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# FEATURE EXTRACTION AND DISCRIMINATION OF PROCYON LOTOR AND NYCTEREUTES PROCYNOIDES ALBUS IN HOKKAIDO, JAPAN USING FOOTPRINT IMAGES

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Abstract. *Animal distribution surveys have been conducted for the purpose of nature conservation, nature development, and animal research. The purpose of this study is to develop a method to discriminate animal species based on the shape and size of footprint images. In this paper, we extracted the features using footprint images and proposed the method to discriminate between Procyon lotor and Nyctereutes procynoides albus in Hokkaido, Japan. The results of the experiment suggest that (i) the preprocessing proposed was found to be useful for extracting the footprint area acquired on soil and snow, (ii) there was a significant difference in finger length between Procyon lotor and Nyctereutes procynoides albus, and (iii) the method of species discrimination focusing on the length of fingers in the footprint images was able to classify Procyon lotor and Nyctereutes procynoides albus with an average accuracy of 87.5%.*
**Keywords:** Footprint, Animal, Image processing, SVM

1. **Introduction.** Wild animal distribution surveys have been conducted for the purpose of nature conservation, nature development, and animal research. For example, monitoring using automatic cameras mounted on trees and attaching GPS transmitters to animals have been conducted [1]. A method for recognizing four types of animals (deer, boar, fox, and rabbit) [2] and a method for classifying carp under water [3] using video data have been proposed. In addition, animal detection from the air using thermal infrared measurement by an unmanned drone has been conducted [4]. In these methods, data was acquired directly from wild animals, so the system needed to operate during the animal's hours of activity.

When acquiring data from wild animal traces, such as footprints on the ground, the traces remain at the location for a certain period of time, so the distribution survey does not always need to consider the activity time of wild animals. Therefore, species identification and understanding the activity range of animals from animal traces can contribute to cost reduction. A method has been proposed to determine the species from footprint images captured in airborne remote sensing images [5]. However, the resolution of the images was larger than the animal footprints, and it was difficult to discriminate

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the species using the shape and size of footprints; stride length was used for species discrimination.

The purpose of this study is therefore to develop a method to discriminate animal species based on the shape and size of footprint retrieved regardless of time of day or night. In this paper, as a basic study, we proposed a feature extraction method using footprint images and conducted species discrimination of Procyon lotor and Nyctereutes procynoides albus in Hokkaido, Japan. The proposed method was able to extract the footprint area acquired on soil and snow and to classify Procyon lotor and Nyctereutes procynoides albus with an average accuracy of 87.5%. This paper consists of six sections. The background and purpose of this study are described in Section 1. In Section 2, we describe target animals and their footprints, and data used in this study. In Section 3, data analysis procedures are described. In Section 4, the analysis results are described and we discuss the usefulness of the proposed method. Section 5 discusses the conclusion of the study.

## 2. **Target Animals and Data Used.**

In Hokkaido, Japan, Procyon lotor, a non-native species, and Nyctereutes procynoides albus, a native species, both occur. Procyon lotor has many prey species and preys on the food of native species, which affect the breeding environment of native species [6]. Therefore, it is necessary to identify Procyon lotor for the purpose of protecting native species. However, it is difficult to distinguish Procyon lotor and Nyctereutes procynoides albus from each other because they are similar in appearance.

20 images of Procyon lotor footprints and 20 images of Nyctereutes procynoides albus footprints were used for the study. All of the Procyon lotor footprint images were acquired on soil. For the Nyctereutes procynoides albus, 12 images were acquired on soil and 8 images were acquired on snow, as shown in Figure 1. Footprint images were acquired under different conditions. Depending on the season when the images were acquired, the type of ground can be roughly divided into soil and snow. In addition, the amount of water contained in the ground varies depending on the weather conditions at the time of image acquisition, and thus the hardness of the ground also varies. Animal footprint images are also characterized by the difference in the way the footprints are made depending on the weight and movement of animals.

## 3. **Proposed Method.**

The footprint discrimination method proposed in this study consists of preprocessing, feature extraction, and discrimination using a linear SVM.

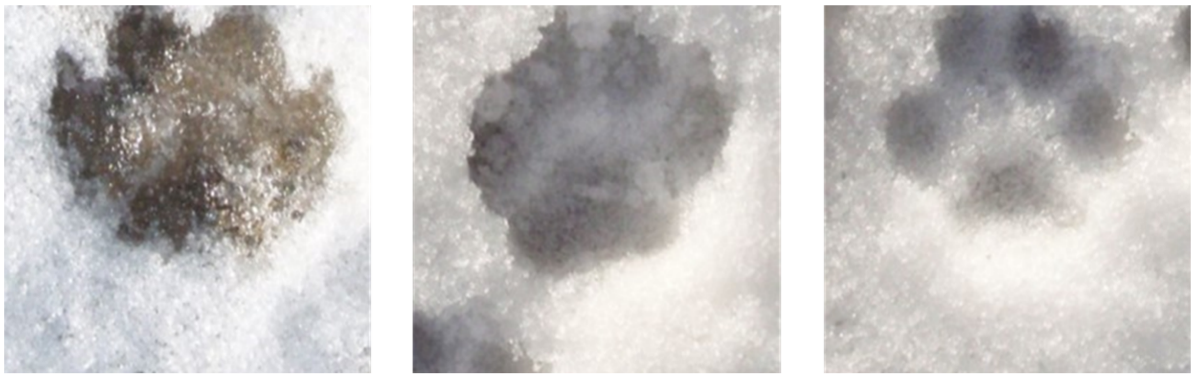
### 3.1. **Preprocessing.**

Footprint images acquired on soil contain a lot of noise due to artefacts such as depressions in the ground and fallen leaves. Examples of noise in footprint images are shown in Figure 1(a). On the other hand, for images in snow (see Figure 1(b)), the color of the non-footprint area is white. The footprint image in snow may also contain white noise in the footprint area. Since snow is softer than soil, it tends to result in an uneven foot imprint. This unevenness appears as a difference between light and dark in the footprint area, causing white noise. The white noise is also caused by the fact that snow crystals reflect sunlight. In this paper, in order to extract features useful for type discrimination from the footprint area, the input image is converted to a grayscale image after normalizing the data used, and preprocessing is applied separately for ground covered with soil or snow.

#### 3.1.1. *Preprocessing for footprints acquired on soil.*

The brightness of footprint images acquired on soil differs from image to image depending on the difference in data acquisition conditions. Therefore, in order to determine an appropriate threshold value from the image, binarization using the discriminant analysis method was applied [7,8]. For the purpose of noise removal, processing by median filter, dilation and contraction were also

(a) Footprint of Procyon lotor acquired on soil



(b) Footprint of Nyctereutes procynoides albus acquired on snow

Figure 1. Examples of data used for the study

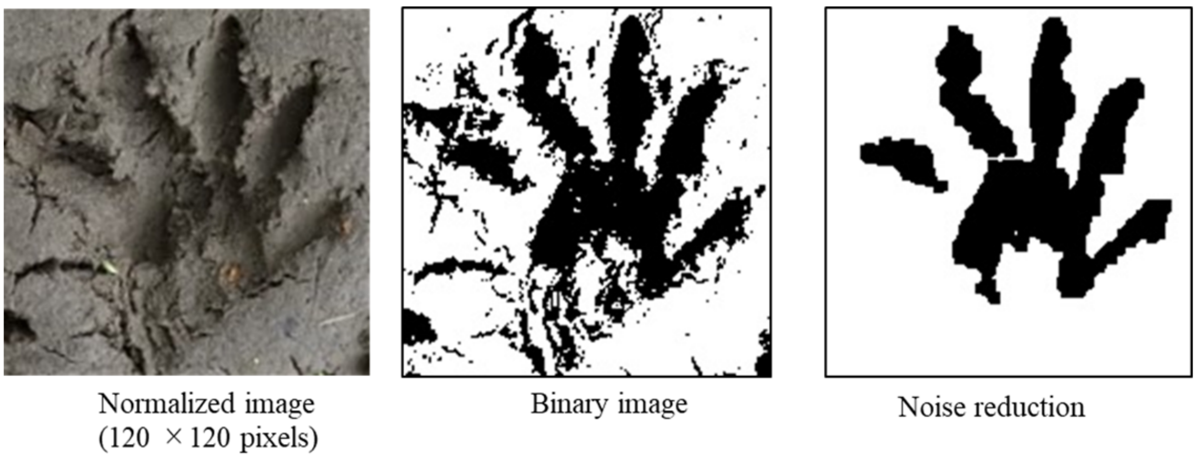



Figure 2. Preprocessing for footprints acquired on soil

applied. In addition, the labeling process was applied to removing the noise areas. Figure 2 shows the results of applying the above procedures.

3.1.2. *Preprocessing of footprints acquired on snow.* The density distribution of the footprint images was calculated for the converted grayscale images. Since the non-footprint area of the snow image is white, as shown in Figure 1(b), the density value in grayscale tends to be higher. Therefore, smoothed images were obtained. To remove noise, we applied median filtering, dilation and contraction processing. In addition, the labeling process was applied, and white pixel areas were removed in the footprint area to remove

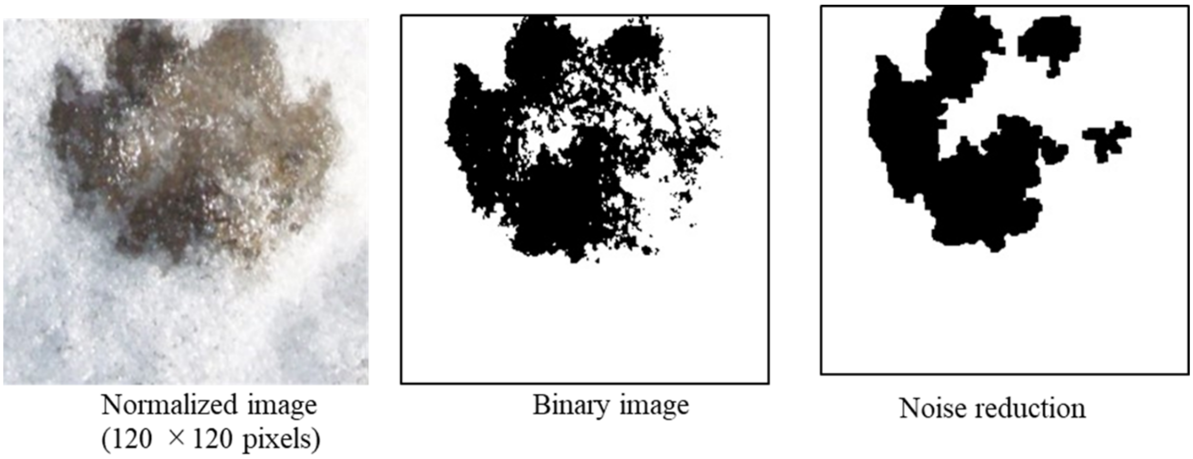



FIGURE 3. Preprocessing for footprints acquired on snow

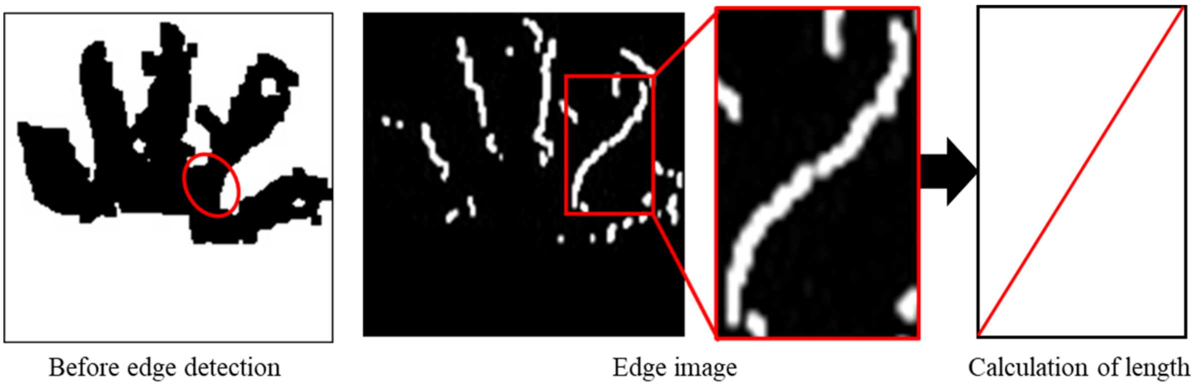



FIGURE 4. Calculation of finger length

noise. Finally, black pixels were removed in the non-footprint area. Figure 3 shows the results obtained by applying the above procedures.

3.2. **Feature extraction.** In this study, it was assumed that the features related to finger length were an effective means of discriminating the target animals. Therefore, an unpaired T-test was conducted to verify the significant differences in the finger length of the target animals. A significance level of 5% (two-tailed) was used as the criterion for the test. Calculation of the t-test confirmed that there were significant differences in the finger lengths of Procyon lotor and Nyctereutes procynoides albus. Therefore, we extracted features focusing on the finger length. In some input images, the finger and palm regions were connected (see red circle in the left image in Figure 4). In these cases, it was difficult to obtain the finger length directly from the input image. The fingers are oriented more-or-less vertically, and the finger and palm regions can be separated by detecting vertical edges in the footprint image. Therefore, we detected the vertical edges using the Sobel filter. An example of a longitudinal edge detection image is shown in Figure 4. The concatenated edges may be diagonal curves. We therefore applied the labeling process to the footprint image after the vertical edge detection to obtain the vertical and horizontal lengths in the bounding rectangle of each label. The length of the diagonal line from the length and width of the bounding rectangle of each label was then obtained. The length of the diagonal line in the bounding rectangle of the edge (hereinafter referred to as the edge length) was taken as the length of the finger.

The obtained edge lengths were sorted in descending order, and the sum of the top N edge lengths was selected as the feature value. In this paper, the following seven types of edge lengths were used as feature values.

1) The sum of the lengths of the top five edges
2) The sum of the lengths of the top 10 edges
3) The sum of the lengths of the top 15 edges
4) The sum of the lengths of the top 20 edges
5) The sum of the lengths of the top 25 edges
6) The sum of the lengths of the top 30 edges
7) The sum of the lengths of all edges

From the above seven types of features, we selected two useful features and performed discrimination using footprint images.

3.3. **Discrimination.** In this paper, we used a linear SVM [9] to classify the obtained two-dimensional data distribution. First, two types of features and their corresponding animal names were input to the linear SVM as training data. Then, the linear SVM learned the boundary that optimally classified the training data. Finally, the boundaries calculated by the training were used for species estimation.

## 4. Experimental Results and Discussion.

4.1. **Examination of preprocessing.** In order to evaluate the usefulness of the preprocessing proposed in this study, an evaluation experiment was conducted. Using three images of soil footprints and three images of snow footprints, corrected images were created in which the areas judged to be footprints were black and the other areas were white. The results were compared with both the results of the proposed method and the binarization process using the discriminant analysis method (hereafter referred to as the comparison method). In addition, we calculated the Intersection over Union (IoU) and the accuracy using the index of confusion matrix [10]. The results obtained are summarized in Table 1. These results indicate that the preprocessing results of the proposed method are good for both conditions in soil and snow.

Table 1. (a) Experimental results on soil footprints, (b) Experimental results on snow footprints

(a)

| | IoU | | Accuracy | |
|---|---|---|---|---|
| | Proposed method | Comparison method | Proposed method | Comparison method |
| Procyon lotor 1 | 0.68 | 0.56 | 0.90 | 0.83 |
| Procyon lotor 2 | 0.71 | 0.48 | 0.93 | 0.81 |
| Procyon lotor 3 | 0.54 | 0.20 | 0.92 | 0.61 |

(b)

| | IoU | | Accuracy | |
|---|---|---|---|---|
| | Proposed method | Comparison method | Proposed method | Comparison method |
| Nyctereutes procynoides albus 1 | 0.57 | 0.45 | 0.90 | 0.80 |
| Nyctereutes procynoides albus 2 | 0.51 | 0.41 | 0.89 | 0.82 |
| Nyctereutes procynoides albus 3 | 0.66 | 0.41 | 0.92 | 0.75 |

4.2. **Selection of two features.** The first type of feature selected was one that had the strongest relationship with the animal that produced the footprint in the target image (hereinafter referred to as the target variable). Therefore, we calculated the correlation ratios of the seven types of features to the target variable. The correlation ratio is a statistic that indicates the degree of correlation between quantitative data such as finger length (hereinafter referred to as quantitative variables) and classes such as animal names. The results obtained are summarized in Table 2. The results show that the correlation ratio of the sum of the top five edge lengths is the highest. Therefore, we selected the sum of the top five edge lengths as the first type of feature. For the second type of feature, we needed a feature that had a strong relationship with the target variable and a weak relationship with the first type of feature. In addition to the correlation ratios with the target variables, the correlation coefficients with the features of the first type were calculated. Here, the correlation coefficient is a statistic that expresses the degree of correlation between two quantitative variables. Therefore, a feature with a high correlation ratio with the target variable and a low correlation coefficient with the first type of feature is desirable as the second type of feature. In this paper, the one with the highest "correlation ratio with the target variable/correlation coefficient with the first type of feature" (hereinafter referred to as correlation ratio/correlation coefficient) was selected as the second type of feature. The results obtained are listed in Table 3. We found that the feature "sum of the lengths of the top 25 edges" had the highest value. Therefore, the feature "Total value of the top 25 edge lengths" was selected as the feature of the second type.

Table 2. Correlation ratio with the objective variable for each feature

| Feature (the sum of the lengths) | Correlation ratio with objective variable |
|---|---|
| The top five edges | 0.54 |
| The top 10 edges | 0.49 |
| The top 15 edges | 0.47 |
| The top 20 edges | 0.46 |
| Top 25 edges | 0.44 |
| Top 30 edges | 0.41 |
| All edges | 0.20 |

Table 3. Correlation ratio with the objective variable for each feature

| Feature (the sum of the lengths) | Correlation ratio with objective variable | Correlation coefficient with the first feature | Correlation ratio/ correlation coefficient |
|---|---|---|---|
| The top 10 edges | 0.49 | 0.94 | 0.52 |
| The top 15 edges | 0.47 | 0.87 | 0.54 |
| The top 20 edges | 0.46 | 0.81 | 0.57 |
| Top 25 edges | 0.44 | 0.76 | 0.59 |
| Top 30 edges | 0.41 | 0.72 | 0.57 |
| All edges | 0.20 | 0.54 | 0.36 |

4.3. **Evaluation results of feature extraction.** The evaluation results of feature extraction are shown in Figure 5. 37 out of 40 images (92.5%) were successfully discriminated using a linear SVM. If the feature extraction for finger length is useful, the accuracy will be higher when the test is conducted with the trained data. This result suggests that the two features obtained from the finger length are useful for discriminating the two species of animals.

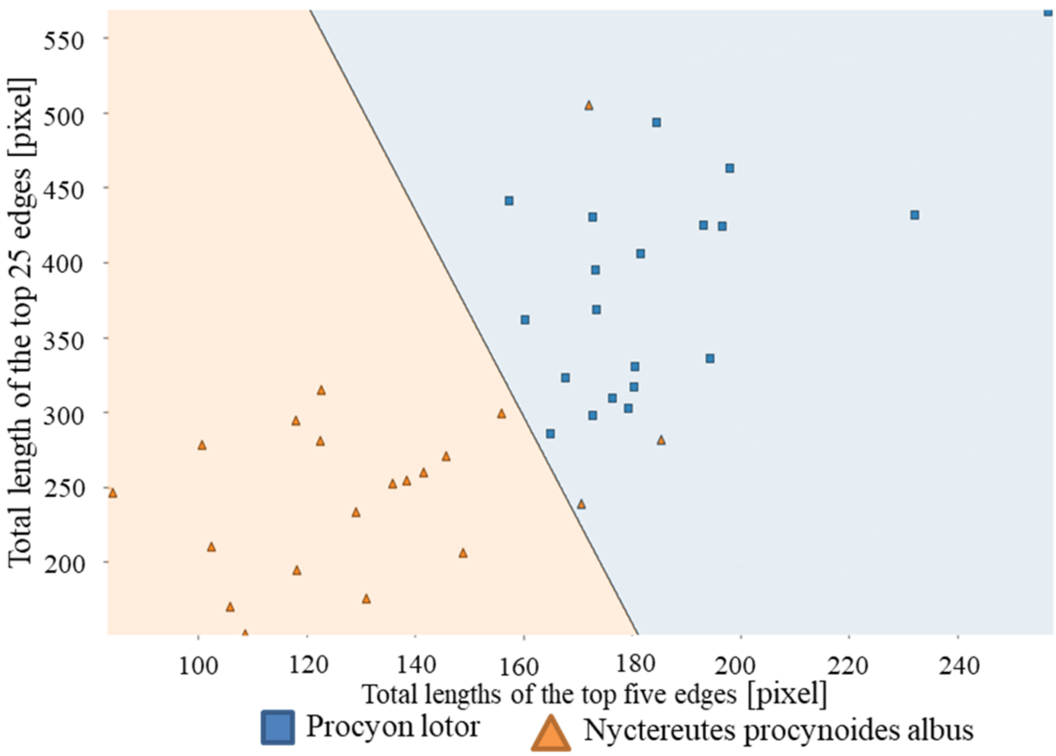



FIGURE 5. Evaluation results of feature extraction using a linear SVM

4.4. **Evaluation of the species identification method.** To evaluate the species discrimination method proposed in this study, cross-validation was conducted. We divided the 40 images into 4 datasets of 10 images each (5 images of Procyon lotor and 5 images of Nyctereutes procynoides albus). We then used three datasets for training and tested on the remaining dataset. As a result of four tests, we obtained an average accuracy of 87.5%. This result suggests that the method proposed in this paper is useful for discriminating Procyon lotor and Nyctereutes procynoides albus.

5. **Conclusion.** In this paper, we extracted features in footprint images and used the method to discriminate between two animal species. The results obtained are summarized as follows.

1) The preprocessing proposed was found to be useful for extracting the footprint area acquired on soil and snow.

2) There was a significant difference in finger length between Procyon lotor and Nyctereutes procynoides albus, indicating that edge length expressing finger length is a useful feature for species discrimination.

3) The method of species discrimination focusing on the length of fingers in the footprint images was able to estimate the species of Procyon lotor and Nyctereutes procynoides albus with an average of 87.5% of accuracy.

Our future scope includes evaluation of effectiveness and applicability of the proposed method by comparing it with state-of-the-art methods, improvement of the method using the features obtained in this paper and consideration of more species of animals targeted in the study.

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