Journal of Korea Multimedia Society Vol. 15, No. 12, December 2012(pp. 1449-1455)

Hippocampus Volume Measurement for the determination of MCI

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ABSTRACT

This paper has developed a system for early diagnosis of senile dementia and mild cognitive impairment (MCI) by developing software to measure the volume of hippocampus. This software consists of two parts; segmentation and analysis. The segmentation part uses ROI and region growing to segment hippocampus region. On the other hand, the analysis part creates a volume rendering of hippocampus. This software is expected contribute in these research fields for dementia diagnosis and its medication planning.

Key words: Hippocampus volume, Brain, Segmentation, MCI, volume rendering

1. INTRODUCTION

Nowadays, the elderly population with dementia is increasing. A statistics shows that approximately 5% of the population in United States of America is over 65 years old. In Japan, 6% of the population is also over 65 years old. In South Korea, with the increasing of aging society, the number of patient with dementia is also increasing gradually. Currently, there are about 400,000 people suffering dementia. It is predicted that there will be 60 million people with dementia in 2020, and 212 million people with dementia in 2050. Brookmeyer et.al even stated that by 2050, 1 in 85 persons worldwide will be living with the disease [1].

In order to prevent the social loss due to the increasing of dementia patients, prevention and treatment of dementia should be developed. In present, the prevention and treatment of dementia have not been developed. The only way to slow down the progress of the disease depends on the early diagnosis of dementia. This method cannot cure or stop the progression of dementia, but it is able to diagnose Mild Cognitive Impairment (MCI), which is the early symptom of dementia.

MCI is a disease which causes forgetfulness to the patient. It is also possible to be dementia in more severe case. The brain function and memory of a person with MCI are reduced if they are compared to the normal person at the same age, however the person is still able to perform daily activities. Every year, there are 12-15% of MCI patients that suffer on dementia. After 3 years, the number is predicted to increase to 50%, and after 6 years the number is also predicted to become 80%. Therefore, it is important to prevent the progress of MCI that turns to dementia using early diagnosis and proper medication.

The diagnosis of MCI using the cerebrospinal

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Receipt date : Nov. 8, 2012, Revision date : Nov. 20, 2012
Approval date : Nov. 26, 2012.

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※ This research was supported by Basic Science research Program through the National research Foundation of Korea (NRF) funded by the Ministry of Education, Science and technology (2012-0002646).

fluid and MCI examination using digital imaging devices such as MRI are available. These are some ways to diagnose a brain disease other than some behavioral or cognitive tests [2]. In the cerebrospinal fluid examination, MCI can be determined on the basis of the value of CSF beta-amyloid1-42 and tau [3]. On the other hand, MRI equipment commonly uses diagnostic method that is harmless to the human body. In addition, a quantitative measurement of the hippocampus in consecutive MR scans enables the physician to identify MCI. It could be the most effective way to diagnose dementia.

In order to determine the MCI, hippocampus volume measurement is needed. Therefore some researchers have been conducting a brain MR imaging-based study. J. Xie et al performed spatially-localized hippocampus shape analysis [4]. Amir Ghanei used dynamic contour segmentation to segment the hippocampus [5]. Fedde van der Lijn tried to segment hippocampus in MR images using atlas registration, voxel classification, and also graph cut [6]. On 2009, even a 7 Tesla MRI device had been used for a research on human brain by Metcalf et al [7].

To measure the hippocampus volume, hippocampus segmentation is needed. There are many methods that had been applied in hippocampus segmentation, e.g. appearance-based modeling [8], watersnake [9], deformable model [10], and likelihood classifier [11]. However, region growing method was used to segment the hippocampus. The volume of hippocampus is inversely proportional to the progress of dementia. Using quantitative hippocampus volume measurement, we will not only be able to identify the existence of MCI but also to find out the progress of the disease. This kind of research has been done continuously by some domestic and international researchers. However, there is still a lack of software to measure the hippocampus volume quantitatively.

In this paper, the purpose of the software development is to make a non-invasive diagnostic method to measure the hippocampus volume in order to determine the MCI, which is important to prevent dementia. The rest of this paper is arranged as follows. In section 2, the research method is explained. This section includes the research materials (the hardware/software environment and the data used for the experiment), the software configuration, and the explanation of segmentation and analysis process used in the paper. In section 3, the experimental results are shown. Finally, section 4 explains the evaluation of the experimental results and our further works.

2. RESEARCH METHOD

2.1 Research Materials

The hardware to run this software were HP Pavilion Elite HPE-470kr (Intel Core i7 870 2.932 GHz, 4.00GB memory, GeForce GTX 460, Windows 7 64bit). The working environment for the software development was Microsoft Visual Studio 2008 SP1 and the main language was Visual C++. The libraries used as software extensions were DCMTK (DICOM Toolkit), OpenCV, OpenGL and CUDA [12]. The developed software can run both on Windows XP, Windows Vista, and Windows 7 operating system.

This paper used sets of images that were acquired from psychiatry department of Haundae Paik Hospital, Busan, South Korea. Each set consists of 130 slices of coronal MR images. These sets were acquired from three male subjects and three female subjects. The MRI device used to acquire these MRI T1-weighted images was Philips 3T MRI machine. The format of the image was standard DICOM which resolution was 512×512 ×130 and the distance between two slices was 1mm.

2.2 Software Configuration

Fig. 1 shows the configuration of the entire system. The software was divided into two parts, segmentation application and analysis application. There was also a database middleware to save the result. The function of segmentation application was to make three-dimensional data by reading the DICOM file of MR images of the patient and to reconstruct the result. The hippocampus area can be chosen by selecting the region of interest after image preprocessing, which includes noise removal and image enhancement. This ROI is the area where region growing algorithm was used for hippocampus segmentation. In order to improve the segmentation accuracy, user can also select an area inside the segmentation result and apply some corrective actions, e.g. opening operations. Then, the final segmentation result image was saved in the database. The analysis application read the file and performed labeling operation on the segmented area. In order to measure the volume of hippocampus, the number of voxels in the hippocampus section was calculated. The volume of hippocampus can be determined by multiplying voxel size and the number of voxel. Finally, this application visualized the hippocampus using ray-casting algorithm.

2.3 Segmentation

The segmentation application for hippocampus was divided into 5 steps: load the DICOM images, reconstruct the input images, apply some preprocessing methods on the reconstructed image (image enhancement), implement the region growing method for hippocampus segmentation, and save the segmented images to the database.

The input of this application was a set of two-dimensional DICOM images. In order to generate a three-dimensional volume data, all two-dimensional DICOM files were sequentially loaded. The DICOM file information of the patient, such as the patient's name, date and time of recording were saved and stored separately. In this reconstruction, the image order must not be changed in order to prevent error that occurred in generating three-dimensional volume data from the two-dimensional images.

The horizontal (x) and vertical (y) dimensions of the generated three-dimensional volume were the same as the width and height of each two-dimensional image. However, the thickness, (z) dimension, of the three-dimensional volume was determined by the number of two-dimensional image slices. Therefore, there was a difference in size between the actual patient brain volume and the generated brain volume. To compensate the size difference that occurred between slices, linear interpolation was used.

The image preprocessing was divided into three parts. Firstly, hybrid median filtering was used to remove the noise in the image. Secondly, contrast stretching algorithm was used to enhance the con-

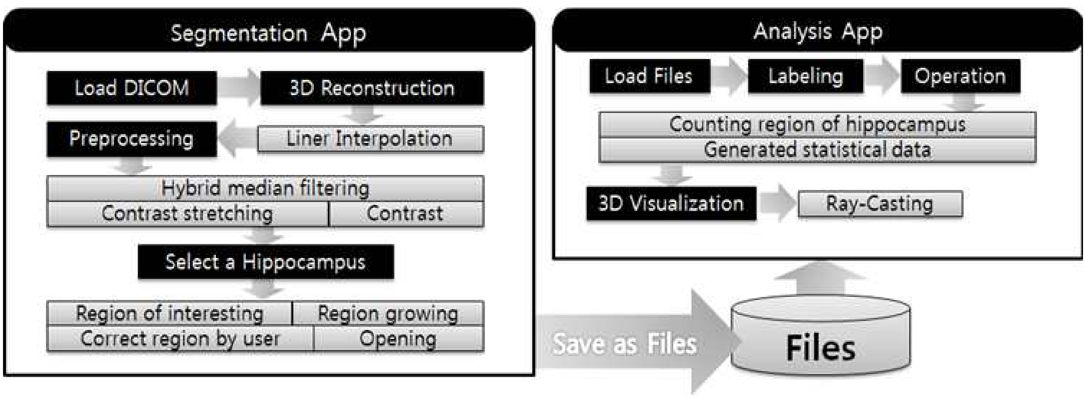

Fig. 1 The entire system configuration.

trast of the image. Finally, user can select the hippocampal region smoothly by adjusting the min and max value of contrast manually.

Hybrid median filtering algorithm was performed to reduce noise and preserve the boundary of the image. The disadvantage of median filtering and Gaussian filtering was the blurred boundaries in the filtered image. This disadvantage can be overcome by hybrid median filtering algorithm which able to preserve the hippocampus boundaries while removing its noise. In order to improve the contrast and the intensity of the image, pixel-based stretching algorithm was used. User can interactively adjust the min and max value of image intensity to obtain the best image.

Fig. 2 shows the process of hippocampus region selection. This selected area was the region of interest (ROI) for segmentation. User should set the ROI in order to minimize the errors that occurred in the ambiguous boundary. Then, user should select any pixel inside the ROI. Region growing algorithm was performed on selected pixel in order to obtain the whole area of hippocampus. Opening operation was used in the next step to minimize errors that occurred because of region growing segmentation. These region growing and opening operations were done for each slice. In this paper, the region selection in two-dimensional space was used to improve the accuracy of hippocampus selection. Direct region selection in three-dimensional space may cause more errors because of the ambiguous boundary between the hippocampus and the tissues on its surroundings. After the segmentation result for each slice was obtained, the files were saved on the database.

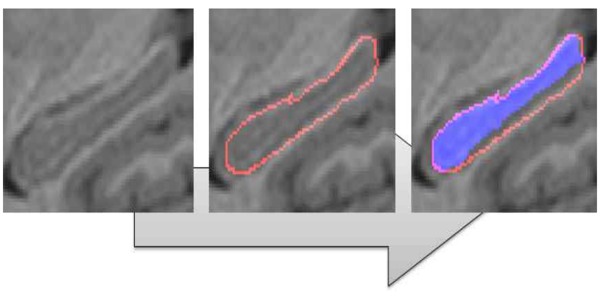

Fig. 2 The selection of hippocampus region.

2.4 Analysis

There were 4 steps to perform the analysis: load the segmented images from the database, apply the labeling operation on each image to distinguish the left and right hippocampus, measure the hippocampus volume, render the result of hippocampus segmentation using three-dimensional volume rendering.

After loading the segmented images, we need to distinguish between the left and right hippocampus. Therefore, three-dimensional labeling algorithm, which is the extension of two-dimensional labeling, was performed. Basically, this three-dimensional labeling algorithm also worked for each slice, but this algorithm also checked the relationship between the pixel in the current slice and the top and bottom slices. After this labeling process finished, the label for each slice was the result from three-dimensional labeling.

As mentioned in section 1, hippocampus volume was an important indicator of MCI. In this paper, the volume was defined as the voxels belonging to the internal volume of hippocampus. The hippocampus volume was measured by multiplying the internal voxels and the voxel size information obtained from the DICOM header file.

Three-dimensional visualization was the last step to be done after finishing the hippocampus volume measurement. Algorithm for visualization was ray-casting volume rendering. Fig. 3 shows the result of ray-casting algorithm for three-dimensional visualization and our Graphical User Interface. User was able to change the minimum and maximum value of the volume density, brightness, view area, etc. to acquire the best visualization of brain and hippocampus.

3. RESULT

Table 1 shows the result of hippocampus volume

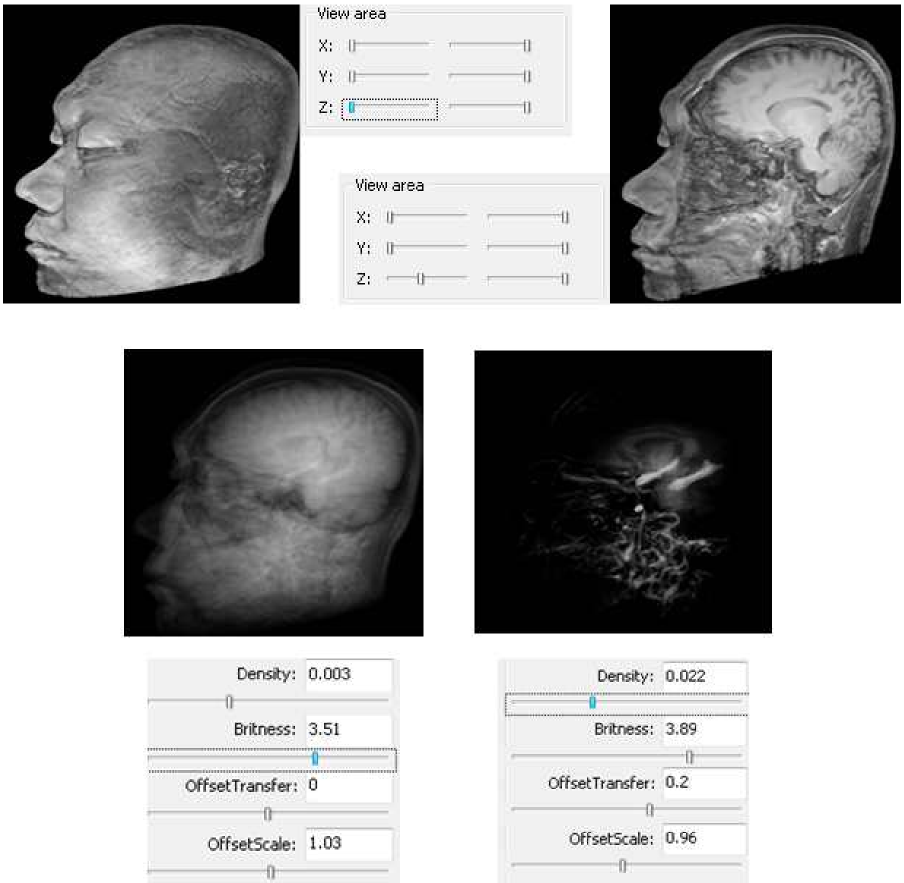

Fig. 3 The result of Ray-casting algorithm and its GUI.

measurement using the developed software. The subjects were three different males and females and the MRI images orientation was coronal. The results showed that the hippocampus volume of male subjects was larger than the female subjects. The average hippocampus volume of the male subjects was 2265.766mm^3 and the average hippocampus volume of female subjects was 1864.255 mm^3. Fig. 4 shows the three-dimensional visualization of the segmented image. In this visualization, the location and size of left and right hippocampus can be distinguished easily.

Table 1. The hippocampus measurement results

No	Male		Female	
	Left	Right	Left	Right
1	2039.334	2494.310	1672.243	1810.022
2	2232.576	2450.765	1950.160	1639.296
3	2142.950	2228.659	1324.109	1789.517

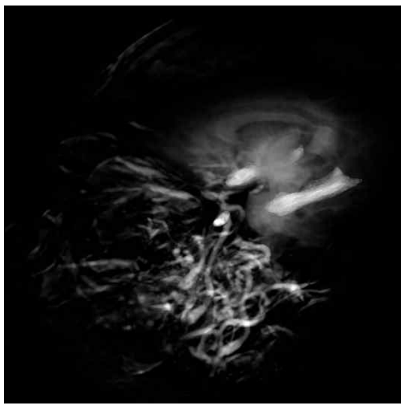

Fig. 4. The result of segmented image.

4. CONCLUSION

In this paper, a system to diagnose MCI from brain MR image by measuring hippocampus volume non-invasively was developed. However, there are a lot of things that still can be improved from this work. A further research in the method to segment hippocampus is the most important thing that can be developed. The error caused by ambiguous boundary between hippocampus and the tissue on its surroundings must be minimized using other segmentation method. An automatic segmentation instead of semi-automatic can also be developed in order to speed up the segmentation process, as one proposed by Chupin et.al. [13]. Even though this software still needs a lot of improvement, early diagnosis of MCI is able to be diagnosed using this software.

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