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Three-dimensional extension of blood vessel network based on extraction of blood vessel shape and the tree-structured analysis in ultrasound volume

超音波ボリューム中の血管形状抽出と木構造解析に基づく血管網の 3 次元拡張

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1. Introduction

Recently, many researches for medical therapy using ultrasound including HIFU and drug delivery have been proposed. Our group has been developing a therapeutic system to control micro objects as microbubbles, cells and thin catheter by making use of acoustic radiation force to reach specified drug only to the desired area through blood vessel network (BVN) and to reduce side effect. To realize this kind of therapeutic system, three-dimensional (3D) structure of BVN near the target area should be understood in advance. Therefore, we have reconstructed *in vivo* BVNs by processing three-dimensional images in ultrasound volume to combine the extracted information between B-mode and Doppler mode volumes [1-2]. Because there are some defects of BVN in the distance direction in B-mode images, and in the azimuth direction in Doppler mode images, the fusion of those information was effective [3]. Also, since the covered area in an ultrasound volume is limited to 70 x 50 x 60 mm^3 apporoximately, combining multiple BVNs, which were obtained from different ultrasound volumes, was carried out to obtain a wider BVN using a position measurement sensor [4]. However, because of breathing and body motion, there was spatial variation between neighbour BVNs, which was a problem of accuracy to extend using multiple BVNs. In this research, we have newly introduced tree-structured analysis after the extraction of blood vessel shape to minimize the effect of the spatial variation between BVNs.

2. Methods

We used Philips iU-22 echography and a 3D probe to obtain ultrasound volumes including objective BVNs from different directions. **Fig. 1** explains the process of 3D thinning [5] to extract the blood vessel centerline from the original volume and the conversion using tree-structured analysis, which reveals connection information between bifurcation and end points, which are defined as nodes. All of the nodes were connected by line segments, which are defined as edges. Here, the distance between the nodes and thickness in the original volume were stored in each edge.

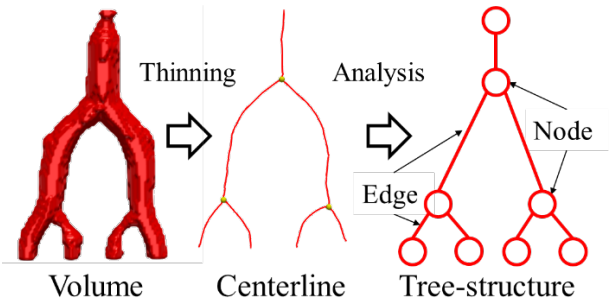

Fig. 1 Transition from blood vessel volume to tree-structure.

Next, we consider two neighbor tree-structures, which share some nodes and edges between them, to extend the BVN as shown in **Fig. 2**. The BVN in the coordinate vol2 is converted to the coordinate vol1, where ${}^{\mathrm{vol1}}p_i$ and ${}^{\mathrm{vol2}}p_i$ are expressed as the common nodes between two coordinates. Eq. (1) indicates the energy function, which derives the appropriate translation matrix ${}^{\mathrm{vol1}}t_{\mathrm{vol2}}$ and the rotation matrix ${}^{\mathrm{vol1}}R_{\mathrm{vol2}}$, by minimizing the value of E. Then, the homogeneous transformation matrix ${}^{\mathrm{vol1}}T_{\mathrm{vol2}}$ between two coordinates is obtained as eq. (2), where two BVNs are integrated in the coordinate vol1 as spatial point registration [6].

$$E = \sum_{i=1}^{N} \{ {}^{\mathrm{vol1}}p_i - ({}^{\mathrm{vol1}}R_{\mathrm{vol2}} + {}^{\mathrm{vol2}}p_i {}^{\mathrm{vol1}}t_{\mathrm{vol2}}) \} \quad (1)$$

$$T = \begin{bmatrix} R_{3\times3} & t_{3\times1} \\ 0 & 1 \end{bmatrix} \quad (2)$$

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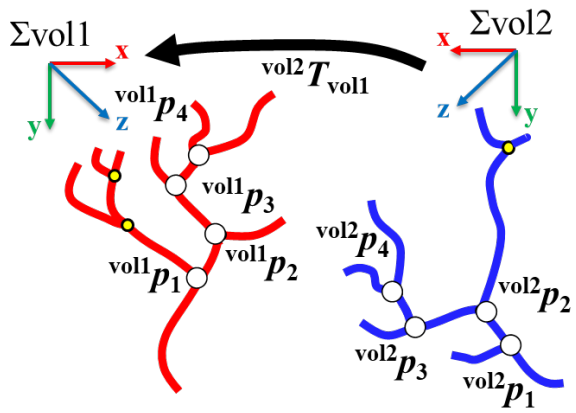

Fig. 2 Spatial point registration between two BVNs.

Next, we consider non-common nodes between two BVNs, which exist only in the coordinate vol2 (source tree) not in the coordinate vol1 (target tree). As shown in **Fig. 3**, two patterns can be considered as (a) the middle node is missing or (b) terminal nodes are missing in the target tree. In (a), the node p_s with the nodes in its branch are added in the target tree in consideration of the position of neighboring two nodes and the edge length between the them. Also, in (b), the node p_{s2} with the nodes in the downstream of p_{s2} are replaced from p_{t2} in the target tree. As the result, the extended tree, which contains all of the nodes in both trees, is obtained.

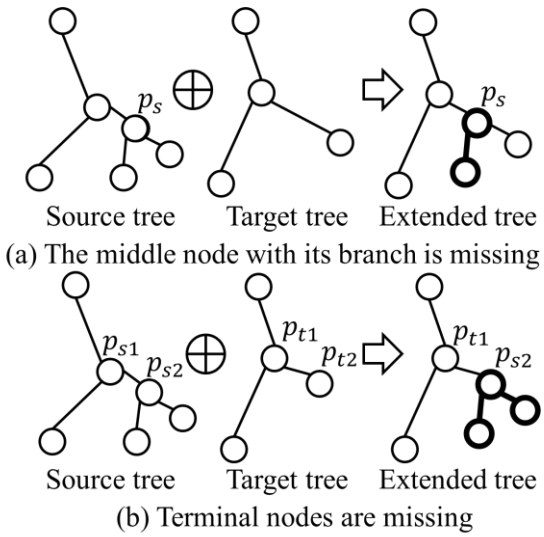

Fig. 3 Extension of missing nodes between two BVNs.

3. Results

The above method was applied to ultrasound volumes of porcine liver. **Fig. 4** shows the result of the extended tree composed of four BVNs, which were taken from four different directions. To verify the shape of the whole BVN, we compared it with the BVN extracted from CT volume, which was obtained from the identical porcine liver using contrast agent. We confirmed there were totally 23 common nodes between them. **Fig. 5** shows the comparison of the edge lengths between the extended tree of BVN with the proposed method and the BVN in the CT volume, which indicates the reliability of the proposed method.

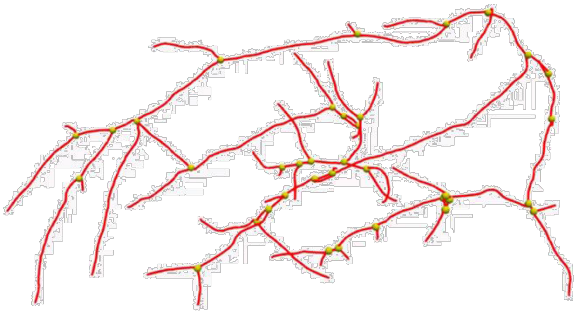

Fig. 4 Extended tree of porcine liver BVN composed of four ultrasound volumes.

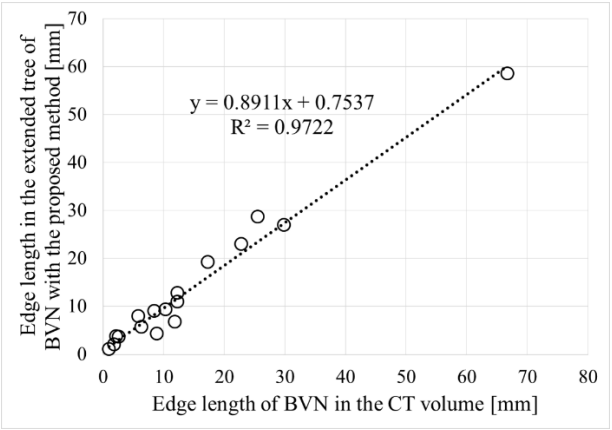

Fig. 5 Comparison of edge lengths in BVN between the extended tree of proposed method and CT volume.

4. Conclusions

We have proposed a new method to spatially extend BVN shape originated from ultrasound volumes by introducing tree-structured analysis, where the structure was converted into nodes and edges. By using a porcine liver, and compared with the BVN in CT volume, the reliability of the proposed method was indicated.

References

1. A.Bossard, T.Kato, and K.Masuda: IEEE EMBC, (2012) 5470.
2. Y.Sugano, S.Onogi, A.Bossard, et al: Proc. of BMEiCON, (2012) BME-2012-88.
3. K.Masuda, T.Yamashita, T.Katai, et al: IEEE Int. Ultason. Symp., (2017) C7-7.
4. S.Onogi, T.H.Phan, T.Mochizuki, et al: ABE, **4** (2015) 27.
5. T.Kato, Y.Taguchi, Y.Sugano, et al: Seitai Ikougaku, **49** (2011) 884. [in Japanese].
6. B.K.P.Horn: J. Opt. Soc. Am. **A4** (1987) 629.