Denoising E-Textile Sensors for Real-World Kinematics Monitoring

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Monitoring kinematics of the human body in real-world environments can be beneficial to applications as diverse as healthcare, sports, human-computer interaction, and more. To this end, we recently reported a wearable textile-based sensor that consists of transmit/receive loops and operates based on Faraday's Law to seamlessly monitor joint flexion angles (e.g., knee, elbow, etc.). The sensor works accurately in its current form, but it is not integrated into fabrics. Once embedded in fabrics, the transmit/receive loops will drift along with fabric movement and hence will impair the sensor's operation. In this work, we aim to model and remove noise associated with e-textile sensors being deformed upon the fabric (namely, e-textile noise), with a focus on kinematics monitoring applications.

To analyze the pattern of e-textile noise, we employed a cylindrical phantom limb with motion capabilities and studied two configurations: (a) loops embedded in a sleeve, and (b) loops without sleeve (control). Using a network analyzer, we measured the transmission coefficient ($|S_{21}|$) of the loop pair at different flexion angles. At the same time, "gold standard" angles were captured using a camera and computer vision software. Measurements indicated that two factors contribute to e-textile noise. The first factor is the varying distance between loops for each measurement. The second factor is the uneven stretching on the fabric sleeve for different flexion angles.

By measuring $|S_{21}|$ at a fixed initial position, the varying distance between two loops can be identified and, hence, calibrated. In turn, this measurement allows us to determine a model for $|S_{21}|$ vs. flexion angle in the absence of uneven fabric stretching. Then, machine learning can be used as a non-linear regulator to offset uneven fabric stretching noise generated during flexion. Therefore, a calibrated and denoised model of $|S_{21}|$ vs. flexion angle can be calculated for any specific setup. The latter can be ultimately used to derive real-time flexion angles during dynamic measurements on an individual wearing the sensor. At the conference, we will provide simulation and measurement data to validate the approach.