SERB Sponsored Research Internships (VRITIKA):

Title: Wearable Sensor-based Human Activity Recognition using Deep Learning Techniques

Summary:

The characterization of locomotion and physical activity carried out is fundamental to better understand, prevent, and treat various health problems. Many systems based on accelerometers and inertial sensors have been proposed to recognize movement and monitor gait performed on an outpatient basis.

Unfortunately, the methodologies proposed so far suffer from some limitations such as being dedicated and then built for a particular type of patients. One of the objectives of this work is to propose new approaches for the recognition of physical activities and gait monitoring from inertial sensors. It is a question here of starting from the kinematic signature of the activity and the subject studied to integrate it into the algorithm.

Deep learning techniques along with simple machine learning algorithms will be implemented to analyse the efficiency of the participant independent classification systems. The methods would be modified with user(/pathology) specific features for an user(/pathologically)-adaptive classification models.

This research also proposes a new approach for the characterization of locomotion. In addition to the spatio-temporal parameters traditionally used in clinical settings for patients' evaluation and monitoring, it proposes to qualify local stability and complexity in movement patterns based on nonlinear methods.

Inertial sensor is used to measure angular velocity, acceleration etc when attached to a human body part while performing daily or sports activities. Deep learning classifier models such as Long Short-term Memory (LSTM) networks are capable of extracting high dimensional features from signal sequences to represent human activities. However, a trade-off between the computational complexity and the performance of activity recognition system should be maintained in a low resource device. We plan to capture the original signal from IMU sensor which is segmented into windows and a set of statistical feature measures is extracted from each window. A stacked Long Short Term

Memory (LSTM) network is to be trained with the sequences of concatenated feature measures instead of the original signal to represent activities. Using feature selection methods: correlation metric as heat map and feature importance, only significant features are selected to train the stacked LSTM network along with conventional classifiers such as support vector machine, random forest and k-nearest neighbor. To evaluate the system performance, a new dataset collection, named Human Physical Activities (HPA) dataset, for sports activities using four inertial sensors will be used along with our captured data sets.

Research Objectives:

The human activity recognition system consists the following steps: signal data pre-processing, feature extraction and selection, and training of classifiers and testing of the trained models.

- One of the objectives of this work is to propose new approaches for the recognition of physical activities and gait monitoring from inertial sensors. This study will focus on activities such as walking, running, and cycling that could be distinguished, regardless of the characteristics of the subjects and the pace of physical activity.

- Deep learning techniques along with simple machine learning algorithms will be implemented to analyse the efficiency of the participant independent classification systems. The methods would be modified with user(/pathology) specific features for an user(/pathologically)-adaptive classification models.

- This research work also proposes a new approach for the characterization of locomotion. In addition to the spatiotemporal parameters traditionally used in clinical settings for patients' evaluation and monitoring, it proposes to qualify local stability and complexity in movement patterns based on nonlinear methods.

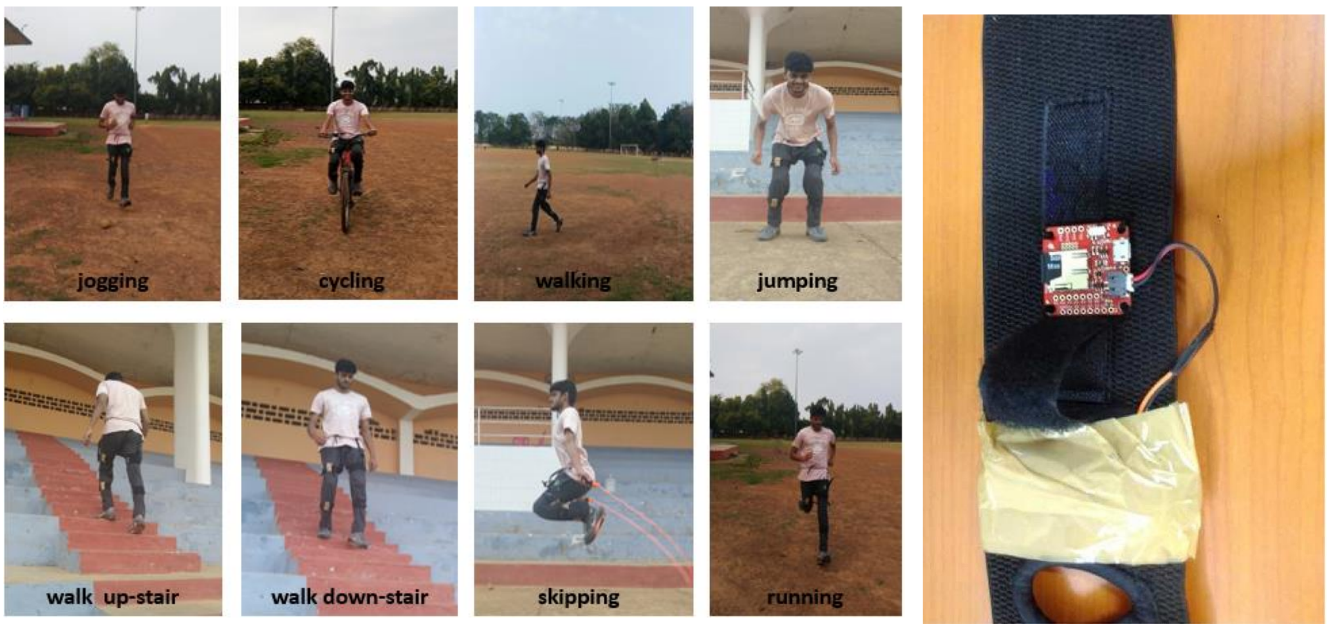
Proposed Methodology:

The pre-processing step includes filtering which is used for removing noise from signals capture from inertial sensors and to make it smooth. In this study a low pass butterworth filter will be used with the cutoff frequency in the range of 10 to 25 Hz. The signal will be after that normalized. The peak dynamic normalization technique will be used on the filtered signal. Peak Dynamic Normalization takes the maximum value from the filtered data and each value of filtered data is divided by this maximum value to get the normalized signal. Various time domain (TD) and Frequency domain (FD) features will be extracted from each segmented signal. The gait signatures will be extracted by measuring kinematics gait parameters of subjects with normal and pathological gait.

The Deep Neural Network (DNN) models will be used for human gait modelling to analyse relationships between actual and predicted gait pattern. The gait signature will be modelled with DNN to illustrate the generalization ability of each model and it uncovers the gait profiles which are estimated by different error metrics. The mathematical background of DNN models in kinematic feature will be given to obtain an intuitive insight into gait modelling for different subjects. The components (joint signatures) and the interconnections among them will provide dynamic behavior of gait and then deal with each component at a time, checking for the correctness of each component in turn and the model as a whole. The performance analysis of DNN model on motion captured data will be validated with subject specific different person's gait model. The performance of various classifiers will be compared for demonstrating better results.

The first experiment will have two objectives. First of all to provide data making it possible to test the algorithms implemented for the recognition of activity as well as for the determination of spatio-temporal parameters during walking. Then, it will allow to compare the results obtained concerning the local stability and complexity in movement patterns based on nonlinear methods between the groups and this, according to the different conditions of realization (slow, normal, fast). The second experiment will enable to test the feasibility of the proposed method in real conditions and also to compare the results in terms of movement local stability and complexity between groups of subjects.

We also plan to use a standard data set named Human Physical Activities (HPA) dataset to evaluate the system performance for sports activities. The new dataset consists of nine static and dynamic movements in outdoor setting. The following physical activities are performed with IMU sensor in NIT-Rourkela demonstrated in Fig 1a.



(a) **(b)**

Fig. 1a. . Activities performed by the participant in data collection process in outdoor wearing Inertial Measurement Unit (IMU) sensors on both thighs and shanks; b). Hardware prototype of IMU sensor

We will use Sparkfun 9DoF MPU-9250 IMU sensors consisting of a tri-axle accelerometer, tri-axle gyroscope, and tri-axle magnetometer, are used for the experiment. Each sensor has a frequency of 100 Hz. A micro SD card, placed in an in-built slot of the IMU sensor, is used to collect the signal values. A closer look at the IMU sensor is shown in Fig. 1(b). Each sensor is attached to the center of an elastic band.

Proposed Plan of Research Work for Research Interns

List of Research Interns	Nature of Work	Research Objectives	Timelines to complete research work	
			Dec 2021	**Jan 2022**
Research Intern 01	Analytical	Algorithm implementation and testing	1). Data Preprocessing Methods 2). Feature Extraction 3). Classification Algorithms	1) Gait characterization 2). Activity recognition
Research Intern 02	Theoretical + Experimental	Data treatments and Algorithm testing	Data analysis methods to investigate spatio-temporal characteristic of normal and pathological gait.	2). Gait feature extraction Through analysis of big data in gait biomechanics and statistical techniques. 1). Deep learning algorithms for Activity recognition
Research Intern 03	Theoretical + Experimental	Experiments in a controlled environment and Software development	To analyze the performance of different classifiers including deep learning techniques when trained with limited number of features	A comparative analysis of the classification methods to understand the importance of different statistical features to represent the characteristics of gait pattern during various activities.