Predicting method of monitoring information for telemonitoring system

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Abstract. According to the forecast problem of monitoring information, the predicting method of monitoring information is proposed based on PSO. In this method, the parameters of predicting model are given based on PSO, and the LS-SVM is adopted to predict monitoring information. Then, the prediction model of monitoring information based on LS-SVM is constructed, and the method of confirming parameters in model is proposed. Finally an experiment is carried out on PhysioNet database, which verifies the effectiveness of the proposed forecasting method.

1. Introduction
Telemedicine technology has been developed rapidly in recent years. At present, the detection and analysis technique of physiological parameters have become the research hotspot[1-3]. Physiological parameters is a weak nonstationary time series, and the prediction methods based on the statistical theory have played an important role in numerical prediction, but these methods have some limitations in the practical application because they are on the basis of linear correlation[4]. Having the nonlinear analysis, the neural network obtains greater progress[5,6], but the obtained values tend to be locally optimal and the forecast effect is not ideal because of its learning problems. Developed on the basis of this theory, support vector machine(SVM) is a new classification and regression tool, and it also is a kind of new machine learning method of small sample. Improving the generalization ability through the structural risk minimization principle, and having advantage of fast convergence speed, global solution, fewer parameters, suitable for small sample data training, etc, SVM has been widely used in pattern recognition, signal processing, modeling prediction and other fields[7-9].

The forecast method of least square support vector machine(LS-SVM) based on particle swarm optimization(PSO) is put forward in this paper, According to the prediction problem for monitoring information in remote health monitoring system[10-11]. In this method, the forecasting model of monitoring information is established using LS-SVM firstly, and the parameters for model are determined by the algorithm of PSO, and the prediction results will be got finally. This method can be used to provide the scientific basis of decision-making for the medical staff, because N steps prediction will be realized through this method.

2. Problem description
The prediction problems of monitoring information are described as follows: the corresponding fitting model is established through regression and analysis of historical monitoring data, and the future
values of monitoring information will be forecast using fitting model established before. Therefore, to achieve the future forecast of monitoring information accurately, regression is one of the most important parts. Regression analysis of monitoring information is expressed as: for any given a new input $x$, inferring the corresponding $y$ according to the type of the training set $T$. A mathematical model is as follows.

Given a training set

$$T = \{(x_i, y_i), \quad i = 1, 2, \ldots, N\}$$ (1)

Where $x_i \in \mathbb{R}^n$ is input, the $y_i \in \mathbb{R}$ and $x_i$ is the corresponding output. If samples of independent and identically distributed based on a distribution of $P(x, y)$ in $\mathbb{R}^n \times \mathbb{R}$ are selected as training set, trying looking for a real-valued function $f(x)$, which can infer the corresponding output $y(\ y \in \mathbb{R})$ according to any input $x(x \in \mathbb{R}^n)$ with $y = f(x)$, and the expected risk of the training set will be minimum.

$$R(f) = \int L(x, y, f) dP(x, y)$$ (2)

Where $L(x, y, f)$ is the loss function given.

![Figure 1. Regression fitting of the monitoring information](image)

The different between regression analysis and classification is their different output $y$, the output $y$ has two values in classification problem, and arbitrary real numbers in the regression analysis. To predict the results of follow-up which does not appear, the task of monitoring information regression is to find a curve $y = f(x)$ which can fit the training samples in the training set of monitoring information. As shown in Figure 1.

3. Forecasting method for monitoring information

LS-SVM is an extension of the standard SVM[12]. With SVM, the support vectors are solved by two programming, but the calculation for matrices of order $m$ will be involved to solve the two plan(where $m$ is the number of samples), and a large amount of computer memory and computing time will be consumed when the matrix memory and computing while $m$ is a very large. While LS-SVM takes two square of the error as a loss function instead of insensitive loss function, in this method, the inequality constraints are transformed into equality constraints and the real problem is transformed into solving a group of linear equation group, thus, the rate of convergence is improved and the calculation is simplified. In order to realize the prediction of monitoring information, LS-SVM is introduced to predict monitoring information in this paper.

3.1. Predicting model of monitoring information

Define the training data set of the monitoring information as $s_j = \{(x_1, y_1), (x_2, y_2), \ldots, (x_1, y_1)\} \in \mathbb{R} n \times \mathbb{R}$, linear function in the high dimensional feature space which is described as follows are used to fit the sample set.

$$f(x) = w^T \psi(x) + b$$ (3)

Where $\psi(x)$ is the nonlinear mapping from the input space to a high dimensional feature space, $w$ is the weigh coefficient vector in a feature space, and $b$ is bias. According to the principle of structural risk minimization, the prediction method of LS-SVM for monitoring information can be expressed as constrained optimization problems as follows:
\[ \min \frac{1}{2} w^T w + \frac{1}{2} \sum_{i=1}^{l} e_i^2 \]
\[ \text{s.t. } y_i = w^T \Phi(x_i) + b + e_i, \quad (i=1 \sim l) \]

In order to solve the optimization problem, the constrained optimization problem will be turned into the unconstrained optimization problem. So the Lagrange function is introduced to transform the optimization problem of formula (2) into the dual space, the Lagrange function of the optimization problem is as follows:
\[ L = \frac{1}{2} w^T w + \frac{1}{2} \sum_{i=1}^{l} e_i^2 - \sum_{i=1}^{l} a_i \left( w^T \Phi(x_i) + b + e_i - y_i \right) \]

Where \( a_i \) is the Lagrange multiplier, \( \lambda \) is a constant. According to the KKT (Karush-Kuhn-Tucker), then \( \frac{\partial L}{\partial w} = 0, \quad \frac{\partial L}{\partial b} = 0, \quad \frac{\partial L}{\partial e_i} = 0, \quad \frac{\partial L}{\partial a_i} = 0 \), that is
\[ \begin{cases} w = \sum_{i=1}^{l} a_i \Phi(x_i) \\ \sum_{i=1}^{l} a_i = 0 \\ a_i = y_i e_i \\ w^T \Phi(x_i) + b + e_i - y_i = 0 \end{cases} \]

For a type (2), linear equations can be obtained as follows when \( w \) and \( e_i \) are deleted.
\[ \begin{bmatrix} 0 \\ e_i' \\ Q + \gamma I a' \\ y \end{bmatrix} = \begin{bmatrix} 0 \\ b \\ a \end{bmatrix} \]

Where \( e_i = [1, \ldots, 1]^T; \quad a = [a_1, \ldots, a_l]^T; \quad y = [y_1, \ldots, y_l]^T; \quad Q = \Phi(x_1) \Phi(x_i). \) According to the Mercer, the kernel function is defined as \( k(x_i, x_j) = \Phi(x_i)^T \Phi(x_j). \)

A and \( b \) will be got by using the method of least squares which can solve the linear equations in type (5). Then the prediction model of LS-SVM for monitoring information can be put forward as follows:
\[ \begin{align*} e_i' \Lambda^{-1} Y \\ b = e_i' \Lambda^{-1} e_i \\ a = \Lambda^{-1}(Y - b e_i) \quad (\text{where } \Lambda^{-1} = Q + \gamma I) \\ f(x) = \sum_{i=1}^{l} a_i k(x_i, x_j) + b \end{align*} \]

### 3.2. Determination of model parameters

The performance of prediction model is greatly influenced by the parameters in LS-SVM, the main parameters are the kernel function parameter \( \sigma \) and the adjust parameter \( \gamma \). Particle swarm optimization is evolutionary computation technology based on swarm intelligence and a new branch in the field of evolution technology, which is made by Dr Eberhart and Dr Kennedy and derived from behavior research for the colony movement of bird and fish[13,14]. The difference between PSO and Genetic algorithm is that PSO finds the optimal solution through inter-individual cooperation and avoids the trouble of the binary code. Thus it is easy for this algorithm to understand and implement with a simple, implicit parallelism. This paper determines the parameters of prediction model for monitoring information with PSO. The process which determines prediction model of LS-SVM for monitoring information is as follows.

1. Initializing particle swarm. Including learning factors, weighing, the maximum number of iterations \( K_{\text{max}} \), the position and velocity of particles are initialized through mapping the adjusting parameter (\( \gamma \)) and kernel width parameter (\( \sigma \)) to a group of particles.
2. Calculating particles’ fitness. This article defines the fitness function as \( F_i = \frac{1}{l} \sum_{j=1}^{l} (y_{ij} - \hat{y}_{ij})^2 \) for each particle. Where \( F_i \) is expressed as fitness value of ith particle, \( \hat{y}_{ij} \) is the ith particle's output for the j samples, \( y_{ij} \) is the expected output for the j sample.
3. Comparison the local optimal solution \( pbi \) with the fitness calculated above, if the fitness is less than
pbi, the fitness will replace the previous pbi; if the fitness pbi is less than the global optimal value of gbi, the particle’s fitness will replace the original global optimal value gbi.

4. Experiment and analysis

4.1. Experimental data

The algorithm is verified by experiment with data in the PhysioNet biomedical signal research resources. PhysioNet is a complex physiological parameters and biomedical research resources based on web, it reduces the funds of data collection and enables researchers to determine the correction and reliable of the experimental data. The 100 length ambulatory blood pressure data are used in the experiment which come form the MIMIC database.

4.2. Experimental results and analysis

The radial basis function is selected as the kernel function of the prediction model for monitoring information in this paper. In 100 blood samples, the first 80 are taken as training samples, while the last are taken as predicting samples. In order to verify the effectiveness of this method, contrast experiments between SVM algorithm and LS-SVM algorithm based on PSO are finished, the results of the experiment are as follows.

The prediction results of ambulatory blood pressure signal are shown in Figure 2 and Figure 3. The result with SVM is shown in Figure 2 and Figure 3 is the others. The prediction error for predicting the dynamic blood pressure with the two methods is shown in Figure 4. From the graph, we can see that the proposed prediction method for monitoring information is better than SVM.

![Figure 2. Predicting results of ambulatory blood pressure with SVM](image-url)
Figure 3. Predicting results of ambulatory blood pressure with the proposed method

Figure 4. the curve of prediction error for ambulatory blood pressure

The mean square deviation (MSE) is introduced in the experiments to conduct quantitative analysis. The MSE with the two algorithms are calculated for the dynamic blood pressure signals, and the results are shown in Table 1 (where the parameters with PSO are gam=790.6295 and sig2=3.736199).

Table 1. MSE OF BLOOD PRESSURE SIGNALS WITH THE TWO DIFFERENT METHODS

| Predicting method  | MSE  |
|-------------------|------|
| SVM               | 0.1502 |
| Proposed method   | 0.0586 |

From the quantitative analysis in Table 1, we can see the proposed forecasting method for monitoring information with which the MSE is 0.0586 is better than the forecasting method with SVM. It also proves the proposed method can obtain better predicting effect.

5. Conclusions

A new predicting method of monitoring information in a remote health monitoring system was put forward in this paper, and its parameters in LS-SVM were determined with PSO algorithm. The
algorithm this paper proposed was verified by simulation with the dynamic blood pressure signals in PhysioNet biomedical signal research resources, and compared with the prediction results which were got by the method with SVM. The results show that the proposed prediction method is obviously better than the method with SVM, and it also proved that the proposed prediction method for monitoring information in this paper is effective.

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