Deep Learning Applications in Medical Image Analysis

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ABSTRACT—These years, with artificial intelligence and machine learning becoming the hotspot of research, several applications have emerged in each of these areas. It exists not only as a kind of academic frontier but also something close to our life. In this trend, the combination of medical care and machine learning becomes more and more tighter. The proposal of its main idea also greatly alleviated the existing situation of unbalanced medical distribution and resources strain. This paper summarizes some application of machine learning and auxiliary tumor treatment in the process of medical resource allocation, and puts forward some new methods of application to realize it closer to human life in the era of artificial intelligence and the explores a good situation of mutual combination of medical industry and computer industry, which is benefit both.

Keywords—machine learning; data mining; artificial intelligence; pathology; diagnotics.

I. INTRODUCTION

A. The general situation of machine learning

Machine learning (ML) is a science which aims to make

machine capable of learning. Machine learning returned to the public's vision after the famous competition between Alpha Go of Google and the Go player Li Sedol, ending with the score 4:1 in 2015. And this event made machine learning more well know among people even among those who were not familiar to computer science and it has caused intense debate in related field. Actually, although machine learning is a young branch of AI, it is not a new subject. ML is broadly defined as the application of certain computer algorithms to a set of data known to the event outcomes, and the ability to learn to training data and predict new data based on learning outcomes. Its core is induction and summary instead of deductive. Early in the medium of 1950s, Samuel, a computer scientist of United States, designed a chess program that could learn by itself through continuous play. This program shows people the ability of machine at the first time, meanwhile, the unpredictable potential of machine to learn came into people's sight. However, as the research continued, machine learning entered a period of cooling off. Until 1970s, it staged a comeback gradually. And during this period of continuous research and development, until today, machine learning has become an important subject including data mining, pattern recognition, natural language processing and so on. It has also become a core of AI.

Now, machine learning is mainly divided into supervised learning, semi-supervised learning and unsupervised learning. Some hot of them is Nearest neighbor classifier, Naïve Bayes classifier, ANN (Artificial Neural Network) and SVM (Support Vector Machine). Among them, ANN has become the hot algorithms that discussed by lots of scientists. ML is a cross-disciplinary field with many domains and it can be studied in a wide range of fields, not only in computer science, but also in medicine, finance and other disciplines, which can improve its own performance by getting new knowledge and skill, and at the same time, simulating human learning behavior.

In today's society, medical care problems have become a hot topic, and problems such as the unbalance and insufficient allocation of medical resources has become increasingly apparent. In this situation, the application of ML has become the unavoidable trend in the current development of medical care. As early as 1972, the scientists in the University of Leeds in the UK has been trying to use artificial intelligence (ANN) algorithms to judge abdominal pain. Now, more and more researchers are committed to the combination of ML and medical care. The methods of pathological diagnosis of tumors, lung cancer, etc. by ML has gradually entered the field of vision. Some companies, such as Alibaba, Amazon, and Baidu have established their own research team working for it.

This introduction of ML in medical care has greatly saved medical resources and provided a new way for citizens to see a doctor and facilitate people's lives. At the same time, the demand of people also provides a new

impetus for the research and development of ML, with promoting its continuous improvement.

B. The main algorithm of machine learning

(a)Decision Tree based Methods

The algorithm of decision tree is a method, which creats a decision tree by existing data and inputs the training set. According to the growth direction of decision tree, the test data can be classified. The main idea of decision tree is which feature is the best, how many branches can be generated and the time when to stop splitting. During this procession, it can be determined by the variable which is called impurity and some other mathematical method. However, due to the fact that it is a greedy approach, decision tree may disable to find the best tree sometimes.

(b) Naïve Bayes and Bayesian Belief Networks

Naïve Bayes is a ML method based on probability theory. It assumes that vents are independent and calculates through prior probability and posterior probability of the target object. The formula is as follows.

$$P(Y|X)= \frac{P(X|Y)P(Y)}{P(X)} \qquad (1)$$

Because this principle of this method is relatively simple, and the prediction efficiency is high although, the conditions

are strict, it is still widely used in the field of natural language recognition and so on.

(c) K-means

In this method, the variable k is chosen by the actual situation. After choosing k objects as the primary center of clusters randomly, it calculates the distance between every object and the center of clusters and then assigns the object into the closest cluster. Until all objects have been assigned, the centroid of every cluster will be calculated again. The process will be repeated until the centroid doesn't change. The algorithm is an iterative and programming is less difficult.

(d) Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is an algorithm that imitates the learning process of human brain, consisting of many nodes which is called neurons connected to each other. Each node represents a special function called activation function. There is a value of weight between two nodes. As a kind of computing model, neural network is divided into forward network and feedback network. Through the input of training set the neural network is trained and different weight values are modified, the nonlinear data will be processed to achieve the purpose of learning.

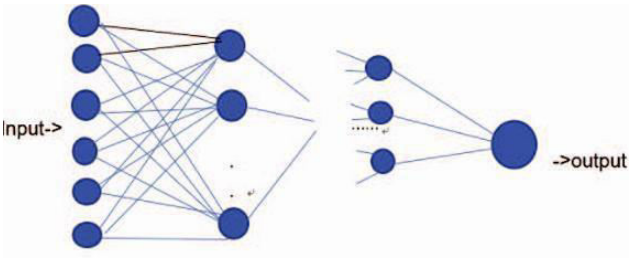

Fig. 1. ANN model

(f)Support Vector Machine (SVM)

SVM is an important part of statistical learning theory, which by transforming input space into high-dimensional space. In the linear classification, the hyperplane and loss function are constructed to solve the minimum of the loss of agent; for the linear indivisible problem, the method can be applied and the method is used to segment the hypersurface with feature space. SVM is often used in the analysis of medical conditions and the judgement of benign and malignant tumors, but it is difficult to implement in large-scale training samples because it may involve the calculation of high-order matrices.

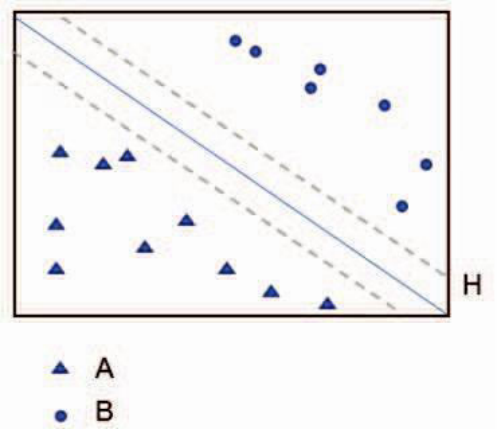

Fig. 2. SVM model

II. INTRODUCTION TO METHODS AND APPLICATIONS OF MACHINE LEARNING IN MEDICAL CARE

A. Assisted tumor diagnosis

With the development of medical technology and artificial intelligence, ML has been studied for the prediction of tumor, follow-up treatment and so on. At present, relevant study has made an significance in breast cancer, lung cancer, skin cancer. Researchers are still advancing research on other cancers.

Taking treatments of breast cancer for instance, SVM is a common method to use, SVM divide the kind of tumor into benign and malignant and then map them in multidimensional space to alleviate complex analysis in two-dimensional space that is relatively simple. It always chooses a best hyperplane which is used to split these data. CHEN et al.[1] found that cancer nest characteristics, cancer nest cell density characteristic and stromal cell structure characteristic were particularly significant in the pathogenesis of breast cancer by data mining on 1150 chromosome images by SVM

Chen and others have the highest accuracy rate of 99% for the nuclear information. Jiang[2] compensating for the semantic gap between low-level and high-level diagnosis, using super hashing based on joint kernel through 3121 breast tissues. In large databases, it distinguished benign cases, the retrieval accuracy reaching 88.1% and the classification accuracy reaching 91.3% in a 16.6ms query time. In the field of skin cancer, Jaworek[3] proposed a more accurate method for distinguishing melanoma. He used Dermoscopic method to preprocess skin images, to remove parts which are not related to skin symptoms. Then he segmented and extracted images, and analyzed color features. Meanwhile, he used gray-level co-occurrence matrix texture rendering. The degree of cancer of skin is judged and the accuracy reached 92%.

In addition, there are many researches analyzing from different angles, such as clinical perspectives and DNA virus data. The accuracy of the prediction using ML is about 85%, and the results are relatively accurate.

B. Applications in medical imaging

Today, when medical resources are limited, the efficiency of medical imaging examination and relevant results don't satisfy most of people. It means that, if ML is used in medical imaging, it will greatly save manpower and improve efficiency. In recent years, ML has been favored by medical practitioners in CT segmentation, MRI analysis, and other aspect of medical images.

In terms of ultrasound detection, Zhu[4] proposed in his article that the artificial neural network algorithm can be used to determine benign and malignant nodules in the thyroid. In this experiment, 618 patients and a total of 689 thyroid nodules, of whom no history of thyroid disease, no history of radiotherapy in the neck, and ultrasound examination. After extracting the morphology, margin, echo, internal combination, calcification, halo sign and color Doppler vascular characteristics of each nodule, they constructed a neural network, where 0 and 1 are used to indicate benign and malignant respectively. To avoid overtraining, a total of 561 nodules participated in the study and constrained the above six eigenvalues and related characteristics respectively. By calculating the error between the output value and the expected value, the weight between neurons

In MRI images segmentation, HUANG[5] proposes to use gray forecast model to reduce the error. He created original sequence by collected data and established G(1,1) model by formula as following:

$$\underline{d}X_1(i)dt+\text{Ị}\,X_1(i)=\ddot{u} \qquad (2)$$

The above equation can be solved by the least squares method, where is the control coefficient, ˗ is the expansion factor, X_0 and (1) is the initial predicted value:

$$X_1(i)=\left[X_0(1)-\frac{\beta}{\alpha}\right]e^{-\alpha(i-1)}+\frac{\beta}{\alpha} \qquad (3)$$

Through this method, the randomness of the original data can be reduced, and the experiment showed it can identify the region of tumor roughly, reduce false positives efficiently, and improve the accuracy of segmentation of tumor. Sarraf[6] classified results of MRI with Alzheimer's disease and normal brain by convolutional neural network (CNN) and structure of LeNet-5, and studied 62335 images, of which 52507 belonged to Alzheimer's disease with high accuracy reaching 98.85%. Dou[7] detected brain microbleeds (CBMs) by establishing a three-dimensional full convolutional network (FCN). This result can reduce a large number of redundant calculations, and greatly speed up the detection speed with the sensitivity is up to 93.16%. Theoretically, this method can also be applied to other medical tests.

Besides the above-mentioned applications, ML has many researches on liver fiber CT and MRI of cancer. Among them, ANN, SVM and clustering algorithms are the more common methods. Which are derived from the main ML algorithms also gradually open up the horizons of researchers.

III. APPLICATIONS OF MACHINE LEARNING IN PRE-DIVISION AND REFERAL

A. Traditional and new ways of medical care

Focusing on researches about ML in medical care currently, its focus is basically on the judgement of the symptoms and the improvement of related medical

measures. Certainly, relevant researches are able to reduce the investment of medical resources and avoid subjective error caused by human's judgement themselves. Considering the development and the existing research, at present, the traditional medical process must be registered in the hospital, and after arriving at the corresponding clinic, it is necessary to go through the inquiries and inspections of the department doctors to obtain a preliminary result. Even in many cases, it is necessary to transfer to other department. Therefore, we may wish to open up a new idea, not only to save the medical resources from the process, but to process the data from the pre-stage of the medical treatment, and classify the different patients by the machine. After the examination, the patients will no longer ask the original doctor for advice, instead, directly to the corresponding department required. The traditional medical steps and intelligent medical steps are compared as follows: was changed. Finally, the result reached 84.3%.

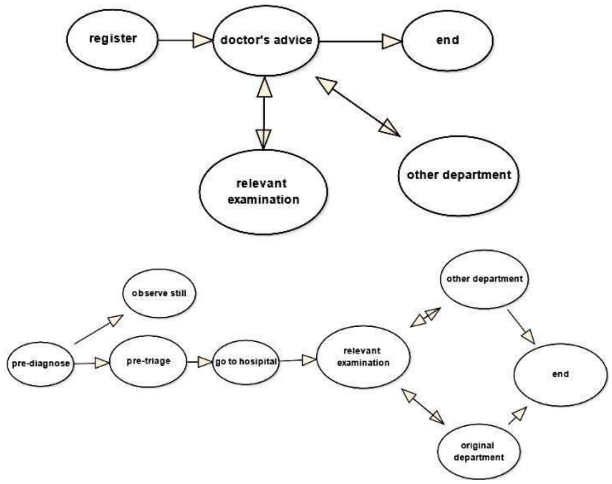

Fig. 3. traditional and new model of medical care

B. Dealing with information

If we want to make sure that the patient's condition is as correct as possible, you must first ensure that we have a database that covers as much relevant information as possible, create a target data set, and then preprocess it (this process may cost 60 About % of the energy), and then through the data conversion to find useful data features, and then data mining.

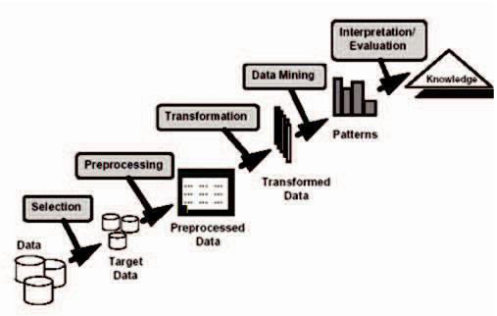

Fig. 4. Steps of data mining [8]

In the pre-processing of information, the past symptoms and cases are first entered into the database. Because there may be some defects in the cases, the decision tree algorithm that is not sensitive to the missing data is used for pre-processing. Use impurity to measure which node to separate, using the form of the entropy formula:

$$E(t) = -\sum_{j} p(j|t) \log_2 p(j|t) \tag{4}$$

$$G_{split} = E(p) - \sum_{i=1}^{k} \frac{n_i}{n} E(i) \tag{5}$$

In all nodes, the largest G value of all node is the current separation node. From this traversal, the most suitable node can be found and it can be classified according to relevant attributes.

During the examination and referral process, it can classify patients into diffrent types, based on the similarity and a high-dimensional data space which can be used to measure the similarity. Here we introduce the coefficient of Jaccard as the standard of measurement. The Jaccard similarity coefficient indicates the ratio of the intersection of two sets to the union of the two sets. For the initial classification, an initial threshold İ is set. The formula is as follows:

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} \tag{6}$$

The Jaccard is calculated as follows, and then, the similarity coefficient will be formed into a similarity coefficient matrix. The sum of each row of the similarity matrix coefficient is calculated, the largest sum recorded as a variable called max, and then the element on the line and the element larger than İ are searched. The column in which the element is located and record the row number, and separate it as the row and column of the new matrix.

Repeat the steps of calculating the row and again, construct a new matrix again, and judge the latest matrix. If all the elements are greater than İ, then go back to initial starts to work again, otherwise it starts from the sum of the second search matrix rows.

$$\mathrm{sim}(i,j) = \frac{|A \cap B|}{|A \cap B| + |A \cap \bar{B}| + |\bar{A} \cap B|} \quad (7)$$

$$\begin{pmatrix} sim_{11} & \cdots & sim_{1n} \\ \vdots & \ddots & \vdots \\ sim_{n1} & \cdots & sim_{nn} \end{pmatrix} \quad (8)$$

The similarity matrix analysis method is used to classify the patient's illness, and the relevant data is transmitted back to the patient and the medical staff, which can effectively help them to conduct intermediate referrals, which greatly saves the investment of the manpower.

IV. PROBLEMS AND CHALLENGES

As a hot topic in recent years, machine learning has developed rapidly, and its application in medicine has gradually enriched. However, it is inevitably limited by multiple factors. The common problems are as follows:

(a) In the medical image analysis, although the error caused by the subjective condition of the doctor is avoided, it is also limited by the objective conditions, such as noises, and other errors are still easy to occur;

(b) Although machine learning has already invested in many researches and applications in assisting tumor treatment, it still requires more financial and personnel requirements to make relevant research and development and to put into large-scale use. At present, it still cannot meet this requirement;

(c) The current research has made achievements in pathological analysis, but it is still not applicable to the illness requiring human resources, such as analgesia and fever, which are more common.

(d) Learning about relevant content means that a sufficient amount of data is needed and a complete database must be established for the patients. This is accompanied by certain security problems. How to ensure that the information is not leaked is also related to doctors, patients and the law.

(e) The adoption of the machine learning method means that simple work can be directly replaced by machines. It means that, at the same time, the employment situation of the relevant personnel and the education level of the medical profession need to be improved.

V. CONCLUSION REMARKS

This article reviews the main methods of machine learning, and summarizes several representative applications after understanding the history of machine learning in the medical field and its current application. The typical ideas and algorithms are summarized. At the same time, the improvement method based on machine learning in the process of visiting is proposed. However, this does not mean that ML is perfect. Whether in terms of technology, ethic or law, it has certain problems. The solution of these problems requires technicians and legal personnel. Working together, and how to strike a balance between manpower and machine is also a problem that everyone of us must face.

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