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Detection of brain aneurysm and route searching to brain aneurysm aim at the development of operation simulation system

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Abstract: In this paper, a system is proposed that is necessary for an operation simulation system helping a trainee perform medical operation to make a cerebral aneurysm avoid exploding. The physician has empirically acquired medical technologies through a medical operation in traditional clinical teaching. However, there is a problem with security and a burden to a patient. So, recently as a new approach for training, the medical operation simulation system using Virtual Reality is attracted. Then, aiming at developing the medical operation simulation system for a cerebral aneurysm, we constructed the necessary function such as detecting a brain aneurysm that is a target of operation, searching for a blood vessel to make a plan of the operation.

Keywords: Medical image processing, Operation simulation, Brain aneurysm, Operation planning

I. Introduction

The physician has empirically acquired medical technologies through a medical operation in traditional clinical teaching. However, there is a problem with security and a burden to a patient. The exercise using a pig is difficult to repeat training, and hardship to conduct because of the cost and the protest by a group of protection of animals.

As a new approach for teaching / training in place of the traditional approach, the medical operation simulation system which utilizes virtual reality (VR) attracts attention. The advantage of VR is that it allows trainee to experience various disease state repeatedly and to evaluate know-how quantitatively.

So, this system aims at constructing a medical operation training system for cerebral aneurysm. We will show below the techniques necessary for an operation simulation system.

1. A visual display of an operation object
2. The force feedback using a haptic device
3. A medical operation planning system
4. Implementation of surgical instrument to cut or deform a virtual organ model

Among them, this search tackles 1, 3 to construct a system that detects brain aneurysm from a medical image, and analyzes structures of blood vessels to find a route to brain aneurysm.

This research is conducted based on our experience on both diagnosis of lug cancer or structural analysis of tracheole from CT images [1][2], how to cut a virtual surface model [3] or a virtual voxel model [4] with a scalpel, and simulation of medical manipulation ICSI using a deformable surface model [5].

II. Brain aneurysm

A brain aneurysm generally means a lump or a tumefaction part occurring in a small artery inside the brain. . As a cause of the occurrence, it is considered that there is a weak part on a brain artery wall by nature, and a blood vessel swells out like a lump because blood flow continues meeting with this part for many years. As the result, it occurs at a divergent position between blood vessels.

Treatment for a brain aneurysm is done to prevent an aneurysm from exploding in future. Main treatment is pinching a lump with a clip or inserting coils into a lump.

III. Detection of a cerebral aneurysm

If it is possible to make the location of a brain aneurysm clear in advance before training or diagnosis, it will help not only a trainee confirm a target but also a doctor determine if medical operation is needed or not. .

The appearance of a cerebral aneurysm is a lump shown in Fig. 1. A cerebral aneurysm occurs near the bifurcation between two blood vessels, and the one whose diameter is more than 2[mm] must be detected.

Two methods are used for detecting a cerebral aneurysm; the first one exploits how much a blood vessel is expanded as an index, the second one uses the distance from a bifurcation as an index.

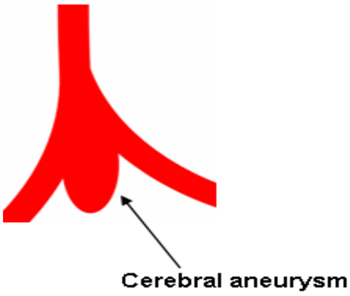

Fig. 1 State of outbreak of cerebral aneurysm

1. Detection of using the domain expansion of a blood vessel

Regarding an aneurysm as a part of a sphere, the domain expansion must be repeated two or more times at the point where a blood vessel swelled like a lump as shown in Fig. 2. In this process, it is necessary to judge the bifurcation of a blood vessel while applying the region growing method. For judging bifurcation, connectedness between the expanded areas is calculated, and if there is no connectedness, then there is a bifurcation between them [6]. When a point included in 27-neighborhoods of the current point labeled with a number i on a blood vessel is judged to be on a blood vessel, it is labeled with the number i+1. Only when there is connection between points given the same label in this process, they are determined to be on the same branch, otherwise, a new branch derives from the point; there is a bifurcation. As shown in Fig.3 the elements given a label 6 are not connected each other, so points labeled with 6 are judged as a bifurcation.

Now let the expansion rate be (A-B)/B, where B and A is the area before and after an expansion, respectively. We define a candidate of a cerebral aneurysm to be the portion where expansion whose expansion rate is more than 1.15 occurred successively at least two times.

In Fig. 2, the areas labeled with a number 4 and 5 are detected as a cerebral aneurysm because it suffices the above condition. But, the area of a peripheral blood vessel is so narrow that the increase rate of the area changes greatly. The goal of the system is to detect an aneurysm of which diameter is more than 2mm, then a small area less than the threshold value is not regarded as a candidate. As the spatial resolution in the axial slices is 0.357[mm], and square measure per one pixel is 0.127[mm^2], the number of pixels necessary to detect a cerebral aneurysm is about 25[pixels].

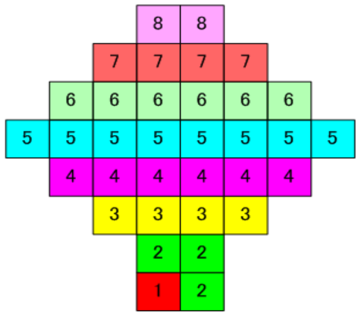

Fig. 2 Detection with the domain expansion

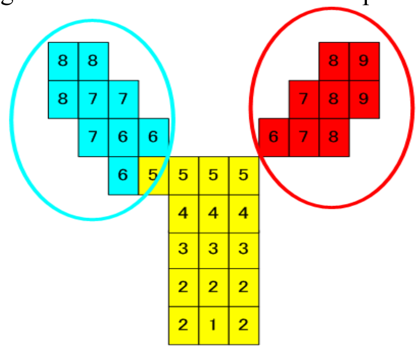

Fig. 3 Detection of the bifurcation

2. Detection using the distance from bifurcations

Though the method described in before section is able to detect candidates of a cerebral aneurysm, this method will cause a thick vessel to be regarded as a cerebral aneurysm. But the fact that a brain aneurysm occurs near a bifurcation will find a real brain aneurysm from candidates detected using the method shown in before section.

But, there are two bifurcations at the both end of one branch, so it needs to decide which one should be used to calculate a distance from an aneurysm to the bifurcation. Then, distance between an aneurysm and two bifurcations are calculated and the nearer one is selected as the bifurcation corresponding to an Aneurysm.

Fig. 4 and Fig. 5 will explain how the method is applied.

In Fig. 4, L1 and L2 show the distance between a candidate aneurysm and two bifurcations; in this case L1 is shorter than L2, so L1 is regarded as a distance to a detected brain aneurysm. In Fig. 5, the lump area at left side is close to the bifurcation, so it is judged as an aneurysm, and the lump area at right side is so far from a bifurcation that it is considered not to be an aneurysm. This system decides whether candidates are an aneurysm or not based on the condition that the distance from an aneurysm to a bifurcation is shorter than 4[mm] or not.

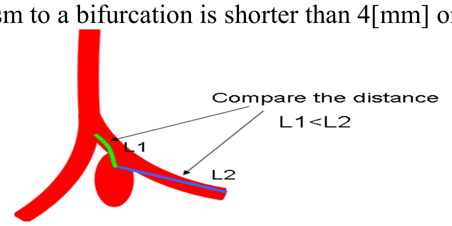

Fig. 4 Compare the distance from bifurcations

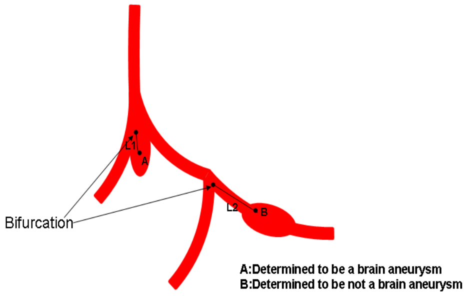

Fig. 5 Detection with the bifurcation distance

IV. Structural analysis of blood vessel for route searching to brain aneurysm

Intravascular operation needs a planning to make a catheter lead to near an aneurysm. Additionally, if the path toward an affected part can be found with a VR system, it is useful not only in an exercise but also in a real operation.

So with use of the result of divergence recognition, a path leading to the affected part is found using A* algorithm.

The process has 3 steps. First, a user decides the aim and start point. Secondly, as an estimate of a cost between the aim point and each bifurcation calculates distance from the aim point to each bifurcation. Finally, it searches the path to the aim point using A* algorithm.

1. Route finding based on structure

Connectivity relation between vertex of blood vessel is necessary to search a path using A* algorithm, but it is generated from the recognition result of bifurcation

Let the label of point be a bifurcation point(i) and that of a branch be branch(j).

The one set of information to be stored includes just a label of bifurcation points that are parent and child of one branch and a label of a branch.

We store this information list structure. The making method of this list is shown in following.

Start the following procedure from i=1, j=1, k=2.

(1) Store point (i) as a parent of branch (j).

(2) Perform a bifurcation recognition, and if a bifurcation point point(k) is found, store point(k) to the an child point of branch(j).

(3) If there are n branches of which parent is point (k), then name the one branch selected from them branch(j+1) and store the rest of them in a stack.

(4) in case point(k) is not an end point, then let i=k, k=k+1, j=j+1, and repeat from (1) to (3).

(5) In case point(k) is an end point and a stack is not empty, then pop up a stack, and set i , k, j to the label of a parent of the selected branch, k+1, j+1, respectively, then repeat from (1) to (3).

(6) In else case, end the process.

The method of this is shown in Fig. 6.

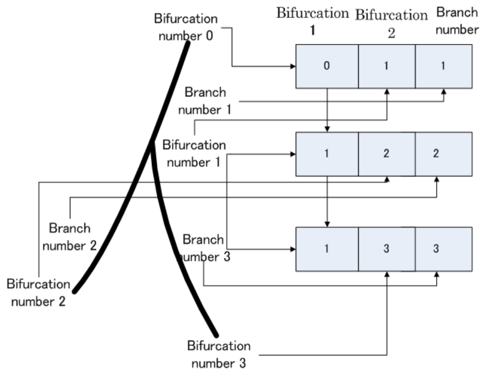

Fig. 6 Acquisition of connection information

V. Execution results

For 4 MRI images provided as samples, detection of brain aneurysm and the route searching to the brain aneurysm using by the structural analysis are tried to verify the validity of the proposed methods. The number of slices is 140, the slice interval is 0.5[mm], and the spatial resolution in the axial slices is 0.357[mm].

1. Detection result of brain aneurysm

Fig. 7 shows detection result using by the proposed method, and candidate of brain aneurysm is colored by yellow.

The proposed method is applied to 4 images and the validity of the method is evaluated based on the criteria shown below. The results are divided into two classes as shown in Table 1; the one uses only the domain expansion information and the other uses both the domain expansion information and the distance from bifurcation.

The number of false positives is used as evaluation criteria. A false positive means that an aneurysm is found in the place where none exists in reality.

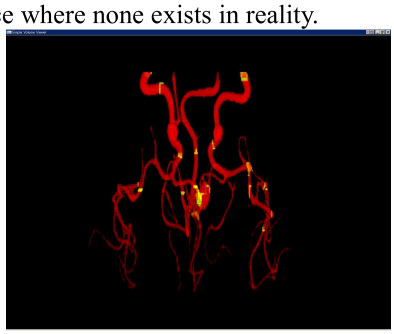

Fig. 7 Detected result of brain aneurysms

Table 1 Result of cerebral aneurysms

	True positive	False Positive [nodules/case]
Not use distance	100%(4/4)	82.25
Use distance	100%(4/4)	36.25

The result of Table 1 shows that proposed method is possible to detect brain aneurysm. And using by the distance from a bifurcation point as an index, the number of false positives decrease about 55.9[%].

But, any other false positives are found in curved portion of vessels. It is because the domain expansion applied to curved portion of a vessel tends to expand the area inside the curve because it is regarded as a part of a vessel.

2. Route searching to brain aneurysm using by the structural of blood vessel

Inserting coils into an aneurysm needs navigation leading a catheter to the diseased part. And before the operation, it needs to plan how to move the coil. So, this system constructs the path planning system from arbitrary part to a brain aneurysm using the analysis result of blood vessels.

The brain aneurysm is decided by referring to the detection result of brain aneurysm.

Fig. 8 shows the aim part (brain aneurysm) and start point. And, Fig. 9 shows the route found by using the structural analysis result of blood vessel and by applying A* algorithm to this analysis result.

The result of Fig. 9 shows that route searching succeeds.

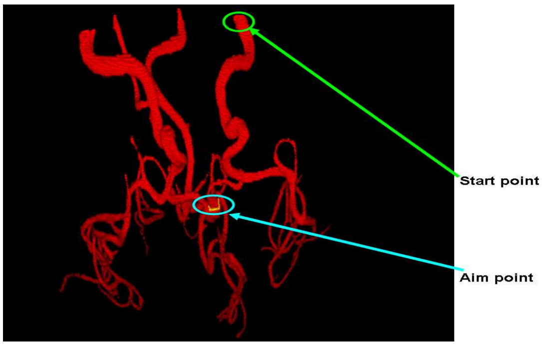

Fig. 8 The aim and start point of search

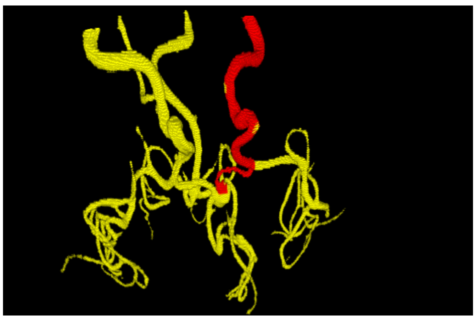

Fig. 9 Route search result to brain aneurysm

VI. Conclusion

Our research aims at building a medical operation training system helping an inexperienced medical student get medical techniques by performing medical operation to a virtual body restored from given sets of CT or MRI images. In this paper, we especially showed detection of a brain aneurysm and route searching to brain aneurysm.

The detection of an aneurysm is attained by reducing false positives using the distance from the bifurcation to the aneurysm as an index, but false positives are still remained. So, improving the precision in detection must be realized by using information on local structural features such as curvature of a blood vessel.

And, a route searching to brain aneurysm succeeds without any troubles. This will contribute to navigate a catheter to an aneurysm to put a set of coils into it to avoid its explosion.

To improve this system, we consider that the addition of samples is necessary to make the system more reliable: we would like to improve the precision in detection by getting much more images.

To build a system making a trainee feel as if he/she were performing real medical operation to the body of a real patient, in addition of drawing the deforming process it is necessary to return the force to a trainee's hand when with a medical tool he/she cuts or pushes tissue inside a head including vessels and brain itself.

VII. Acknowledgement

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