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Design of a Low-Cost, Portable, Sensor Device for Longitudinal, At-Home Analysis of Gait and Balance

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Abstract : The purpose of this project is to develop a low-cost, portable sensor device that can be used at home for long-term analysis of gait and balance abnormalities. One area of particular concern involves the asymmetries in movement and balance that can accompany certain types of injuries and/or the associated devices used in the repair and rehabilitation process (e.g. the use of splints and casts) which can often increase chances of falls and additional injuries. This device has the capacity to monitor a patient during the rehabilitation process after injury or operation, increasing the patient's access to healthcare while decreasing the number of visits to the patient's clinician. The sensor device may thereby improve the quality of the patient's care, particularly in rural areas where access to the clinician could be limited, while simultaneously decreasing the overall cost associated with the patient's care. The device consists of nine interconnected accelerometer/ gyroscope/compass chips (9-DOF IMU, Adafruit, New York, NY). The sensors attach to and are used to determine the orientation and acceleration of the patient's lower abdomen, C7 vertebra (lower neck), L1 vertebra (middle back), anterior side of each thigh and tibia, and dorsal side of each foot. In addition, pressure sensors are embedded in shoe inserts with one sensor (ESS301, Tekscan, Boston, MA) beneath the heel and three sensors (Interlink 402, Interlink Electronics, Westlake Village, CA) beneath the metatarsal bones of each foot. These sensors measure the distribution of the weight applied to each foot as well as stride duration. A small microntroller (Arduino Mega, Arduino, Ivrea, Italy) is used to collect data from these sensors in a CSV file. MATLAB is then used to analyze the data and output the hip, knee, ankle, and trunk angles projected on the sagittal plane. An open-source program Processing is then used to generate an animation of the patient's gait. The accuracy of the sensors was validated through comparison to goniometric measurements (±2° error). The sensor device was also shown to have sufficient sensitivity to observe various gait abnormalities. Several patients used the sensor device, and the data collected from each represented the patient's movements. Further, the sensors were found to have the ability to observe gait abnormalities caused by the addition of a small amount of weight (4.5 - 9.1 kg) to one side of the patient. The user-friendly interface and portability of the sensor device will help to construct a bridge between patients and their clinicians with fewer necessary inpatient visits.

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