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Tissue elasticity imaging based on wave number vector analysis for continuous vibration wave excitation

連続波加振のための波数ベクトル解析に基づく組織弾性映像法

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1. Introduction

Measurement of shear wave characteristics of living tissue such as velocity and absorption is considered to give valuable information about tissue mechanical characteristics such as stiffness and macro structure of tissue. An acoustic radiation force impulse (ARFI) imaging has been proposed for this purpose. This method uses an ultrasonic wave of relative large sound pressure in order to give an acoustic radiation force to the tissue. However, there are still a lot of discussions about the safety and the temperature rise of the tissue. We have been proposed a method which uses low frequency vibration of frequency less than a few thousands Hz in order to produce the shear wave inside the tissue.[1)] Since the method uses vibration wave with amplitude of 100 microns or less, biological effects to tissue are small enough. However, a problem of low frequency vibration wave excitation is formation of stranding wave inside the tissue. Shear wave, which is reflected from the tissue boundary, produces the standing wave in the vicinity of boundary and the estimation accuracy of shear wave velocity decreases due to the standing wave component. In addition, complicated propagation of shear wave inside the tissue also becomes a problem in estimation of shear wave velocity.

In this paper, a novel method of shear wave velocity measurement, which uses low frequency vibration excitation, is proposed.

2. Proposed Imaging System

2.1 Developed system

There are two factors which degrade accuracy of elasticity measurement. The First problem is complicated shear wave propagation inside tissue. For this problem, we developed 3D ultrasonic wave pulsed Doppler system. US wave transducer array with 4 elements is mechanically scanned in order to acquire the US Doppler signals in three dimensions. Center frequency, the burst length and PRF of US wave are 5 MHz, 4 wavelength and 10 kHz, respectively. The bandwidth of received IQ signal is set to 1.4 MHz. It takes 4 sec to obtain 3D Doppler signals for volume of interest of 40*40*7 mm.

2.2 Wave number vector analysis based imaging

The second problem when low frequency vibration wave is the occurrence of standing wave inside the tissue. For this problem, we proposed a novel estimation method which is based on wave number vector analysis. Flow chart of the method is shown in **Figure 1**. By assuming the displacement much smaller than the wavelength of the US wave, the instantaneous displacement is estimated from the IQ signals by arc-tangent method. Then, the complex amplitude is derived by applying Fourier analysis. For complex amplitude data which are acquired for 3D volume, 3D Fourier transformation is applied in order to translate them to wave number vector space. On the wave number space, the vector norm relates with the wavelength of shear wave and the vector angle corresponds to the propagation direction of the wave. Hence, each shear wave can be extracted and the propagation characteristics are estimated even when multiple shear waves are propagated simultaneously on the same region of tissue. Moreover, by this algorithm, it is possible to derive vibration velocity map for each vibration frequency independently if shear waves are excited by multi frequencies. Wave number vector filtering has additional feature in tissue characterization by shear wave, because visco-elastic properties for different propagation directions are estimated simultaneously if multiple shear waves, such as reflection or refraction of the shear wave, propagate inside the tissue,

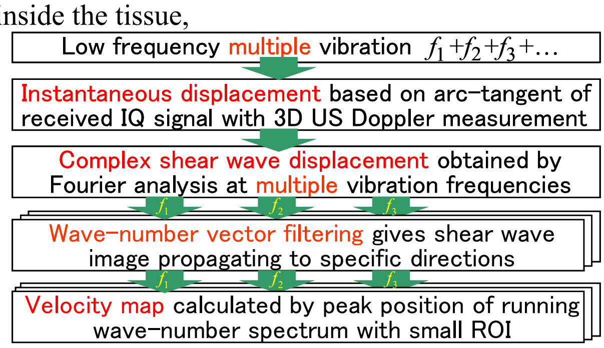

Fig. 1 Flowchart of shear wave velocity estimation

3. Phantom experiment

Phantom experiments were carried out to demonstrate the validity of wave number filtering and shear wave propagation velocity imaging. We use a two-layered agarose gel phantom which consists of 1.0% and 1.5% agarose powder density for upper and lower layers, respectively. **Figure 2** shows the result. Fig. 2(a) shows measured displacement of shear wave at the vibration frequency of 750 Hz. Since the lower layer shows faster propagation velocity than that of the upper layer, the boundary acts as a strong reflector. Fig. 2(b) shows wave a number vector spectrum. We see an additional spectrum peak which is due to the reflected wave from the boundary. Fig. 2(c) shows a filtered displacement image having the propagation direction between 0 and 90 degrees. It is possible to see a shear wave which propagates to upper right direction from the image. Fig. 2(d) shows estimated velocity map. ROI for moving filter is set to 7.5 mm square. In spite of the existence of strong reflection, the velocity of the upper layer shows good agreement with that obtained in homogeneous medium.

4. In-vivo experiment

In-vivo experiments were carried out as a demonstration of this system. Target is brachial muscle in the upper arm for man in their 20's. The vibration frequency is set to 500 Hz. Scan speed of US transuducers is 10 mm/s. **Figure 3** shows an example of in-vivo results. The transparent color image in Fig. 3(a) shows real part of complex displacement image at 500Hz. B-mode image is also shown as a gray scale image in the background of the image. Fig. 3(b)-(d) show the images obtained by applying wave number filter of the forward, upward and downward direction, respectively.

5. Conclusions

We proposed a novel elasticity imaging method using continuous vibration wave excitation. To improve the estimation accuracy of shear wave, we adopted 3D US wave Doppler signal acquisition and wave number vector filtering. From phantom experiments, effectiveness of the system was shown. From in-vivo results, anisotropic information of elasticity was obtained.

Acknowledgment

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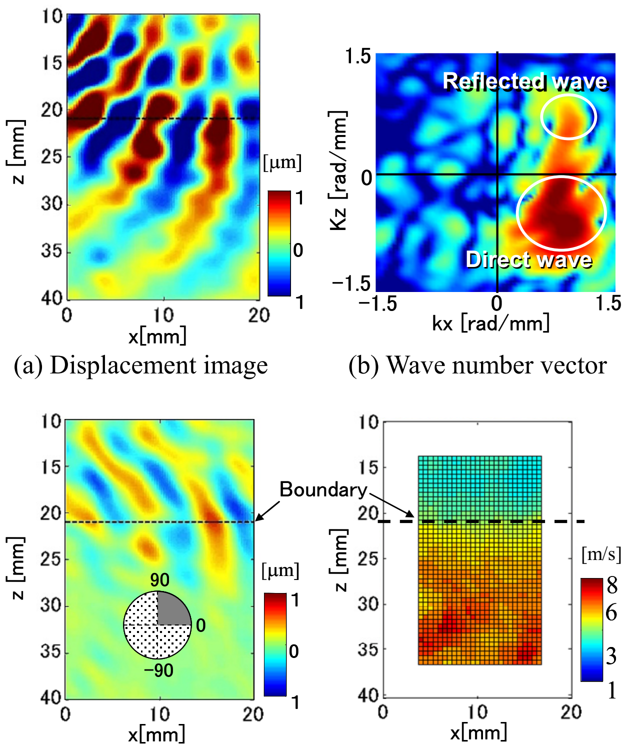
References

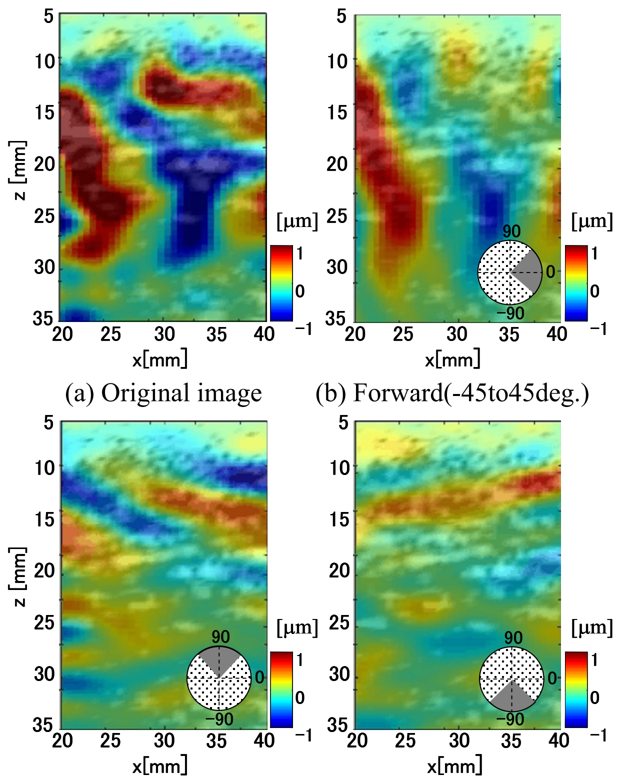
1. Y. Yamakoshi, J Sato and T Sato, *IEEE Trans. UFFC*, **37** (1990) 45-53.
2. T. Miwa, R. K. Parajuli and Y. Yamakoshi, *JJAP*, **50** (2011) 7HF07.



(a) Displacement image (b) Wave number vector

(c) Filtered image (d) Velocity image

Fig. 2 Phantom experimental results (Two layered agarose gel phantom (Agarose powder density; upper layer :1.0% lower laver :1.5%)



(c) Upward(45to135deg.) (d) Downward(-135to-45 deg.)

Fig. 3 In-vivo experimental results. (Target: upper arm loaded with 0.5 kg weight)