PROPOSAL OF IMAGE PROCESSING FOR RIP CURRENT VERIFICATION

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In Japan, rip currents are a major cause of drowning accidents, as many beachgoers fail to recognize them. Previous research has shown that visualizing rip currents can help users avoid them. While AI-based systems have been developed to detect rip currents from fixed-point camera images, these systems involve high initial costs for AI model creation and equipment. This study explores a cost-effective approach to visualizing rip currents using image processing and evaluates whether beachgoers can identify them effectively. The method involves calculating the difference between consecutive images, with areas of motion highlighted in green. Rip currents were identified by focusing on uncolored areas in the processed images. Data was collected over 45 minutes on three days when lifeguards confirmed the presence of rip currents. A total of 360 responses were gathered from 20 subjects who watched both original and processed videos, marking rip current locations. Accuracy was evaluated by comparing the subjects' marked areas with those of lifeguards using the Intersection over Union (IoU) metric. Results showed no overall improvement in IoU when comparing processed and unprocessed videos. However, under sunny conditions, the IoU improved up to 62%. In conclusion, this method can enhance beachgoers' rip current verification in clear weather conditions which was considered a high number of users, potentially helping beachgoers avoid hazardous areas.

Keywords: rip current; *image analysis*; *image processing*; *wave condition*; *Wakasawada Beach*

INTRODUCTION

There are from 2,000 to 3,000 rescues every summer at bathing beaches in Japan. 54 % of drowning accidents were caused by rip currents (Ishikawa, T. et al., 2014), therefore rip currents are the main cause of drowning accidents in Japan. As measures against drowning accidents, life savers inform beach users and put up flags and signboards. During the peak season, a single lifeguard is responsible for overseeing more than 1,000 beachgoers. Therefore, beachgoers themselves must pay attention to the rip current. However, there are problems such as the beachgoers cannot perceive the place of rip current occurrence and do not understand the risk of the rip current. According to the results of the questionnaire survey to one hundred beachgoers in Japan, there is a strong relationship between beachgoers perceiving the rip current area and swimming away from the rip current area (Endo, S. et al., 2022). Under these circumstances, the approach that focuses on visualization is progressing. For example, an AI system was created that detects rip currents and alerts beachgoers through the application (Ishikawa, T. et al., 2021). The application allows information to be provided to many people. Additionally, it always enables continuous monitoring. However, the system requires an initial investment, along with ongoing costs for installation, AI development, and maintenance during the season. Therefore, to analyze the rip current surveys, a method for visualizing rip currents with average images can be used. It is a method for visualizing currents by averaging consecutive images of the coast into a single image (Lippmann and Holman, 1989). The breaker zone is shown in the lighter-shaded area, and the current area is shown as the darker-shaded area. This method costs slightly as long as you have the image data, but it cannot be applied instantaneously in real-time. So, in this study, we suggest a new approach to visualize rip currents in real time using image differences to verify whether beachgoers can recognize rip currents easily using image processing in real-time (Figure 1).

Figure 1. Example of average images.

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METHODS

Introduction of the study beach

The study beach is Wakasawada beach which is located on the west coast of Japan (Figure 2). Figure 3 shows an overhead view of the study beach. This beach has an approximately 1 km shoreline. This beach is surrounded by Wada Harbor, Haseki Island, therefore the wave direction from the North is dominant. The camera was installed and took approximately 3 frames per second, and the shooting range was 60 degrees. Figure 4 shows an example of image shooting from this camera. As a result of the color dye survey near the shoreline in the study area, a rip current was observed on the 24th of February 2021 as shown in Figure 5. Figure 6 shows wave conditions in 2021, and $H_{1/3}$ = 1.3 m, $T_{1/3}$ = 8 s at the time of the color dye survey. $H_{1/3}$ = 0.8 m was the average, and the maximum was $H_{1/3}$ = 6.8 m occurring on January 7th.

Figure 2. Location of study beach

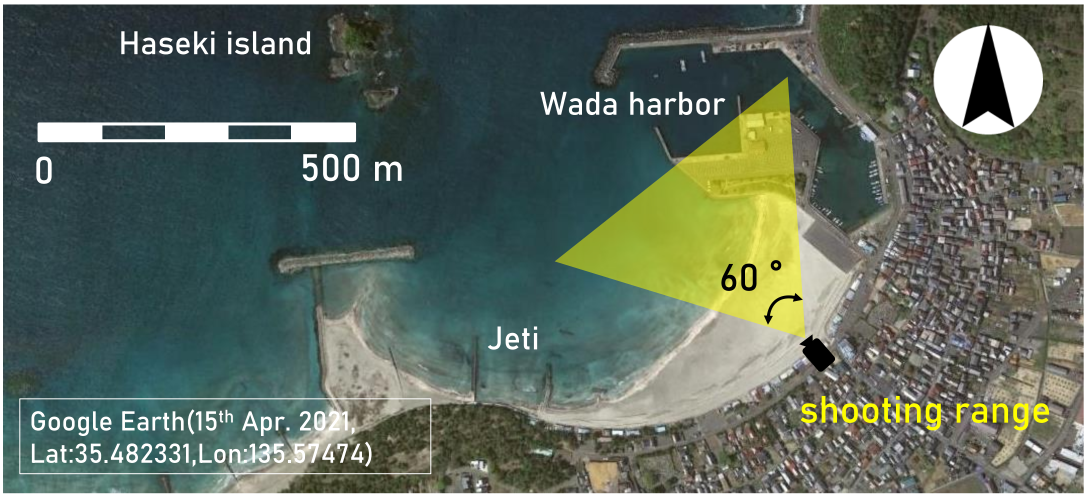

Figure 3. Overhead view of study beach.

Figure 4. Example of image shooting from this camera.

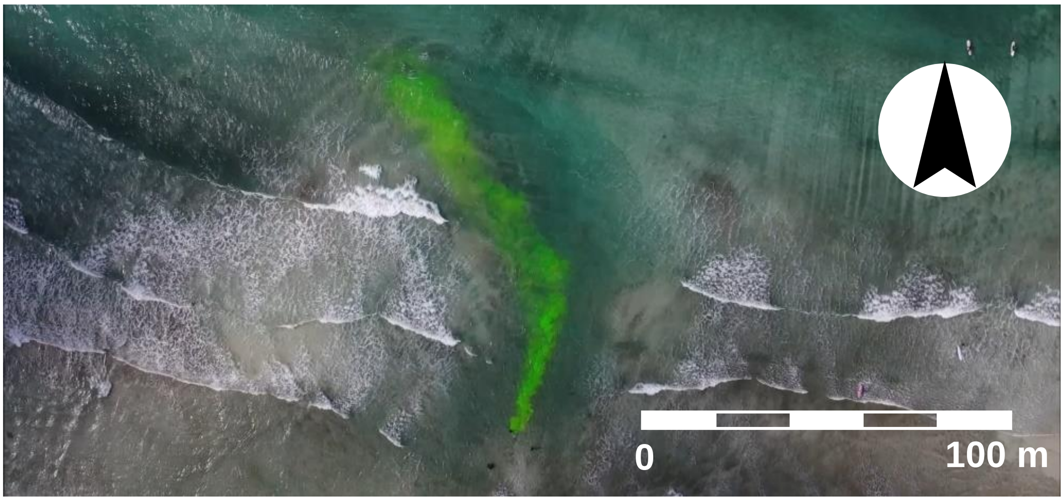

Figure 5. Results of the color dye survey on 24th February 2021

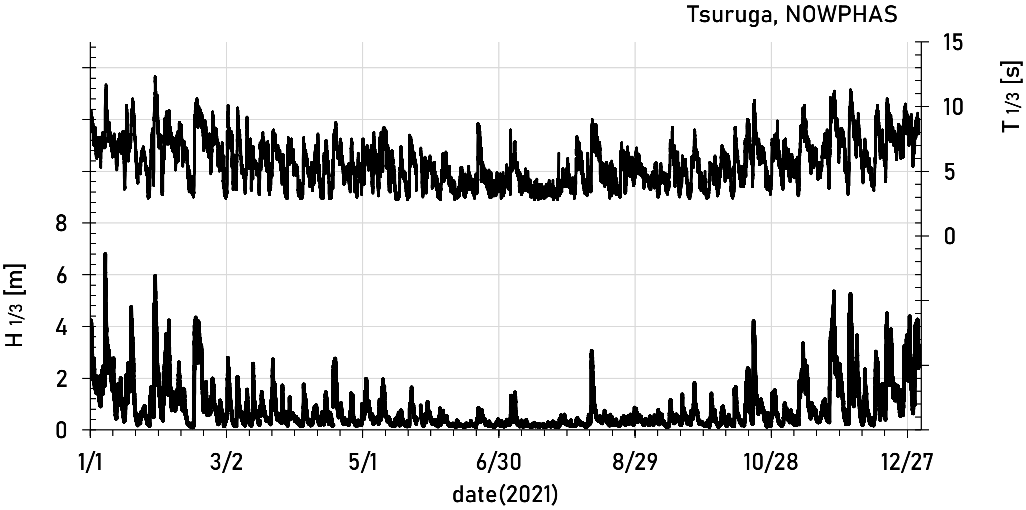

Figure 6. Example of image shooting from this camera.

Collect beach images with rip current.

First, three experienced lifesavers reviewed 26 hours of footage of the beach to acquire images of the beach during the rip current. As a result, three videos were selected for each of the three days of 11 March 2021, 22 March 2021, and 5 April 2021, each lasting five minutes. Each video was designated as Case 1 to Case 9 (Figure 7). To verify the actual occurrence of rip currents, image averaging was applied to Cases 1 to 9, and the results are shown in Figure 7. The rip current was able to be seen in all cases. For example, the results of Case 1 (11th March 2021, 11:05-11:10) are shown in Figure 8. Image averaging is a method of visualizing the flow by averaging a series of images of the shore into a single image. The following steps are used to create an average image. First, prepare consecutive images to be averaged. Note that the images must be consecutive to perform averaging. Second, obtain the pixel value of each pixel in the first image. Each pixel stores three values called pixel values as shown in Figure 9. Pixel values represent red, green, and blue, respectively, which have a maximum of 255 and a minimum of 0. If the number of vertical pixels in the image is *h*, the number of horizontal pixels is *w*, the red pixel value is *r*, the green pixel value is *g*, and the blue pixel value is *b*, then an image is given by:

$$\mathrm{I} = \begin{bmatrix} (r_{11}, g_{11}, b_{11}) & \cdots & (r_{1w}, g_{1w}, b_{1w}) \\ \vdots & \ddots & \vdots \\ (r_{h1}, g_{h1}, b_{h1}) & \cdots & (r_{hw}, g_{hw}, b_{hw}) \end{bmatrix} \tag{1}$$

At last, an averaged image is calculated by:

$$\mathrm{I}_{ave} = \frac{\sum_{k=1}^{n} \mathrm{I}_k}{n} \tag{2}$$

Figure 7. Result of the image averaging.

Figure 8. Example of average images (Case 1, 11th March 2021, 11:05-11:10).

Figure 9. Example of the pixel value.

Apply image processing

For Cases 1 to 9, the proposed analysis method using the difference between consecutive images was applied (Figure 10). It was considered that the use of image differencing would make the movement of waves clearer and make it easier to recognize areas of unbroken waves, which is a feature of rip currents. In detail, the analysis was conducted in the following steps. It was conducted using the programming language Python's image analysis module, pillow, and OpenCV.

1. To facilitate image analysis, smoothing was applied to the entire video and converted to greyscale.
2. Calculate the difference between two consecutive images (Figure 11).
3. Create a mask image by binarizing the pixel values for which the difference between the images is more than 30 to 255 white and the other pixels to 0 black (Figure 11). If the first image is A, the second image is B, the mask image is M and the positions of the respective pixels are i, j, then the processes 1-3 can be shown as in Equation 3.

$$M_{i,j} = \begin{cases} 255 & \text{if } \left|A_{i,j} - B_{i,j}\right| > 30, \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

4. The areas that were white in the mask image are made green and the black areas are made transparent in the original image, and the differences are visualized by superimposing them (Figure 12).

The reason why the difference in the pixel values was set to 30 or more is that when the difference was set to about 50, the coloring was not rendered in green despite the difference. When the difference was set to about 10, the coloring was too sensitive, and green coloring was seen in areas other than where the waves were breaking (Figure 13).

Figure 10. Result of the image processing using different consecutive images.

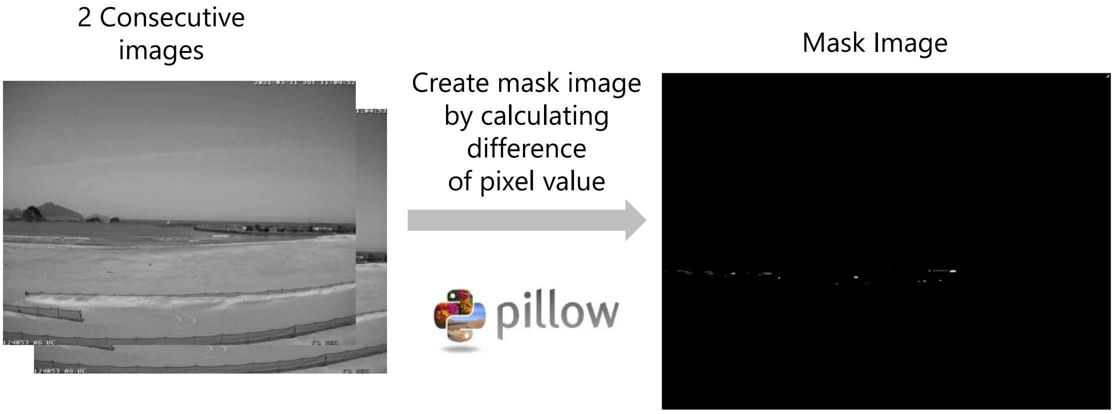

Figure 11. Creating the mask image.

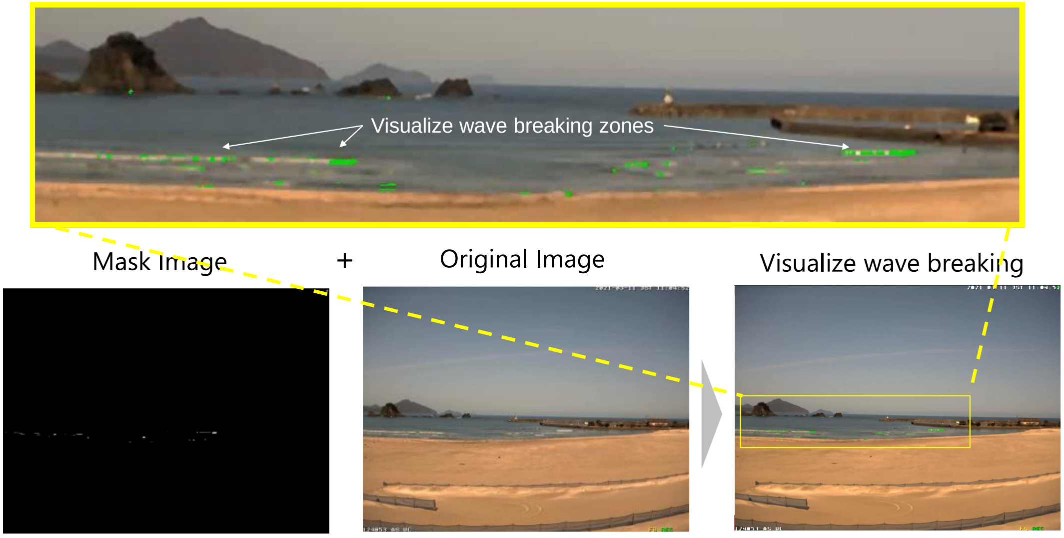

Figure 12. Result of the image processing and visualizing wave braking.

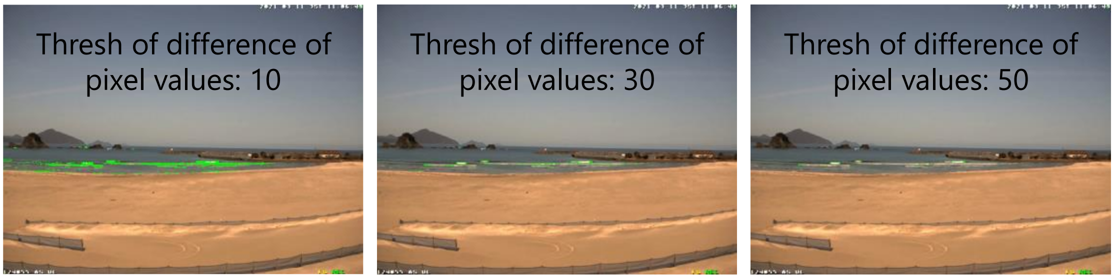

Figure 13. Difference between thresh of difference of pixel values.

Investigate the difference in verification of the rip current area with and without image processing

Image analysis was performed on the videos from Case 1 to 9, and three experienced lifesavers specified the areas where the rip currents were occurring in polygons, as shown in Figure 14. The areas covered by the area were considered the correct areas where the rip currents were flowing. Next, a total of 18 videos of Case 1 to 9 were prepared, including the original video without image analysis and the video with image analysis, and were viewed randomly by 20 subjects. After viewing the videos, the subjects designated areas where they thought the rip currents had occurred using polygons (Figure 15) and compared them with the areas designated by experienced lifesavers using IoU (Intersection over Union). This allows the user to determine which of the two is more likely to identify the areas where rip currents occur, depending on whether image processing was used or not. The IoU measures the degree of overlap between the predicted and correct areas and was calculated as shown in Figure 16. Values are expressed in the range 0 to 1, with the closer to 1, the more accurate the verification.

Figure 14. Example of specified areas where the rip currents occurred by experienced lifesavers.

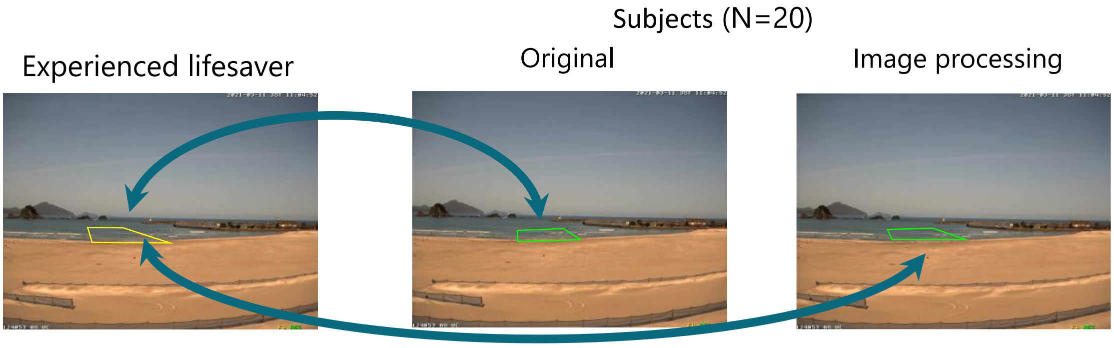

Figure 15. Polygon-based identification of rip current areas by subjects after video viewing.

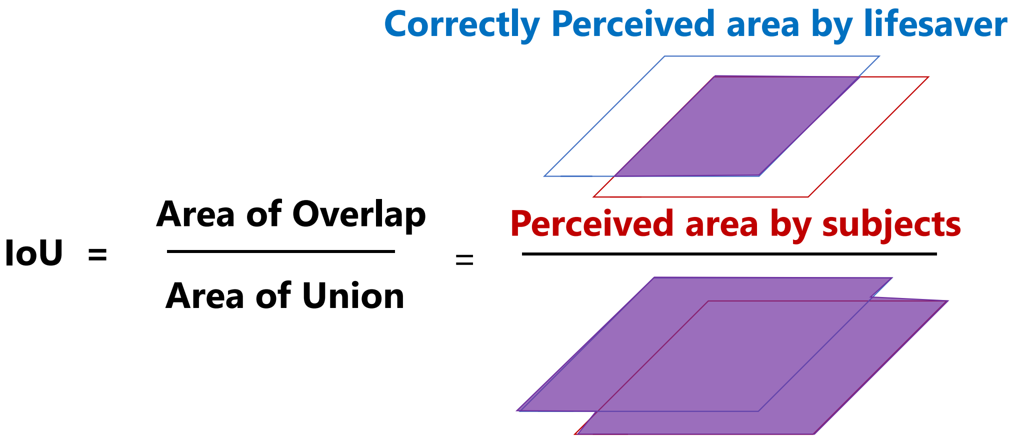

Figure 16. Conceptual diagram of IoU (Intersection over Union).

RESULTS

Figure 17 shows box plots of the IoU with and without image analysis and the difference in IoU with and without image analysis for all videos in Cases 1 to 9. Contrary to expectations, there was no difference in the public's perception of rip currents with and without image analysis for Cases 1 to 9 overall. On the other hand, Figure 18 shows box plots of the difference in IoU with and without image analysis for each case. In cases 1, 2, 3, and 9, there was an improvement in the IoU up to 62% in verification of rip currents with and without image processing, and the weather in each case was sunny. Conversely, there was hardly any improvement in the verification of rip currents with and without image analysis on rainy and cloudy days. Figure 19 shows an example of a rainy day in Case 4. It was considered that on such bad weather days, the differences between consecutive images became smaller and it was difficult to recognize the location of the occurrence of rip currents. On the other hand, Figure 20 is an example of a sunny day in Case 1. The difference between consecutive images was large and the area where the waves break was able to be identified, so it was considered that it was easier to recognize the location of the occurrence of rip currents.

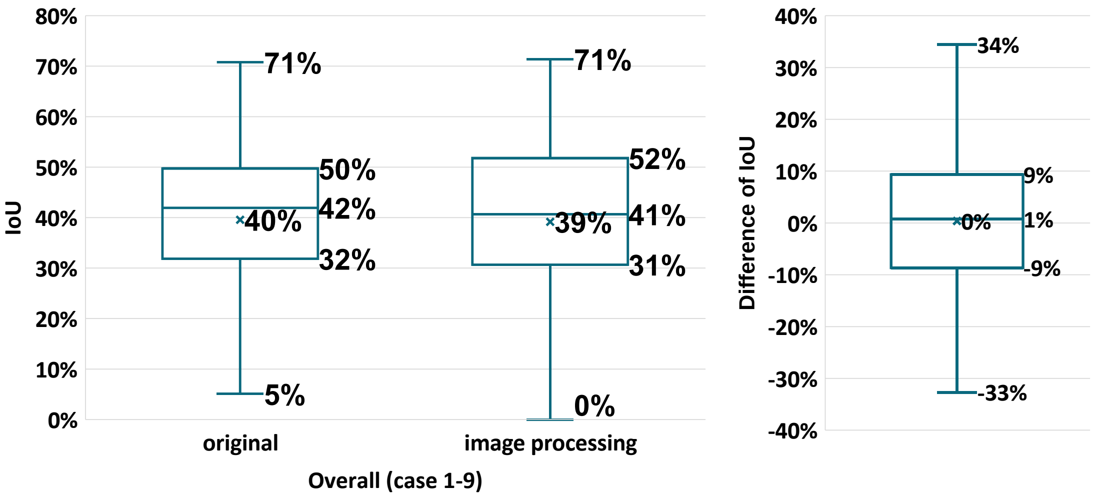

Figure 17. The box plot of experimental results in overall cases.

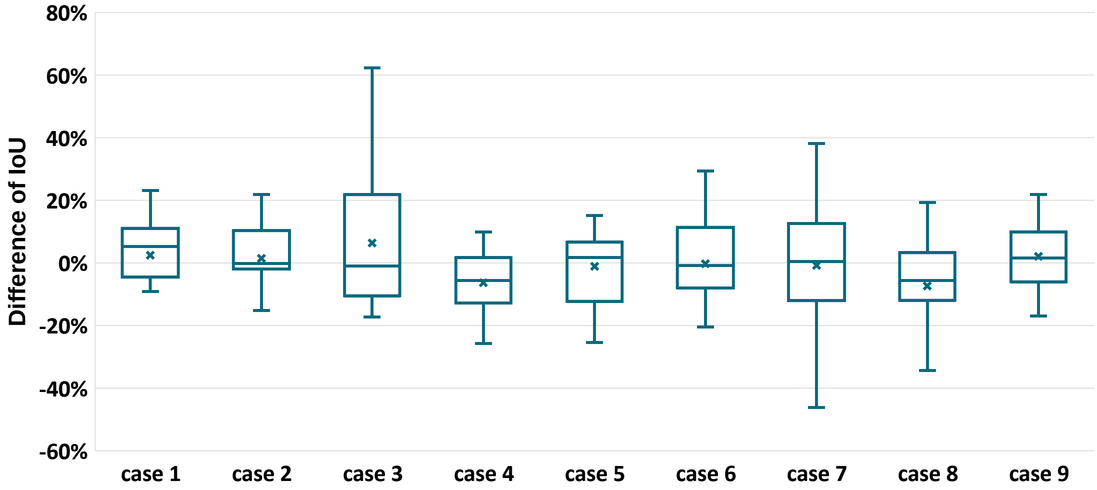

Figure 18. The box plot of difference of IoU between image processing and original in each video.

Figure 19. The result of the image processing in Case 4.

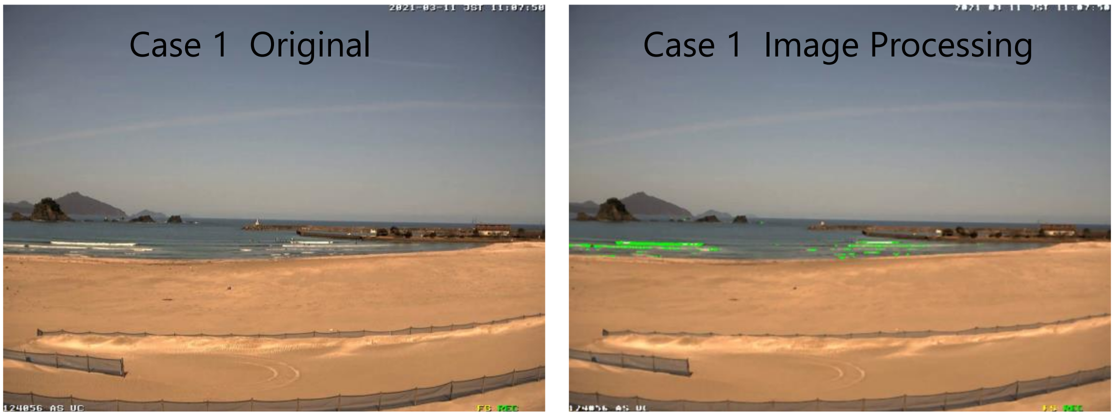

Figure 20. The result of the image processing in Case 1.

CONCLUSIONS

This study aimed to verify whether beachgoers can easily recognize rip currents using image processing in real-time. The results showed the beachgoers did not improve their verification of where the rip currents occur with and without image analysis in the overall video. However, under sunny conditions, the verification of where the rip currents occur by beachgoers was improved. Thus, it was found that this method can enhance beachgoers' rip current verification in clear weather conditions which was considered a high number of users, potentially helping beachgoers avoid hazardous areas.

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