Dementia Diagnose Based on Machine Learning Using Doppler Radar Image for the Elderly Person

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Abstract

Dementia often happens in the elderly person, as a disease caused by Parkinson's or Alzheimer's disease, etc. However, to diagnose dementia, the elderly have to go to a hospital to see a doctor, which increases the burden with the increasing age. In this research, we propose a computer-assist method to help diagnose dementia without going to the hospital. In detail, spectrogram images are made from gait data measured by Doppler radar. Then several machine learning methods, including SVM, KNN, Naive Bayes, Decision Tree, Random Forest, and a proposed NN model, are applied to help diagnose dementia. The experimental results have proved the effectiveness of the proposal. The highest accuracy is 82.1% of NN in these models. However, we conclude the Ensemble which has the highest Recall score such as 72.2% is the best for diagnosis assist because the diagnosis assist method requires the least number of misdiagnoses in positive patients.

Keywords

Machine learning, Dementia diagnosis, Doppler radar image, the Elderly person

1. Introduction

Dementia is a disease that is mainly caused by a condition such as Parkinson's disease[1] or Alzheimer's disease[2], etc., in the elderly person. The early diagnosis of the disease is important because the seriousness of dementia leads to difficulty in treatment. However, with the increasing age, going to the hospital and seeing a doctor become a hard burden for an elderly person. Hence, it needs to make a method that realizes easily dementia diagnosis without going to the hospital and seeing a doctor.

This research attempts to diagnose dementia from daily behavior without needing a diagnosis to go to the hospital. Walking is one of the daily behavior, and it is known that gait has human characteristics including health situate. Also, a study by Buracchio et al.[3] has reported that there is a great relationship between gait speed and cognitive abilities because gait requires

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multiple cognitive abilities such as attention, execution, and spatial cognition. Hence, this paper focuses on gait and tries to prove the relationship between gait and dementia. Then, we propose a machine learning assistance method to help with dementia diagnosis.

Currently, researchers apply camera-taken or scanned RGB images for classification which are widely used in industry[4], cultural heritage protection[5], etc. However, the quality of the camera-taken or scanned image deeply influences the classification results. Furthermore, before the classification, the processing should detect the object first. To overcome this problem, some researchers try to use doppler radar to obtain the gait data to help classify by human information. Nojiri et al., apply machine learning methods to help Apathy Diagnose [6, 7] based on doppler radar. Wang et al., apply the deep learning methods to help gender classification based on doppler radar. Hayashi, et al., proposes a machine learning-based classification of human behaviors and falls in restroom [8] based on doppler radar.

From the introduce research knowledge, this paper proposes a dementia diagnosis method based on machine learning using doppler radar images for elderly person. In detail, this paper uses Doppler radar images as gait data and proposes a novel feature extraction method for the Doppler radar images of elderly persons. The models of machine learning for helping dementia diagnosis in this paper are support vector machine(SVM)[9], k-nearest neighbor(KNN)[10], naive bayes[11], decision tree[12], random forest[13], neural network(NN)[14] and ensemble model. The effectiveness of dementia diagnosis using Doppler radar images by machine learning is applied to elderly participants.

2. Related works

MMSE (Mini-Mental State Examination) and RDST (Rapid Dementia Screening Test) are conventional methods that can quantitatively evaluate the severity of dementia. The MMSE is an internationally used dementia screening test that conducts a total of 11 items of cognitive function tests such as orientation of time and place, calculation, and sentence recitation. However, Kalde et al.[15] developed the RDST because it takes too long and is unfamiliar. The RDST is a new test method that meets the ideal dementia screening test conditions [16] such as

- Can be performed in a short time
- Easy to accept without burdening the patient
- Easy to score
- Not significantly affected by culture, language and education
- Between evaluators high reliability and reassessment reliability
- High coexistence validity and predictive validity

The RDST consists of two tasks: language fluency test (VFT) and number conversion task. The RDST-J[1] has the following excellent conditions and has been confirmed to be useful to some extent[17].

- Enforcement and scoring time is as short as 3 to 5 minutes,

[1]Japanese version of RDST

- It does not require any special tools or techniques, so it is easy for non-specialists to get used to.
- Since it is a task close to the daily life scene, it is well accepted from the inspected person.
- Good sensitivity and specificity

For these works, research on dementia diagnosis by machine learning using Doppler radar images has not progressed much.

3. Dataset Creation

This section introduces how to create a dataset. The dataset consists of 117 images and labels, and we call it EPDDRI dataset[2].

3.1. How to make Doppler Radar Image

As shown in Fig.1, a Doppler radar is equipped at 0.86 m, which is the height of the body gravity center, and the walking of 10 m toward the radar is measured.

The Doppler radar image shown in Fig.2 is a spectrogram image of the signal data obtained from this measurement using the short-time Fourier transform (STFT).

3.2. How to label

Verbal fluency tests (VFT) is applied for label the dataset. VFT is a kind of psychological test in which participants have to produce as many words as possible from a category in a given time. In this research, the participants have to write as many words as possible from a animal category in two minutes. the words number is used as the score of cognitive ability for labeling. The threshold for non-dementia and dementia is set to 11.

[2]the Elderly Person Dementia Doppler Radar Image dataset

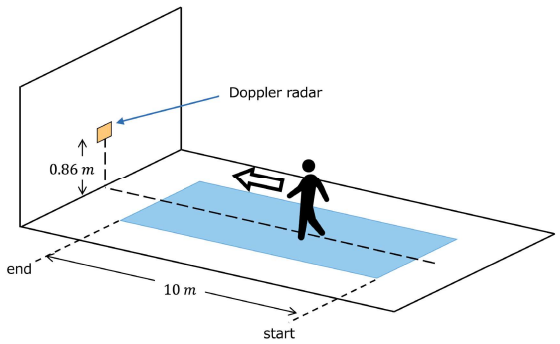

Figure 1: Measurement of walking by Doppler radar

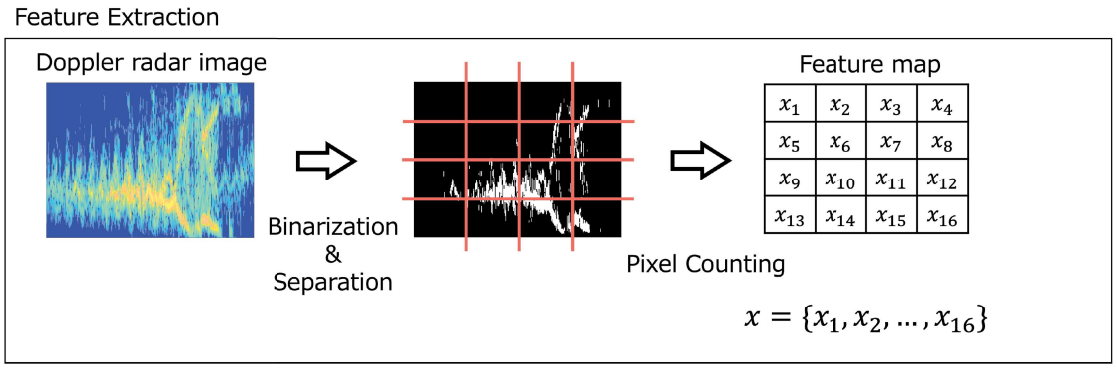

Figure 2: Feature Extraction

4. Dementia Classification for Machine Learning

The proposed dementia classification method is based on machine learning. Features are extracted from the Doppler radar images of the EPDDRI dataset for classification. As shown in Fig.2, features are extracted by image binarization ⟶ region segmentation ⟶ pixel counting. SVM, KNN, Naive Bayes, decision tree, random forest, NN, and ensemble models are used as classifiers.

Support vector machine(SVM)

SVM is a supervised learning model that classifies data by maximizing the margin between a hyperplane (decision boundary) and the nearest training data (support vector). This algorithm is a classification based on linear separability, and non-linear classification is also possible by using the kernel method.

K-nearest neighbor(KNN)

KNN is a classifier that finds the k closest data in the feature space based on a distance measure and gives k majority class labels. This is a basic classifier that does not require a discriminant function.

Naive Bayes

Naive Bayes is a simple method for building a classifier, an algorithm that performs classification by assuming a simple conditional probability model. Naive Bayes uses Bayes' theorem(1) by regarding each feature as independent.

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \tag{1}$$

Decision tree

A decision tree is a tree structure data or diagram created for decision making, classification, discrimination, prediction, etc. The conclusion of the leaf node can be obtained by following the branch according to the conditions of each node.

Random Forest

Random Forest is a decision tree-based algorithm that constructs a model with better generalization performance by averaging multiple decision trees, each with high variance. A random bootstrap sample of size n which selected with replacement and a decision tree is grown using randomly selected explanatory variables. The decision tree is grown by randomly extracting d features without replacement and partitioning the nodes by maximizing (for example) the information gain. After this is repeated k times, the predictions for each decision tree are summarized and classified by assigning class labels based on majority voting.

Neural Network(NN)

NN is a mathematical model that mimics the network structure of neurons in the brain. The model is constructed with multiple layers of interconnected nodes, and is used for pattern recognition, data classification, future prediction, etc. The model proposed in this paper is a five-layer NN as Table1.

Table 1
NN Layers

Layer name	type	nodes	Activation
Input Layer	Fully-connected	16	ReLU
Second Layer	Fully-connected	32	ReLU
Third Layer	Fully-connected	64	ReLU
Fourth Layer	Fully-connected	128	ReLU
Ounput Layer	Fully-connected	1	Sigmoid

Ensemble model

The Ensemble model is a learning model generated by fusing multiple basic models. The basic classifiers used in the ensemble model are KNN, decision trees, random forests, and NN.

5. Experimentation

5.1. Experimental conditions

Python 3.9 is used for programming the feature exaction and machine learning design. Scikit-learn and keras is used as python framework. The hardware environment is that CPU is Intel(R) Core(TM) i7-10700 and Memory is 16GB.

5.2. Accuracy of the Machine Learning Models

Table2 shows the classification Accuracy, Recall, Precision, and F1-score of each model, which are listed in equations (2)-(5).

NN is the best model in terms of Accuracy, Precision, and F1-score. SVM and Naive Bayes are not good at Recall score such as 41.7%. A possible reason why these Recall scores are low

is derived from imbalanced of the EPDDRI dataset. On the other hand, the Accuracy of these models are relatively good because scores of these models for non-dementia are high. Hence, KNN, Decision Tree, Random Forest, and NN are selected as the basic models for Ensemble learning except for SVM and Naive Bayes. The Recall score of Ensemble is 72.2% which is the highest in all proposed models. In addition, Random Forest has some high Recall and other scores are good.

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \tag{2}$$

$$Precision = \frac{TP}{TP + FP} \tag{3}$$

$$Recall = \frac{TP}{TP + FN} \tag{4}$$

$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall} \tag{5}$$

Table 2
Dementia Classification by Machine Learning Models

model	Accuracy	Recall	Precision	F1
SVM	0.752	0.417	0.652	0.508
KNN	0.684	0.611	0.489	0.543
Naive Bayes	0.735	0.417	0.600	0.492
Decision Tree	0.684	0.528	0.487	0.507
Random Forest	0.778	0.639	0.639	0.639
NN	0.821	0.583	0.778	0.667
Ensemble	0.615	0.722	0.426	0.536

5.3. Discussion

Among the machine learning models, the classification accuracy of NN is the best in terms of Accuracy, Precision, and F1-score. However, Recall score is more important than Accuracy and Precision when applying these models to a computer-assist method. The reason is that Recall is a score that indicates how many dementia-positive patients are classified into positive. Hence, the most accurate model as a classifier is NN, and the Ensemble model is suitable for diagnostic assistance. However, Accuracy, Precision and F1 of Ensemble model are weak compared to NN, which should be improved. Accordingly, NN is recommended when Accuracy, Precision and F1 are emphasized, while Ensemble is recommended when Recall is emphasized. It is important to use them properly according to the purpose.

6. Conclusion

This paper propose a dementia diagnosis assist method by machine learning using Doppler radar images of walking. The results show that each model achieve a different good score. When Recall score is important, Ensemble is recommended, while NN is recommended when the score of Accuracy, Precision, F1 is important. This means that it is important to use them properly according to the purpose. A computer-assist of diagnosis requires the least number of misdiagnoses in positive patients, and the Recall score is top priority. Hence, the best model proposed for diagnosis assist is Ensemble model based on KNN, Decision Tree, Random Forest and NN.

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