Journal of Industrial Information Technology and Application *ISSN(Online): 2586-0852*
Vol.7 No.3

Detection of Soft Foreign Materials in Food using Sub-Terahertz Radar

Donghoon Kwak[1)], Seungeon Song[2)], Jonghun Lee[3)], Youngduk Kim[4,*)]
[1)2)3)4)]Division of Automotive, DGIST, Daegu 42988, Korea

Abstract: In the food industry, hygiene management is an important issue. In particular, it is crucial to prevent foreign materials because ingestion of foreign materials can cause serious harmfulness such as tooth damage and food poisoning. Accordingly, research on the detection of foreign materials through non-destructive testing is being actively conducted. There are two kinds of conventional methods for foreign material detection. The first method is surface inspection by detecting foreign materials on the surface of food through vision or spectroscopy. The second method is penetration inspection such as X-ray inspection and metal detector inspection. However, these methods can only detect metal or hard foreign materials. Therefore, it cannot detect soft foreign materials such as insects. To solve this problem, we propose a penetration inspection using sub-terahertz radar. This method can detect both hard and soft foreign materials. It is even harmless to the human body, making it suitable for food non-destructive inspection. However, signals obtained by penetrating food through terahertz waves contain a lot of noise. In this paper, we also propose a preprocessing method for denoising to accurately detect foreign materials. After preprocessing, noise is significantly attenuated and only the food edge line and foreign substances are emphasized.

Keywords: Terahertz, Radar, Image-Processing, Foreign material detection

1. Introduction

Although food is essential for human life, sometimes food also causes fatal harm to people through foreign materials. Therefore, hygiene management is very important in the food industry. There are many ways to manage food hygiene such as reinforcing worker hygiene rules and keep food production environment clean. However, it is impossible to perfectly prevent the inflow of all foreign materials. Therefore, screening for foreign materials in food through non-destructive testing is essential. Since the

* Corresponding author: ydkim@dgist.ac.kr
Received: Aug 5, 2023; Accepted: Sep 16, 2023; Published: Sep 30, 2023

existing visual screening method of workers has many side effects such as additional labor costs and decreased production speed, various automatic non-destructive inspection systems are being developed. The most representative solutions are visual surface inspection methods using a machine vision camera [1] and spectroscopic inspection using a hyperspectral camera [2], and food penetration inspection methods include X-ray inspection and metal detector. However, there are very few foods that can prevent foreign materials only by surface inspection. In addition, X-ray inspection [3] and metal detectors [4] are limited to metal or hard foreign materials, which is not applicable to soft foreign materials such as insects, rubber, vinyl, etc. On the other hand, in the case of terahertz waves, it is most suitable as a next-generation foreign materials detection system because it basically detects both soft and hard foreign materials in food with low moisture content.

Terahertz waves refer to electromagnetic waves in the range of 0.1 THz to 10 THz. These waves have lower transmittance than microwaves but higher resolution, and have lower resolution that light waves but higher transmittance. [5] Terahertz waves can penetrate non-metallic and non-polar materials to detect internal objects, but cannot penetrate into products containing high moisture. Due to these characteristics, foreign material inspection is possible only for foods with low moisture content than about 15%, and foreign materials inside and outside food can be detected during processing or distribution without damaging the product. [6]

2. Materials and Equipment

A. Materials

As the selection criteria for the target food, we choose dried seaweed considering the fact that it should be moderately thick with low moisture. Dried seaweed is one of the representative traditional food in Korea and consumed worldwide. The main product of dried seaweed is packaged in 100 sheets bundle (also known as ‘tot’). A bundle of dried seaweed has a moderate thickness and low moisture content. Therefore, it is very suitable for penetrating inspection using terahertz waves. The foreign material used in the experiment is a worm. Target food and foreign material are shown in Figure 1.

(a) (b)

Figure 1. Materials (a) Target food (seaweed) (b) Foreign material (worm)

B. Equipment

The terahertz radar used in the experiment has a frequency of 0.1 THz. A terahertz below 1THz is called sub-terahertz. The equipment consists of a source that transmits terahertz waves and a scanner that receives them. The scanner has adopted a line scan type scanner for application to food manufacturing sites. This makes it possible to inspect food moving at high speed on a conveyor belt. The specifications of the terahertz source and scanner can be seen in Table 1. and also can check test-bed concepts in Figure 1.

Table 1. SPECIFICATIONS OF THE TERAHERTZ RADAR

Source	
Frequency	0.1 THz
Power	100mW
Scanner	
Number of pixels	256
Pixel size	1.5 x 3 mm^2
Dimensions of device	450 x 160 x 44 mm^3
Image acquisition rate	5000 fps

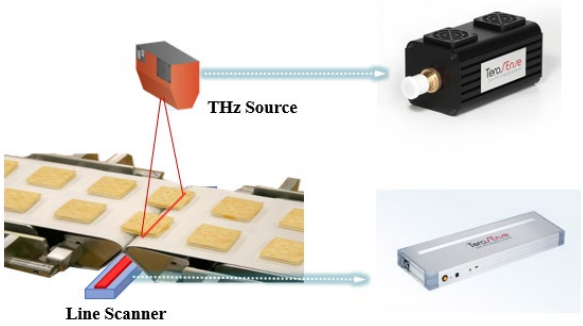

Figure 2. Testbed concept

3. Method and Result

The raw signal obtained through the terahertz scanner is not uniform. It contains a lot of noise. In order to obtain a stable signal, some preprocessing is required. We propose a three-step preprocessing method.

First, apply a Gaussian filter to the signal to blur it. Second, the column dc and raw dc of the blurred image are subtracted respectively. Finally, perform the dot product of the two results. The process is shown in Figure 3.

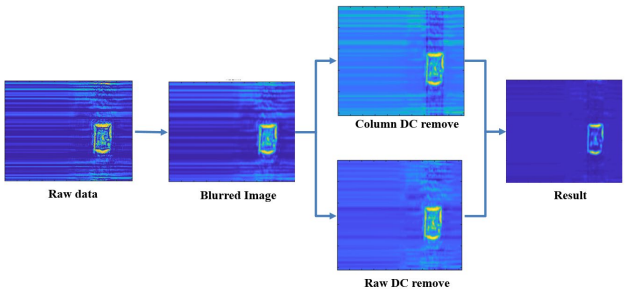

Figure 3. Flow chart of preprocessing method

As a result, most of the noise disappears and only the signal of the worm located in the center remains strong. Through experiments, it was confirmed that soft foreign materials inside food can be detected.

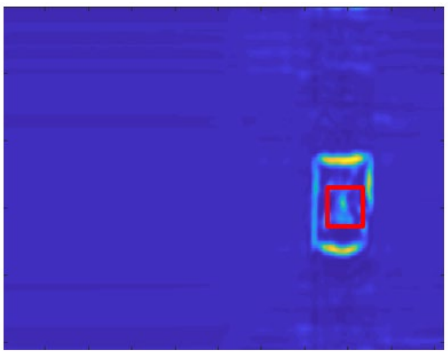

Figure 4. Foreign material identification

4. Conclusion

The purpose of this study is to confirm the possibility of developing a food penetration inspection system using terahertz waves. When selecting the target food, it is necessary to consider whether the moisture content is low and the thickness that allows terahertz waves can penetrate. In the experiment, the unbalanced signal intensity was corrected through the proposed preprocessing method, and the possibility of identifying soft foreign materials was confirmed.

In the future research, we will develop automatic foreign material system by using object detection algorithms. The signal applied with the proposed preprocessing method will have a positive effect on deep learning algorithm training.

Acknowledgment

"This work is supported by a grant (no.22163MFDS466) from MFDS of Korea"

References

[1] Son, Guk-Jin, et al. "U-Net-Based Foreign Object Detection Method Using Effective Image Acquisition System: A Case of Almond and Green Onion Flake Food Process." *Sustainability* 13.24 (2021): 13834.

[2] Kwak, Dong-Hoon, et al. "Rapid foreign object detection system on seaweed using VNIR hyperspectral imaging." *Sensors* 21.16 (2021): 5279.

[3] Haff, Ronald P., and Natsuko Toyofuku. "X-ray detection of defects and contaminants in the food industry." *Sensing and Instrumentation for Food Quality and Safety* 2.4 (2008): 262-273.

[4] Giles, N. "Metal detector technology for the food industry." *Alimentación, Equipos y Tecnología* 245 (2009): 32-36.

[5] Pawar, Ashish Y., et al. "Terahertz technology and its applications." *Drug invention today* 5.2 (2013): 157-163.

[6] Mathanker, Sunil K., Paul R. Weckler, and Ning Wang. "Terahertz (THz) applications in food and agriculture: A review." *Transactions of the ASABE* 56.3 (2013): 1213-1226.