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具步態診斷與防跌預測並連結防護裝置的新型智慧鞋設計

Design of Novel Smart Shoes with Protection Device for Gait Diagnosis and Fall Prediction

隊伍名稱｜最後一舞 The Last Dance

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研究領域

微機電系統、半導體微製程、感測與量測自動化、工程科技教育

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研究領域

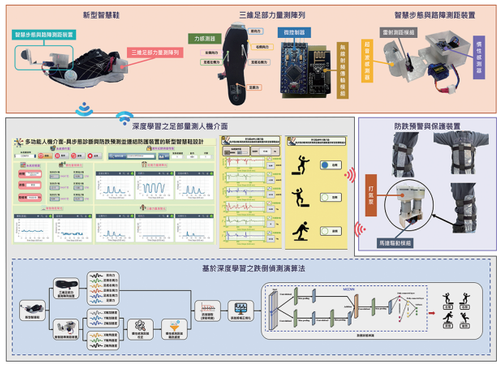
穿戴式智慧技術、人工智慧與深度學習、機電系統整合、智慧復健輔具

作品摘要

本作品設計具步態診斷與防跌預測並連結防護裝置的創新型智慧鞋，研究整合三維多參數感測、智慧模擬建模、自動控制及機電整合等技術，研究開發即時動態分析與預警保護的智慧鞋裝置。本裝置功能包含：(1)創新的高靈敏度三維足部力感測與量測陣列、(2)智慧步態與路障量測裝置、(3)多對一信號無線傳輸技術、(4)步行參數深度學習模擬與跌倒預測模型、(5)防跌預警與保護裝置、和(6)可視化互動式人機介面。

本新型智慧鞋以雷射感測器準確量測垂直地面的行走步高與行走步頻，並以超音波感測器量測路障距離，上述量測均輔以慣性感測器量測步行角度變化，驅動伺服馬達自動校正補償動態角度誤差，藉此準確地量測行走步高、步頻和路障距離。系統量測資訊以無線射頻模組傳輸至可視化互動式人機介面即時顯示分析；並同時傳輸至手機APP，進行記錄與提醒。當量測路面出現障礙，智慧鞋將訊息傳輸至可視化互動式人機介面和手機，即時以語音警示注意路況障礙。本智慧鞋亦提供步幅、步伐節奏、步伐速度、擺動週期時間、站立週期時間、步頻、步高、步幅時間變異性、站立週期的時間變異性和百分比、擺動週期的時間變異性和百分比等動態步態參數的穩定性分析，可用於判斷步態健康趨勢。相較於參考文獻和傳統的二維足底力感測器，本三維足部力量測陣列增加了約四倍的足部壓力動態變化靈敏度，可以快速地比對健康與跌倒預測模型，使智慧步態量測、路障感測與即時防跌預測保護得以執行。同時，可視化互動式人機介面執行完整行走歷程記錄、量測比較分析、預警指示、保護驅動和補償修正。

此外，本智慧鞋動態量測足底和足側的三維力分布及慣性感測器量測步行動態訊號，透過基於深度學習的防跌預測分析，建立可能跌倒的判斷模式。當感測陣列偵測到步態不穩有跌倒的可能狀況，系統即時提出危險警示信號，並通知無線射頻傳輸模組啟動防護氣柱的氣泵充氣，提供輔助支撐和保護。實驗測試分析結果顯示，本智慧鞋設計實現高靈敏度的步態智慧感測分析、防跌預警和即時防護效果，可提供醫療單位進行步態參數的大數據收集分析。未來更強化防跌提醒與有效的保護裝置，能應用於老幼傷殘者照護，改善跌倒受傷者的身心和家庭傷害，提升需要者的動態活動能力和照護功能。



圖一 具步態診斷與防跌預測並連結防護裝置的新型智慧鞋設計系統架構圖。

Abstract

This project has developed a new smart shoe with gait diagnosis and fall prevention prediction and connected with protective devices. This research applied three-dimensional multi-parameter sensing, intelligent simulation modeling, automatic control and electromechanical integration technologies to develop the smart device with real-time dynamic analysis and early warning protection. The functions of this design include: (1) innovative high-sensitivity three-dimensional foot force sensing and measurement array, (2) smart gait and roadblock measurement device, (3) many-to-one signal wireless transmission technology, (4) deep learning simulation of walking parameters and fall prediction model, (5) warning to prevent fall with protection device, and (6) visual interactive human-machine interface.

This novel shoe with smart function uses laser sensors to accurately measure vertical step height and step frequency, and uses ultrasonic sensors to measure the distance to roadblocks. Above measurements are supplemented by inertial sensors to measure changes in gait angle, and drive servo motors to automatically correct and dynamically compensate for angle deviations. The measurement information is transmitted to the human-machine interface via a wireless radio frequency module for real-time display and analysis. The information is also transmitted to the APP of cell phone for recording and reminder. This work analyzes the stability of dynamic step height and cadence for examining gait health trend. By comparing with references, this three-dimensional foot force measurement array design increases the sensitivity to foot dynamic variations about 4 times than two-dimensional foot force sensors. This device can quickly compare health and fall prediction models, enabling smart gait measurement, roadblock sensing and instant fall prevention prediction. When there are obstacles on the measured road, the smart shoes transmit measured information to the human-machine interface and cell phone. It provides voice warning to inform pay attention to road obstacles. The interactive human-machine interface performs measurement recording, comparison, early warning and fall prevention protection, and compensation correction.

The smart shoes dynamically measure force distribution on the sole and side of the foot, and inertial sensors measure walking dynamic signals. Through fall prevention analysis based on deep learning, a judgment model for possible fall prediction is established. When the sensing array detects unstable gaits and possible fallings, the system supplies a danger warning signal. It also notifies the transmission module to start the pump and inflate the protective air column for providing auxiliary support and protection. Experimental test results show that this smart shoe design achieves high-sensitivity intelligent gait sensing analysis, fall prevention warning and instant protection. It can provide medical units to collect big data and to analyze gait parameters. In the future, the fall prevention reminders and effective protection devices will be strengthened and be used to care for the elderly, young and disabled. It will be able to improve the physical and mental injuries by falls, and provide better care in dynamic walking activity.

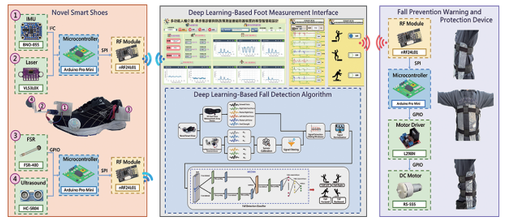


Fig. 2 Design of Novel Smart Shoes with Protection Device for Gait Diagnosis and Fall Prediction system structure.