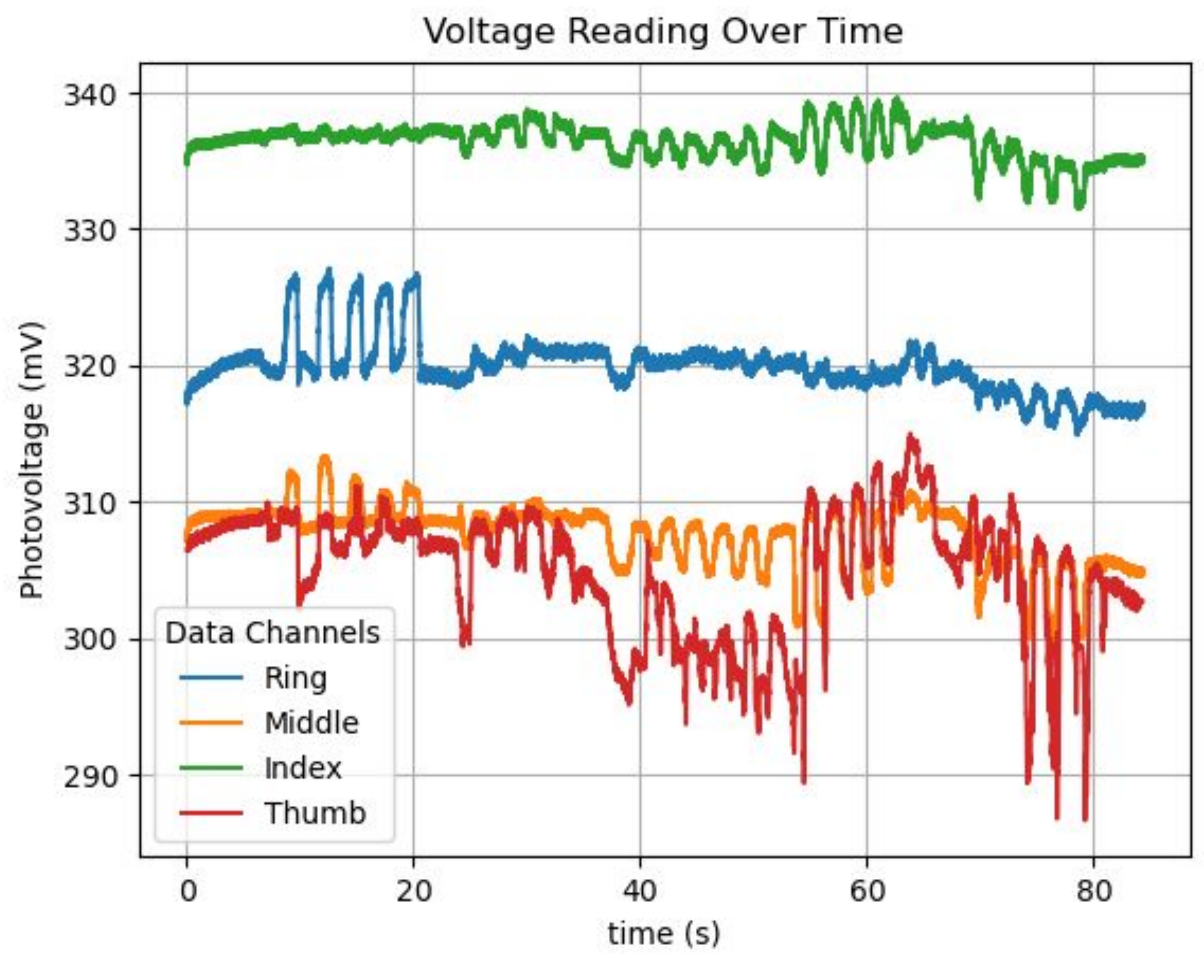

Figure 4. Graph of recorded voltage changes over time from 4 channels. The 5th channel was excluded during data processing due to minimal changes.

Next Steps

We plan to explore modified designs by adjusting the number of PDs and their placement by utilizing forearm digitorum muscles. Applying filters and a machine learning classification algorithm can also assist in accuracy and precision. One potential application of these NIR sensors would be as controllers in robot-assisted surgery, making surgeons' actions feel more akin to real-life surgery to improve their performance.

References

[1] Castaneda, D., Esparza, A., Ghamari, M., Soltanpur, C., & Nazeran, H. (2018). *A review on wearable photoplethysmography sensors and their potential future applications in health care*. International journal of biosensors & bioelectronics. doi: 10.15406/ijbsbe.2018.04.00125

[2] Pollreisz, D., & TaheriNejad, N. (2019, August 8). *Detection and removal of motion artifacts in PPG Signals - mobile networks and applications*. SpringerLink. doi: 10.1007/s11036-019-01323-6