1P2-9

Position and angle detection system using photo-acoustic transmitter for catheter devices

光音響超音波発信源を用いたカテーテルの位置、角度検出システム

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1. Introduction

Ultrasound imaging is a powerful method as a guide for perticular percutaneous catheter interventions. It can obtain real-time cross-sectional images of tissues and devices without radiation-exposure or contrast agents. It is used as a guide of, for example, a guidewire for percutaneous endovascular intervention[1] or a catheter for transcatheter aortic valve implantation[2].

Recently, a position-tracking method using an ultrasound source attached to devices[3,4] is attracting attention as a new technology for ultrasound-guided treatment. It detects the position of a device in one's body by detecting ultrasound signals emitted from an ultrasound source with a size of less than 1 mm in the device. Potential applications of this technology include being, for example, marker for breast surgery[3] and visualization of a needle for biopsy[4]. As a miniture ultrasound source, a transducer based on the Photo-Acoustic(PA) effect is promising. Since this type of transducer is based on an optical fiber, the diameter of device can be in sub-mm order.

Previously, we reported a concept of ultrasound position-tracking system for a guidewire [5] (Figure 1). In addition to the position, the angle of the device is also important information to the device operators in order to more acculaterly control the devices. For example of a guidewire, an operator controls direction of travel by bending the tip of the wire and rotating it in a vessel. In this presentation, we present a feasibility study of ultrasound tracking system that can detect both the angle and the position.

2. Methods

Fig.2 shows the proposed method of angle detection. Our system detects the position of the device by making an ultrasound image of an ultrasound source in a device. Therefore the angle of the source is also measureable from the image.

In this study, we made an ultrasound source whose shape was rectangular. We firstly made a polydimethylsiloxane (PDMS) (Sylgard 184, Dow Corning Toray) plate, in which an optical fiber(FG105LCA, Thorlabs) for laser irradiation was placed. A rectangular block was made by cutting it out from the plate. Reduced graphene oxide(805084, Merck), dissolved in toluene, was painted on the block. After drying, we coated the block with PDMS dissolved in toluene.

To generate a signal, we used a nanosecond

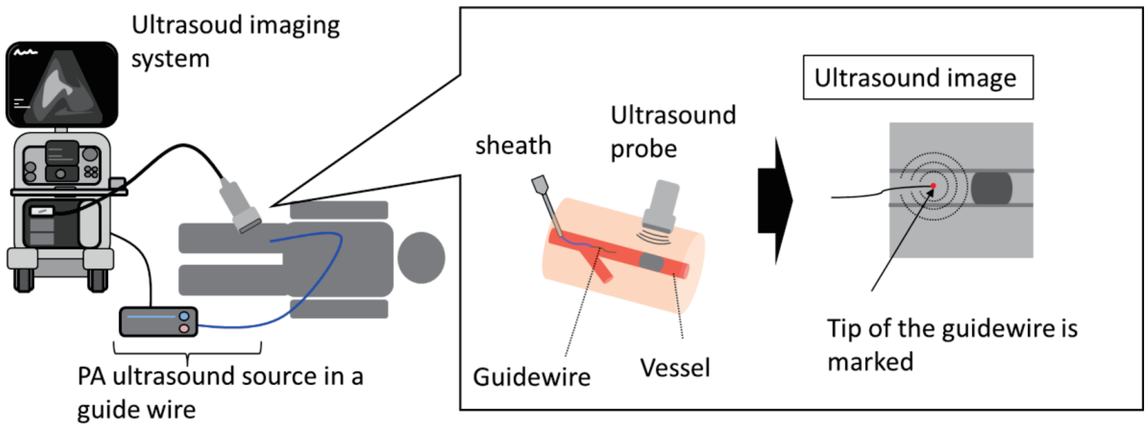

Figure 1. Our ultrasound position-tracking system

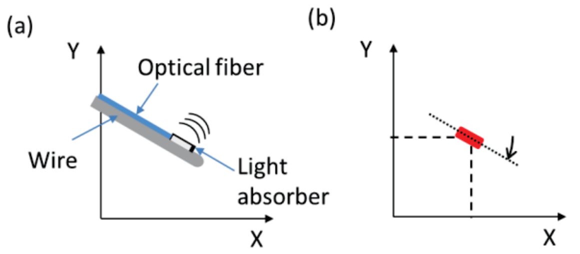

Figure 2. Conceptual diagram of our method to detect angle of a device: (a) image of a device and an ultrasound source, (b) an ultrasound image of a rectangular ultrasound source. The angle of the source is measured from the angle of the rectangular shape.

pulsed laser (Tech-1053, Laser Export), whose wavelength, maximum pulse energy, repetition rate, and pulse duration are 1053 nm, 1 mJ, 1 kHz, and 4 ns, respectively. A research ultrasound imaging system(Vantage 256, Verasonics) and ultrasound linear probe (L11-5v) with a center frequency of 7.8 MHz received the PA signals and create images of ultrasound source based on standard delay-and-sum method. All measurement was performed in degassed water.

3. Results and Discusssions

Figure 3(a) shows an image of our rectangular ultrasound source. The angle of the source was set to 15 degrees. In Figure 3 (a), 3 edges of a rectangular shape was clearly seen. The last edge was not apparent in the image, since this edge is on the opposite side of laser beam irradiation from the optical fiber. The position of the source is measurable from the image in Figure 3 (a).

Figure 3(b) shows actual and measured angle of the ultrasound source. Angle of the beacon was measured from the upper edge of the rectangular shape by linear fitting. The graph shows an almost linear line and the error from ideal line (shown as the dotted line) was less than 3 degrees. The result shown in Figure 3 demonstrates that this technique can measure the angle in the imaging plane.

We showed the measurement of an angle in the imaging plane, however, there is another freedom of rotation in the plane perpendicular to the plane. We assume that the angle can probably be measured from the projected length of lines in the rectangle, but it is a remaining challenge for the future.

4. Conclusion

We developed a technique to detect the angle of devices with an ultrasound source. A transparent

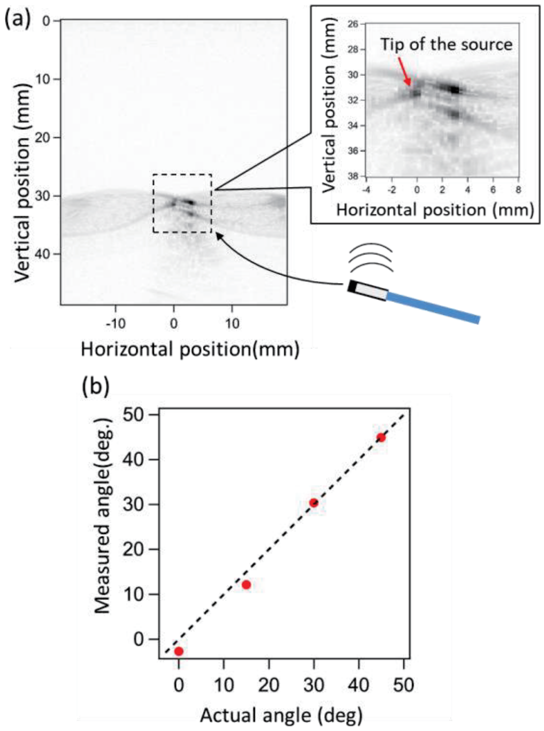

Figure 3 (a) Ultrasound image of rectangular ultrasound source. The angle of the source was set to 15 degrees. (b) Measured and actual angle of ultrasound source

and rectangular part was attached to the end of optical fiber, and black pigment was painted on the window. We succeeded in obtaining the rectangular shape of the source as an ultrasound image and the angle of the source was measured from a line in the rectangle. Estimated angle in the imaging plane had an error less than 3 degrees. Estimating angle of the other freedom of rotation is remaining as a challenge for the future. This technology has the potential to improve the accuracy of treatment with catheter devices.

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