Detection of Pinbones in Japanese Shime-saba

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***Abstract*—Shime-saba is a Japanese seafood marinated in salt and rice vinegar, which makes it last longer and gives it a sashimi-like flavor. The vinegar softens most bones, but pinbones remain hard and need to be removed. The food processing industry manually removes these bones. However, this process needs to be automated to cope with the shortage of human resources. This study attempts to detect the location of the tips of pinbones by using infrared imaging techniques to highlight bone features and quantifying these features based on image geometry. The shape of the response image obtained by correlating the gaussian template image to the infrared-irradiated shime-saba image revealed that the tip of the remaining bone resembled convex-up shapes. These shapes were detected by applying a quadratic surface equation to the resulting image after pre-processed, allowing the location of the tips of pinbones to be determined by picking their maxima. Future work will include a deep learning solution to improve the detection accuracy of pinbones.**

Keywords-fishbone; infrared imaging; bone detection; image geometry; template matching; computer vision.

I. INTRODUCTION

Improvements in quality inspection and food supply chain visualization have become necessary to guarantee the safety and quality of food products as well as their traceability. Methods have been developed to automate these tasks to accomplish these tasks more efficiently and cost-effectively [1]. Robotics can play an important role as a solution. However, the food industry has been slow to adopt robotics relative to others. The use of robots instead of people in food processing is expected to have many tangible, intangible, social, and economic benefits [2][3]. Hygiene and safety risks, as well as high labor and social costs, will drive the adoption of robots in the food industry.

Fish and fishery products have long been a large part of the Japanese diet. Traditional Japanese seafood preparations include the shime-saba (mackerel marinated with sugar, salt and rice vinegar) and dried or salted fish for preservation. Raw foods such as sashimi and sushi, as well as deep-fried foods such as tempura, have also enriched Japanese food culture [4]. Hachinohe City, Aomori Prefecture is the center of production of shime-saba. It was the first city in Japan to begin producing shime-saba in 1968. Although the number of mackerel landings is decreasing, the production of shime-saba is on the uptrend.

The food industry in Japan is suffering from a chronic shortage of labor. While there are efforts to actively introduce robots, it is difficult for small and medium-sized companies to consider introducing robots by themselves. The processing of shime-saba requires human intervention to remove the bones remaining in the fish body. Vinegar can soften most bones, but the middle bone remains hard and must be removed manually, as shown in Figure 1. This work is physically demanding because of the long hours spent standing. In addition, more workers are needed to ensure production capacity.

The objective of this study is to develop an image sensing system that detects the pinbone tips of shime-saba to assist the deboning robot. Our system identifies the tip of the bone by analyzing features from fillet image of shime-saba taken by a camera that can capture images in both visible and near-infrared light. The shape geometry of the fillet image is analyzed from its features, and the geometry representing the tip of the bone is automatically identified. Finally, we will discuss the implementation of this system and consider further improvements in detection accuracy.

The rest of this paper is organized as follows. Section II describes related works on fish bone detection using image sensing techniques. Section III describes our proposed method for detecting pinbone tips from near-infrared transmitted images. Section IV summarizes our results. Finally, Section V concludes our work.

II. RELATED WORKS

Traditionally, tweezers or needle nose pliers have been used to remove bones from fish fillets. Today, hand-held pin bones have been made available, allowing for easier manual deboning. To use these machines to remove bone, the tip of the bone must first be located. Therefore, an important step in the automation of bone removal is to find the bone tip.

Image sensing techniques such as X-ray, Ultraviolet (UV), and infrared spectroscopy have been proposed for detecting fish bones. Mery et al. (2011) developed an X-ray machine vision approach to detect fish bones in fish fillets [5]. Their device is a digital radiography system consisting of an X-ray source and a flat panel detector. Filter banks including Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), and Gabor were used to extract features from the resulting X-ray images. The results showed that by photographing the fish bones, which are arranged in strips and range from 14 mm to 47 mm in length, these bones can be detected with a high accuracy. Wang et al. (2015) investigated the fluorescent properties of cod bone under UV irradiation and found that the optimum wavelengths of excitation and

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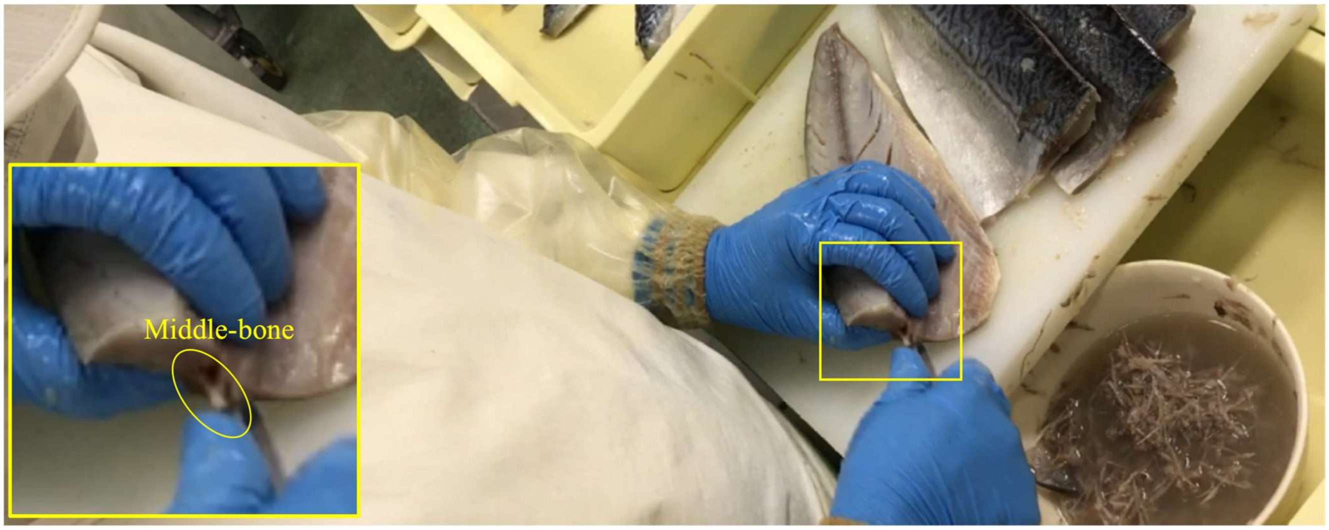

Figure 1. Removal of the remaining middle-bone from the shime-saba manually.

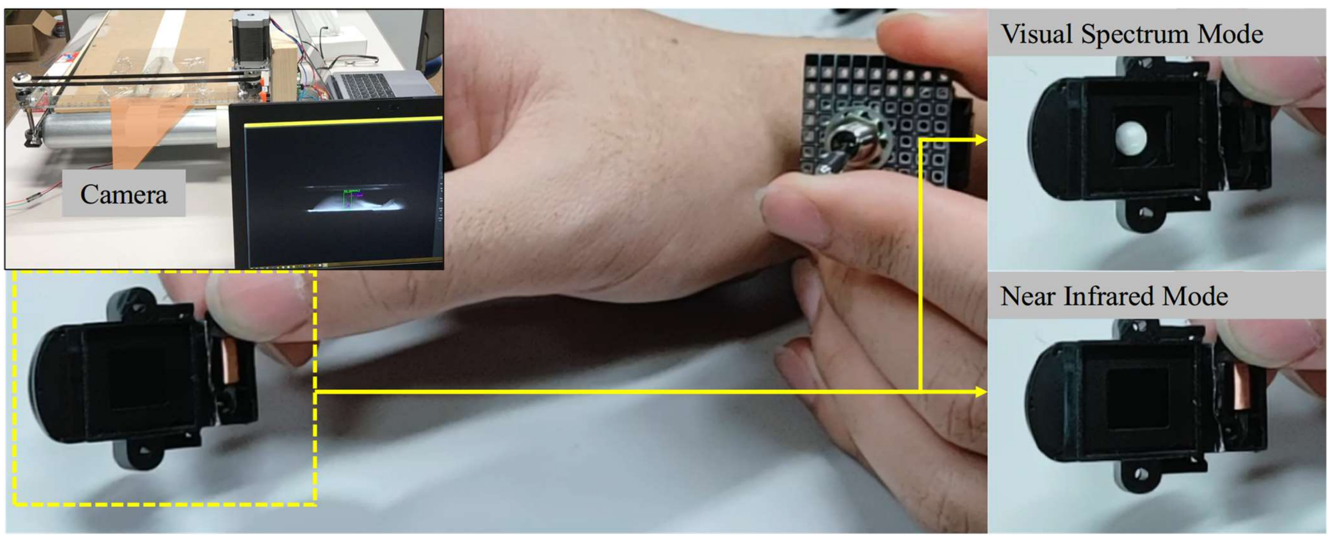

Figure 2. The device for NIR imaging in this study.

emission were 320 nm and 515 nm. They were the first to develop UV fluorescence-assisted candling for detecting fish bones, but the detection accuracy was lower than that of X-ray-based techniques [6]. Wei et al. (2018) used infrared spectroscopy to identify fish bone contents in surimi. The absorption peak in the infrared spectrum at around 9,890 nm wavelength was observed from fish bones. Song et al. (2019) proposed a fish bone detection based on Raman hyperspectral imaging technique to improve detection rate and achieve automatic detection [7]. This technique was found to effectively detect fish bones down to a depth of 2.5 mm.

The above optical sensing at various wavelengths has been used to bring up the feature values of fish bones in an attempt to locate the position of the bones in the body of the fish. However, putting these technologies to practical use in food processing facilities is problematic due to their high cost. Furthermore, while it can detect bones of a certain length, it is not capable of detecting objects where only the tip of the bone can be seen.

III. Methods

In this study, we focus on the broad application of near-infrared light to food analysis, based on various sample presentation techniques [8]. In addition to reflection, Near Infrared Ray (NIR) absorbed and transmitted from the sample may be used to detect the presence or absence of pinbones in the fish body. Here, we attempt to detect the tips of pinbones by photographing the NIR transmitted through the fish body.

A. *Image Acquisition*

The device for NIR imaging in this study is shown in Figure 2. The camera can capture images in the wavelength

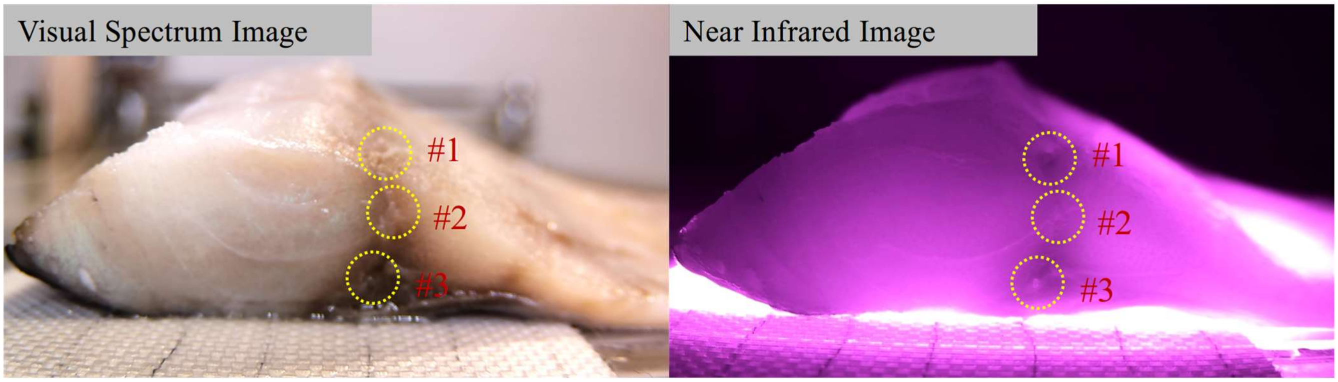

Figure 3. Three bones in the shime-saba to be deboned.

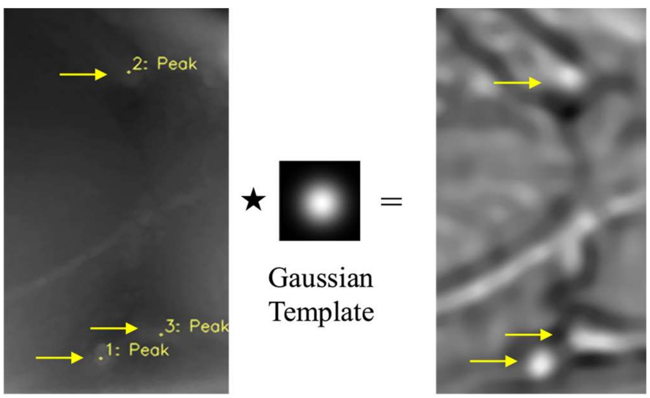

Figure 4. The response image obtained by pre-processing.

range from visible spectrum to near-infrared spectrum. To obtain images in each band, an infrared filter is attached to the camera lens. By switching these filters electronically, both visible and near-infrared images of the fish body can be captured. For the NIR source, 840-nm near-infrared LEDs were used.

As shown in Figure 3, there are three pinbones in the shime-saba mackerel to be deboned. The presence of these bones is not clear in the visible spectrum image, so boning staff must touch the fillet to check for their presence. In contrast, the NIR image reveals features at the tip of the pinbone.

B. *Pre-processing*

To enhance the features of the bone tips in the NIR images, these images were correlated with a Gaussian template image. This template image produces a response image with the region of image maxima as the convex-up region of the image. As shown in Figure 4, the obtained response image shows that the region at the tip of the bone is clear as a convex-up image. The extent of the convex structure can be adjusted by changing the size of the Gaussian template image.

C. *Detection of Bone Tips Using Qudratic Surface*

Given the above observation, we developed a morphometric characterization algorithm to determine geomorphometric features (e.g., peaks, pits, ravines, or ridges) from the derived response images. The quadratic surface is fitted to the image within a moving local analysis window using least-squares [9], with the general equation being

$$z = f(x, y) = Ax^2 + Bxy + Cy^2 + Dx + Ey + F \quad (1)$$

where (x, y) is the location's coordinate, z is the pixel value calculated by the quadratic function, and A to F are the coefficients of the quadratic function. By analyzing the second-order coefficients A to C, the shape of the quadratic surface can be characterized as follows.

Elliptic paraboloid: $B^2 - 4AC < 0$ (2)

Hyperbolic paraboloid: $B^2 - 4AC > 0$ (3)

Parabolic paraboloid: $B^2 - 4AC = 0$ (4)

Here, if A=B=C=0 then the quadratic is a plane. Equation (2) divides the quadratic surface into convex-up and concave-up. If the center of the convex-up surface is within the analysis window, this surface can be determined as the peak. Hence, this property can be used to determine the location of the pinbone tips from the response image.

IV. Experiments and Results

Experiments were conducted to detect pin bones in non-processed shime-saba using the equipment shown in Figure 2. Since the pinbones are in the center of the fillet, this region was preprocessed as a Region-of-Interest (ROI) and used to approximate the quadratic surfaces. Figure 5 shows the candidate pinbones detected in the fillet. There are several convex-up regions in the ROI, but the five candidates with the largest difference in convexity were displayed. Among these candidates, the presence of the pinbones were confirmed. Thus, the five convex-up candidates from the sample of fillets used in this study can be used to narrow down the candidates for the correct pinbone locations. At this point, we will continue to work on how to select the correct pinbone from among the candidates.

V. Conclusion

In this study, an image sensing system for detecting the pinbone tips of shime-saba was developed. By analyzing the surface geometry of a fillet transmitted by near-infrared ray,

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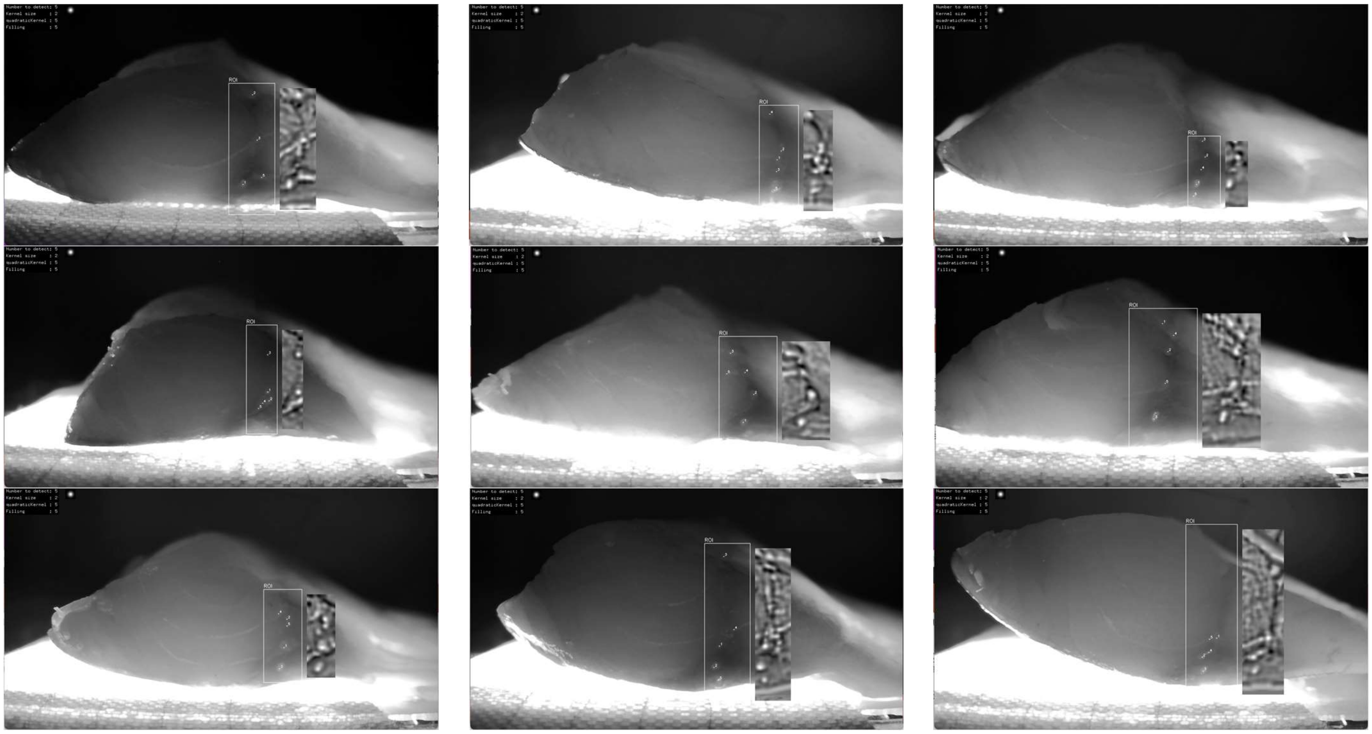

Figure 5. Candidates for the pinbones in shime-saba.

we were able to identify convex-up shapes that represent the tips of the bones. At this point, we were able to narrow down the convex shapes in the center of the fish body to five in order of size. The future focus will be on identifying tips of the bones from the candidates identified by the current system, including deep learning solutions.

Acknowledgment

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