

# Fabric EMG Sensors for Monitoring and Spasticity Detection of Individuals with Spinal Cord Injury and Stroke

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High-dosage rehabilitation is beneficial for functional recovery, which encourages the spinal cord injury (SCI) patients to use their affected limbs as much as possible. Rehabilitation in home settings could provide high-dosage rehabilitation of activity of daily living (ADL). However, SCI and stroke individuals typically suffer from spasticity, which significantly limits the movement control and quality of their daily lives thus the dosage. Hence, a system that can monitor the physiological condition and measure spasticity in their daily life is desirable. The purpose of this study is to customize the soft fabric sensors to maximize the comfort, measure muscle activities for SCI individuals, and to develop machine-learning-based algorithms to detect muscle spasticity.

The wearable technology has numerous fields of applications capturing and emphasizing several key trends such as sports and leisure, healthcare, apparel, fashion, and consumer electronics. However, it is still rarely adopted by individuals with SCI or stroke as those devices are typically rigid, heavy, bulky and uncomfortable. Our soft sensing fabric [1-2] is substantially different from other solutions because it is made of textile that is flexible, foldable, stretchable, washable for multiple times. Unlike rigid wearable device and other health monitor devices, soft sensing fabric interfaces to the body via unobtrusive, conformal, and compliant textile material and also measure the bio-potential signal (ECG and respiratory signal), motion information (accelerate, angular velocity), activities detection (walking, running, climbing, and falling), and biofeedback (falling alarm, heart rate, heart rate variability, respiratory rate). Fig.1 gives the detailed configuration of our fabric EMGs. The five electrodes capture EMG signals from different muscles, which are biceps and triceps for the upper limb, and gastrocnemius and tibialis anterior for the lower limb. Fig.2 shows one subject wearing our sensing fabric along with the real-time recording of the EMG signal.

Spasticity is the symptom of abnormal muscle contraction due to neurological disorders, such as spinal cord injury, stroke, multiple sclerosis, and cerebral palsy. Assessing the progression of spasticity during clinical interventions and at home is key to rehabilitation efficacy and care management. In order to discriminate the spasticity in the subjects with SCI, we collected data from one SCI subject and trained a classification model. Features are statistics extracted from sliding windows. Based on the data analysis, it is observed that

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the two most important features are Mean-Absolute-Value and Root-Mean-Square. Fig. 3 shows the dataset with the linear boundary of our model. The red points represent spasticity, while the blue points represent voluntary contraction, and it is straightforward to separate the two groups by a green line. Our model achieves an accuracy of 96.6%.



Fig. 1. (Top) Microcontroller integrated into the textile sensor for EMG measurement and wireless transmission. (Bottom) The configuration of our fabric EMGs.



Fig. 2. (Left & Right) An SCI subject wearing our fabric sensor on his upper and lower limb respectively. (Medium) The real-time recording for the EMG signal.



Fig. 3. Extracted data points of EMGs with the linear boundary of our model.

## REFERENCE

- [1] Shen C L, Huang T H, Hsu P C, Ko Y C, Chen F L, Wang W C, Kao T, Chan C T, "Respiratory rate estimation by using ECG, impedance, and motion sensing in smart clothing," Journal of Medical and Biological Engineering, 2017.
- [2] Shen C L, Jou G T, Huang T H, Ko Y C, Chen F L, Wang W C, Hsu P C, Kao T, Chan C T. "Smart EMG sleeve for muscle torque estimation," Uncertainty Modelling in Knowledge Engineering and Decision Making: Proceedings of the 12th International FLINS Conference, 2016.