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PrivLet: A differential privacy and inverse wavelet decomposition framework for secure and optimized hemiplegic gait classification

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ABSTRACT

Hemiplegia is a neurological disorder restricting the movement of one side of the body. As this is a chronic condition, it requires repeated diagnosis over a period of time and is best if done remotely. Hemiplegia produces a noticeable influence on gait. Gait or the walking pattern could be studied by using Inertial Measurement Unit sensors. As smartphones contain embedded inertial measurement units, this makes them suitable for a low-cost, readily available solution for gait monitoring. The process can be automatized by utilizing machine learning algorithms. However, general machine learning algorithms are not practical for handling privacy as they require all data at once to train the model and accordingly, the client data needs to be sent to the server for processing. Therefore, to solve this we propose a differential privacy-based hemiplegic gait classification model in which we can control the privacy coefficient for a trade-off of accuracy. The experiment also utilizes a multidimensional inverse wavelet decomposition technique for more robust detection. The experiment was conducted on 35 human subjects with informed consent and necessary institutional review board approval. The decomposition resulted in hemiplegic gait classification accuracy of 100% surpassing the State-of-the-Art. Moreover, to ensure privacy, an accuracy range of 24.7% to 88.8% was obtained based on different coefficients of privacy trade-off. The framework can be implemented to establish a remote healthcare mechanism where the patients themselves can monitor their gait and obtain preliminary advice where healthcare professionals are inaccessible. The codes for the experiment are available at https://github.com/subhrangshu/PrivLet.

1. Introduction

Gait refers to the study of patterns of body movements that are responsible for locomotion in human beings. These gait patterns differ from person to person, but they tend to maintain a bilaterally symmetrical pattern [1]. The gait pattern of a perfectly healthy person varies considerably from that of a person with various abnormalities. Such abnormalities arise due to various underlying health conditions [2]. They mainly include various neurological disorders such as Parkinson's disease, Diplegia, Hemiplegia, and Huntington's Chorea [3]. Hemiplegia is a kind of paralysis that is caused by damage in the brain or spinal cord that affects only one side of the body. According to a report published by the Regional Office of the Eastern Mediterranean of the World Health Organization, there are about 5 million people annually affected by Hemiplegia [4]. It mainly occurs due to problems affecting the Central Nervous System (CNS) [5]. Some of the most common causes of this condition include strokes, concussions, seizures, brain tumours, etc. Some of these cases can be treated by addressing the underlying cause and by various forms of therapy to recover motor function. Fig. 1 shows the distribution of observations of gait recorded with the help of IMU sensors placed near the sternum of the chest. Here in the x-axis of the figure, 'Ax', 'Ay', 'Az' and 'Gx', 'Gy', 'Gz' are the x, y and z axes of the accelerometer and gyroscope respectively. The y-axis of the figure represents the magnitudes of the readings from the accelerometer and gyroscope scaled within a range of 0 and 1. Accelerometer x, y and z axes respectively record sideward, upwards and forward motion. Gyroscope x, y and z axes respectively record anterio-posterior sway, torso movement and lateral sway. In comparison to normal gaits, hemiplegic gaits tend to have a distinct pattern of distribution. Similar patterns are also visible on all axes of the gyroscope. Based on this property, a classifiable relationship can be

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