Intent Recognition in Gait Transition Using Wearable Pressure Sensors with Deep Learning

ByungUk Rho[1], GeonWoo Park[1], KeumJung Lee[1], SeungHoon Gang[1], Keonyoung Oh[1]
[1]BioRobotics Lab, School of Mechanical Engineering, Kyungpook National University, Daegu, Republic of Korea
Email: kyoh@knu.ac.kr

Summary

This study proposes an LSTM-based gait transition intention recognition method using wearable lower-limb pressure sensors. An insole-type pressure sensor, an IMU sensor, and a cuff-type pressure sensor were used to record a series of motions, including sitting, standing, walking, and running. Deep learning techniques were then applied for classification and real-time prediction. The accuracies of the predicted movement states based on data from the IMU, insole-type pressure, and cuff-type pressure sensors were 95.03%, 97.52%, and 85.96%, respectively.

Introduction

Gait intention recognition technology predicts and classifies lower limb motions, allowing assistive devices to provide appropriate support in real time. Intention recognition using electromyography (EMG) and electroencephalography (EEG) offers relatively fast recognition results, but is difficult to set up and susceptible to external factors such as sweat. IMU sensors are easy to wear, but have limitations, including slower signal detection compared to EMG and accumulated errors over prolonged use. To overcome these limitations, this study proposes a gait transition recognition method using wearable pressure sensors with a Long Short-Term Memory (LSTM) model, enhancing resistance to external interference resistance while maintaining ease of use [1].

Methods

The experiment involved two healthy participants, both aged 20 years, who performed a sequence of actions: sitting (20s), standing (15s), walking (20s), and running (15s). Each session lasted 70 seconds, and data were collected a total of 15 times. The sensors included an insole pressure sensor, a cuff-type pressure sensor, and an inertial measurement unit (IMU) with sampling frequency of 50Hz [2]. We selected LSTM network as our deep learning model, which consists of a sequence input layer, two LSTM layers with 300 units each, batch normalization for stability, a fully connected layer for class mapping, and a Softmax layer for final predictions. A total of 15 datasets were used, with 12 datasets for training and 3 datasets for testing [2].

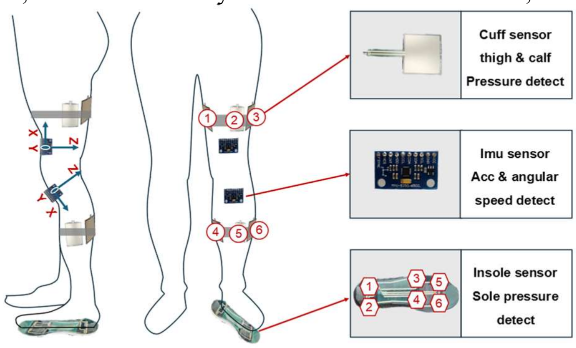

Figure 1: Wearable Sensors in Gait Analysis.

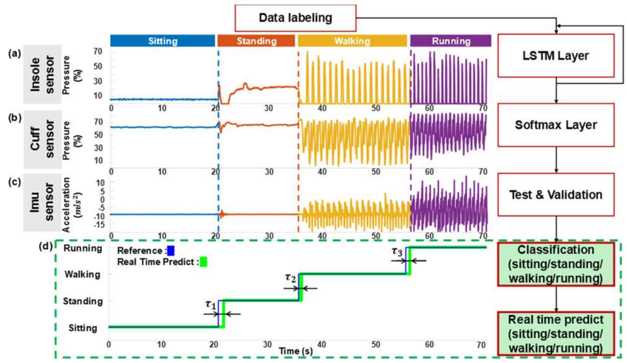

Figure 2: (a-b) Representative sensor values from channel 1 with relative pressure percentage (calculated by dividing raw values by 1023 and multiplying by 100). (c) IMU x-axis values from the anterior thigh. (d) Real-time gait prediction using insole sensor.

Results and Discussion

Experimental results showed that the IMU, insole pressure, and cuff pressure sensors achieved accuracy rates of 95.03%, 97.52%, and 85.96%, respectively, while real-time inference achieved accuracy rates of 98%, 97.8%, and 70.4%. The values for gait transition (sitting-to-standing, standing-to-walking, walking-to-running) were 0.32, 0.36, and 0.16 for the insole pressure sensor, 0.84, 0.82, and 0.52 for the cuff pressure sensor, and 0.08, 0.2, and 1.12 for the IMU sensor.

Conclusions

The proposed intention recognition method, based on wearable pressure sensors and LSTM model, showed accuracy comparable to IMU-based methods. This highlights its potential for real-time motion intention recognition and control in wearable assistive and rehabilitation systems. Future research will integrate the model into an exoskeleton to evaluate its real-time control performance.

Acknowledgments

This research was conducted with the support of the Korea Institute for Advancement of Technology (KIAT) grant funded by the Korean government (Ministry of Trade, Industry and Energy, MOTIE) (P0020616, The Competency Development Program for Industry Specialist).

References

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[2] Y. Liu et al. (2023). *Comput Biol Med*, **163**, 107192