ISSN: 2664-9640

Classification of Atrial Fibrillation Based on Support Vector Machine

Weifang Xie*, Yun Zou, Zunhuang Cai

Fujian Forestry Vocational & Technical College, Nanping, Fujian, China

Abstract

Abnormal pulse wave is a sign of atrial fibrillation. Aiming at the problems of high noise interference and high data dimension after feature extraction in atrial fibrillation detection, a support vector machine (SVM) method based on multilevel wavelet decomposition was proposed. Atrial fibrillation signals were decomposed by multilevel wavelet to obtain the wavelet coefficients, and then the obtained wavelet coefficients were extracted through nine statistical parameters to obtain the frequency domain features. Finally, the dimensionality reduction detection method based on support vector machine was introduced to realize the detection of atrial fibrillation. In order to reduce the data dimension, simplify the calculation, improve the detection accuracy, and screen out the optimal feature type and the optimal feature set required for AF detection and determine the type of atrial fibrillation. Experiments show that the proposed method can accurately classify the pulse wave, so as to accurately get whether the patient has atrial fibrillation

Keywords

Atrial fibrillation, photoplethysmography, pulse wave, classification.

1. Introduction

With the aging of the population, the incidence of heart disease continues to increase in recent years, a serious threat to people's health worldwide. Atrial Fibrillation (AF), commonly referred to as Atrial Fibrillation for short, is the most common type of heart disease, and is a common persistent arrhythmia. Atrial fibrillation caused by stroke and deterioration of cardiac function is an important cause of disability and death. Among the traditional methods for detecting atrial fibrillation, the most commonly used is Electrocardiography (ECG) collected by Holter and then evaluated by doctors. However, due to the limitations of Holter in detection time, it is easy to cause the missed detection situation of ‘no disease occurred during detection and no detection occurred during detection’[1]. Photo PlethyamoGraphy (PPG) has many advantages such as non-invasive detection, stable performance, safe and reliable, strong adaptability, etc. At the same time, combined with the rise of portable wearable devices in recent years, it is of great significance to use PPG technology to collect atrial fibrillation signals and realize the detection of atrial fibrillation through data-driven method[2].

In actual life, the incidence of atrial fibrillation may be higher, because some patients are likely to miss diagnosis and treatment if the symptoms are not obvious. Therefore, how to accurately detect the occurrence of atrial fibrillation in patients has become a priority. Atrial fibrillation can be classified into three types due to its onset time: paroxysmal AF usually lasts no more than 7 days, and in most cases it can revert spontaneously to Normal sinus rhythm (NSR) within 48 hours; Persistent atrial fibrillation usually lasts for more than 7 days and requires medication or shock to revert to NSR[3]; Permanent atrial fibrillation does not terminate spontaneously or will resume after termination. How to realize the primary screening detection and type determination of atrial fibrillation has become a key problem to be solved.

2. Related work

In recent years, PPG technology has attracted extensive attention from experts and scholars in various medical fields due to its performance advantages in many aspects. In this paper[4], we propose a method for heart rate monitoring using PPG technology in sports activities. This method uses the multi-measurement vector model in sparse signal recovery to jointly estimate the spectrum of PPG signal and simultaneous acceleration signal, which can identify and remove the spikes of motion artifact in PPG signal. Blood perfusion was evaluated by conventional pulse oximeter estimation of arterial oxygen saturation using pulsed AC and continuous DC dual-wavelength PPG signals[5]. Finally, PPG signals were collected from the forearms of 21 healthy volunteers to verify the effectiveness of the method. A new low cost, small size, portable and easy to use blood flow sensor based on PPG technology was developed to evaluate the quality of arteriovenous fistula in hemodialysis patients by non-invasive reflective PPG technology[6].

With the mature application of PPG technology combined with data-driven method in other medical detection, some foreign scholars began to promote this technology to the field of atrial fibrillation detection, in order to make up for the shortcomings in the automatic detection of atrial fibrillation based on ECG technology[7]. A PPG-based acquisition and AF detection algorithm is introduced for smart phones with low computing cost and memory requirements. Finally, the detection is completed by sequential forward selection and Support Vector machine (SVM) [8].

In conclusion, although PPG technology has attracted much attention in recent years, intelligent detection of atrial fibrillation based on PPG technology is still a frontier research direction so far[9]. Foreign scholars are still in the initial stage of research in this field, while domestic research in this field is still a gap.

3. Proposed method

Photoelectric volumetric pulse wave (PPG) technology measures changes in blood flow in the blood vessels due to the heartbeat by irradiating the skin and measuring changes in light absorption or reflection, thereby estimating electrical heart rate signals for AF detection. However, due to the movement of the human body or the relative movement between the skin and the wearable device in the process of signal collection, the collected signal will be mixed with large noise. Therefore, in view of the problems existing in the detection of atrial fibrillation, such as high noise interference of atrial fibrillation signal and high data dimension after feature extraction.

3.1. Principal component analysis - SVM

PCA[10] algorithm can not only be directly used to detect atrial fibrillation, but also PCA is a multivariate statistical method that can transform multiple related features into a few unrelated features in atrial fibrillation data set. In other words, the dimension-reduction processing of high-dimensional features can be carried out under the condition of minimum information loss in atrial fibrillation data as far as possible.

In this article, using PCA - the core of the SVM method to detect atrial fibrillation, is first by PCA projection the high dimension of input data to low dimensional data space, in as far as possible to maximize the selected principal components variance, maximum limit retains the original data feature information and atrial fibrillation under the premise of not related to each other, and then the selected principal components as input data to the SVM[11] classification, in order to reach the purpose of detecting atrial fibrillation.

Assume that the input atrial fibrillation data has the characteristics of m dimensions, $X = \{x_1,\ x_2,\ x_3,\ \dots,\ x_m\}^T$, set$\Gamma_1$as the first principal component of X, it can be expressed as:

$$\Gamma_1 = \omega_1 X = \omega_{1,1}x_1 + \omega_{1,2}x_2 + \cdots + \omega_{1,m}x_m$$

Where,ω_1 is the weight. Because in practice, the usual case is $||\omega_1||$ = 1.

Set ϕ is a vector of covariance matrix, characteristic value of $\delta_1 \geq \delta_2 \geq \cdots \geq \delta_m \geq 0$, then the characteristic vector orthogonal unit $P = (p_1, \ p_2, \ \ldots \ , \ p_m)^T$ satisfy:

$$P^T \phi P = diag((\delta_1, \delta_2, \ldots, \delta_m)$$

Set Γ_2 as the second principal component of X, the second principal components in $||\omega_2||$ = 1. conditions, can be obtained:

$$\mathrm{cov}(\Gamma_2, \Gamma_1) = \omega_2^T \phi p_1 = \delta_1 \omega_2^T p_1$$

Under normal circumstances, the number of principal components is selected by cross test or cumulative contribution rate method. The cumulative contribution rate method means that the selection of the number of principal components should refer to its contribution to the feature set. The greater the contribution rate is, the more information of the original feature carried by the principal component is, and the stronger the ability to explain the original feature is. The contribution rate can be expressed as:

$$\sigma_j = \frac{\delta_j}{\sum_{i=1} \delta_i} \times 100\%$$

The cumulative contribution rate of the first j principal components is:

$$\sigma_{total} = \frac{\sum_{i=1}^{j} \delta_i}{\sum_{i=1} \delta_i} \times 100\%$$

The method of selecting the cumulative contribution rate generally requires several tests to make the cumulative contribution rate of the first J principal components reach a certain proportion (such as 85% or more than 90%). After determining the number of principal components, this part of principal components is used as the input data of SVM for classification.

To sum up, PCA-SVM is an algorithm that obtains the principal components of atrial fibrillation data samples based on PCA transform to reduce the data dimension and eliminate the correlation between the data, and then classifies the principal components obtained through SVM classifier to improve the accuracy of atrial fibrillation detection.

3.2. Classification of atrial fibrillation based on support vector machine

Because the principal components obtained by the PCA-SVM algorithm cannot maintain a one-to-one correspondence relationship with the original features of atrial fibrillation data, and the original features cannot be reconstructed by the obtained principal components. Therefore, the PCA-SVM algorithm cannot explain the physical significance of the obtained principal components in the process of projecting high-dimensional atrial fibrillation data into low-dimensional data space.

In order to solve the problem[12] of high data dimension and large noise interference in the detection of atrial fibrillation, and to find the optimal feature set, a feature extraction method in frequency domain based on multilevel wavelet partition analysis was selected to combine with SVM-RFE. Comparing PCA-SVM and SVM-RFE algorithms, both of them are based on SVM classifier to reduce the dimension of atrial fibrillation data and eliminate the correlation between data to improve the detection accuracy.

ISSN: 2664-9640

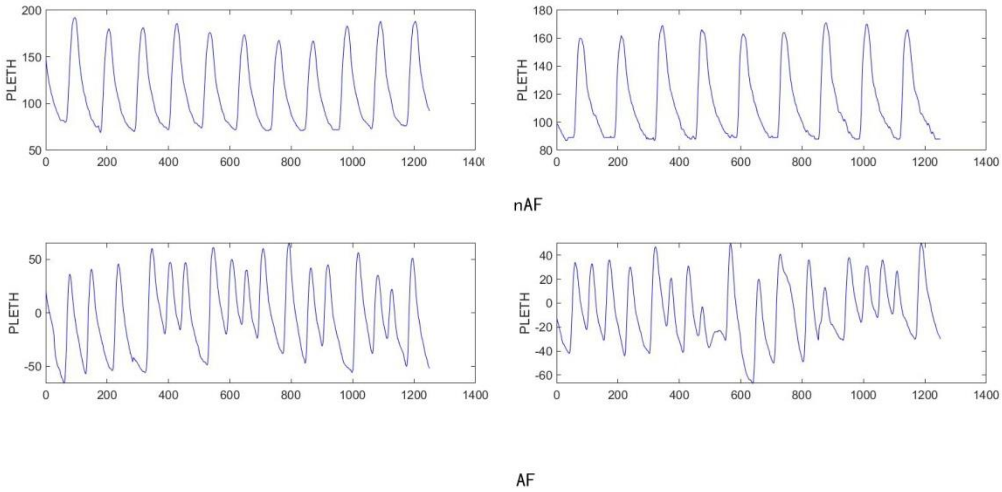

Figure 1 Detection results for Patients

As shown in the figure above, NAF is the normal pulse wave, AF is the patient with atrial fibrillation. The pulse wave shape of healthy people is stable, while the pulse wave shape of patients with atrial fibrillation is not stable.

4. The experiment

The Confusion Matrix, also known as the error matrix, is used to determine the classification performance of classifiers. As shown in Table 1, the following four basic indicators can be obtained:

Table 1 Confusion matrix

Confusion matrix		real	
		Positive	Negative
Predictive	Positive	TP	FP
	Negative	FN	TN

The True value is Positive, and the classification result is the number of positives (True Positive, TP). The true value is Positive, and the classification result is the number of Negative (False Negative, FN). The true value is Negative, and the number of classifications is Positive (False Positive, FP). The True value is Negative, and the classification result is the number of Negative (True Negative, TN).

According to the above four basic indicators, the following three evaluation criteria can be obtained: accuracy, sensitivity and specificity.

Table 2 Detection accuracy (%) of each patient

patient	Bior4.4			Coif4			Db4		
	F	L	Ac	F	L	Ac	F	L	Ac
1	59	5	93.31	21	2	84.54	52	6	95.52
2	62	4	95.22	45	2	82.84	34	6	96.29
3	37	5	96.71	16	5	88.90	26	7	97.34
4	16	4	100.0	19	4	100.0	12	2	100.0
5	4	1	100.0	30	4	100.0	23	4	100.0
6	57	5	100.0	33	2	100.0	54	5	100.0

ISSN: 2664-9640

7	19	5	97.29	15	3	90.23	12	6	98.32
8	18	5	100.0	17	1	100.0	35	7	100.0
9	60	5	96.90	45	3	92.33	45	6	97.23
10	45	6	95.81	15	4	90.53	34	6	98.56
Global	38	5	97.52	27	3	92.94	33	6	98.33

In the above table, bior4.4, coif4 and DB4 represent three kinds of wavelet functions, f represents the optimal feature number of each wavelet function, l represents the optimal decomposition level, and AC represents the accuracy. In most cases, the best detection results can be obtained by feature extraction of PPG signal according to the segmentation time slot of 10 s.

5. Conclusion

For detecting atrial fibrillation atrial fibrillation signal noise existing in the high dimension data after the big, feature extraction, atrial fibrillation after signal feature extraction, feature of the strong correlation between lead to atrial fibrillation, atrial fibrillation signal cannot be detected after the large amount of data and feature extraction such as strong nonlinear relation between data, the key problems to be settled urgently before will be proposed in this paper based on multilevel wavelet decomposition method of support vector machine (SVM) af detection. It was applied to the trial of AF detection based on PPG signal of real patients, and compared with the traditional data-driven detection method. Through our method can accurately detect atrial fibrillation, through the analysis of pulse wave, we can further achieve the classification of different atrial fibrillation.

Acknowledgments

This paper is supported byFujian Province Young Teachers Educational and scientific Program(JAT191261, Pulse-wave and Atrial Fibrillation Identification Based on Complex Network and Deep Learning Techniques).

References

[1] PikoNejc,BevcSebastjan,HojsRadovan,NajiFranjoHusam,Ekart Robert. The association between pulse wave analysis, carotid-femoral pulse wave velocity and peripheral arterial disease in patients with ischemic heart disease[J]. BMC Cardiovascular Disorders,2021,21(1).

[2] SaugelBernd, KouzKarim, ScheerenThomasW.L., GreiweGillis, HoppePhillip, RomagnoliStefano, Backer Daniel. Cardiac output estimation using pulse wave analysis-physiology, algorithms, and technologies: a narrative review[J]. British Journal of Anaesthesia,2020,126(prepublish).

[3] SaugelBernd, KouzKarim, Scheeren Thomas W L,GreiweGillis, HoppePhillip, RomagnoliStefano, de Backer Daniel. Cardiac output estimation using pulse wave analysis-physiology, algorithms, and technologies: a narrative review.[J]. British journal of anaesthesia,2020.

[4] Matthew P. Harber,AllisonMcCurry,NicholasCarlini,BrandonKistler,Bradley S. Fleenor. Caffeine ingestion alters central hemodynamics following aerobic exercise in middle-aged men[J]. European Journal of Applied Physiology,2020(prepublish).

[5] M. Judith Leo,S. Suchitra. SVM Based Expression-Invariant 3D Face Recognition System[J]. Procedia Computer Science,2018,143.

[6] Tsun-KuoLin,Zhi-ke Peng. PCA/SVM-Based Method for Pattern Detection in a Multisensor System[J]. Mathematical Problems in Engineering,2018,2018.

ISSN: 2664-9640

[7] ChenhuiHu,JorgeSepulcre,Keith A. Johnson,Georges E. Fakhri,Yue M. Lu,Quanzheng Li. Matched signal detection on graphs: Theory and application to brain imaging data classification[J]. NeuroImage,2016,125.

[8] Zhou Sixuan,Liu Dong. Prediction of Daylighting and Energy Performance Using Artificial Neural Network and Support Vector Machine[J]. American Journal of Civil Engineering and Architecture,2015,3(3A).

[9] Andrade Jason G.,Wells George A.,Deyell Marc W., et al. Cryoablation or Drug Therapy for Initial Treatment of Atrial Fibrillation[J]. New England Journal of Medicine,2021,384(4).

[10] Wazni Oussama M., DandamudiGopi, SoodNitesh, HoytRobert. Cryoballoon Ablation as Initial Therapy for Atrial Fibrillation[J]. New England Journal of Medicine,2021,384(4).

[11] Marine Joseph E.. Early Ablation for Paroxysmal Atrial Fibrillation — Safety First[J]. New England Journal of Medicine,2021,384(4).

[12] Bisson Arnaud, BodinAlexandre,. Sex, age, type of diabetes and incidence of atrial fibrillation in patients with diabetes mellitus: a nationwide analysis[J]. Cardiovascular Diabetology,2021,20(1).

Weifang Xie was born in 1994. She is currently a research assistant with Fujian Forestry Vocational & Technical College. Her research interests include computer vision and the application of deep learning in the classification of bio-ore and Flammulina mushroom. (244019250@qq.com)

Yun Zou, born in 1993, She is currently a research assistant with Fujian Forstry Vocational & Technical College. Her reserach interests include landscape architecture and forstry therapeutic.

Zunhuang Cai was born in 1975. He is currently a associate professor with Fujian Forestry Vocational & Technical College. His research mainly focuses on image recognition and machine vision technology.