Application of Computer-Aided Diagnosis Algorithm in CT Images of Urinary Calculi

Yaming Gao¹, Laijian Huang², Bin Chen¹ and Zhaobang Liu³, *

¹College of Information Engineering, Yangzhou University, Yangzhou 225127, Jiangsu, China
²Wenzhou People’s Hospital, Wenzhou 325699, Zhejiang, China
³Suzhou Institute of Biomedical Engineering Technology, Chinese Academy of Sciences, Suzhou 215163, Jiangsu, China

*Corresponding author e-mail: liuzb@sibet.ac.cn, gao_yaming@126.com

Abstract. In recent years, computer-aided diagnosis has developed from pure theory to clinical trials, which has proved its feasibility and applicability in the diagnosis of breast cancer and pulmonary nodules. Therefore, combined with the actual medical background, computer-aided diagnosis is used in the analysis of urinary calculi components in patients, and the composition and structure of calcium oxalate calculi and anhydrous uric acid calculi are accurately analyzed, which has important guiding significance for the clinical treatment and prevention of urinary calculi.

1. Introduction

With the improvement of people's quality of life, the incidence of urinary tract stones has also increased, which has become an important issue related to health. So, as far as its simple components are concerned, calcium oxalate is the most common, accounting for more than 80% of the stones, followed by anhydrous uric acid, accurate identification of the components of stones has important guiding significance for its follow-up treatment [1]. CT images of calcium oxalate and anhydrous uric acid stones are shown in Figure 1.

![Figure 1. CT image of calculi.](calcium_oxalate_and_anhydrous_urate_stones.png)
There are many methods for calculus composition analysis, such as chemical qualitative analysis, element or component analysis, structural analysis, phase analysis, etc. But these methods either need large-scale instruments, or can not be specific quantitative analysis, which are not fast and reliable enough.

At the same time, the development of information technology and artificial intelligence makes computer-aided diagnosis more and more concerned. Medical staff needs to deal with a large amount of information every day, which will inevitably lead to errors and omissions. Computer-aided diagnosis not only relieves the pressure of doctors' work, but also greatly improves the work efficiency, which makes medical diagnostic methods gradually change from experience-oriented mode to more scientific and accurate digital mode, and has made breakthroughs. Medical imaging diagnosis is one of them [2].

Therefore, the cross-sectional CT images, sagittal and coronal planes, combined with machine learning algorithm, accurately analyze the composition and structure of calcium oxalate and anhydrous uric acid in urinary calculi to assist doctors in diagnosis. CT tomography is shown in Figure 2.

![CT tomography](image)

Figure 2. CT tomography.

Computer-aided diagnosis technology combined with image processing and machine learning plays an important role in medical diagnosis. From the initial theoretical research to clinical diagnosis, it provides effective assistance for the diagnosis of various diseases. The key technologies involved are as follows:

Firstly, the stone image is preprocessed and segmented.

Secondly, multi-class features are extracted from the image and feature selection is carried out.

Then, the selected features are put into the classifier for training, and the classification model is obtained.

Finally, the model is used to diagnose and classify, so that the doctor can prescribe the right medicine and make early diagnosis and treatment.

This has played a very good reference role in medical diagnosis. Now the technology has entered the stage of clinical application and has great research value.

2. Image preprocessing and segmentation

Preprocessing mainly uses image enhancement technology. Traditional image enhancement technology is mostly based on image processing in spatial domain. This paper includes gray adjustment and sequence interpolation.

Gray-level adjustment is an image enhancement method based on gray-level histogram. The distribution of pixel brightness in an image can be visualized by using gray-level histogram. The quality of the image can be adjusted by histogram equalization and normalization, so as to make the image clearer. In this paper, the normal pixel value of CT image is changed to the CT value for medical purposes, and the content within [300, 1300] Hu is intercepted for gray adjustment to enhance the image details.

Sequence interpolation is one of the key techniques of three-dimensional reconstruction. In medical diagnosis, the continuous two-dimensional images are synthesized into three-dimensional models of human tissues and organs, which can reflect the regional information more intuitively, authentically and comprehensively. It is helpful for doctors to understand the condition objectively and increase the
success rate of treatment [3]. In this paper, the linear interpolation method is used to unify the super-resolution image.

Aiming at image segmentation, this paper regards the results of artificial segmentation by clinical experts as the golden standard, uses 3D Slicer software to extract the lesion area manually, and then cuts it to get more accurate ROI window [4]. The flow of preprocessing and segmentation is shown in Figure 3.

![Figure 3. Pretreatment and Segmentation Flow Chart.](image)

3. Feature extraction and selection

Feature extraction is a concept in computer vision and image processing. It refers to the use of computers to extract image information and determine whether each image point belongs to an image feature [5]. Because the density of stones in vivo varies greatly, this paper extracts two-dimensional and three-dimensional features from the gray level of CT images, as shown in Table 1.

| Feature description | Feature composition | Feature dimension | Feature number |
|---------------------|---------------------|------------------|---------------|
| Grayscale feature   | CTmax, CTmean, Variance, Entropy, Inclination, Kurtosis | 2D, 3D           | 6, 6          |

Feature selection refers to the process of selecting N features from the existing M features to optimize the specific indicators of the system. It is a process of selecting some of the most effective features from the original features to reduce the dimension of the data set. It is an important means to improve the performance of the classifier and also a key data preprocessing step before image data
classification [6]. In this paper, relief algorithm is used to filter the features of stone image. It is a feature weight algorithm. According to the correlation of each feature and category, different weights are given to the features. The features whose weights are less than a certain threshold will be removed.

4. Classification

Because the CT image data used in this paper is limited, and the support vector machine itself can better solve the practical problems of small sample, non-linearity, high dimension and local minimum, so this paper chooses SVM classifier.

At the same time, in the selection of kernel function, the SVM classifier based on Gauss radial basis function is a kind of strong locality kernel function. It can map a sample to a higher dimensional space. It has better performance on both large and small samples, and it is suitable for the small number of features and the normal number of samples. So this paper uses the SVM classifier based on RBF kernel function.

5. Experiment

(1) Experimental data and environment

1) Experimental data:
In this paper, we collected the DCM data set of CT images of stones from Wenzhou People's Hospital, including 48 patients with calcium oxalate and 47 patients with anhydrous uric acid. The resolution of intra-layer pixels is 512*512 and the spacing is 5 mm.

2) Experimental environment:
Operating system: Windows 7; CPU: Intel (R) Core (TM) i7-7500 CPU @ 3.40 GHz (3401 MHz); Memory: 8GB; Programming software: MATLAB R2016a.

(2) Evaluation methods

1) Hierarchical 10-fold cross-validation method
In hierarchical cross-validation, the data set is divided into ten parts, so that the proportion between categories in each part is the same as that in the whole data set. Nine of them are used as training data in turn, and one is used as testing data. Correct rate will be obtained in each experiment. The average of the accuracy of 10 results is used to estimate the accuracy of the algorithm.

2) Parameter adjustment
Most machine learning algorithms have some parameters that need to be set. The performance of the model will be different if the parameters are set differently. Therefore, in the process of model selection and evaluation, in addition to the selection of the applicable algorithm, the parameters of the algorithm itself need to be set.

In order to select the optimal parameters and optimize the classification model, this paper uses 5 fold cross validation method and AUC index to set the step size of each classifier parameter and adjust it.

3) Performance metrics
The Confusion matrix is an error matrix, based on which many metrics can be obtained, as shown in Table 2.

| Real situation     | Prediction results |              |
|--------------------|--------------------|--------------|
| Positive example   | TP                 | FN           |
| Counter example    | FP                 | TN           |

Table 2. Confusion matrix.
ACC = \frac{\text{Number of correctly classified samples}}{\text{Total sample size}}

The transverse axis of ROC curve:

\[ \text{FPR} = \frac{\text{FP}}{\text{TN} + \text{FP}} \]

Longitudinal axis of ROC curve:

\[ \text{TPR} = \frac{\text{TP}}{\text{TP} + \text{FN}} \]

According to the predictive probability of the classifier, the thresholds are constantly updated, and coordinate points corresponding to multiple confusion matrices are obtained. Then ROC curves are drawn according to coordinate points and AUC values are calculated.

(3) Experimental steps and results

After gray adjustment and sequence interpolation of image data, the gray features of 2D and 3D are extracted. The first 10 features are selected by relief algorithm, and the results are evaluated by RBF_SVM classifier. The final auxiliary diagnosis algorithm is obtained. As shown in Figure 4, Figure 5 and Table 3, the ACC value of 10 results is about 0.77, while the AUC value of ROC curve is about 0.84. Therefore, the algorithm can basically realize the classification of calcium oxalate and anhydrous uric acid stones and assist doctors in diagnosis.

![Figure 4. ACC and AUC values of auxiliary diagnosis algorithm.](image)

![Figure 5. ROC Curve of Auxiliary Diagnostic Algorithms.](image)
Table 3. Auxiliary Diagnostic Algorithms ACC, AUC Value.

|    | ACC     |     AUC   |
|----|---------|----------|
|  1 | 0.7731  | 0.8463   |
|  2 | 0.7647  | 0.8361   |
|  3 | 0.7647  | 0.8268   |
|  4 | 0.7731  | 0.8463   |
|  5 | 0.7815  | 0.8460   |
|  6 | 0.8067  | 0.8567   |
|  7 | 0.7563  | 0.8353   |
|  8 | 0.7563  | 0.8339   |
|  9 | 0.7563  | 0.8426   |
| 10 | 0.7731  | 0.8432   |
|    | average | 0.8058  |
|    | value   | 0.8412  |

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The person in charge of this article:
Name: Gao Yaming
Mobile phone: 15052563062
E-mail: gao_yaming@126.com

Author's Profile:
Gao Yaming: Master's degree in image processing and machine learning, 321023199410060219, 15052563062, School of Information Engineering, Yangzhou University, Medical Works Institute No. 88 Keling Road, Science and Technology City, Suzhou City, Jiangsu Province, 215163, gao_yaming@126.com.

Huang Laijian: Deputy Chief Physician. His main research area is urology.
Chen Bin: Associate Professor. The main research fields are machine learning, image processing and big data.
Liu Zhaobang (Communications Author): Associate Researcher, Supervisor, Main Research Areas are Medical Image Processing, 15051431737, 0512-69588115, Medical Works Institute, No. 88 Keling Road, Science and Technology City, Suzhou City, Jiangsu Province, 215163. (liuzb@sibet.ac.cn).

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