# Trajectories Prediction of the Black-Tailed Gull Using the Inverse Reinforcement Learning

Kanon Takemura
*Graduate school of Environmental Studies*
*Nagoya University*
Nagoya, Japan
takemura.kanon@k.mbox.nagoya-u.ac.jp

Tsubasa Hirakawa
*Department of Computer Science*
*Chubu University*
Kasugai, Japan
hirakawa@mprg.cs.chubu.ac.jp

Yuichi Mizutani
*Graduate school of Environmental Studies*
*Nagoya University*
Nagoya, Japan
yuichi-san@nagoya-u.jp

Hirokazu Suzuki
*Graduate school of Environmental Studies*
*Nagoya University*
Nagoya, Japan
suzuki.hirokazu@nagoya-u.jp

Michi Tsuruya
*Graduate school of Environmental Studies*
*Nagoya University*
Nagoya, Japan
o2ruo2ru@gmail.com

Ken Yoda
*Graduate school of Environmental Studies*
*Nagoya University*
Nagoya, Japan
yoda.ken@nagoya-u.jp

***Abstract*—Revealing the route selection of wild animals is of fundamental importance in understanding their movements and foraging strategy. In this study, we attached GPS loggers to black-tailed gulls *Larus crassirostris* and recorded their movement trajectories during their foraging trips. Using inverse reinforcement learning (IRL), we analyzed the factors that affected their route selection. During the training phase, using pre-defined feature maps, we estimated a reward map that may affect the decision making of black-tailed gulls. The reward map can be used for predicting the trajectories of the gulls during the test phase. In addition, the resultant weight vector enabled us to analyze to which degree the black-tailed gulls favor each area.**

***Keywords—animal movement, bio-logging, interpolation, inverse reinforcement learning, reward map, tracking data***

## I. Introduction

Breeding seabirds conduct foraging excursions between the breeding colony and feeding sites. There have been many studies regarding what properties determine the feeding sites of seabirds. However, foraging seabirds choose not only their feeding sites, but also the course used to move to these sites. Revealing how seabirds select their routes is important in understanding their foraging strategy. This study examined how black-tailed gulls Larus crassirostris, omnivorous seabirds of the Laridae family, fly over land during their foraging trips. A recent study showed that gulls breeding on Kabushima Island, Aomori, Japan, forage for anchovies at sea, aquatic insects in paddy fields, and food waste at fishers' markets. The gulls must fly over various locations (e.g., roads, rivers, and buildings) to obtain terrestrial prey because their colony is adjacent to urban areas. Therefore, the route selection of gulls might depend not only on the prey species but also the landscape.

In this study, we constructed reward maps from the GPS data of gulls using Inverse Reinforce Learning (IRL) to unravel the factors affecting their route selection. The reward maps provide information regarding what areas gulls often fly over and their favored prey sites. Herein, we discuss the application potentiality of the reward maps on wildlife movements.

## II. Method

### A. Study site and species

Fieldworks was conducted from April to July in 2010–2018 on Kabushima Island. We used several types of GPS loggers (GiPSy-1 (2010), GiPSy-2 (2011–2014), GiPSy-4 (2015–2016), Axy-Trek (2017–2018), all were developed by Technosmart, Italy). We set the sampling rates of GiPSy-1, GiPSy-2, GiPSy-4, and Axy-Trek as 1 fix/min, 5 fixes/min, 30 secs/fix, and 1 min/fix, respectively. We attached GPS loggers to the backs of adult gulls using waterproof tape (tesa 4651, tesa SE, Germany). After the deployment, we released them near their nests. After several days to a week, we recaptured the tagged gulls and retrieved the loggers. We then connected the loggers to a PC and downloaded GPS data using special software.

### B. Pre-processing

The raw data obtained from the GPS loggers contain the date, time, latitude, longitude, ground speed, the number of satellites, and decrease in the GPS precision. We preprocessed the raw data for IRL through the following three steps.

- Converting the original file format (.txt) into a useful file format (.csv).
- We removed records outside the fixed area (135-150° E, 35-45° N) from the data. We calculated the speed between two positions and removed overly fast records (> 80 km/h).
- We extracted the points outside the colony (141.556106–141.558863° E, 40.536746–40.540920° N) from the filtered data. We calculated the distances between the gulls and the colony, and their duration from the colony using the data. We extracted foraging trips by the define (total traveled distance: > 1 km, duration: > 1 hour).

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### *C. Inverse Reinforcement Learning*

IRL is a type of the reinforcement learning. Through reinforcement learning, we acquire actions that maximize the reward value through trial and error. On the other hand, IRL is a problem to estimate the rewards required to reproduce the actions of the observed (GPS) trajectories. In this study, because the trajectory (the most suitable action) of a black-tailed gull was clarified using a GPS logger, we were able to find a reward reproducing such action from the trajectory data.

First, we constructed a feature map that might affect the route decision of a black-tailed gull. We used map data called land use subdivision mesh data (raster version) provided by the National Land Numerical Information download service [2]. These data include each land use in a 100 x 100 [m] mesh. We used 12 types of land use (see Figure 1). We displayed a land use subdivision mesh using the map software ArcGIS, and extracted a map within a specified range to construct the feature maps. We used a map around Hachinohe city within the range of the home range of the black-tailed gull. The feature maps were prepared in four ways for each land use type. The first is a binary map representing the target availability division and other areas (see Figure 2(a)). The three other types of maps are exponential distance to the target division over different parameter, which uses [3] as reference (see Figure 2(b)~(d)). These maps mean the distance between an area and the closest area belonging to a land use class. The value of sigma is arbitrary. We constructed 12 x 4 feature maps.

We applied preprocessed data and the feature maps to the IRL. Through learning, we were able to obtain the weight for each feature map. We constructed a reward map using the feature maps and linear sum of their weights. We were able to predict the movement path from the reward map. The reward map is an index indicating to which degree a black-tailed gull likes or dislikes an area.

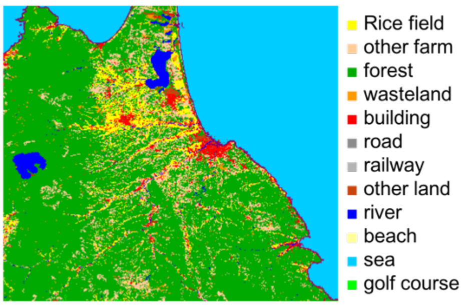


Fig. 1. Original map. As the legend, we categorize 12 types of land use. We create feature maps to use this map.

## III. Result

Figure 2 shows a feature map of a rice field that we constructed. The binary map indicates the rice field, shown in red (0), and the other areas in blue (-1). Other maps have different sigma values (1.50, 3.00, and 5.00). Figure 3 shows a prediction result of trajectory from the obtained reward map. Note that, predicted trajectory is probabilistic and we display the results as heat map.

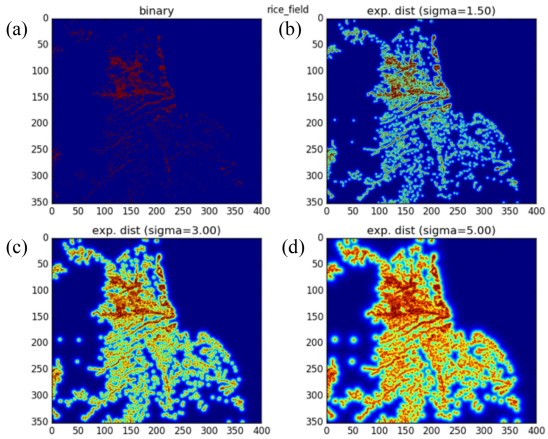


Fig. 2. An example of feature maps. These maps represent "rice field". (a) binary map (b) sigma=1.50 (c) sigma=3.00 (d) sigma=5.00. Wamer color indicates higher probability and cooler color indicates lower probability.

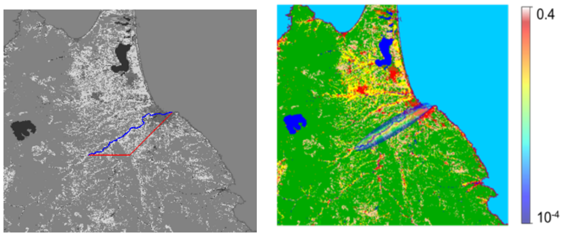


Fig. 3. An example of predicted trajectory. (a) The blue line shows the ground truth trajectory (GPS) and the red line shows the predicted trajectory. (b) The heat map shows the probability distribution that a black-tailed gull visits the location. Wamer color indicates higher probability and cooler color indicates lower probability.

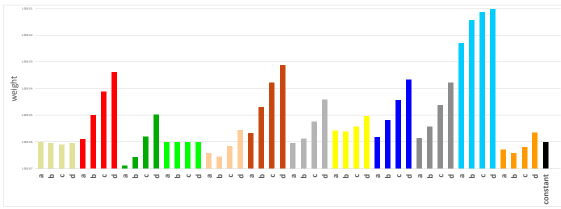

Fig. 4. The weight of each area obtained from the result of IRL. a:binary, b:sigma=1.5, c:sigma=3.0, d:sigma=5.0. Each color shows the same land use as Figure 1. The vertical axis shows the weights of gulls visiting and the horizontal one shows each type of land use. This figure shows gulls favor buildings and other_land. This figure shows gulls favor "sea" and "other land".

## IV. Problem

Our finding showed that black-tailed gulls prefer "other land" and "sea" (Fig. 4). Especially, "other land" which is subdivided by mesh contains various types of land use, for example, ports, artificial lands, athletic stadiums and so on. In addition, the "buildings" include private homes, buildings, and factories. Therefore, to precisely analyze the black-tailed gull's favor with respect to the other land type, we need to categorize the other land into more specific types. we need to create totally new maps of finely land use, because there are no maps with more subdivision in detail. It is the biggest PROBLEM now.

Moreover, trajectories used in the training phase contains movements over both sea and land. Trajectories flying over sea might be insufficient for analysis of trajectories flying over land because feature maps with respect to sea are highly considered. For efficient analysis, we need to use data over land only.

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