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Intelligent recommendation algorithm for social networks based on gradient particle swarm optimization

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Abstract. Aiming to improve the intelligent recommendation ability of users in social networks, an intelligent recommendation algorithm for social networks based on gradient particle swarm optimization (GPSO) is proposed. Under the limited sample training, the user association relationship model of social network is constructed, and the hybrid kernel function and the global kernel function are constructed to extract the correlation amount feature of the social network recommendation information. The hybrid particle swarm optimization algorithm is used for adaptive learning of social network recommendation, Logistic chaotic mapping is used to control the convergence of recommendation process, and the potential characteristics of network users and the universality and ergodicity of social features are analyzed. The particle swarm optimization and adaptive optimization of social network recommendation are implemented by using gradient algorithm to realize swarm intelligence recommendation of social network user information. The simulation results show that the proposed algorithm is more accurate and convergent, and it avoids falling into the local optimal solution in the process of intelligent recommendation of social network. The intelligence and global stability of social network recommendation are improved.

1. Introduction
Social network is a personalized network to realize self-learning and multimedia information services according to users' personal preferences. The user information and learning resources information on social networks need to be classified and stored adaptively according to users' preferences. The resource scheduling ability and user potential feature extraction ability of social network are improved, the resource scheduling and personalized recommendation of social network are carried out with multi-source distributed design method [1]. In complex social networks, personalized recommendation and optimal scheduling of resources are carried out according to users' historical access records and preferences, so as to promote the use of information and improve the dynamic interaction ability of social networks. It has great significance to study the personalized intelligent recommendation algorithm of social network in order to promote the optimization design of social network.

Traditionally, the methods include intelligent particle swarm optimization algorithm, association rule mining algorithm, and personalized recommendation and community discovery methods for social networks. Data clustering recommendation algorithm and fuzzy PID recommendation algorithm etc., according to the optimization design of multi-level social network topology structure, the data clustering center of social network personalized recommendation is established according to the characteristics of recommendation task and information distribution. The association rule mining method is used to design the social network recommendation algorithm to improve the personalized expression ability of the social network. The related literature designs the social network
recommendation algorithm, and obtains the certain research result. Among them, a social network community discovery algorithm based on the parallel recommendation\cite{4}, which is based on the social network user behavior value. As independent variables, the user consumption value and loyalty are used as independent variables to establish a fuzzy decision model for social network community discovery, and to optimize the design of social network recommendation model with association mining method. However, the computational cost of this method is high. Social networks recommend poor real-time performance. NING Xueli proposed a social network community discovery and recommendation algorithm based on difference factor evaluation and intelligent PSO. The synchronous tag of social network community is established, and the characteristic quantity of community association attribute is extracted. This paper analyzes the relationship between the interaction degree and the recommendation effect, and realizes the personalized recommendation of social network. This method is not intelligent in the process of social network recommendation, and the global optimization ability of the recommendation process is not strong.

In the relational model, the hybrid kernel function and the global kernel function are constructed to extract the association feature of the social network recommendation information, and the hybrid particle swarm optimization algorithm is used for the adaptive learning of the social network recommendation. Then the convergent control of the recommendation process is realized by Logistic chaotic mapping, and the universality and ergodicity of the potential and social characteristics of the network users are analyzed. The particle swarm optimization and adaptive optimization of social network recommendation are implemented by using gradient algorithm to realize swarm intelligence recommendation of social network user information. Finally, the simulation experiments are carried out to demonstrate the superior performance of this method in improving the personalized intelligent recommendation ability of social networks.

2. Social network recommendation information model and association feature extraction

2.1 Social network recommendation Information transfer model

Aiming to realize the personalized recommendation and feature recognition of social network, a parallel recommendation algorithm is used to extract potential features and information mining of users, and a hybrid kernel function and a global kernel function are constructed to extract the associated features of the recommendation information of social networks. The fuzzy decision function of social network recommendation information is obtained by using limited sample training. The self-group nonlinear mapping $\Phi: x \in \mathbb{R}^n \rightarrow \mathbb{R}$ is constructed to represent the information conduction space of social network. Fuzzy decision and intelligent PSO are used to map recommendation information of social network to High dimensional feature space $G \{x_1, y_1, x_2, y_2, \ldots, x_n, y_n\}$. It is assumed that the recommended training sample set of social networks is $x_i \in \mathbb{R}^n$, where the personalized feature $x_i \in \mathbb{R}^n$ represents the input vector of the recommendation model and the target measurement value of personalized recommendation is $n$ as the sample number. Combined with association rule mining algorithm, the objective function of intelligent recommendation of social network is obtained as follows:

$$\min \quad \frac{1}{2} \|d\|^2 + C \sum_{i=1}^{n} (\xi_i^2 + \xi_i^2)$$

subject to $y_i - (w^T \Phi(x_i) + b) \leq \varepsilon - \xi_i, w^T \Phi(x_i) + b - y_i \leq \varepsilon - \xi_i^2, \xi_i^2 \geq 0, i = 1, 2, \ldots, n; C > 0 \quad (1)$

Where, $\xi_i$ and $\xi_i^2$ represent semantic ontology attribute and association rule variable, generalization learning algorithm is adopted, the adaptive learning of recommendation process is used, the recommended cost factor, it is used to realize the punishment control of dividing the right and wrong sample, adopt Using particle swarm optimization control\cite{7}, the difference function of personalized recommendation is obtained as follows:
\[ f(x) = \sum_{i=1}^{n} (a_i - a_i^*) K(x_i, x_j) + b \]  

Where: \( a_i \) and \( a_i^* \) denote the recommended attribute value and the number of template categories, \( K(x_i, x_j) \) is a symmetric kernel function satisfying the Mercer condition, and \( b \) denotes the recommendation threshold.

The feature vector set of each data element is constructed. The local kernel function (RBF kernel function) and the global kernel function (polynomial kernel function) are taken as the control decision function\(^{[8]}\), and a hybrid kernel function recommended by the social network is constructed. The expression of the function is described as follows:

\[ K_{\min} = \beta K_{\text{poly}} + (1 - \beta) K_{\text{rbf}}, \quad \beta \in (0,1) \]  

Where, \( K_{\text{poly}} = [(x \cdot x_i) + 1]^2 \) denotes the RBF kernel function of trust reliability of social network. \( K_{\text{rbf}} = \exp(-\|x - x_i\|^2) \) is the influence of adjusting two kernel functions on the total mixed kernel function, that is, weight coefficient. Based on this, the information conduction model of social network recommendation is constructed, and the user feature extraction and personalized recommendation design of social network are carried out based on particle swarm optimization.

2.2 Association feature extraction of recommendation information in social networks

On the basis of constructing mixed kernel function and global kernel function, the association feature extraction of social network recommendation information is carried out, and the convergent control of recommendation process is realized by Logistic chaotic mapping, and potential users of complex social network are obtained. Variable, expressed by quaternion as \( \{S_1, S_2, \ldots, S_n\} \). taking personal potential feature and social potential feature as control constraint change, the characteristic extraction conduction control model of personalized recommendation is obtained as follows:

\[ \alpha_{\text{desire}} = \alpha_1 \frac{\text{Density}}{\sum_i \text{Density}_i} + \alpha_2 \frac{AP}{AP_{\text{max}}} \]  

Where

\[ \alpha_i + \alpha_z = 1, \alpha_2 \in [0,1] \]

\[ \alpha_i = \frac{\text{max}(AP_i) - \text{min}(AP_i)}{AP_{\text{max}}} \]  

Under the constraint control of association rules, the potential association characteristics of complex social networks are obtained as:

\[ e_{\text{i,j}}(i, j) = \frac{\alpha_{i}(i)a_i b_j(o_{i})\beta_{i}(j)}{\sum_{i,j} \sum_k \alpha_{i}(i)a_i b_j(o_{i})\beta_{i}(j)} \]  

Among them, \(|\text{Re}(u)|\) denotes the point set of coefficients, \( \text{Re}(u) \) indicates the number of user nodes, \( a_y \) indicates the information of user score measure of social network, \( \text{Order}(\text{Re}(u)) \) indicates the amount of mutual information, and \( \text{Order}(\text{Re}(u)) \) indicates the nodes in complex social network communication channel according to their user personality. The matching degree of the characteristics of chemical behavior \(^{[9]}\). Combining association rule constraint and chaotic mapping, the clustering information of social network is clustered adaptively. The output of clustering is obtained as follows:

\[ f_{y\rightarrow M}(z) = (f_{y\rightarrow z}(z), f_{y\rightarrow x}(z), f_{y\rightarrow -z}(z)) = (f_{y\rightarrow z}(z), h_x \ast f_{y\rightarrow z}(z), h_y \ast f_{y\rightarrow z}(z)) \]  

In the above formula, \( f_{y\rightarrow z}(z) \) represents the user item score recommended by the social network, thus obtaining the quaternion of the association feature extraction recommended by the social network as follows:
\begin{equation}
\max \{ |Ch(u) - Ch(u) \cap Ch(u_1)| + |Ch(u) \cap Ch(u_2)|,\ |Ch(u_2) - Ch(u) \cap Ch(u_1)| + |Ch(u) \cap Ch(u_2)|,\ |Ch(u_3) \cap Ch(u_1)|\} = \max \{|Ch(u)|,\ |Ch(u_2)|\} \leq \Delta
\end{equation}

In the above expression, \( Ch(u) \) represents the association rule coefficient, and adds the node \( v \) to the \( R2(u) \) to realize the adaptive feature extraction from the personalized user features.

### 3. Recommendation algorithm optimization

#### 3.1 Gradient particle swarm optimization

On the basis of constructing mixed kernel function and global kernel function to extract the association feature of social network recommendation information, an improved social network intelligent recommendation algorithm is designed. In this paper, a kind of social network based on gradient particle swarm optimization is proposed. Network intelligent recommendation algorithm, using the initial value sensitivity of chaotic mapping, Regularity, universality, ergodicity and so on, the global optimization control of the recommendation algorithm is carried out, and the Logistic mapping is constructed, the expression of which is shown as follows:

\begin{equation}
y_{i} = \mu y_{i}(1 - y_{i})
\end{equation}

In each iteration, the global extremum \( G_{best}(t) \) and individual extremum \( G_{best}(t) \) , control gradient particles are obtained as the following expressions of personalized recommended gradient particle swarm optimization for social networks:

\begin{equation}
\begin{aligned}
V_{i}^d (t + 1) &= W \cdot V_{i}^d (t) + C_{1} \cdot R_{1} \cdot (P_{best}(t) - P_{i}^d (t)) + C_{2} \cdot R_{2} \cdot (G_{best}(t) - P_{i}^d (t)) \\
P_{i}^d (t + 1) &= P_{i}^d (t) + V_{i}^d (t + 1)
\end{aligned}
\end{equation}

Combining with the gradient particle swarm optimization, the iterative step size optimization adjustment of the recommendation process is carried out. In the \([w_{min}, w_{max}]\) interval, the adjustment formula for the intelligent recommendation of social network is obtained as follows:

\begin{equation}
w(t + 1) = 4.0w(t) (1 - w(t))
\end{equation}

\begin{equation}
w(t) = w_{min} + (w_{max} - w_{min}) w(t)
\end{equation}

The ratio \([w_{min}, w_{max}]\) is the range of the inertia factor, which is generally taken as \([0.5, 0.6]\).

#### 3.2 Realization of social network intelligent recommendation algorithm

The hybrid particle swarm optimization algorithm is used for the adaptive learning of social network recommendation, and the Logistic chaotic map is used to control the convergence of the recommendation process \([11]\). Chaos is introduced into the optimization of inertial factor \( w \), and in the process of gradient particle swarm optimization, the chaos is introduced into the learning process of the gradient particle swarm optimization. Introducing the search radius \( R_i \) and \( R_2 \), the following update formula is obtained as:

\begin{equation}
R_i (t + 1) = 4.0R_i(t)(1 - R_i(t))
\end{equation}

Where, \( R_i(t) \in (0,1), i = 1,2 \). According to the clustering of users, the fuzzy characteristic quantity of community distribution is extracted, and chaos is introduced into the learning factors \( C_1 \) and \( C_2 \), and the updated formulas are expressed as follows:

\begin{equation}
C_i(t + 1) = 4.0C_i(t)(1 - C_i(t))
\end{equation}

\begin{equation}
C_i(t) = C_{min} + (C_{max} - C_{min})C_i(t)
\end{equation}

Where, \( i = 1,2 \), \([C_{min}, C_{max}]\) is the initial population model to represent the gradient particle swarm optimization (GPSO). According to the position of the current particle, the fitness of the particle is determined, and the convergence control is carried out under the condition of precocity. The convergence control coefficient is defined as:
\[ \delta^2 = \sum_{j=1}^{m_i} \frac{E_j - F_{\text{avg}}}{F} \]  

(16)

Association rule mining and local optimization control method are used, the updating formulas recommended by social network are expressed as follows:

\[
\begin{align*}
V_j^2(t+1) &= W(t) \cdot V_j^2(t) + C_j(t) \cdot R_j(t) \cdot (P_{\text{best}}^j(t) - P_j^2(t)) + C_j(t) \cdot P_j^2(t) \cdot (G(t) - P_j^2(t)) \\
P_j^j(t+1) &= P_j^j(t) + V_j^j(t+1)
\end{align*}
\]

(17)

The convergence control of the recommendation process is realized by using Logistic chaotic mapping, and the universality and ergodicity of the potential and social characteristics of the network users are analyzed. The SVM parameter fitness function is presented as follows:

\[ F_{\text{fitness}} = \frac{1}{m} \sum_{i=1}^{m} (y_i - \gamma_i)^2 \]  

(18)

According to the result of threshold judgment, the convergence criterion is judged, and the particle swarm optimization and adaptive optimization of social network recommendation are carried out with gradient algorithm to realize the swarm intelligence recommendation of social network user information.

4. Simulation experiment and result analysis

The accuracy and convergence of this method in realizing the intelligent recommendation of social network is tested, the simulation experiment is carried out. The experiment is designed by Matlab 7, the social network used in the experiment is the network data of Sina Weibo, and the BookCrossing number is used. According to the set as the test set, the number of users tested is 2000, the test function of particle swarm optimization is ZDT series test function, the number of particles set in D-dimensional space is 100, the population size is set to 20, and the intelligent recommended simulation time is 24 s, running iterations 6000 times, the result of user potential feature mining of social network is shown in figure 1.

![Figure 1. User feature mining results of social networks.](image1)

![Figure 2. Learning curve of intelligent recommendation for social networks.](image2)

Taking the latent features of social network users mined in figure 1 as input test sample set, the adaptive learning of social network recommendation is carried out, and the convergence curve is obtained as shown in figure 2.

Figure 2 shows that the adaptive learning ability of intelligent recommendation of social network using this method is strong, and the mining of potential features and social features of social network is universal and ergodicity. Further test the error of different methods for social network recommendation, and get the contrast result as shown in figure 3. The results of analysis figure 3 show that the accuracy of the proposed method is good, and the convergence of swarm intelligence optimization is strong, so as to avoid falling into the local optimal solution of the social network intelligent recommendation process.
5. Conclusions
In this paper, an intelligent recommendation algorithm for social networks based on gradient particle swarm optimization (GPSO) is proposed. Under the limited sample training, the user association relationship model of social network is constructed, and the hybrid kernel function and the global kernel function are constructed to extract the correlation amount feature of the social network recommendation information. The hybrid particle swarm optimization algorithm is used for adaptive learning of social network recommendation, Logistic chaotic mapping is used to control the convergence of recommendation process, and the potential characteristics of network users and the universality and ergodicity of social features are analyzed. The particle swarm optimization and adaptive optimization of social network recommendation are implemented by using gradient algorithm to realize swarm intelligence recommendation of social network user information. The simulation results show that the proposed algorithm is more accurate and convergent, and it avoids falling into the local optimal solution in the process of intelligent recommendation of social network. The intelligence and global stability of social network recommendation are improved. This method has good application value in intelligent recommendation and personalized learning of social network.

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