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RECOGNITION SYSTEM OF HUMAN PHYSICAL ACTIVITY BASED ON TIME-FREQUENCY FEATURES OF SENSOR DATA

Abstract

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INTRODUCTION

Human activity recognition has always been a popular research field, which can provide the most important guarantee for the development of medical assistance [1], smart home, safe driving, human-computer interaction[2], health management [3] and other fields. In 1990, Forste's research [4] proposed to use inertial sensors such as three-axis accelerometers to collect behavior data and use classification algorithms to identify human activities, indicating the reliability of wearable sensor-based human activity recognition technology.

The accuracy of human activity recognition methods largely depends on the extraction and selection of features.

Vijay Bhaskar Semwal[5] proposed an optimized feature selection using bio-geography optimization technique and spatio-temporal features for human walking activities recognition. They have explored six machine learning algorithms for the classification of gait activities, namely, Support Vector Machine (SVM), K-nearest neighbor(kNN), random forest(RF), decision tree(DT), gradient boosting(GB), and extra tree classifier(ET). All these algorithms have been tested rigorously and achieve high accuracy of 91.64% in RF, 90.14% in SVM, 82.6% in kNN, 86.51% in DT, 88.34% in ET and 89.96% in GB respectively on HAG datasets.

Buber and Guvensan[6] combined 15 time features with k-NN and performed the best with a recognition rate of 94% based on smartphone accelerometer data.

Chen[7] proposed an LSTM-based feature extraction method to recognize human activities using tri-axial accelerometers data. They used LSTM units to construct two-layer LSTM networks, using a sliding window of length 50(2.5s) for data segmentation, and achieved 92.1% accuracy on the WISDM dataset.

Ignatov[8] presented a user-independent deep learning-based approach for online human activity classification and proposed the use of convolutional neural networks for local feature extraction together with simple statistical features that preserve information about the global form of time series. As a result, a recognition rate of 93.3% was achieved on the WISDM dataset .

Most of the features used in HAR research are time domain features, frequency domain features or non-manual features. Non-manual features use the model to compute the desired signal features. Non-manual features have no logic, and if something goes wrong, there is no way to find a solution to it. The environment in which the human body moves is usually complex, so the vibration signal measured by the accelerometer usually has non-stationary and time-varying characteristics. The traditional statistical features in the time domain or frequency domain usually describe the running state of the human body in a certain motion,

but it is impossible to observe the frequency information of the non-stationary vibration signal changing with time, and the local analysis of the vibration signal cannot be performed, that is, time resolution and frequency resolution are low.

Therefore, In this work, we propose an method to extract time-frequency features based on wavelet transform. And we use a variety of classification methods to evaluate the performance of the approach.

GENERAL DESCRIPTION OF WORK

Relevance of the subject

The work corresponds to paragraph 1 «Digital information and communication and interdisciplinary technologies based on them» of the State Program of innovative development of the Republic of Belarus for 2021-2025. The work was carried out in the educational institution Belarusian State University of Informatics and Radioelectronics.

The aim and tasks of the work

The aim of the work is to improve performance of human activities recognition algorithm based on time-frequency features of accelerometer smartphone data.

To achieve this aim, the following tasks were solved in the dissertation:

1 Collection and preprocessing of the acceleration smartphone data .

2 Extraction and selection of the time-frequency features from the acceleration data based on the discrete wavelet transform and principal component analysis.

3 Choice of classification model are implemented by means of training, testing and evaluating of the different classifiers with using ACC sensor data set .

Personal contribution of the author

With the development of Micro-Electro-Mechanical System, wearable sensor-based human activity recognition systems have important applications in various fields such as health management, motion analysis, military and industry. In this thesis, we propose a time-frequency features extraction method based on wavelet transform, which extracts 5 time-frequency features, namely wavelet entropy, wavelet energy, wavelet waveform length, wavelet coefficient variance and wavelet coefficient standard deviation. The experimental results are evaluated on the publicly available benchmark WISDM dataset including accelerometer data. Our model achieves 99.2%, 99.1% and 95.6% test accuracy on Subspace kNN, Bagged tree and Gaussian SVM respectively.

Author's publications

According to the results of the research presented in the dissertation, 4 author's works was published, including: 4 articles and abstracts in conference proceedings.

Structure and size of the work

The dissertation work consists of introduction, general description of the work, four chapters with conclusions for each chapter, conclusion, bibliography, eight appendixes.

The total amount of the thesis is 81 pages, of which 39 pages of text, 40 Figures on 12 pages, 10 tables on 8 pages, a list of used bibliographic sources (38 titles on 3 pages), a list of the author's publications on the subject of the thesis (4 titles on 1 pages), code appendixes on 5 pages, graphic material on 13 pages.

Plagiarism

An examination of the dissertation «Recognition System Of Human Physical Activity Based On Time-frequency Features Of Sensor Data» by Xia Yiwei was carried out for the correctness of the use of borrowed materials using the network resource «Antiplagiat» (access address: https://antiplagiat.ru) in the on-line mode 29.03.2021. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 98.07 %)

SUMMARY OF WORK

The **introduction** address the problems of recognition system of human physical activity based on time-frequency features of sensor data.

The **general description of work** shows the connection between the work and the priority areas of scientific research, the aim and tasks of the research, the personal contribution of the applicant for a scientific degree, the approbation of the dissertation results.

In the first chapter, it briefly introduces the general process of the human behavior recognition model, and introduces in detail the acquisition of acceleration data using mobile phones and matlab software, the preprocessing of ACC data and the segmentation of ACC data

In the second chapter, it mainly proposes a time-frequency feature extraction method based on wavelet transform. 75 features were extracted by wavelet transform, and dimensionality reduction was carried out by PCA method, and the

10 features with the largest variance were retained. Finally, the kNN classification algorithm is introduced.

In the third chapter, it introduces the three major indicators for evaluating the model, including sensitivity, precision , and F1-score., and then introduces the experimental effects of different algorithms on different datasets, including WISDM dataset, HAPT dataset and Mobiact dataset. Finally, a comparison is made with other international research results.

CONCLUSION

The main achievements of the thesis are：

1 Research on data acquisition and processing method of raw acceleration sensor, the designed data acquisition process collects the acceleration sensor data of various actions such as basic actions through the software, and realizes the filtering denoising and fragment segmentation.The ACC data preprocessing process was implemented using a fourth-order BLP filter to enable the denoising of the ACC signal.Fixed sliding window was used to segment the ACC data,the window length of Acc signal is equal to 256 time samples and the overlap of the window is equal to 50%.

2 Complete the time and frequency feature extraction and screening of the acceleration sensor data. On the basis of the wavelet method, the wavelet db6 is used as the wavelet base, and the acquired signal is decomposed by 4-level wavelet, so as to obtain the time-frequency characteristic of the signal. The time-frequency features extracted in this thesis include wavelet energy entropy, wavelet energy, wavelet coefficient variance, small wavelength and wavelet coefficient. And the ACC signal has three axes, so there are 75 features.

3 The environment in which the human body moves is usually complex, so the vibration signal measured by the accelerometer usually has non-stationary and time-varying characteristics. The traditional statistical features in the time domain or frequency domain usually describe the running state of the human body in a certain motion, but it is impossible to observe the frequency information of the non-stationary vibration signal changing with time, and the local analysis of the vibration signal cannot be performed, that is, time resolution and frequency resolution are low.The advantages of wavelet transform are as follows:

a) Wavelet transform not only has the nature of frequency analysis, but also can represent the time of occurrence, which is beneficial to analyze and determine the phenomenon of occurrence of time (compared to Fourier transform only has the nature of frequency analysis).

b) The multi-resolution transformation of wavelet transform is beneficial to the extraction of different features of each resolution (image compression, edge extraction, noise filtering, etc.).

c) The wavelet transform is an order of magnitude faster than the fast Fourier transform.

d) For the mutation signal, at the mutation time point, the Fourier transform needs to use a large number of triangle waves to fit (Gibbs effect). The wavelet transform is not 0 at the sudden change, and the correlation coefficients of other regions are 0, which saves a lot of storage space.

4 Based on time-frequency features, this paper completes the behavior recognition research of different algorithms on three datasets. The results show that the subspace kNN is the most suitable for WISDM, and its test accuracy can reach 99.2%. In the HAPT dataset, the trained model for labeled trees is the best with 98.2% test accuracy, while weighted kNN is the best model for Mobiact with 99.8% test accuracy. These three modes are basically able to identify basic daily behaviors. The focus is on comparing the effects of the weighted KNN algorithm on three public datasets.On the WISDM dataset, the weighted kNN (k=10) achieves 96.2% test accuracy, 90.9% average F1 score, 98.55% average precision and 86.8% average sensitivity .On the HAPT dataset,the weighted kNN (k=10) achieves 97.7% test accuracy, 97.9% average F1 score, 97.8% average precision and 98.1% average sensitivity .On the MobiAct dataset, the weighted kNN (k=10) achieves 99.8% test accuracy, 97.4% average F1 score, 97.0% average precision and 97.8% average sensitivity .In summary, the weighted knn algorithm has the best model effect on the MobiAct dataset, followed by the model effect on the HAPT dataset, and the worst model effect on the WISDM dataset. Because the sampling frequency on the MobiAct dataset is the highest, 80hz. The sampling frequency of the HAPT dataset is 50hz, and the sampling frequency of the WISDM dataset is only 10hz. The sampling frequency of acceleration data seriously affects the fidelity of time-frequency features.

Future work：

Human activity recognition technology has a wide range of application value and good research significance. Further research work in the future can include:

1 Increase the types and placement of wearable sensors. In this way, we can obtain various types of sensor action signals at multiple positions of the body, collect human behavior information more comprehensively, and further improve the recognition accuracy. Increase the type of recognition action. It can increase the recognition of some excessive actions, such as sitting on the stand, standing back and waiting, and can also add some complex behaviors composed of multiple

basic movements in daily life, such as sweeping the floor, washing dishes, playing basketball and so on.

2 Further analyze the time-frequency characteristics, and explore the influence of the number of different wavelets, different wavelets decomposition layers, and the statistical characteristics of different wavelets on the accuracy of action recognition. The sampling frequency of the data set can also be increased, because wavelet analysis is the response frequency. Increasing the sampling frequency can collect the frequency information of human motion more comprehensively, so as to collect better wavelet characteristics.

List of authors publications

1-A. Xia Yiwei. Recognition System Of Human Activities Based On Time-Frequency Features Of Accelerometer Data / Xia Yiwei, Ma Jun, Yu Chuyue, Ren Xunhuan, Boriskevich Anatoliy Antonovich // The fifth edition of the IEEE International Conference on Intelligent Systems and Computer Vision 2022 (in publish).

2-A. Ma Jun. Framework for Estimating Distance and Detecting Object on Mono-camera / Ma Jun, Yu Chuyue, Xia Yiwei, Ren Xunhuan, Boriskevich Anatoliy Antonovich // The fifth edition of the IEEE International Conference on Intelligent Systems and Computer Vision 2022 (in publish).

3-A Yu Chuyue. Design of school bell automatic control system based on single-chip microcomputer / Yu Chuyue, Xia Yiwei, Du Zongqi, Liu Zhenghua// Телекоммуникации: сети и технологии, алгебраическое кодирование и безопасность данных : материалы Международного научно-технического семинара (Минск, ноябрь – декабрь 2021 г.) Telecommunications: Networks and Technologies, Algebraic Coding and Data Security – Минск : БГУИР, 2021. – pp. 69-71

4-A Yu Chuyue. Design Of Smart Code Lock / Yu Chuyue, Xia Yiwei, Zhao di, Hu Zhifeng // Телекоммуникации: сети и технологии, алгебраическое кодирование и безопасность данных : материалы Международного научно-технического семинара (Минск, ноябрь – декабрь 2021 г.) Telecommunications: Networks and Technologies, Algebraic Coding and Data Security – Минск : БГУИР, 2021. – pp. 72-74.