VESSEL SEGMENTATION BASED ON BONE-TO-BONE ELIMINATION IN BRAIN CT ANGIOGRAPHY

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Abstract -- In this paper, we propose a vessel segmentation method in brain CT angiography. Its main idea is to remove bones by a bone-to-bone elimination procedure between two series of images, instead of a time-consuming registration algorithm. Some vessel pixels may be removed by mistake during this bone removal procedure. We invent the idea of conditional dilation to restore lost vessel pixels. Whenever a vessel region is identified, we change its outer boundary to background values so that the later region growing can find out the whole vessel structure. Since the registration computation is no longer required, the segmentation process takes less time and makes it feasible for an interactive 3D segmentation in clinical applications.

Keywords : vessel segmentation, image registration, interactive segmentation, computed tomography, conditional dilation

I. INTRODUCTION

CTA (Computed Tomography Angiography) is a technique used to visualize blood vessels throughout the body to detect abnormal narrowing for diagnosing arterial diseases. For better visualization effects, contrast materials are injected to make vessels displayed in higher levels, often close to bone levels. The vessel segmentation thus becomes quite difficult if vessels and bones are within similar level ranges and partially connected.

One common solution to the above problem is to align CTA images with corresponding CT images (without contrast materials). Bones can thus be removed by cross-referencing these two series of images, making vessels easier to be identified, which was called Matched Mask Bone Elimination (MMBE) [1][2]. The alignment procedure, however, requires a precise registration algorithm, which is quite time-consuming and difficult to have satisfactory results in clinics[3][4].

In this paper, we propose a new way of utilizing both CT and CTA images. Our method does not reply on perfect image registration between these two series of images for bone subtraction, which is quite time-consuming and not feasible in clinics. Instead, we adopt a bone-to-bone searching procedure to remove most of the bone pixels. Our method requires less computation and could be incorporated into an interactive segmentation framework.

II. METHODS

For explanation purpose, a CTA image, highlighting both bones and vessels as shown in Fig. 1(a), is defined as a target image. A CT image, highlighting bones only as shown in Fig. 1(b), is defined as a reference image.

Our method consists of the following steps.

A. Simple Threshold

A simple threshold operation is applied to both target and reference images. For the target image, both vessels and bones are segmented out, but often connected. The threshold value is chosen so that all vessel pixels are reserved. For the reference image, the segmentation results contain only bone structures.

Fig. 1 (a) original target image, (b) original reference image, (c) thresholding of (a), (d) thresholding of (b). The threshold value is 150.
B. Preliminary Elimination

For each pixel, labeled as PR, of the reference image, its corresponding pixel PT is defined as the pixel with same coordinates in the target image. For each PT, a circular search region is given and every pixel inside this region is visited. All visited pixels with higher gray levels are considered to be bone structures, and thus removed by assigning background levels, as illustrated in Fig. 2 (a). The bone-to-bone search process between the reference and target images is the key to avoid registration computation.

C. Morphological Erosion

Due to the partial volume effect, part of the bone boundary remains. A simple erosion operation is applied to remove all the remaining bone boundary pixels. However, the vessel region is unavoidably eroded, as illustrated in Fig. 2 (b), and becomes smaller than its real size.

D. Conditional Dilation

In order to keep the vessel region complete, a conditional dilation is then applied. Although this operation proceeds on the target image, it cross-refers to the reference image for both conditional pixel-adding and stop conditions. During the conditional dilation process on the target image, only those pixels are added if their corresponding pixels on the reference image have non-zero levels, as illustrated in Fig. 2 (c). A dilation ratio is defined to be the comparison of the area of an object after and before the dilation. The conditional dilation stops when this ratio is smaller than a pre-defined value.

Whenever a vessel region is identified in the target image, its outer pixels are labeled as background pixels in original CTA images, so that the vessel region is disconnected from its neighbors, especially connected bone structures, as illustrated in Fig. 2 (d).

E. Region Growing

Once vessel regions are isolated from its neighborhood, a simple 2D or 3D region growing algorithm can be applied to segment the vessel structure.

Fig. 3 gives other segmentation results to demonstrate our method can identify vessels well, even when vessels and bones are actually connected.

III. CONCLUSION

Image registration plays a vital role in MMBE vessel segmentation. However, it is quite complicated and time-consuming. In this paper, we propose the concept of "vague search", instead of "precise alignment", to eliminate bone structures. We also invent the conditional dilation technique to fix the possible loss of vessel pixels during the vague search process. Several experimental results show that our method works quite well if vessels and bones are connected visually in CTA images. Since our algorithm is simple and could be incorporated into interactive 2D/3D segmentation framework in the future.

REFERENCES