Extraction of pulmonary vessels and tumour from plain computed tomography sequence

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Abstract. Human lungs consist of various lobes and segments; the right consisting of 3 lobes and 10 bronchopulmonary segments and the left consisting of 2 lobes and 10 bronchopulmonary segments. A CT data of cancerous lung is taken and is segmented along with the vascular tree and tumor. The algorithms used for the study include Hessian matrix and Otsu’s multiple thresholding. The resultants will be fused and visualized in 3D fashion using Visualization Tool Kit (VTK), which is considered to be the future work. Later this part of the module will be further added to the application development process which finally will be provided to the cardiothoracic surgeons. This will enable them to the pre-planning of cardiothoracic surgery.

Keywords. ITK, Visual Studio, Segmentation, CT data, Image processing

1. Introduction

Nowadays, developing lung carcinomas has become quite common amongst both males and females due to unhealthy practices. To remove these tumors from the lungs it is essential for the patient to undergo a surgery. Medical image processing plays a crucial role in a better planning and visualization of these surgeries. As the technology keeps developing at a rapid speed, the technology for the processing of images has reached a higher level as well. Medical image processing refers to the capturing of raw medical data and processing it to create visual representations of the body’s interior parts. This helps in a better medical intervention and clinical analysis.

The imaging techniques reveal the internal parts of the body that have been hidden by the bones and skin. Also, it helps in establishing the anatomy and physiology database for the identification of any kinds of abnormalities. Considering the lung cancer, in particular, the imaging techniques play a vital role in detecting the cancer cells. Once they are detected, the doctor is assured of a tumor in lungs and can further perform the surgery.

Knowing the exact location of these cancerous cells and the blood vessels in a lung is necessary in order to perform the surgery. Image processing performed on the CT data of the lungs helps in locating these cells. This detects the exact position of both the blood vessels and the cancer cells. Medical image processing extracts the lung vasculature and the tumors separately. Later, Fusion of them will be
performed after they are extracted and will be seen in a 3D manner. In order to make it easier for the surgeons to perform the cardiothoracic surgery, a new methodology is proposed.

This methodology includes processing a CT lung data by extracting the blood vessels and the tumor cells. The blood vessels of the lungs are extracted from the Hessian matrix and the cancerous cells are extracted through otsu's multiple thresholding methods. Visualization will be performed by volume rendering to view the resultant images in 3D.

The other part of this paper is organized in the following manner, the summary of the existing relevant approaches, the procedure for the proposed methodology, the process of implementation of the proposed method, the evaluation of the results obtained and drawn conclusions.

2. Literature review
In the literature, many approaches have been proposed regarding the blood vessel segmentation. The summary of the already existing approaches related to the segmentation is given below.

Automatic segmentation of pulmonary structures in the thoracic CT was proposed by Van Rikxoort et. al. [1] This methodology includes segmentation of lungs, lobes, vasculature, fissures, and segments. The segmentation is performed using threshold values. Another approach by Sameet et. al. [2] includes the extraction of the lobes of lungs vasculature segmentation and 3D modelling. The process includes iterative global thresholding method, vessel tracking, and vessel continuity checking. Goncalves et. al. [3] proposed a method for lung nodule segmentation. The methodology includes multiscale segmentation using Hessian-based strategies that calculate shape index and curvedness. Hetal J.Vala et. al. [4] in International journal of Advanced Research in Computer engineering and technology, Feb 2013 proposed that otsu algorithm is suitable for image thresholding due to its simple calculation. It is used for automatic region-based segmentation.

Vijay et. al. [5] suggested a system to the presence of lung cancer using MATLAB with various image processing techniques like segmentation, feature extraction etc. Abdillah et. al. [6] proposed marker control watershed and region growing approaches for segmenting the CT scan images. In a research paper Makaju et. al. [7] proposed a method to sort different lung cancer detection techniques based on their accuracy over processing CT images. Seyed et. al. [8] proposed this methodology. In this method, Hessian based vessel enhancement filter is used to improve the Hessian based segmentation of vessels.

3. Proposed methodology
The methodology proposed consists of the following steps:

- Extraction of lung vasculature.
- Extraction of tumor cells.

3.1 Extraction of lung vasculature
The methodology proposed is presented with the use of CT lung data. The CT data is obtained from The Cancer Imaging Archive (TCIA) Database. TCIA is a service which has a large archive of medical images of cancer. It is a project funded by cancer imaging program of the national cancer institute with National Biomedical Image Archive (NBIA) as its core software. NBIA is an open source web application maintained by National Cancer Institute (NCI) of United States. NCI’s Cancer Imaging program was intended to support data sharing of the cancer images to the research community and now most of the images have been migrated to the TCIA. The CT lung data is in the Digital Imaging and Communications in Medicine (DICOM) format consisting of both thoracic and abdomen region. DICOM is the standard format for the medical images which can be integrated with the medical
imaging devices like scanners. It is an international standard for storing, retrieving, processing the medical image data. Totally it has got 437 slices. Thoracic cavity consists of heart, lungs, trachea, and oesophagus. For the study, only the thoracic region is taken, it is resized to 256x256 as shown in Figure 2 from 512x512 as shown in Figure1 and the type is also changed to 8 bit using ImageJ and is converted into Analyze (.hdr and .img) format by "DicomSeriesReadImageWrite2" because it consumes intense RAM which may shut the application. This data is given as a single sequence to the command prompt and corresponding results are obtained which are viewed ImageJ applications. The proposed methods are applied by the ITK (Insight Segmentation Toolkit). ITK is an open source package toolkit and an object-oriented system used mainly for image processing, segmentation and registering of digital data such as CT, MRI etc.

Figure 1. Input image
Segmentation is used for identifying and classifying data. Registration is the process of aligning and getting the correspondence between two data. The ITK operations performed are as follows:

- ITK configuration
- Generation of binaries
- Building ITK libraries

Each of these operations is explained in detail below.

Firstly, The Insight Segmentation Toolkit (ITK) is configured using CMake, a cross-compiler. A source code is provided and build folder is created for the binaries. Once the configuration process is done, the binaries are created using the same application. This folder consists of the required C++ source files which are taken from the ITK libraries that are from the examples. The scripting for the building is done in the CMakeLists.txt.

After the generation of binaries, it is built using Visual Studio, an IDE (Integrated Development Environment) in order to obtain the executables. The C++ files are given as an input to the Visual Studio that consists of the C++ compiler which converts C++ source files to executable files. The executable files generated by the compiler are:

- DicomSeriesReadImageWrite2.exe
- VesselnessMeasureImageFilter.exe
- OtsuMultipleThresholdImageFilter.exe

Once the binaries are built in the native compiler, .exe files are generated. Data is executed using the executables generated.

The processing tools are all placed in local drive. Once the executable files are created, the arguments are passed in the command prompt (CMD) and the resultant images are viewed in the ImageJ application. The project folder is created inside which the entire needed C++ source files and the CMakeLists.txt (case sensitive) consisting of the script is placed. The scripting is done as:
cmake_minimum_required(VERSION 2.8)
project(project)
find_package(ITK REQUIRED)
include(${ITK USE FILE})
find_package(ItkVtkGlue REQUIRED)
include(${ItkVtkGlue_USE_FILE})
set(Glue ItkVtkGLue)
add_executable(DiacomSeriesReadImageWriter2 DiacomSeriesReadImageWriter2.cxx)
target_link_libraries(DiacomSeriesReadImageWriter2 ${ITK LIBRARIES})
add_executable(VesselnessMeasureImageFilter VesselnessMeasureImageFilter.cxx)
target_link_libraries(VesselnessMeasureImageFilter ${ITK LIBRARIES})
add_executable(OtsuMultipleThresholdImageFilter OtsuMultipleThresholdImageFilter.cxx)
target_link_libraries(OtsuMultipleThresholdImageFilter ${ITK LIBRARIES})

It is then configured, generated and built similarly. The project folder can be added with additional files but for every single change, it has to be built again.

The Hessian matrix, located in the ITK libraries, is used for the segmentation of the tubular structures and it’s in name of "VesselnessMeasureImageFilter". It is a 3x3 square matrix of second order partial differential equation of a scalar function describing the local curvature of the function with many variables. In the Eigen value decomposition, Eigen values and Eigen vectors are obtained, out of which the Eigen values are used for the identification and segmentation of blood vessels. The filter takes the image of the hessian pixels as an input and preserves the pixels having Eigen values close to 0 and as greater negative values (for more bright tubular structures). The hessian filter takes into account that the Eigen values play an important role in differentiating between the orientation and shape of the structures. The Gaussian filter is used for the smoothening of the image. In Gaussian filter the image is blurred in order to remove the noise in it.

3.2 Extraction of tumor cells

The extraction of tumor cells is performed using "Otsu Multiple Thresholding Image filter", whose files are located in the ITK libraries that are in the examples. The Otsu’s multiple thresholding techniques are used to convert a grey scale image to a binary image. The image consists of object and background. The thresholding minimizes the misclassified pixels by knowing the grey level distribution. The binary threshold image created from this filter consists of foreground and background components.

In this section, the available datasets from TCIA are introduced. These are used to test the algorithms Hessian Matrix and Otsu’s Multiple Thresholding for the blood vessel and tumor segmentation respectively. This provides the proof of concepts for the proposed approach. These are then used in the experiment to test the proposed methods. The outcome of the experiment is shown in the evaluation and results section where the input data has been segmented into blood vessels and cancer cells.

4. Results and Discussion

In this section, the experiment is performed to evaluate the results of the proposed methodology. The dataset consisting of input images is given as a sequence and the blood vessels and carcinoma are segmented. The results show the segmentation of blood vessels as shown in Figure 3 and the blood vessels are enhanced using ImageJ as shown in Figure 4, the heart and the tumor are clearly segmented as shown in Figure 5 and Figure 6 respectively. Then the results will be fused to provide the exact position of the cancer cells which helps to plan the cardiothoracic surgery accordingly.
Figure 3. Vessel segmented

Figure 4. Vessel segmented enhanced
Figure 5. Slice 60- Resultant of Otsu’s multiple thresholding

Figure 6. Slice 138- Resultant of Otsu’s multiple thresholding
5. Conclusions

This study proposes the segmentation of lung vasculature and tumor cells using CMake, Visual Studio, and ImageJ applications. Blood vessel and lesion segmentation has various important applications and is useful in terms of medical technology. In order to be precise regarding the location of the tumor cells and vascular structures, it is essential to extract them from the input data. To overcome the problems faced by the doctors regarding the exact locations of vessels and cancerous cells during the cardiothoracic surgery, segmentation comes to the rescue. It becomes easier for the surgeons to plan their surgery accordingly.

This proposed methodology is effective and efficient in the segmentation of blood vessels and carcinoma. The experimental results prove that it is quite a competitive method when compared to the other segmentation approaches. In future, the resultant data obtained here will be fused and visualized in a three-dimensional fashion using VTK.

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7. References

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