ABSTRACT

This research aims to design and develop a smart insole system based on capacitive pressure sensors (CPS) to support gait classification for an Ankle-Foot Orthosis (AFO) rehabilitation robot. The CPS was designed using flexible PCB material and integrated into eight sensing points to detect plantar pressure distribution during walking. The data acquisition method implemented in the system utilizes an RC time constant approach without external resistors, relying solely on the internal pull-up resistors of the Arduino Mega 2560 Pro microcontroller. The testing process was conducted in three main stages: sensor reading validation using reference capacitors to assess linearity, static pressure testing using a force gauge, and human trials to identify pressure distribution patterns across the four gait stance phases (stay, toe, heel, and swing). The results indicate that the system is capable of measuring capacitance values ranging from 3.88 pF to 12.96 pF, with an initial average error between 12.57% and 18.62%, which was significantly reduced through linear regression, yielding an R^2 value between 0.95 and 0.99. In human trials, channels C5 and C8 exhibited the highest and most consistent responses in detecting gait phases. The system also successfully classified gait stance phases using a binary logic approach based on toe and heel pressure distribution. However, the system is currently limited to static pressure tests due to equipment constraints, thus not fully representing dynamic walking conditions. Furthermore, improvements in the flexible PCB design are necessary to enhance the system's adaptability to foot movement. Overall, the smart insole demonstrates strong potential to support robotic rehabilitation systems.

Keywords: Smart Insole, Capacitive Sensor, Gait Classification, RC Time Constant, Flexible PCB, Rehabilitation Robot.