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Motion analysis of liver blood vessel using multi-resolution registration
多重解像度レジストレーションによる肝臓血管変動の解析

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1. Introduction

Recently, the minimally invasive treatment that uses ultrasound to control a micro object in blood vessel have been proposed [1]. In order to realize the treatment, it is necessary to position the ultrasound transducer on body surface with high accuracy. Therefore, we have developed the transducer positioning system using a parallel link robot [2]. However, it was not possible to measure the motion of the treatment targets due to respiratory. In the preceding research, variation of the target organ or blood vessel on echogram was tracked using a metal marker and measured its position comparing X-ray images [3]. However, because those methods required high invasiveness, we aimed to develop the tracking system using ultrasound without other modalities. In this research, we analyzed the motion of liver vessels by using multi-resolution registration of ultrasound images.

2. Methods

Image registration is widely used to find correspondence between two image modalities using nonlinear optimization. Since most of them calculate a brightness gradient, there is a limitation in accuracy of local correspondence. Therefore, we propose a multi-resolution registration between two image modalities to avoid locally optimal solutions. **Fig.1** shows a schematic diagram of the multi-resolution registration, where left and right pyramids indicate image (2D) and volume (3D) spaces, respectively. From the bottom to the top, resolution is decreased from the original, meanwhile the number of level increased. In the level 1 and 2, a Gaussian filter was applied to reduce the resolution to 1/3 and 1/5, respectively. After image registration is applied in the highest level, the similar registration continues in lower levels, which has an advantage to avoid the local optimal solutions that occur in simple registration [4].

Fig.2 shows a system configuration, which includes an echography (PHILIPS, iU-22) and a 3D position sensor (NDI, Polaris Spectra). Here we define the positional relationship between two coordinate system as a homogeneous transformation matrix, which from ΣA to ΣB is expressed as ${}^{A}\boldsymbol{T}_{B}$, for example. In Fig.2, totally 5 coordinates were defined. ΣGlobal is the coordinate originated the 3D position sensor. ΣProbe represents the position of ultrasound probe in which an infrared tracker attached. ΣEchography represents echogram plane originated the tip of the probe. ΣHuman represents human body and y_H is defined along the body axis. ΣTarget represents the position of target.

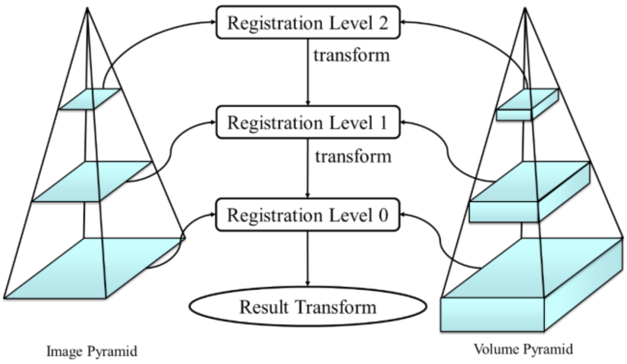

Fig.1 Schematic diagram of multi-resolution registration.

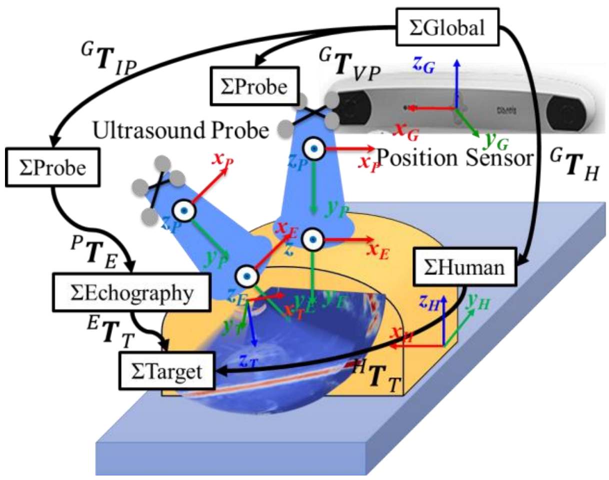

Fig.2 System configuration to track target motion in internal organ.

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Fig.3 shows the flowchart of the proposed system. First, an ultrasound volume is recorded as a reference and the matrix ${}^{G}\boldsymbol{T}_{VP}$ is obtained, where V indicates the volume data. Next, the iterative process is performed while successive ultrasound images are obtained measuring ${}^{G}\boldsymbol{T}_{IP}$, where I indicates the image data. Then comparing between ${}^{G}\boldsymbol{T}_{IP}{}^{P}\boldsymbol{T}_{E}$ and ${}^{G}\boldsymbol{T}_{VP}{}^{P}\boldsymbol{T}_{E}$, if there is an error in the previous frame**,** it is refreshed. To perform multi-resolution registration, the position of the target ${}^{E}\boldsymbol{T}_{T}$ is repeatedly repositioned. Finally, the position of the target ${}^{G}\boldsymbol{T}_{T}$ during the performance is obtained from eq. (1).

$$ {}^{G}\boldsymbol{T}_{T} = {}^{G}\boldsymbol{T}_{IP}{}^{IP}\boldsymbol{T}_{E}{}^{E}\boldsymbol{T}_{T} \qquad (1) $$

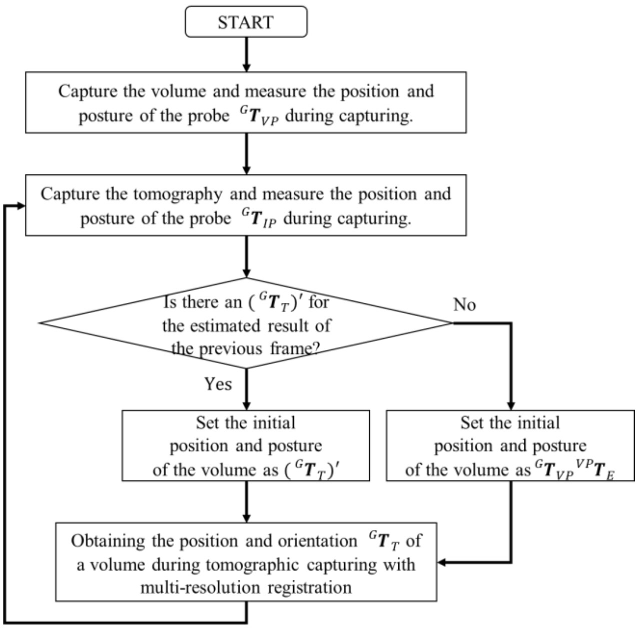

Fig.3 Flowchart of the proposed system.

The target position x_h, y_h, and z_h in ΣHuman are transformed into the coordinate system of ΣHuman using eq. (2) to calculate the displacement from the initial position.

$$ {}^{H}\boldsymbol{T}_{T} = ({}^{G}\boldsymbol{T}_{H})^{-1}\,{}^{G}\boldsymbol{T}_{T} \qquad (2) $$

3. Results

To evaluate the performance of the proposed system, we targeted the motion of bifurcation in portal vein of healthy subject (male, 24 y.o.). The subject was asked the procedure to inhale and stop breathing during volume acquisition. In the same situation a series of echograms was acquired every 0.2 sec. Figs. 4 and 5 show time variations of the target position during acquisition of echograms using the multi-resolution registration and a preceding method of simple registration, respectively. In **Fig.4**, displacement of the target was quantitatively obtained up to 15 mm within 80 s. Because the variation was continuous in each coordinate, it is thought that a three-dimensional trajectory due to the respiration was obtained. Compared with **Fig. 5**, the deviation in both of x_h and z_h became smaller, which indicates the stability of the registration was enhanced using the multi-resolution rather than single registration.

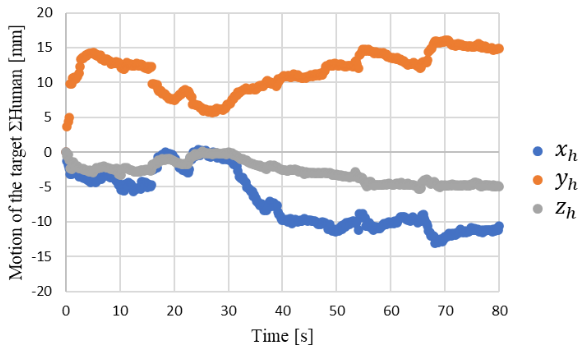

Fig.4 Time variation of target position using multi-resolution registration

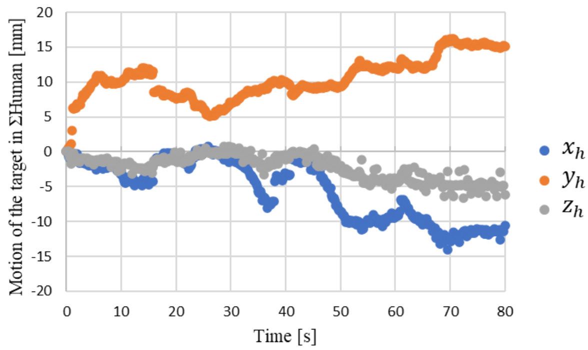

Fig.5 Time variation of target position using simple registration.

4. Conclusions

In this research we examined a multi-resolution registration between 2D echogram and 3D volume of ultrasound using the motion of liver blood vessels in the human body. The proposed method reduced the deviation in x- and z-direction, which are perpendicular to the body axis, compared to simple registration.

References

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