Occuluded Object Detection by Ultrasonic Sensors

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Abstract

Crops are required to be processed in sanitary manner for lunchbox production in industries. Particularly, foreign object detection is crucial to guarantee consumer's health. Actually, foreign objects are mainly detected by human's eyes. For the automation, image processing is an example, however, is not effective for hidden objects. We propose a method of foreign object detection with ultrasonic reflection analysis. In our experiment, we selected four crops (lettuce, spinach, perilla and *komatsuna*) for masking material, and a coin for occluded objects. The coin were attached on the backside of the masking material. We recorded reflected wave moving the material linearly. As the result, reflection intensity doubled by the existence of occluded object.

Keywords: Ultrasonic reflection, Occluded object detection

1. Introduction

Under the problem of population ageing and worker shortage in agriculture [1], automation of management, harvesting, and foreign object detection is becoming a challenging task. Above all, foreign object detection and elimination is an essential process to guarantee human health. Foreign objects are generally mixed with crops by attaching crop surfaces, or getting into the gap of leaves. Particularly, the latter case can often be overlooked in visual check. Physical strain of workers may grow up for searching foreign objects while moving leaves with care. Non-destructive manner is proper for the automation of foreign object detection.

Here, we propose to introduce ultrasonic wave analysis for foreign object detection, and analyzed waveform of reflected wave of crop surface.

2. Related Works

For the examples of automatic foreign object detection, Image processing method [2], X-ray analysis [3], Hyper-spectral imaging [4], Ultrasonic wave processing [5] are well applied. For image processing case, stone, metal piece in grain are detected by 94 [%][6]. However, hidden objects cannot be found by image processing. Hyper-spectral image can be valid for detecting objects which are not easily seen by naked eyes, which is enabled by multiple color channels of images. On the other hand, hyper spectral image [7] needs larger memory than usual color image. Such image analysis requires technique for reducing information. For X-ray technique, 100[%] of metal pieces were found in bread or cheeses [8], however, X-ray cannot easily transmit in water [7], and harmful to human beings. Ultrasonic wave can be applied to check inside sample without contact by sensors. P. Pallav, et. al. sandwiched a sample with a receiver and transmitter and analyzed the transmission of ultrasonic wave, then succeeded in finding a 2[mm] size of glass and rubber [9] B-K. Cho et, al. also found a 3[mm] size of glass [10], however, if a crop is large, a transmitter and receiver cannot enclose a thick sample. Furthermore, operation of the transmitter and receiver requires technique to avoid collision on crops.

To eliminate the need of operating transmitter and receiver, we propose to analyze reflected wave from the masking material which includes the reflected wave from foreign objects, And, we aim at expanding area on a crop surface for recording the reflection by multiple receivers.

3. Proposed Method

Figure 1 shows the experimental environment of our proposal. Acoustic reflection moves in various directions depending on the surface roughness of masking object, thus, intensity of the reception varies dramatically with only a receiver. To alleviate the uneven intensity, we attach multiple receivers (Figure 2(a)(b) shows the side view, top view, each other). The table in the figure is

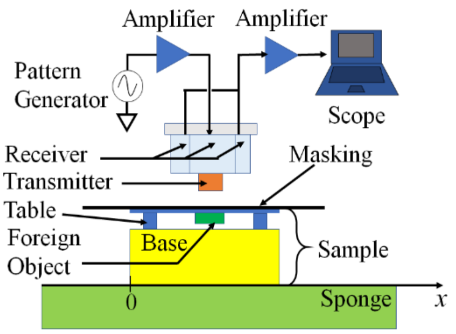
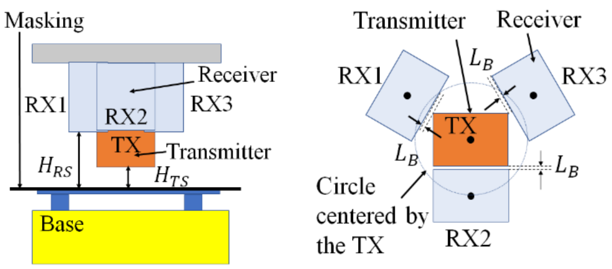


Fig. 1 Proposed Experimental Environment



(a) Side View (b) Top View

Fig. 2 Arrangement of a Transmitter and Receivers

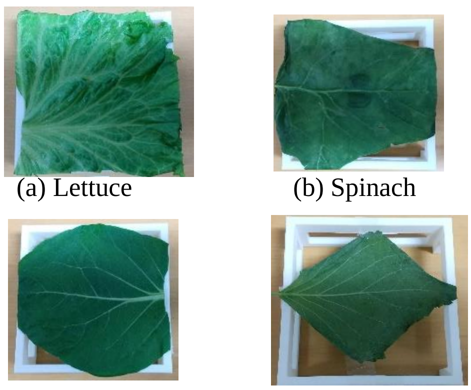
fixed with a masking material, which is distant from the transmitter by H_{TS}[mm], and the receiver by H_{RS}[mm]. The polyethylene base under the table is prepared for removing echo. A sample is made up by the base, table, masking material, which is moved manually in the direction of x-axis in Figure 1. Thus, change of reflected wave can be observed depending on the presence or absence of a foreign object. We satisfy the condition of $H_{TS} < H_{RS}$ to focus ultrasonic beam on one spot of the masking. Three receivers enclose a transmitter, and aligned at even interval on the circle whose center matches with the transmitter. The receivers are far from the transmitter by L_B[mm]

4. Experiment

4.1. *Method*

As the experiment, we used four vegetables (Lettuce, Spinach, *Komatsuna*, Perilla, Figure 3) as masking materials, then attached foreign object (10 yen coin) back side of the masking on the table (Figure 4). We moved the sample and recorded change of the reflected waves.

In the environment of Figure 1, we output ten cycles of sign waves from the pattern generator, and input the waves (Amplitude is denoted by A) into the transmitter. Then, we obtained the reflected waves with three receivers and summed them up for the analysis. We set time interval of emission by nearly 5 [sec], and repeated



(a) Lettuce (b) Spinach

(c) *Komatsuna* (d) Perilla

Fig. 3 Maskings

(a)Foreign Object (b) Location of the Attachment

Fig. 4 Foreign Object

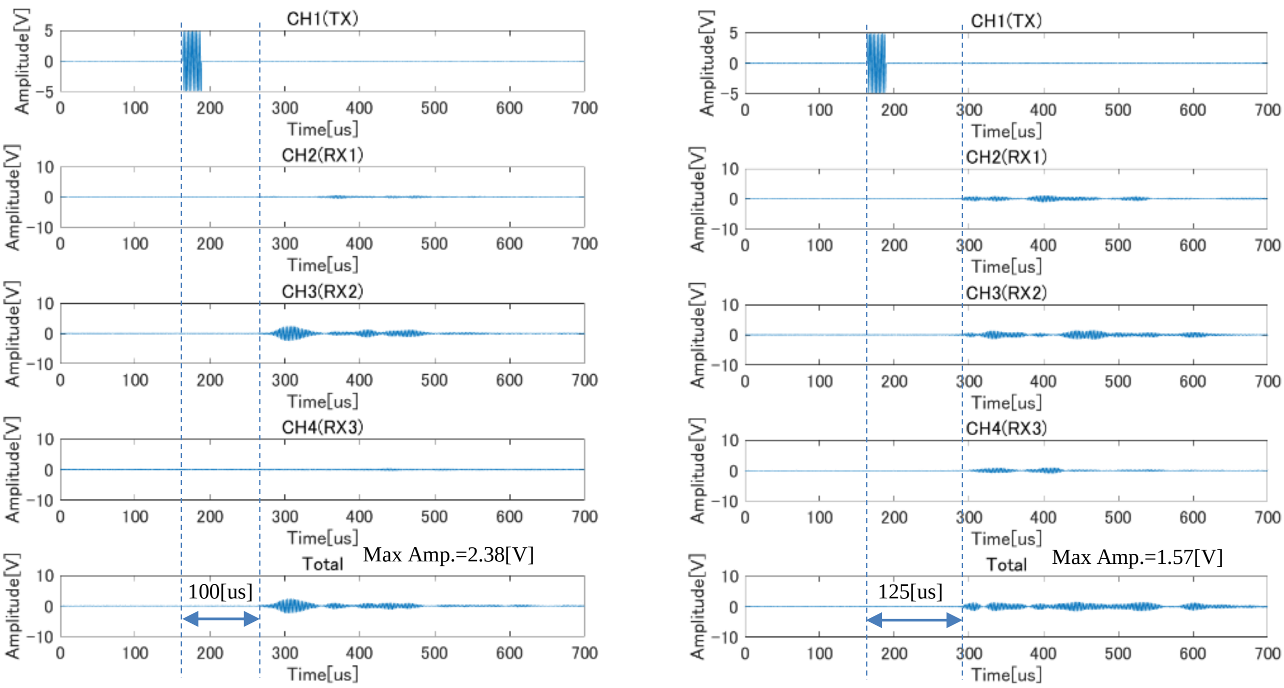
the emission, recording reflection, and sample displacement alternatively. The location of sample is measured by x-axis of the sample's back, which varies in the range of $-50 \leq x \leq 50$ [mm]. At *x*=0[mm], receiver is located over the foreign object. We recorded reflected wave which was amplified with gain *G*. Table 1 shows the parameter setting for the experiment.

Table 1 Parameter Setting

Symbol	Value
H_{TS}	10[mm]
H_{RS}	20[mm]
L_B	1[mm]
A	±50[V]
G	x120

4.2. *Result and Discussion*

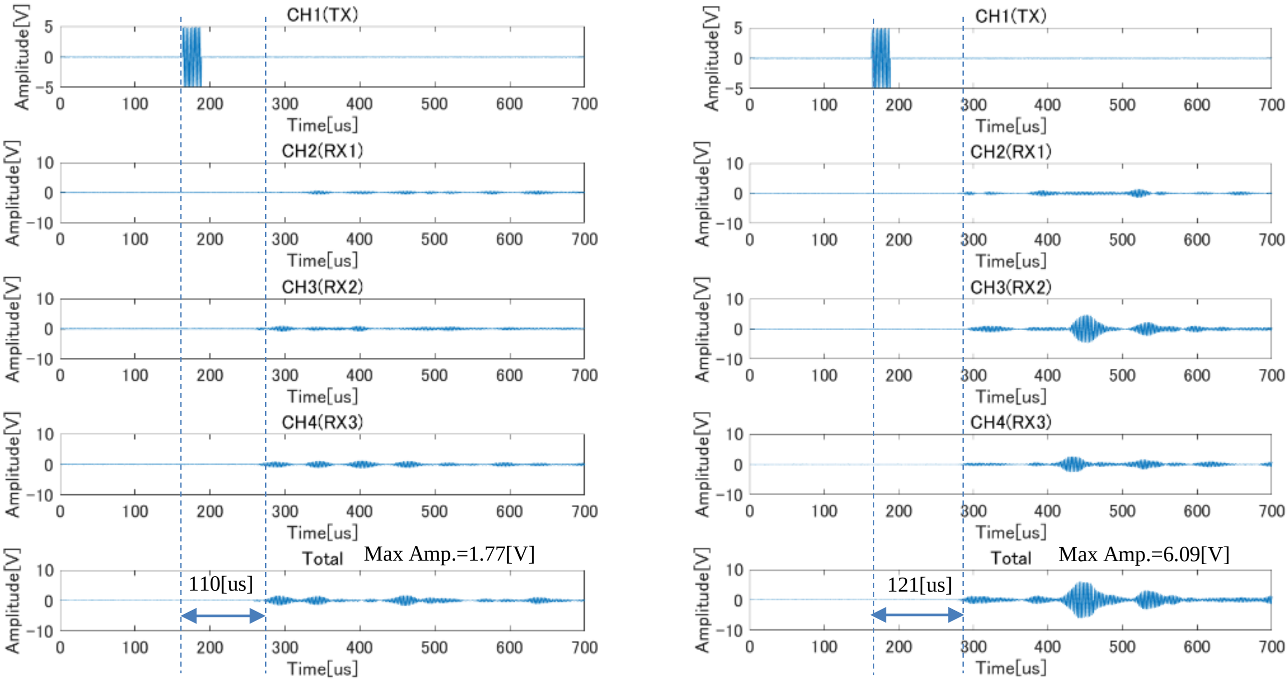
The amplified reflection is shown as Figure 5(Lettuce), Figure 6(Spinach), Figure 7(*Komatsuna*), Figure 8. (Perilla). The amplitude of summed reflection from three receivers, and elapsed time from emission to reception are also shown in the same figures. In case foreign object (10yen coin) is attached backside of the masking, apart from lettuce, the amplitude of the reflection increased to twice or more. However, the increase of the amplitude was as shown in the echo between transmitter and the masking. The time was different from the first arrival of reflection at receiver. Considering sonic velocity is equal to 340 [m/s], nearly 90 [us] is required to reach receivers because $H_{TS} = 10$[mm], $H_{RS} = 20$[mm]. However, the wrinkles on the masking caused of the error (10-20 [us] longer than the calculation). With foreign object attached, the time of arrival delayed more as the result of sinking material by the weight of coin. If H_{TS} is small, transmitted wave easily hits the coin, however, the reflection interfered each other, which made the analysis harder. H_{TS} should be adjusted so that no interference occurs.



(a)No Foreign Object

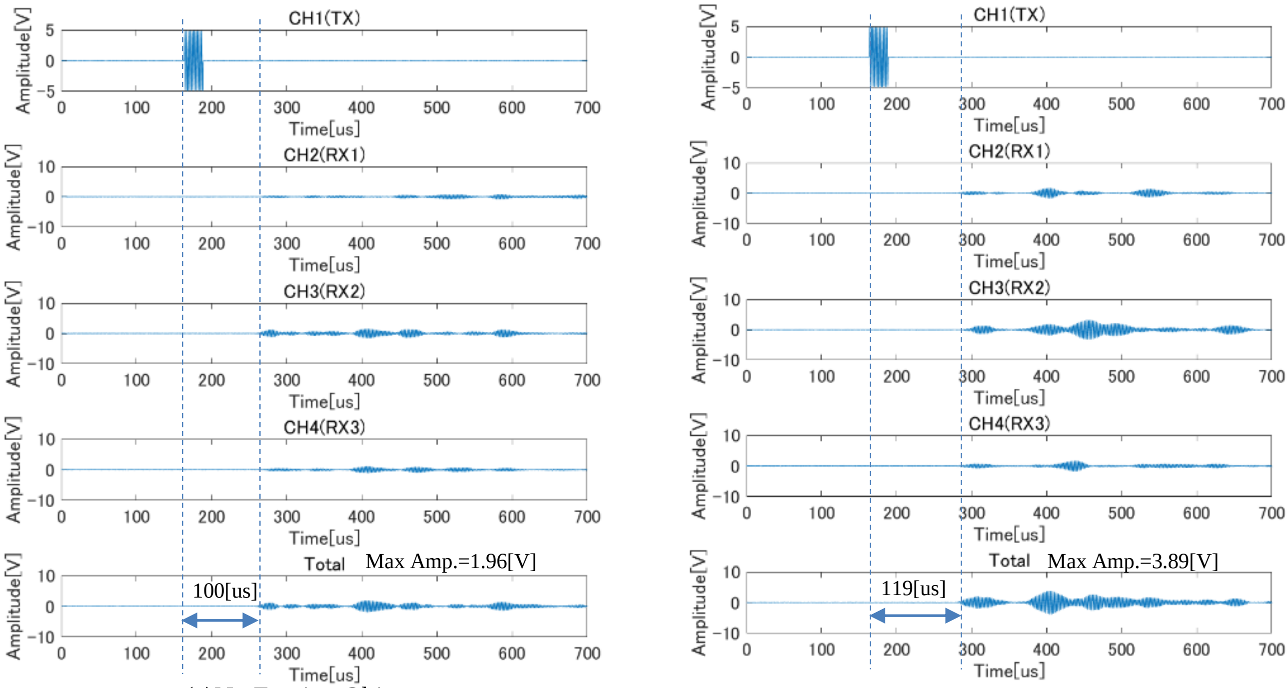
(b) With Foreign Object

Fig. 5 Reflection from Lettuce (*x*=0)



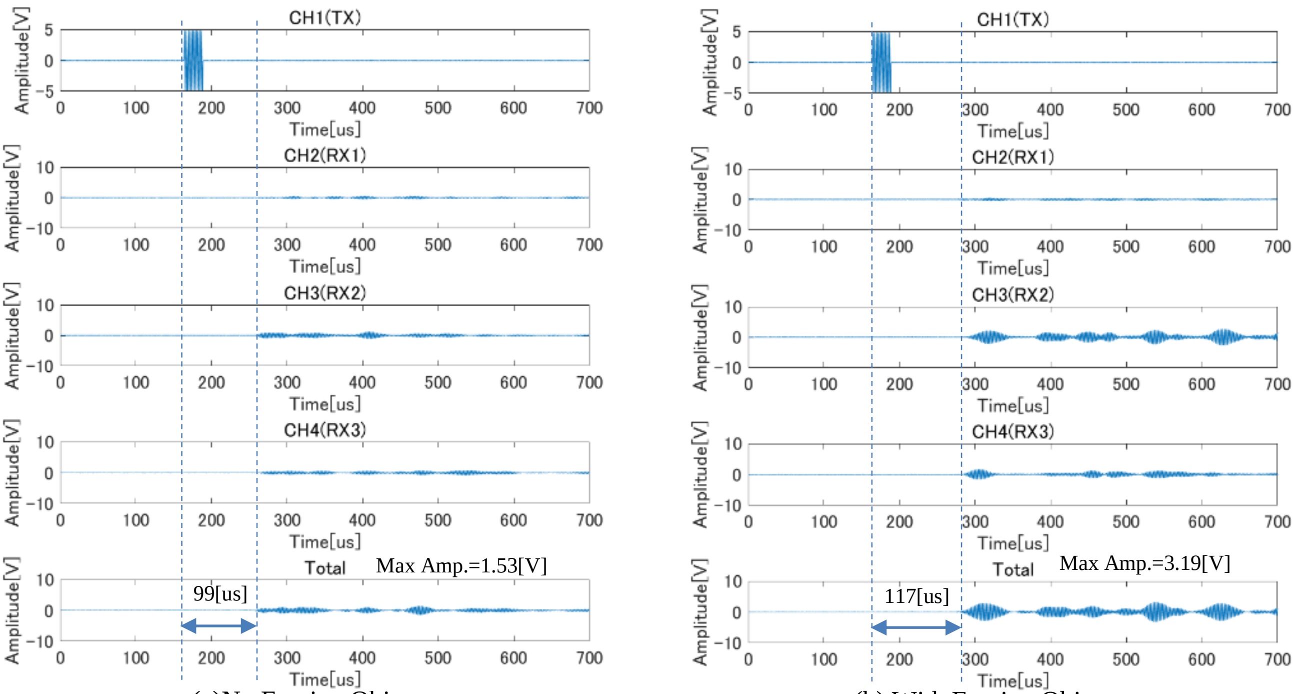
(a)No Foreign Object (b) With Foreign Object

Fig. 6 Reflection from Spinach (x=0)



(a)No Foreign Object (b) With Foreign Object

Fig. 7 Reflection from *Komatsuna* (x=0)



(a)No Foreign Object (b) With Foreign Object

Fig. 8 Reflection from Perilla (x=0)

5. Conclusion

We chose four vegetables as masking for the experiment of foreign object detection. As the result, the maximum amplitude of the reflection increased to more than twice if foreign object (coin) is attached backside of the masking (but for lettuce). However, reflection interference was a problem for the analysis if the short distance(H_{TS} = 10[mm]) was set between the transmitter and masking. The distance should be reconsidered so that the interference is prevented.

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Authors Introduction

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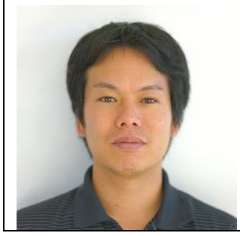

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