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DEEP LEARNING FRAMEWORK FOR ACTIVITY RECOGNITION BASED ON SMARTPHONE ACCLERATION DATA, CONVOLUTIONAL NEURAL NETWORK AND LONG SHORT TIME MEMORY

Abstract
for a Master's Degree
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INTRODUCTION

In recent years, the research of Human Activity Recognition (HAR) technology based on human-computer interaction system has attracted a high attention [1-2]. Human behavior recognition is an important part of pervasive computing and can be widely used in areas including medical services for the elderly, intelligent environments, and internet security. With the development of sensor technology and micro processing technology, a variety of micro sensors are embedded in communication devices, which brings great convenience to human behavior recognition systems based on communication devices. Portable smartphones not only have computing and communication capabilities, but also have a large audience as a developable and programmable device that can distribute self-written applications. Today's smart devices offer great convenience to human life. Human activity recognition based on the built-in sensor information of cell phones enables physiological feedback and effective health protection for people, contributing to the realization of active and healthy aging, providing numerous services such as health detection, sports tracking, and elderly monitoring for human beings.

Human activity recognition is an important area of research in human behavior analysis and human-computer interaction. Research in these areas uses different machine learning algorithms to recognize people's daily activities, such as walking, running, etc. Most of the activity recognition is done using machine learning algorithms for differentiation operations, and with the advent of big data, the manual extraction of feature engineering often becomes a disadvantage for machine learning algorithms. How to use smartphone sensor information to distinguish different human activities and improve the accuracy has become a hot and difficult issue need to be solved.

The aim of this thesis is to Improve the accuracy of the CNN-LSTM hybrid algorithm proposed in this thesis for human activity recognition.

The research content of this thesis is divided into three parts, the first part of the data analysis and noise reduction of the UCI-HAR dataset, the second part of the analysis of existing deep learning algorithms, while proposing a hybrid CNN-LSTM algorithm model to distinguish human activities, through continuous training, so that the accuracy of the algorithm continues to improve. In the third part, the model is evaluated, and the system is implemented, and the model proposed in this paper is compared with other human activity recognition algorithms. The experimental results show that the model proposed in this thesis

can improve the quality of human behavior recognition, with higher accuracy in a variety of settings, and good adaptability.

The aim of the work is to increase recognition accuracy of different human activities using the acceleration sensor data from the smartphone and deep learning.

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

1 Data collection on different human activities by using smartphones.

2 Pre-processing algorithm of the acquired dataset of accelerometer sensor.

3 Human activity recognition algorithm based on hybrid CNN-LSTM neural network model.

4 Evaluation of Human activity recognition algorithm performance using confusion matrix and accuracy.

GENERAL DESCRIPTION OF WORK

Relevance of the subject

The work corresponds to paragraph 1 «Digital information and communication and interdisciplinary technologies, production 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 within the framework of research work 21-2033 "Processing, coding and transmission of information in network-centric systems".

The aim and tasks of the work

The aim of the work is to increase recognition accuracy of different human activities using the acceleration sensor data from the smartphone and hybrid deep learning.

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

1 Choice and analysis of dataset with the different human physical activity types.

2 Pre-processing of the smartphone sensor data.

3 Human activity recognition algorithm based on CNN-LSTM neural network.

4 Evaluation of the recognition algorithm performance using confusion matrix and classification accuracy.

Personal contribution of the author

The content of the dissertation reflects the personal contribution of the author.

1 Preprocessing and temporal feature extraction of acceleration sensor data in public datasets.

2 Construction and implementation of algorithm structure.

3 Evaluate the results of the proposed CNN-LSTM hybrid algorithm.

Task setting and discussion of the results were carried out together with the supervisor, Associate professor, Boriskevich Ilya.

Testing and implementation of results

The main provisions and results of the dissertation work were reported and discussed at:

1 Yang, Z. X. Human physical activity recognition algorithm based on smartphone data and long short time memory neural network / Z. Y.Chen, Z. X. Yang, H. Li // BIG DATA и анализ высокого уровня = BIG DATA and Advanced Analytics : сборник научных статей IX Международной научно–практической конференции, Минск, 17–18 мая 2023 г. : в 2 ч. Ч. 1 / Белорусский государственный университет информатики и радиоэлектроники ; редкол.: В. А. Богуш [и др.]. – Минск, 2023. – С. 21–28.

2 Yang, Z. X. Human physical activity recognition algorithm based on smartphone data convolutional nerual netwoek and long short time memory / Z. X. Yang, Z. Y.Chen // Международный научно–технический семинар «Технологии передачи и обработки информации»г. Минск, март – апрель 2023 г. / Белорусский государственный университет информатики и радиоэлектроники ; редкол.: В.В. Чепикова [и др.]. – Минск, 2023. – С. 102–107.

The results of the thesis are used in scientific and technical products of Belarusian State University of Informatics and Radioelectronics.

Author’s publications

According to the results of the research presented in the dissertation, 2 author’s works was published, including: 2 articles in scientific journals recommended by the Higher Attestation Commission, with a total amount of 15 author’s pages.

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 64 pages, of which 46 pages of text, 29 figures on 4 pages, 11 tables on 3 pages, a list of used bibliographic sources (21 titles on 2 pages), a list of the author's publications on the subject of the thesis (2 titles on 1 page), 1 appendix on 6 pages, graphic material on 9 pages.

Plagiarism

An examination of the dissertation « Human physical activity recognition algorithm based on smartphone data convolutional neural network and long short time memory» by Yang Zixiao was carried out for the correctness of the use of borrowed materials using the network resource «Antiplagiat» (access address: https://antiplagiat.ru) in the online mode 31.05.2023. As a result of the verification, the correctness of the use of borrowed materials was established (the originality of the thesis is 84.88%).

SUMMARY OF WORK

The **introduction** addresses the problems of improving the accuracy of human activity recognition, and the applications of human activity recognition in different fields and some problems of human activity recognition any are pointed out, and the basic information of the CNN-LSTM algorithm proposed in this thesis is introduced.

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**, we reviewed the current state of research in the field of human activity recognition (HAR), compared the advantages and disadvantages of machine learning and deep learning in HAR. We proposed algorithm for processing accelerometer data based on using of window segmentation, smoothing filtering, and data normalization. It is set that the optimal parameters of accelerometer data processing algorithm are window size 128 samples, frequency sampling 50 Hz, window overlap 50%, moving average filtering (window length = 10 samples).

In the **second chapter**, the proposed algorithm is based on combining one-dimensional CNN-LSTM neural network model for 6 physical activity classes recognition. Algorithm allows one to extract deep features vector from the input accelerometer data using the three-layer convolutional neural network, and the short and long dependencies between the deep features by means of the LSTM neural network. It is defined that three-layer convolutional neural network contains the following parameters:

– model parameters: weight coefficients of first convolution layer (64), the bias of the first convolution layer (64), weight coefficients of second convolution layer (20480), the bias of the second convolution layer (64), weight coefficients of third convolution layer (20480), the bias of the third convolution layer (64).

– hyperparameters: for the first convolution layer, the input channel (1), the output channel (64), kernel size (5), the stride (2). For the second convolution layer, the input channel (64), the output channel (64), kernel size (5), the stride (2). For the third convolution layer, the input channel (64), the output channel (64), kernel size (5), the stride (2).

It is set that LSTM neural network contains the following parameters:

– model parameters: the input tensor shape (100,64), LSTM units is 128, Output tensor shape (100,128).

– hyperparameters: the hidden layer (3), hidden unit size (128), learning rate (0.001), dropout (0.9).

It is set that full-connected layer contains the following parameters:

– model parameters: the weight matrix [128,6], the bias is [6].

– hyperparameters: the number of neurons in the fully connected layer is 1000.

It is set that deep feature vector length in output CNN is equal to 64, the deep feature vector length in output LSTM is equal to 128, it is defined that deep probability value vector length in output fully connected layer is equal to 6.

In the **third chapter**, the confusion matrix and accuracy rate are used to evaluate the proposed hybrid CNN-LSTM recognition algorithm accuracy. In the training set, the recognition accuracy of our proposed hybrid CNN-LSTM algorithm for six different human activities in the training set: laying is 100 %, walking is 99 %, walking upstairs is 92 %, walking downstairs is 84 %, sitting is 95 %, and standing is 90 %, and the average accuracy is: 94.00%. We have compared several famous LSTM algorithms with our proposed hybrid model algorithm, among which the accuracy of Bidirectional LSTM algorithm is 92.67%, Res-LSTM accuracy is 91.60%, and Baseline LSTM algorithm accuracy is 90.80%, the accuracy of hybrid CNN-LSTM algorithm proposed is 94.00% which has the best performance in the same dataset.

CONCLUSION

1 With the rapid expansion of the smartphone market and the rapid development of micro-sensors, human activity recognition become one of the most important research fields of the real world. In this master thesis, we propose a human activity recognition algorithm based on CNN and LSTM, which can identify six different human activities, including Laying, Walking, Walking upstairs, Walking downstairs, Sitting, and Standing.

2 In this master's thesis, the accelerator which build into the smartphone is used to obtain the original human activity signals. The sampling rate was set to 50Hz, as for the sliding window (128 samples/window) with 2.56 second and 50% overlap was selected, the moving average filtering (window length = 10 samples). We use the time series data as the input, and the data are preprocessed, feature extraction, model establishment and training on Python.

3 The algorithm proposed in this master's thesis is based on combining CNN-LSTM neural network for 6 physical activity classes recognition. We propose an algorithm that leverages a three-layer convolutional neural network to extract deep feature vectors from the input accelerometer data. Then, we use a long short-term memory (LSTM) neural network to capture the short and long-term dependencies among the deep features. It is defined that deep feature vector length in output CNN is equal to 64, the deep feature vector length in output LSTM is equal to 128, it is defined that deep feature vector length in output fully connected layer is equal to 6.

4 The evaluation of the results showed that the average recognition accuracy of our proposed CNN-LSTM hybrid algorithm for six different human activities can reach 94.00%. Among them: laying is 100 %, walking is 99 %, walking upstairs is 92 %, walking downstairs is 84 %, sitting is 95 %, and standing is 90 %. At the same time, to evaluate the performance of our proposed hybrid model algorithm, we conducted experiments with several well-known LSTM algorithms as baselines. The results show that our algorithm outperforms Bidirectional LSTM (92.67% accuracy), Res-LSTM (91.60% accuracy), and Baseline LSTM (90.80% accuracy).

LIST OF AUTHOR'S PUBLICATIONS

1 Yang, Z. X. Human physical activity recognition algorithm based on smartphone data and long short time memory neural network / Z. Y.Chen, Z. X. Yang, H. Li // BIG DATA и анализ высокого уровня = BIG DATA and Advanced Analytics : сборник научных статей IX Международной научно–практической конференции, Минск, 17–18 мая 2023 г. : в 2 ч. Ч. 1 / Белорусский государственный университет информатики и радиоэлектроники ; редкол.: В. А. Богуш [и др.]. – Минск, 2023. – С. 21–28.

2 Yang, Z. X. Human physical activity recognition algorithm based on smartphone data convolutional nerual netwoek and long short time memory / Z. X. Yang, Z. Y.Chen // Международный научно–технический семинар «Технологии передачи и обработки информации»г. Минск, март – апрель 2023 г. / Белорусский государственный университет информатики и радиоэлектроники ; редкол.: В.В. Чепикова [и др.]. – Минск, 2023. – С. 102–107.