

Fall Detection Method Based on Convolutional Neural Network

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Abstract: With the improvement of people's living standards and social medical conditions, the average life expectancy is gradually lengthening, and the proportion of the elderly in the global population is also growing. China is a big country with a large population, and the problem of population aging is becoming increasingly prominent and severe. When elderly people live alone at home without others to care for them, falls become the most common and dangerous phenomenon due to the decline of physical function and the influence of certain diseases. Therefore, rapid, efficient and accurate identification and judgment of human falls are of great significance, which can effectively alleviate the threat to the life and health of the elderly and the social medical burden of falls. This paper mainly carried out a fall detection method based on convolutional neural networks, aiming to improve the accuracy of human fall detection through the natural advantages of convolutional neural networks in image recognition, and provide better solutions for medical monitoring and elderly care.

Keywords: Fall detection, Inertial sensor, Convolutional neural network.

1. Introduction

The At a time when the quality of personal life and the level of social health care have been greatly improved, the most prominent problem brought about by the continuous rise in global average life expectancy is that the proportion of older people in the global population is becoming more and more heavy. The elderly are affected by the decline of physical function and disease factors, making fall a very common but extremely dangerous phenomenon, and the incalculable treatment cost brings a greater economic burden to the family and society. This paper mainly studies the methods and systems of fall detection based on convolutional neural networks, aiming to improve the accuracy of human fall detection through the natural advantages of convolutional neural networks in image recognition, and provide better solutions for medical monitoring and elderly care. According to different implementation methods, fall detection technology can be roughly divided into the following three types^[1]: fall detection technology based on visual information^[2], fall detection technology based on scene perception^[3], and fall detection technology based on portable.

2. Research on Theoretical Methods of Fall Detection

2.1. Posture of daily activities

Daily activity posture refers to the common behavior posture that the human body does not harm itself in life, which can generally be divided into the following categories: static state, normal walking, bending action, squat action, running action, jumping movement, etc. At the same time, there are some less common actions in life, but because some of the physical characteristics are similar to the fall action, it will also cause interference to fall detection and recognition, such as sitting or lying down slowly leaning against an object. The above daily activity posture can be divided into intense action and ordinary action according to the intensity of the action. How to accurately extract and judge the fall movement in the various and complex daily activities of the human body is the

focus of this paper. The movement of falling is inevitably violent, so it is relatively easy to identify the difference between falling and stationary, normal walking and other ordinary movements. What needs to be explored is the difference between violent movements and falls in daily life and make an accurate judgment.

2.2. Fall movement posture

The definition of the fall action has been explained above, but there are many types of causes for falls, which can be basically divided into internal causes and external causes. The internal reasons mainly refer to the different physical qualities and psychological conditions of different individuals. Especially for the elderly, the influence of aging or disease can lead to weakened muscle strength and decreased nerve responsiveness, which further makes the elderly too late or unable to make appropriate behavioral responses when dealing with emergencies and fall. For the elderly group, the physical condition of the internal cause is the most important cause of fall. On the other hand, the psychological condition of the human body can also lead to unconscious falls. The types of external causes of falls are also very complex, and the main sources are the influence of the behavioral environment at that time, such as the slippery ground and the existence of not obvious obstacles in the road.

When the body falls, from the initial state to the final state of lying on the ground, although the process takes a very short time, it can still be divided into four stages: the initial stage, the weightless stage, the impact stage, and the recovery stage. Initial stage: The human body is in a relatively stable or static state before falling, and this stage coincides with the above daily behavior activities. Weightlessness stage: Due to the influence of internal or external factors, weightlessness will occur in a very short period of time, if there is no external force, it can be approximately regarded as a short free fall movement. Impact stage: This stage is the stage in the fall that causes the main injury. After a short period of weightlessness, without the support of the object and the loss of the center of gravity, the human body hits the ground to form a moment of overweight, which will cause unpredictable damage to the

human body, especially the elderly may have a fatal impact. Recovery stage: Affected by the severity of the impact stage and the difference in human physical fitness, some recovery stages are very short, and can be supported to stand up on the spot to recover to the initial stage. If the impact is severe, some recovery processes may take a long time or even fainting on the ground.

2.3. Common detection algorithms

K-nearest neighbor algorithm is a supervised learning classification algorithm proposed by Cover and Hart in 1953. It is one of the highly efficient and easy to understand algorithms commonly used in text classification, image recognition, character detection and other fields in machine learning. The core idea of the algorithm is: a sample point is compared with the nearest K samples around it, and the distance between the sample and K samples is usually calculated according to mathematical principles. If a category accounts for a majority of the K samples, the sample under test is also assigned to that category.

Support vector machines were first proposed in 1963, proposed by Corinna and Vapnik in 1993 and published in their current version (soft margin) in 1995. SVM is considered to be one of the best algorithms in recent decades before the advent of deep learning algorithms due to its excellent performance. SVM is a very common and efficient supervised learning model, especially in the field of binary classification applications. The basic principle is to map the feature data to the data points in the space, and through data training and calculation to find a line or hyperplane to optimally distinguish the data into two categories, so that the line or hyperplane can also make a good distinction to the newly emerged data points.

Logistic regression has become one of the most commonly used algorithms in machine learning due to its superior performance. Although it carries the word "regression", it is a classification method. Logistic Regression is commonly used in epidemiology and other medical diagnosis, such as studying the risk factors of certain diseases and predicting the probability of disease occurrence based on risk factors. Therefore, logistic regression can also be applied to the binary task of fall detection and judgment. The main process of logistic regression is as follows: similar to linear regression, first determine the required prediction function, that is, the appropriate classification function; Then the Cost function is constructed to calculate the deviation between the predicted output (h) and the class (y) of the training data, and the loss value of all the training data is recorded as the $J(\theta)$ function. Because the smaller the value of $J(\theta)$ function, the higher the accuracy of classification prediction, the minimum value of $J(\theta)$ function is obtained by optimizing the parameters of the function.

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3.1. Three-axis attitude data processing

In order to facilitate the unified processing and comparison between the open data set and the self-tested data set, the data need to be segmented and normalized. Because the fall is a short action, its occurrence time is often no more than 2 seconds, so the data in the database every 2 seconds to intercept the data characteristics of the human body. The selected open data set and self-test database are collected at a

frequency of 100 Hz, so 200 triaxial acceleration values and 200 triaxial angular velocity values will be intercepted every 2 seconds, and each triaxial data contains data in the three directions of x, y and z axes. Therefore, the total amount of data intercepted in 2 seconds is $2 \times 100 \times 3 \times 2$, a total of 1200 data.

This research innovatively maps the data in the x, y and z axes into the RGB gamut map[4], making full use of the natural advantages of convolutional neural networks in image processing and the correspondence between information elements. Therefore, after the above data segmentation is completed, 200 acceleration values and 200 angular velocity values collected by the X-axis are arranged into a pixel matrix form, and the first 200 are acceleration values, that is, (0,0) to (9,19) are acceleration values of the X-axis. The last 200 are angular velocity values, i.e. (10,0) to (19,19) are angular velocity values for the x axis, and the y and z axis data are operated similarly.

3.2. Convolutional network design for fall detection

As can be seen from the RGB gamut diagram of falls and other daily behavior activities mentioned above, falls are obviously different from other activities, which is an important basis and basis for this study to adopt convolutional neural networks for fall recognition and classification[5]. In order to ensure the accuracy and speed of fall detection, a lightweight fall recognition algorithm based on convolutional neural network, FR-CNN algorithm, is designed in this paper. The network frame of FR-CNN consists of two convolutional layers, two pooling layers, and two fully connected layers.

Select the data required for the experiment in the SisFall and MobiFall public datasets. Since this study did not distinguish between forward and backward fall types, 1000 groups of daily behavior activity data and 500 groups of fall behavior data were selected from SisFall and MobiFall, totaling 3000 groups of data, and labeled respectively for convenient classification.

Select 80% of the total data as the training set and 20% as the test set. That is, 2400 sets of data were used for the training of parameter optimization of each layer of the model, and 600 sets of data were used to evaluate the performance of the fall recognition model. In this paper, the fall recognition algorithm FR-CNN independently built under the TensorFlow architecture was adopted. The parameters of model training were set as follows: batch size was 32, learning rate was 0.001, and the number of training steps was 10000.

In order to scientifically compare with other fall detection methods, the FR-CNN network was trained on a public data set in this experiment. As shown in the table, the accuracy, sensitivity and specificity indexes of FR-CNN reached 98.48%, 98.55% and 99.70%, respectively. Under the premise of processing the same data set, FR-CNN, Random Forest[6], Decision Tree[7] and other algorithms have the highest accuracy, sensitivity, specificity and other key evaluation indicators of fall recognition. The accuracy was 18.88% higher than that of the lowest SMO, the sensitivity 17.43% higher than that of the lowest Decision Tree, and the specificity 3.58% higher than that of the lowest SMO. The results show that this method has great advantages in fall detection and recognition and can meet the needs of medical monitoring.

4. Conclusion

At a time when the quality of personal life and the level of social health care have been greatly improved, the most prominent problem brought about by the continuous rise in global average life expectancy is that the proportion of older people in the global population is becoming more and more heavy. The elderly are affected by the decline of physical function and disease factors, making fall a very common but extremely dangerous phenomenon, and the incalculable treatment cost brings a greater economic burden to the family and society. This paper mainly studies the methods and systems of fall detection based on convolutional neural networks, aiming to improve the accuracy of human fall detection through the natural advantages of convolutional neural networks in image recognition, and provide better solutions for medical monitoring and elderly care. The main research contents of this paper are summarized as follows:

By summarizing and analyzing the relevant techniques of human fall detection in domestic and foreign literatures, the realistic background and significance of the current research are analyzed. Different detection technologies and methods are classified and compared. In order to realize portability and privacy, the fall detection technology based on inertial sensor is selected.

Aiming at the confirmed fall detection technology, a research algorithm based on convolutional neural network is proposed by comparing the advantages and disadvantages of the theoretical analysis of human posture and the commonly used detection algorithms such as K-nearest neighbor, support vector machine and logistic regression. The innovative normalization of three-axis attitude data is mapped to 0-255 RGB color gamut maps. A lightweight fall recognition algorithm based on convolutional neural network, FR-CNN algorithm, is designed. It consists of two convolution layers, two pooling layers, and two fully connected layers. Compared

with Random Forest, Decision Tree, SMO, Naive Bayes, Bayes Net, Bagging and other methods, the accuracy, sensitivity, specificity and other evaluation indexes are higher than other algorithms. The results show the advantages of this method in fall detection and recognition, which can better meet the needs of medical monitoring, and also provide a reliable algorithm basis for human fall detection and alarm system.

References

- [1] PANNURAT N, THIEMJARUS S, NANTAJEEWARAWAT E. Automatic Fall Monitoring: A Review[J]. *Sensors*, 2014,14(7): 12900-12936.
- [2] MIAO, YU, ADEL, et al. A posture recognition based fall detection system for monitoring an elderly person in a smart home environment[J]. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society*, 2012, 16(6): 1274-1286.
- [3] ZIGEL, YANIV, LITVAK, et al. A Method for Automatic Fall Detection of Elderly People Using Floor Vibrations and Sound Proof of Concept on Human Mimicking Doll Falls[J]. *IEEE Transactions on Biomedical Engineering*, 2009, 56(12):2858-2867.
- [4] Süssstrunk S, Buckley R, Swen S. Standard RGB color spaces[C]// *Color and imaging conference*. Society for Imaging Science and Technology, 1999, 1999(1): 127-134.
- [5] He Jian, Zhang Zihao, Wang Xiaoyi, Yang Shengqi. A Low Power Fall Sensing Technology Based on FD-CNN[J]. *IEEE Sensors Journal*, 2019, 19(13): 5110-5118.
- [6] Lunetta K L, Hayward L B, Segal J, et al. Screening large-scale association study data: exploiting interactions using random forests[J]. *BMC genetics*, 2004, 5(1): 1-13.
- [7] Safavian S R , Landgrebe D . A survey of decision tree classifier methodology[J]. *IEEE Transactions on Systems, Man, and Cybernetics*, 1991, 21(3): 660-674.