Construction of real-time mental health early warning system based on machine learning

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Abstract. With the great development of computer technology, it is feasible to apply robot learning to the prediction and diagnosis of mental illness. Establishing an online psychological health warning system helps psychologists to know the mental health status of patients and makes rapid intervention. Based on the principle of machine learning, the design idea of constructing online psychological early warning system were proposed here by using the patient's daily performance and textual representation. The system included: client, server, doctor, and family. The client collected user text data and offered basic client technology; the server provided business logic of the web backend, database and mental health rating warning for client, doctor and family; the doctor mainly displayed the binding user status. When the mental health level of users was poor, early warning should be warning so that doctors can intervene in time. The relevant auxiliary treatment information for the patient would be send to family side, which help for the family therapy. This system provides a new way for doctors to monitor patients with mental illness, which but further study and training is needed to establish an effective model.

1. Introduction
With the development of information technology, the popularity of data has rapidly expanded. Various fields have emerged from the rapid development of computer and network technologies, such as education, service industry, industrial field, health medicine, and so on. [1]. Machine learning (ML) is considered a suitable method for analyzing big data. In the 1950s, Alan Turing first proposed the concept of machine learning and created the Turing test to determine whether the computer has intelligent. Arthur Muir realized machine learning for the first time [2]. AS the efforts of ML researchers and the rapid development of computing power, ML have been widely used in various fields including medical care since the 1990s.

The development of medical technology enables people to measure various forms of human biology such as genes, cerebral blood flow and EEG at relatively low cost, while the accuracy is higher than before [3-4]. These high-quality data have great potential to advance the health care sector by deepening our understanding of human disease mechanisms. In order to effectively analyze these mechanisms, a different approach than traditional ones is needed.

Machine learning technology has its advantages in dealing with big data. Before the emergence of the importance of big data, ML researchers have studied and designed machine learning algorithms to process large-scale data [5]. ML is known "An important part of big data analysis," [6], and help to solve medical and health issues, such as early diagnosis of disease, real-time patient monitors, patient-centered care, etc.
At present, mental health medical resources are scarce, the number of psychologists is small and it is difficult to treat a large number of patients. In the traditional way of consulting, the number of patients that psychologists can receive is very limited and it is difficult to manage large-scale patients. It is impossible to monitor and analyze the patient's psychological situation in time, many mental patients do not know their own psychological situation. Therefore, a mental health early warning system is needed that can track, rank and alert the mental state in time.

ML and network technique might help to the system. ML analysis of the text data provided by patients, diagnoses predicts the patient's mental health. Deep learning or neural network algorithms are well known as the main algorithms of artificial intelligence (AI). Choosing the right algorithm is the basis of the early warning system.

2. Application of ML algorithm in the field of mental health

The ML algorithm is mainly divided into two types: supervised learning and unsupervised learning. Supervised learning (SL) is the most commonly used method based on ML diagnosis, which has clear labels and definitions. The data of SL has a clear logical relationship, which help to predict unknown data through existing data. The training set of SL includes input and output that is features and goals. All data should be use attributes and the corresponding value representation (label). For example, the personal characteristics such as height, weight, eye color are the attributes that describe a person. The label is the value of a specific target attribute of the data that we want to predict from other attribute information. Such as colour of eye in a person is black is a data as attribute and might be labeled as Asian. The main purpose of the supervised ML model is to predict the label or value of the corresponding given attribute.

The SL model can be viewed as a mapping from attribute to label. The label of the data can be discrete value and classification. If the label is a classification, the ML task is a classification problem. Then, if the label is a number in a contiguous space, it is a regression problem. For example, in the case of classifying a patient's disease, each patient is an instance of the data, the patient's measurement condition is an attribute and the patient's disease is a category. The ML algorithm uses attributes to predict the disease category. When given much measurement data of many patients, the ML model can be established and then used to prediction patient's disease before the medical professional makes the diagnosis. The SL algorithm requires representative data. The actual diagnostic tag supervision is modeled by the training process. The model needs to make predictions, and if the prediction is error, it would be corrected until the outputs are correct. After the model training is completes, it can be use to predict the diagnostic label of the new patient with the measurement attribute.

Unsupervised learning is different from supervised learning. The main purpose of unsupervised learning is not to predict target attributes, but to process data without supervision. Unsupervised learning methods are rarely used in the clinical field, but can be used in conjunction with SL techniques for additional analysis.

The representative SL algorithms are support vector machine (SVM), gradient hoist (GBM) random forest, Naive Bayesian and K-nearest neighbor algorithm (KNN).

In ML technology field, the algorithms involved SVM, GBM, Random Forest, KNN, Naive Bayes have been reported to be used in the diagnosis of post-traumatic stress syndrome [7-9], schizophrenia [10-11], depression [12], autism [13-14], bipolar disorder. SVM is a common technique in mental health. It has been applied to all areas of mental health and most SVM classifiers in the paper show high accuracy of over 75%. Because in the field of mental health, data is less which means that the measured eigenvalues are discrete and the features represent only some of the features of the data points. This data sparsity is one of the reasons why SVM works well in this area. In some cases, different ML technologies are used together for feature selection. The Ensemble method of GBM and Random Forest process many features simultaneously without feature selection, which is also used as the primary algorithm to classify some mentally healthy patients. It showed good SVM performance with the accuracy of a classifier slightly below 60% on the test sample, which means that the ML algorithm may not guarantee the high precision of the classification by itself. We also found that KNN
and Naive Bayes have only been used with SVM, but in some cases, their performance is comparable to or higher than SVM in table 1 [15].

**Table 1.** The algorithms were reported in mental health.

| Algorithm     | Advantage                                                                 | Disadvantage                                                                 |
|---------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|
| SVM           | High accuracy in the actual training process                              | The data should be careful data preprocessed carefully and a proper kernel is needed to accurately analyze complex data |
|               | High accuracy in the actual training process                              | Training learners takes more time than other algorithms                       |
| GBM           | By adding weak learners, the algorithm can automatically make up for the shortcomings in dealing with some attributes | Difficult to explain the relationship between attributes and objectives        |
|               | Relatively short time is needed in training and forecasting                | The prediction speed may be relatively slow random forests                   |
| Random forest | Providing intermediate conditional probability of attributes            | Difficult to explain the relationship between attributes and objectives       |
| Naïve bayes   | No training process required                                               | Unrealistic assumption: independence of all attributes                        |
| KNN           | No training process required                                               | Prediction time increases rapidly with the number of data or attributes      |
|               |                                                                           | Requires more additional data should be added even a small increase in the number of functions to be considered |
|               |                                                                           | Highly dependent distance measurement to be used                             |

3. **Design and construction of real-time mental health early warning system**

3.1 **Structural design**

The technical system framework of big data includes data collection, data processing, data analysis and application service generally. The design goal of this system is to analyze the emotion and word frequency of the user's comments, monitor the user's psychological state in time and give early warning. By combining the objectives of the system with the existing big data technology system and the related network public opinion monitoring and early warning system, the structure of the dynamic early warning system for mental health comments is proposed, as shown in Figure 1.

The system includes five functional parts: client, server, doctor, and family. The client mainly collects user text data and basic client technology by data collecting, web page crawler and API mapping. The server provides business logic of the web backend, database and mental health rating warning for the client, doctor and family. The main business logic of the server is sentiment analysis and health rating. The sentiment analysis is based on semantic analysis and the text classification is mainly SL by machine learning to structure the corpus with manual annotation. The doctor side displays the state of the user bounding with the doctor and gives an early warning when the user's
mental health level is poor, so that the doctor would give intervention opinions for patients or their families psychological intervene. The family side receives Information on adjuvant therapy for the patient from doctor, which help family members of the patient have scientific psychological intervention knowledge for family therapy (Figure 1).

![Dynamic warning structure](image-url)

**Figure 1.** Dynamic warning structure.

### 3.2 Corpus selection and emotional analysis

Through the network tracking and early warning system, the patient's psychological situation might be tracked in real time. The traditional one-to-one and face-to-face consultation mode might be transformed into a one-to-many real-time tracking and early warning inquiry mode, which provides doctor great convenient to understand the psychological situation of patient. The daily expression of the physical object statement or the text information from patients contains rich emotional colors. These emotional daily expressions provided by patients or family members is the corpus of machine learning. The corpus are divided into two categories, namely positive text corpus and negative text corpus. ML process the emotional corpus and train the two categories corpus.

Emotion analysis is implemented by Python program, mainly using snow NLP algorithm and Jieba word segmentation algorithm. Firstly, a corpus in the field of webcast should be built. Due to the lack of research on daily language information texts and the lack of a complete corpus, training emotion analysis corpus based on the combination of dictionary and daily language are proposed here. Through sorting out and deemphasizing the emotion Dictionary of CNKI (China National Knowledge Infrastructure, CNKI) and the Chinese emotion Dictionary of Taiwan University, a new emotion dictionary is formed. The labeled data and the corresponding polar words in the emotion dictionary are written into positive and negative TXT respectively which are used as training texts and loaded into the emotion analysis module for training to construct the emotion analysis corpus.

On the basis of the training results, the high-frequency words obtained by the Jieba segmentation algorithm are written into the training text. The continuous addition of high-frequency words makes the emotional analysis corpus richer, which is conducive to improving the accuracy of emotional analysis. After training, the number of corpora will increase and the corpora are also enriched. According to the results of the above analysis of emotional tendency, negative comments are sorted out, word segmentation and word frequency calculation are carried out with Jieba, and high-frequency words are extracted, sorted out and added to the training text.

### 3.3 Algorithm delection
The naive bass algorithm is chosen as the algorithm for text research experiments, because it has very high stability, easy implementation, low error rate, simple logic, small resource occupation overhead and strong theoretical. All the corpora are divided into positive corpus and negative corpus. The probability of (0,1) interval is analyzed for the text through the sentiment analysis of machine learning. The probability of (0-0.5) is regarded as negative text data and the probability of (0.5-1) is considered positive text data. Python including the English text sentiment analysis Natural Language Toolkit (NLTK) and the Chinese text sentiment analysis Snow NLP, is selected for Natural language processing. Snow NLP is a python class library for processing Chinese text sentiment analysis, which is an efficient and accurate sentiment analysis of natural language processing based on machine learning for text data analysis.

3.4 Evaluation indicators and early warning pushing
The average value of text statistics to assess user's level of mental health rating in this system uses. Three grades is divided, which is poor, worse, better and good. The test data from user's data in system, according to the above-mentioned probability value greater than 0.5 is regarded as a positive statement, and a probability less than 0.5 is regarded as a negative statement. The evaluation function is used to count the number of positive sentences and negative data and calculate the mental health level according to the formula.

Formula for calculating negative rate and positive rate was the following:

\[ N = \frac{n}{M} \times 100\% \]

\[ P = \frac{p}{M} \times 100\% \]

\[ A = \frac{1}{T} \sum_{t=1}^{T} \frac{P}{M} \times 100\% \]

\( N \) is negative rate, \( n \) is the number of negative texts and \( M \) is the total number of texts.

\( P \) is positive rate, \( p \) is the number of positive texts and \( M \) is the total number of texts.

\( A \) is average health rate, \( P \) is positive rate, \( t \) is the measurement of the “t” time and \( T \) is the total number of measurement.

(1) The average health rate is 1%-30% means poor mental health.
(2) The average health rate is rated at 31%-60% means the mental health is worse
(3) The average health rate is 60%-80% means the mental health is better
(4) The average health rate is 80%-100% means the mental health is good

During the early warning cycle, the warning threshold is set to 30% that is if the average health rate is lower than 30%, an early warning report will be issued to inform the doctor to conduct mental health intervention and treatment.

The function of early warning push module is to push early warning messages to users, family members and doctors according to the emotional value of comments. In this study, Delphi method is used to determine the limits of early warning indicators. In this study, experts in the field are invited to predict the early-warning indicators. Experts believe that the positive emotion word frequency less than 30% should be used as the limit of the polarity of early-warning, that is, when the positive emotion value is less than 0.3, the user's mental health is poor, and the early-warning intervention needs to be carried out by the doctor in time. When the positive emotion is less than 0.6, the user's mental state is no better, and the user should be self-regulation.
3.5 Feasibility analysis of system

The system automatically collects and analyzes data, implements interventions, saves time and effort, and makes up for the shortcomings of a large number of face-to-face treatments such as untimely treatment, not comprehensive, and expensive.

The implementation of the system is feasible. Firstly, the public opinion early warning based on text has already had a successful attempt in tourism, online community and other fields, which indicates that the emotional prediction of the text has a realistic possibility and provides a powerful reference for online mental health early warning. Secondly, with the development of text mining and big data technology, it provides a powerful technical guarantee for the realization of online mental health early warning analysis and early warning system. Finally, the application of the system can help the psychiatrists to carry out effective supervision and improve the level of medical services.

However, as the system processing is too objective and mechanical human participation also requires sometimes, which to make the data collection, analysis, and intervention more scientific and reasonable.

4. Future application of online psychological warning system

4.1 Treatment and tracking of patients with mental illness

The treatment course of mental illness, especially mental illness, was generally longer. Treatment of some psychological diseases needs to be supplemented by drug treatment. Different diseases also have different treatment courses. For example, the supportive treatment of psychosis at least lasted several months, while long-term psychoanalysis is mainly used for neurosis and other problems may be longer. With the development of modern psychotherapy, short-term treatment such as cognitive and behavioral therapy appears, which may take three months to half a year. Family therapy may take longer time.

Though the frequency of contact and meeting with doctors was decreased greatly, it was still necessary to track the changes of patients' psychological state during the family therapy period. Patients, family members and doctors can provide timely information about the physical and mental status of patients through the terminal remote psychological early warning system to follow-up patients’ states and remind patients to adjust themselves or seek help timely.

4.2 Mental health status tracking of special population

The online psychological early warning system was not only applied to the tracking of patients with common psychological diseases, but also can be applied to monitoring the physiological and psychological state of special groups, such as drug addicts, prisoners with high negative emotions, key personnel of community correction, etc.

Due to the particularity of environment or personality, the psychological status of special groups is often closely related to their behavior tendency. Such as drug addicts whose body was harmed by drugs, even after the compulsory detoxification stage, they were still repeatedly awakened by drug memory, anxiety, and extremely unstable personal emotions. Psychological early warning system could help doctors and police to track and supervise the mental state of drug addicts by the online terminal.

Prison is a special place, prisoners more or less had psychological problems. It was a difficult work for prison police to reform and psychologically correct the large number of prisoners in prison, especially some prisoners might have mental and psychological diseases. The application of online psychological early warning system would be greatly reduce the work of prison police and improve the accuracy of high-risk prisoner screening.

Unlike management in prison, the safety management of community prisoners was a great challenge to judicial police. At present, information technology has been applied to grid management of community prisoners. Online psychological early warning system could be combined with grid management technology, which can provide another guarantee for the judicial department to master
the psychological dynamics of community prisoners and increased safety management of community prisoners.

4.3 Maintenance of mental health status of ordinary residents
Mental health knowledge is more and more popular all over the country, while the professional mental health resources was poor. It was difficult to obtain psychological personnel for remote areas, which would be make up by online mental health early warning system in a certain extent. Online mental health warning system would also promote the development of mental health in remote areas and bring timely remote diagnosis of mental health for ordinary residents in need.

With the popularity of smart home and health management system, online mental health early warning system would be expected to play a role in the elderly care and health maintenance.

5. Conclusion
The mental health early warning system of Internet and machine learning were studies in this paper by using Naive Bayesian algorithm, which included client, server, doctor, and family. Through the client to collect data, the server performs semantic analysis and health evaluation and feeds the data back to doctor side and family side. This system provides a new idea for doctors to monitor the mental health of patients with mental illness, but model training was needed to build an effective model.

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