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ScienceDirect

Procedia Computer Science 129 (2018) 21–27

Procedia Computer Science

www.elsevier.com/locate/procedia

2017 International Conference on Identification, Information and Knowledge in the Internet of Things

Template-Matching-Based Detection of Freezing of Gait Using Wearable Sensors

Cheng Xu [1,2], Jie He [1,2,*], Xiaotong Zhang [1,2], Cunda Wang [1,2] and Shihong Duan [1,2]

[a]*School of Computer and Communication Engineering, University of Science and Technology Beijing, Beijing 100083, China*
[b]*Beijing Key Laboratory of Knowledge Engineering for Materials Science, Beijing 100083, China*

Abstract

Parkinson's disease (PD) lead to lots of injuries associated with fall incidences every year, causing lots of human suffering and assets loss for patients. Freezing of Gait (FOG), which is one of the most common symptoms of PD, is quite responsible for most incidents. Although lots of research have been done on characterize analysis and detection methods of FOG, large room for improvement still exists in the high accuracy and high efficiency examination of FOG. In view of the above requirements, this paper presents a template-matching-based improved subsequence Dynamic Time Warping (IsDTW) method, and experimental tests were carried out on typical open source datasets. Results show that proposed IsDTW not only embodies higher experimental accuracy (92%), but also has a significant runtime efficiency.

Selection and peer-review under responsibility of the scientific committee of the 2017 International Conference on Identification, Information and Knowledge in the Internet of Things (IIKI2017).

Keywords: Parkinson's disease; freezing of gait (FOG); template matching; Dynamic Time Warping (DTW); wearable sensors.

1. Introduction

Parkinson's disease (PD) is a kind of common neurological disorder caused by dopamine and gradually loss function of other subcortical neurons. PD usually causes the patients' movement function disorder, starting from tremors of one side body or activity clumsy, and further involves the contralateral limb [1, 2]. Clinical manifestations

* Corresponding author. Tel.: +86-010-6322-4781;
E-mail address: hejie@ustb.edu.cn;

Selection and peer-review under responsibility of the scientific committee of the 2017 International Conference on Identification, Information and Knowledge in the Internet of Things (IIKI2017).
10.1016/j.procs.2018.03.038

of Parkinson's disease are mainly for static tremor, bradykinesia, myotonia and freezing of gait (FOG). Among them, FOG is a kind of typical symptom. The patient is not easy to maintain the balance of the body, and is likely to fall on the road surface with even a bit uneven. Its typical symptoms are loss of ability to walk in a sudden, feet stuck on the ground and disable to move in a few minutes or no longer to move again. FOG seems to be common in the start period of walking, turning, moving close to the target or when one is worried whether he is able to get through the known obstacles, e.g., getting through the revolving door. Every year, fall incidence rates range from 50% to 70%, and it's one of the main reasons for being disability to PD patients [1-8].

For both drug and non-drug therapy methods, the detection and forewarning of FOG are significantly important. Wearable sensors are widely used to realize the real-time detection and alarming of FOG for PD patients. Previous studies usually focus on the fusion of sensors like baroceptor, IMU, etc. They capture the sensor signals when PD patients in activity and do deep analysis of the wavelets, give out alarms before FOG occurs. The research topics about forewarning of FOG based on wearable sensors mainly concentrate on the selection of sensors [5], locations [9] and high effective algorithms [10].

Different from the traditional statistical methods, template matching is a high effective recognition method with both high recognition accuracy and efficiency, which has been applied for physical activity. Muscillo et al. [11] proposed user-dependent templates to target recognition of arm-specific tasks. Likewise, Chen and Shen [12] focused on recognizing activities performed with the right upper limb using a classification framework based on template matching. Stifefmeier et al. [13] proposed an innovative approach consisting of encoding motion data into sequence of finite symbols and performing activity recognition by using string-matching algorithms. However, to the best of our known, no effort has been paid in the real-time detection of FOG.

To summarize, traditional statistical methods for FOG detection have low accuracy and efficiency, and it can hardly meet the requirements for practice real-time applications. Template-matching methods is of high performance advantages, however, it is seldom used in FOG detection. The purpose of this paper was to investigate the use of template matching for the detection of FOG.

2. Template-Matching Methods

Template matching algorithm is an approach for comparing two time sequences in term of both their state and dynamics. Time series can be used for classifying primitive physical activities from data provided by wearable sensors, such as accelerometers. Template Matching is a high-level machine learning technique that identifies the parts on one sample that match a predefined template. Template Matching techniques are flexible and relatively straightforward to use, which makes them one of the most popular methods of subsequence detection.

2.1. Euclidean Distance

Euclidean metric, namely Euclidean distance, is a common adopted definition of distance. It refers to the actual distance between two points in Multidimensional space, or the natural length of vector (namely the distance between this point and the origin point). Respectively, denote $X=[x_1, x_2, ..., x_i, ..., x_m]$ and $Y=[y_1, y_2, ..., y_i, ..., y_n]$ as two temporal sequences. Thus, the distance d_i ($i=0, ..., n-m-1, n<m$) could be calculated from vector X and Y. For the ith sample, the regularized Euclidean distance could be represented as $d_i=\sqrt{\sum_{k=1}^{m}(Y(i+k)-X(k))^2}$.

2.2. Dynamic Time Wrapping (DTW)

In daily life, there is no doubt that Euclidean distance is the most frequently used distance measuring method. However, for some special applications, Euclidean distance is of obvious defects, especially temporal sequence with different length. DTW could be used to measure the similarity or distance of these two sequences. The core of DTW is based on the idea of dynamic programming, automatically searching for the optimal path with local optimization method. Taking the minimum accumulation of distortion between two vectors as the objective, could avoid errors caused by different time length.