PLUG-IN MODULES ON PLUTO FOR IDENTIFYING INFLAMMATORY NODULES FROM LUNG NODULES IN CHEST X-RAY CT IMAGES

Yasushi Hirano

Information Technology Center,
Nagoya University
Furocho, Chikusa, Nagoya 464-8601,
Aichi, Japan
E-mail: hirano@itc.nagoya-u.ac.jp

Nobuhiko Seki and Kenji Eguchi

School of Medicine, Teikyo University
Kaga 2-11-1, Itabashi 173-8605, Tokyo, Japan

ABSTRACT

We introduce an implementation of plug-ins on PLUTO. These plug-ins discriminate inflammatory nodules from other types of nodules in chest X-ray CT images. The PLUTO is a common platform for computer-aided diagnosis systems on Microsoft Windows series and it is easy to add new functions as plug-ins. We coded two plug-ins. One of the them calculates features based on medical knowledge. The other plug-in calculates parameters to classify the type of nodules, and it also classifies nodules into inflammatory nodules and others using SVM. These plug-ins are coded using MIST library which is produced at Nagoya University, Japan. In our previous study, the MIST library was parallelized, so that we can utilize a number of CPUs to calculate features and SVM learning/classifying depending on the amount of computation.

Using these plug-ins, it became easy to extract features to discriminate inflammatory nodules from other types of nodules and to change parameters for feature extraction and SVM learning/classifying with GUI interface. The accuracy of the classifying result is 100% with 78 solid nodules which contains 43 inflammatory nodules and 35 other type of nodules.

Keywords: Inflammatory nodule, Chest X-ray CT image, GUI, PLUTO Plug-in, Computer-aided diagnosis

1. INTRODUCTION

Recent progress of CT scanner made it possible to observe a large quantity of very small nodules in chest X-ray CT images. These nodules could not be observed in CT images taken by conventional CT scanners. Although this make it possible to find cancers in early stage, a lot of benign nodules which need to be defined by a biopsy or long-term follow-up have been found. This led to studys of Computer-Aided Diagnosis (CAD) system for small nodules and studys to develop features from CT images [1][2]. The main aim of these study is to judge whether the nodule in interest is benign or malignant. On the other hand, judging these nodules needs long-term follow-up or biopsy. These tests give not only patients suffering mentally and physically, but also put strains upon medical doctors.

Parts of benign nodules such as lymphoid hyperplasia, granuloma and so on can be given their definite diagnosis only using their medical findings of CT images without follow-up and/or biopsy by expert medical doctors. In this papar, the authors call such type of benign nodules as “inflammatory nodules”.

The authors have developed image features to discriminate inflammatory nodules from the other type of nodules, and obtained 80% of accuracy[3][4]. The purposes of studys in papers[3][4] are only a proposal of features and a performance evaluation, so that the computer programs developd in these studys are not eazy to use for medical doctors. In this paper, the authors propose GUI programs for discriminate inflammatory nodules and the other type of nodules using features which we developed. Thess GUI programs are developed as plug-ins for PLUTO[5], the common platform for CAD, which is developed in Grant-in-Aid for Scientific Study on Priority Areas from the Ministry of Education, Culture, Sports, Science and Technology(MEXT), Japan : “Intelligent Assistance in Diagnosis of Multi-Dimensional Medical Images”. And the plug-ins in this study are developed using the MIST library[6] which was developed in the 21st Century COE (Center of Excellence) Program organized by the MEXT : “Intelligent Media Integration for Social Information Infrastructure” as the main image processing subroutines.

2. INFLAMMATORY NODULE

In this paper, the terget type of tumor is small solid nodule. It is pointed out that expert medical doctors can identify certain types of solid benign nodules such as lymphoid hyperplasia, granuloma and so on by obsereavating CT images. In this paper, We call these benign nodules as “inflammatory nodules”, and the other types of nodules as “other type”. Specifically, as shown in Figure 1, “other type” contains benign nodules except for “inflammatory nodules” and malignant nodules (cancers). The purpose of study is discrimination “inflammatory nodule” from “other type” automatically.

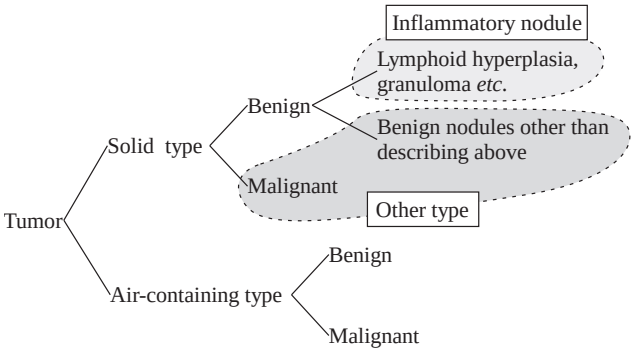
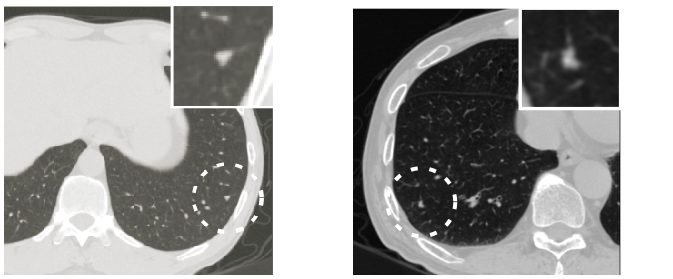
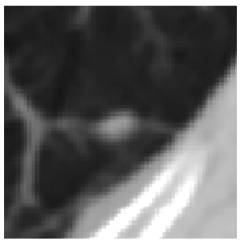


Fig. 1: Definition of Inflammatory nodule and other type of nodule

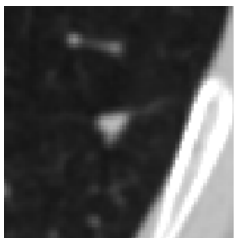


(a) Inflammatory nodule (b) Other type of nodule(Canccer)

Fig. 2: Examples of an inflammatory nodule and other type



(a) Vein connection and linear structure between nodule and pleura



(b) Linear boundary

Fig. 3: Examples of medical findings which characterize inflammatory nodules

2.1 Medical findings to identify inflammatory nodules

In the two-dimensional observation for CT slices, it is pointed out that most of inflammatory nodules have following seven medical findings[3][4].

- Boundary of nodule is smooth.
- CT values inside nodule are almost uniform.
- A distance between the nodule and the pleura range from 5 to 10mm.
- Linear structure exists between the nodule and the pleura.
- The diameter of nodule is less than 5mm.
- Nodule has linear boundaries, and the shape of the nodule is polygonal.
- Pulmonary veins connect to corners of nodules.

Figure 2 shows the examples of inflammatory nodules and other type (cancer). Nodules exist in dotted circles. Enlargements of nodules are shown at upper right areas in these figures. In the case of a inflammatory nodule (Figure 2(a)), because the tissue of the nodule stay in a secondary pulmonary lobule near the pleura and the pulmonary veins exist along interlobular septums, the above medical findings can be observed. For instance, it is confirmed that a inflammatory nodule(Figure 2(a)) have an almost uniform CT values inside of the nodule and linear boundaries in comparison with an other type (Figure 2(b)).

Figure 3 shows enlargements of inflammatory nodules. It is observed that a blood vessel connects to a corner of a inflammatory nodule and a linear structure exists between a nodule and a pleura (Figure 3(a)), bounraries of a nodule is linear and the shape of the nodule is polygonal(Figure 3(b)).

2.2 Quantification method for medical findings

The previous medical findings are quantified by the methods in the papers[3][4]. The following features are used in the experiments.

+ Calculated in two-dimensinal processing
  - Complexity of the boundaries of the nodule
  - Uniformity of CT values in the nodule
  - Distance between the nodule and the pleura
  - Existence of linear structures between the nodule and the pleura
+ Calculated in three-dimensinal processing
  - Diameter of the nodule
  - Planarity of the boundaries of the nodule
  - Connection of blood vesseles to the corners of the nodule

3. PROGRAM FOR DISCRIMINATION OF INFLAMMATORY NODULES

Programs to discriminate inflammatory nodules from other type of nodules were implemented as plug-ins for PLUTO (Figure 4). Basic functions such as loading and displaying CT images, acquiring mouse events and so on are provided by PLUTO. The plug-ins developed in this study takes in charge of the following functions:

- Calculation of features to the nodule which is designated by mouse action
- Output of features to a file

- Learning SVM parameters for discrimination using known nodules
- Calculation of features and discrimination for unknown nodules

The users can change parameters for calculation of features, learning and discrimination using GUI (Figure 5, Figure 6).

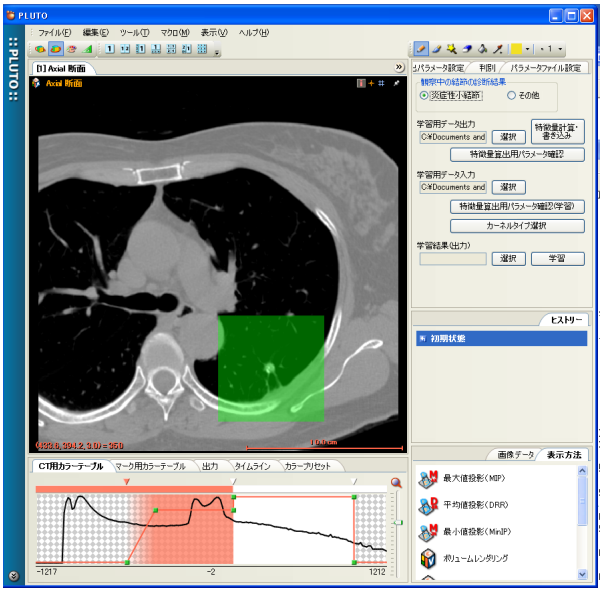


Fig. 4: Plug-in to classify nodules

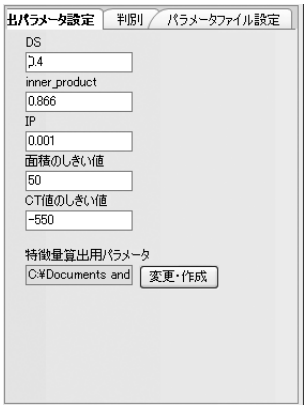


Fig. 5: Parameter setting for feature extraction

The main image processing subroutines such as the Euclidean distance transformation or thinning in the calculation stage are the functions which are coded for MIST library [6]. One of the authors have been parallelizing functions in MIST library using MPI (Message Passing Interface) [7][8] in [9]. Because it is easy to replace the conventional MIST functions with the parallelized MIST functions, when users need lerge computation power to process a lerge number of CT images at a time or discriminate using more features, they can compute in parallel using PC cluster constructed by Microsoft Computing Cluster Server[1]. We used TinySVM[10] as the discrimination function.

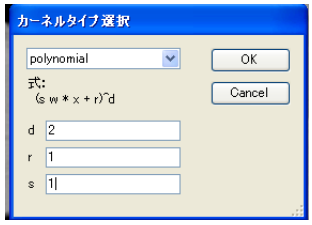


Fig. 6: Parameter setting for SVM

Figure 7 shows an example of the classification process. In this process, the user simply needs to select the SVM parameter file obtained in learning process, designate the nodule in interest with a mouse-click on the CT image, and click the “Classification” buttonin at the upper right in Figure 7. With only these simply actions, the user can obtain the classification result.

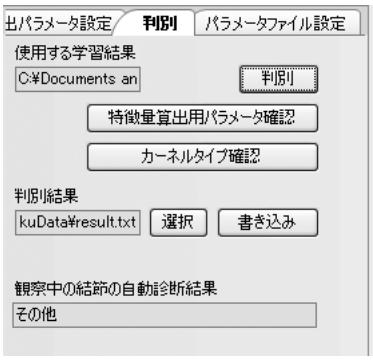


Fig. 7: Example of classification result

4. EXPERIMENTS

An experiment to discriminate inflammatory nodules from the other types were performed. The classifer is an SVM implemented as a plug-in for PLUTO, and the kernel of the SVM is polymomial.

4.1 Experiment samples

The CT images used in the experiment are taken by SIEMENS SOMATOM PLUS at the National Shikoku Cancer Center, Japan. the number of the CT images is 78 which contain 43 inflammatory nodules and 35 other type of nodules. All nodules are solid type and their diameter in three-dimensinal space are smaller than 10mm.

[1]The conventional and parallelized MIST library can be used on arbitrary ANCI C++ computation environment. The parallelized MIST can be used on arbitrary MPI evironment, and the MPI is the standard parallel programing library that is ordinarily installed on large-scale computation evironments. But the PLUTO can be used only on the Microsoft Windows, because the PLUTO needs .NET Framework and C# functions. This led to the limitation that the plug-ins developed in this paper work on only Microsoft Windows

Table 1: Spacification of CT images used in this experiment

Image size [voxels]	512 512 7 25
Pixel spacing[mm]	0.35-0.48
Reconstruction pitch [mm]	2.0
Slice thickness [mm]	2.0

Table 2: Classification result

		MD	
		Inflammatory	Other
System	Inflammatory	36	13
	Other	7	22

The details of the CT images are shown in Table 1.

4.2 Experimental results

The accurary of the classification was 100% using the resubstitution method and 74.4% using the leave-one-out method. The discrimental result evaluated by the leave-one-method is shwon in Table 2. In the result using the leave-one-out method, the precision is 73.5%($= \frac{36}{36+13}$) and the recall is 83.7%($= \frac{36}{36+7}$). It is cofirmed that the false positives occur frequently.

It takes about 2 minuites to calculate features after the user designated the nodule in interest by his mouse with obsearving CT image and about 1 minuite for classify. In the previous method[3][4], the user has to check the position of the nodule in interest using some CT viewer in advance and input it into the classification program.

5. DISCUSSION

The performance evaluated by the leave-one-out method was not enough to use in clinical use. It is needed to improve parameters for feature calculations and a cllasifier. A development to quantify new medical findings is also needed.

The previous method took a lot of time and labor. The proposed method, on the other hand, the procedures such as a feature calculation, a learning and a discrimination are simplified so much that the developed plug-ins can be used in clinical use.

6. CONCLUSION

In this paper, plug-ins for PLUTO were introduced. The plug-ins quantify medical findings as features and discriminate inflammatory nodules from the other type using these features. It became easy to set parameters for feature calcuretion and discrimination with intuitive operations using the proposed plug-ins in comparison with the previous study. In addition to these advantages, the users can select their computation environments in accordance with their computation scales. That is to say, the users can use the sequential or parallel computation enviroments. This will give the plug-ins a way of clinical use or effective search for optimal parameters.

The future works include a definition of the omtimal parameters for feature calculation, an evaluation by medical doctors, an application to higher resolution CT images, and an inplementetion for batch processing.

7. ACKNOWLEDGEMENTS

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