Temporal Pattern Recognition for Gait Analysis Applications Using an "Intelligent Carpet" System

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***Abstract*—We report on the demonstration of a novel floor sensor system for gait analysis in the time domain. The ability of the system to detect changes in gait was evaluated using pattern recognition techniques. The selected machine learning models successfully classified 10 different walking manners performed on the floor sensor system. Their range was defined in terms of the amplitude, frequency and type of the temporal signal. Between three and five consecutive footsteps were captured per gait experiment. For the data analysis five machine learning time series features were engineered for assessment of 12 machine learning models. The tested machine learning models includes linear, non-linear and ensemble methods. The top F-score performance obtained was 88% using a finely tuned Random Forest model. We conclude that pattern recognition in gait activities monitored by the floor sensor system is suitable for gait analysis applications, ranging from biometrics to healthcare.**

***Index Terms*—pattern recognition, gait analysis, temporal analysis, time series classification, floor sensor system, machine learning.**

I. Introduction

Gait analysis has a wide range of applications from biometrics [1] to healthcare [2]. Typically, such analysis is performed by measuring temporal and spatial parameters, such as cadence, stride length and walking base. This paper presents the first results of gait analysis in the time domain. They are based on an original floor imaging sensor system ("Smart carpet" or "Intelligent carpet") that exploits plastic optical fibres (POFs) to sense deformation when pressure is applied as a result of humans walking on its surface. The system is a unique combination of hardware and software resulting in an innovative cost-efficient design. A novel non-planar tomographic technique [3] allows real-time reconstruction of footsteps in the carpet [4].

The floor sensor system, allows spatio-temporal information of footsteps to be recorded, stored and analysed over theoretically unlimited periods of time. The large volume of data obtained with the system can be used for training machine learning models for gait analysis, covering a multitude of scenarios. Possible target application areas are sports, security, healthcare [5] and many more.

Floor sensors systems have been used to distinguish human postural activities. In [6] Headon and Curwen recognize movements undertaken by a single user. The recognition is achieved by analysing the Ground Reaction Force (GRF) in a weight-sensitive floor. The changes in the GRF arise from activities performed by a single user at the same position, including jumping, sitting, rising, etc. A hidden Markov model was used for activity classification. The classification accuracy was close to 100%.

The research presented in this paper is an initial attempt to determine whether the smart carpet is capable to detect changes in gait resulting from the execution of several manners of walking, enacted by a single user of the system. The 10 different manners of walking cause variations in the gait parameters which are captured during several consecutive footsteps. To the best of our knowledge, there have been no research studies to date that analyse the performance of a floor sensor system to distinguish several manners of walking as presented in this paper.

II. Relevant work

The gait of a person can be detected with a floor sensor system by measuring the footstep GRF. When compared with other sensing technologies, one of the main advantages of a floor sensor system is its unobtrusiveness, as the user interacts with an unmodified everyday floor surface (carpet), via the gravitational force during routine walking. The system is also resistant to light or sound interference that affects other sensing technologies such as vision or sound sensors [7] such technologies also invade the users privacy, which can conflict with adopting the sensing technology in the home environment [8].

In the activity recognition domain by using floor sensor systems, Saripalle [9] used force platforms to infer the centre of pressure of individuals for the classification of human postural and gestural movements. The study volunteers performed 11 body movements for classification by linear and nonlinear supervised learning methods. Depending on the latter, the classification accuracy ranged from 79% to 92%.

A. Supervised learning algorithms for pattern recognition

Supervised learning is by far the most widely used type of machine learning. The technique has been applied for pattern recognition in many domains ranging from cancer research [10] to image recognition [11]. In this paper, 12 supervised learning models are used in search for the best classification performance of manners of walking by using machine learning features. Linear learning models include Linear Support Vector Machines, Logistic Regression and Perceptron. Non-linear and ensemble learning models include Random Forest, AdaBoost,