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Wearable Loop Sensors for Joint Flexion Monitoring: Dynamic Motion Capture

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Monitoring kinematics in the individual's real-world environment, i.e., outside of the lab and in a continuous manner, is bringing forward unprecedented opportunities in healthcare, sports, consumer electronics, and more. Today's "gold-standard" technology for monitoring kinematics entails the use of on-body retro-reflective markers tracked by infrared cameras. Expectedly, this technique is limited to contrived environments. Alternative approaches have been reported, but they are again restricted to lab environments (markerless cameras); are obtrusive and suffer from integration drift (Inertial Measurement Units, IMUs); require line-of-sight (time-of-flight sensors); and/or obstruct natural movement (bending sensors).

To overcome limitations in the state-of-the-art, we have recently reported new classes of e-textile sensors that can be embroidered into garments to monitor joint kinematics "in the wild". By embedding transmit (Tx) and receive (Rx) electrically small resonant loops right above and below the joint (e.g., knee), respectively, the sensor can detect the relative angle between the two loops as based upon Faraday's law. As a proof-of-concept, sensors to date have been tested for static angles (instead of dynamic motion) [1, 2].

In this work, we take a major step forward and validate our joint flexion sensors for dynamic activities. We start with a calibration step that maps transmission coefficient values to angles across the range of motion. Dynamic motion is emulated on phantom limbs and transmission coefficient values are captured using a network analyzer. We, finally, compare the deciphered angles vs. "gold standard" ones captured by a camera. Results show good agreement and empower our sensors to be reliably tested on human subjects under dynamic settings in the future. Once developed, our sensors will provide an excellent tool for several rehabilitative and diagnostic applications, among others.

1. V. Mishra and A. Kiourti, "Wrap-Around Wearable Coils for Seamless Monitoring of Joint Flexion," *IEEE Transactions on Biomedical Engineering*, **66**, 10, October 2019, pp. 2753–2760, doi: 10.1109/TBME.2019.2895293.

2. V. Mishra and A. Kiourti, "Wearable Electrically Small Loop Antennas for Monitoring Joint Flexion and Rotation," *IEEE Transactions on Antennas and Propagation*, **68**, 1, January 2020 pp. 134-141, doi: 10.1109/TAP.2019.2935147.