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Estimation of position and velocity for a moving large target with specular surface using simultaneous transmission of M-sequence ultrasound signals

M 系列信号同時送波による鏡面反射面を有する大きな移動物体の位置・速度評価

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1. Introduction

Two-dimensional information of the position and velocity of the target can be obtained by the pulse-echo method using multiple sound sources and receivers in the air[1]. If multiple sources are used, high-resolution measurement can be performed efficiently, but the time required for measurement become longer, which is disadvantageous for the measurement of moving objects. We have realized high-resolution measurement without changing the measurement interval by simultaneous transmission of different M-sequence signals[2]. However, for a target with specular surface and sufficiently large compared to the wavelength, it is not easy to estimate the true position and velocity of the target because the position of the ultrasound reflection point on the object surface differs for each transducer pair. In this report, for a cylindrical target such as a utility pole or a sign pole, we propose a new method to estimate the position, velocity, and size of the object using the propagation time of the reflected ultrasound.

2. Measurement configuration

Figure 1 shows the configuration of the experimental devices. Two loudspeakers and three microphones are placed on a straight line, and the target styrofoam cylinder with a diameter of 200 mm was linearly moved at a constant speed of 240 mm/s. The measurement signal is 11th-order M-sequence modulated ultrasonic signal with a carrier frequency of 50 kHz, and a combination of signals called a preferred pair that can reduce the interference noise due to simultaneously transmission from two speakers. At a frame rate of 24.43 fps, 74 continuous images of 3.0 s are obtained.

3. Estimation method

Figure 2 shows the acoustic image obtained from the measurement signals. Since the target is an object that is large and moving for multiple transducers pairs, the positional relationship between the reflection point of the ultrasound and the center position of the target changes. For this reason, it is necessary to estimate the true position (center position) and velocity of the object from the acoustic data. When the target object can be approximated as a cylinder, the center position and its moving velocity and its radius are estimated by the following procedure.

Step 1 From correlation results of the received signals for transducer pairs, draw multiple ellipses where there is a possibility of reflection points on the surface of the object (dotted line in **Fig. 3**). This is the same procedure for the conventional acoustic image. Assuming the radius of the circle circumscribing each ellipse, the trajectory of the center of the circle can be found as the blue solid line in **Fig. 3**.

Step 2 By adding signal amplitude information to the drawing of the center of the circumscribed circle of the ellipse, the position of the center of the target cylinder can be obtained by finding the location of the maximum amplitude in the image as shown in **Fig. 4**.

Step 3 Repeat Step 2 while changing the radius. Let the radius at which the intersection in the image has the maximum luminance be the estimated radius. If the assumed radius matches the radius of the object, the intersection points are concentrated at one point and the intersection amplitude is expected to be maximized.

4. Estimation result

Figure 5 shows the comparison between the setting value of the center position in the experiment and the estimation result by proposed method in the previous section, and **Fig. 6** shows the comparison between the setting value of the velocity of the center position and the estimated value. **Figure 7** shows the relationship between the radius of the target cylinder and the maximum brightness of the image when the target is stationary. The red dot in **Fig. 7** indicates the radius where the brightness is maximum. **Figure 8** shows the relationship between the radius of the target cylinder and the maximum brightness of the image

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at each time when the target is moving. The red line in **Fig. 8** indicates the estimated radius at which the brightness is maximum.

5. Conclusion

In this report, we investigated the estimation method of the position, velocity and radius of a large target with specular surface. It was shown that the size of the target and the position and velocity of the target can be estimated when the object can be approximated by a cylinder. In the future, we will investigate the estimation method for the target of which cross-sectional shape is not a circle and the estimation method when the target moves on a curved line.

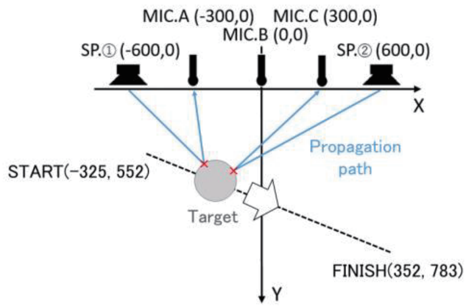


Fig. 1 Measurement configuration.

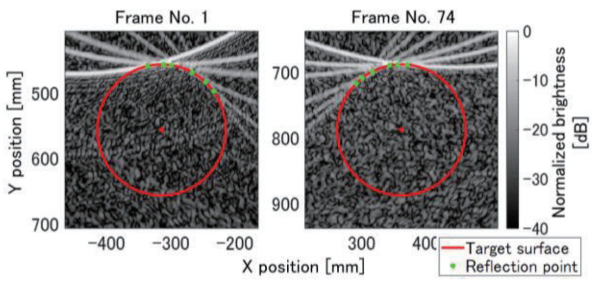


Fig. 2 Positional relationship between reflection point and center of the target.

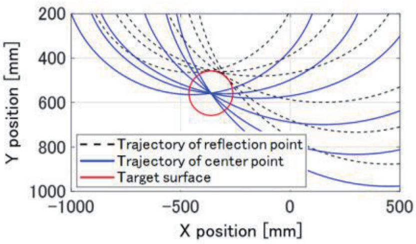


Fig. 3 Estimation of center position.

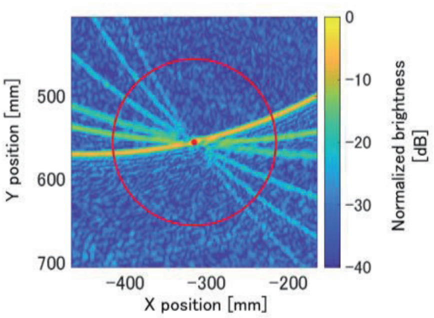
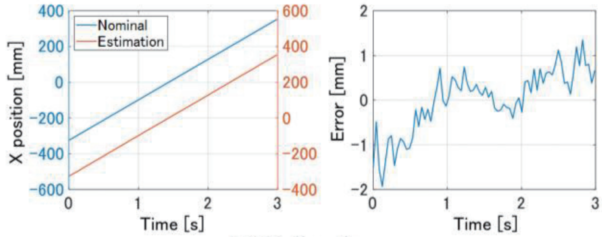


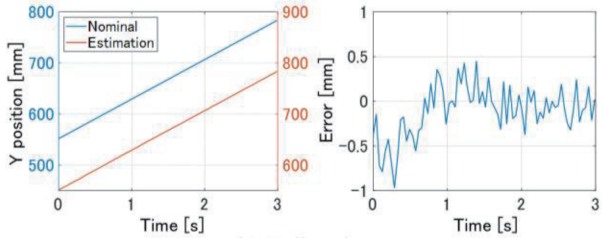
Fig. 4 Image for estimating the center position.

References

1. Y. Ikari et al.: Jpn. J. Appl. Phys. 54 (2015) 07HC14.
2. K. Ogasawara et al.: IEICE Technical Report US2010-18 (2010-06) p. 25-30.

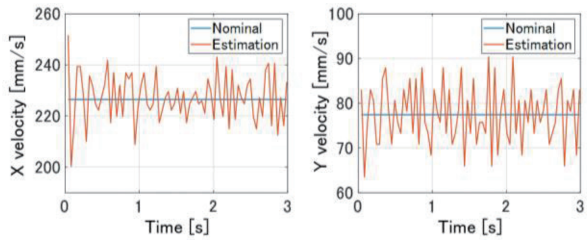


(a) X direction.



(b) Y direction.

Fig. 5 Estimation result of center position.



(a) X direction. (b) Y direction.

Fig. 6 Estimation result of center position's velocity.

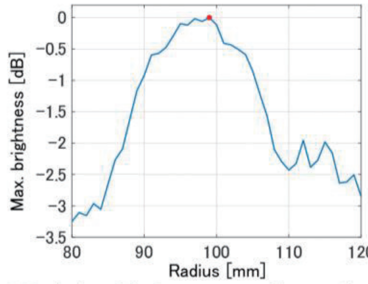


Fig. 7 Relationship between radius and maximum brightness when the target is stationary.

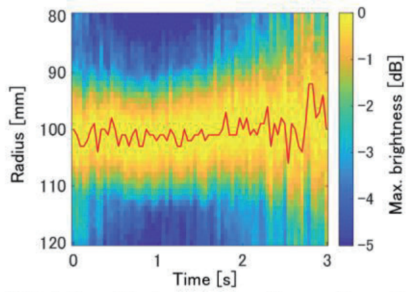


Fig. 8 Relationship between radius and maximum brightness when the target is moving.