STAT 482 PROJECT REPORT

ANIMAL MOVEMENT in Foraging

Model applied
Random Walk

Submitted to
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CONTENTS

I. Introduction

Alongside my studies in statistics, I have been interested in animal behavior, particularly how animals search for food. This process called animal foraging, involves balancing the need to explore new areas and the need to be efficient in finding food. Environmental factors and memory can influence these movements. I've often wondered if animals move randomly when foraging or if their past experiences guide their movements. To explore this, I decided to analyze whether animal movement follows a random pattern or if memory plays a role in how they search for food. This study allows me to apply my statistical knowledge to a real-world animal behavior problem, combining my academic interests with my curiosity about how animals navigate their environment.

II. Background

Foraging is a vital behavior for animals, as they need to find food to survive. Studying how animals move while foraging can help us understand how they balance exploring new areas and using the places they already know to find food. Random walk models are often used to represent animal movements, assuming that the animal's movements are random and independent of previous steps. However, animals don't always move randomly. Memory often influences their decisions, such as returning to areas with abundant food or avoiding places they've already searched. This analysis will explore whether animal movements in the dataset follow a random walk or are influenced by memory. We will look at the movement's step lengths, turning angles, and displacement over time to understand if memory plays a role in foraging. By studying this, we can gain a better understanding of animal behavior and improve models for ecological research.

III. Data description

The dataset used for this analysis was obtained from the article *Memory Effects on Movement Behavior in Animal Foraging* by Bracis, Gurarie, Van Moorter, and Goodwin (2015), published in *PLOS ONE*. This study focuses on animal movement during foraging and includes data on key aspects like step lengths, turning angles, and displacement over time. The dataset helps us understand how animals search for food and how various factors, including memory,

affect their movement patterns. By analyzing this data, we can gain insights into whether animals follow random movement patterns or if their previous experiences guide their foraging decisions.

For this analysis, the key metrics are:

- **Turning Angles**: The Mean Cosine/Sine Turning Angle shows how consistent the animal's direction is. It helps us understand if the animal is moving in a straight line with a goal (like finding food) or moving randomly.
- **Distance Traveled**: This includes both the total distance and the average distance the animal covers while foraging. We use this data to see how the availability of resources affects how far the animal moves.
- **Resource Regeneration Rate**: This looks at how quickly resources, like food, become available again in the area. It helps us see how the availability of food influences the animal's movement patterns.

By studying these key metrics, we can better understand how animals search for food and whether their movement is random or guided by memory and resource availability.

IV. Result

A. Average Distance Traveled by Resource Regeneration Rate

I examined how resource regeneration rates impact animal movement patterns. Using R Studio, I visualized the data through a chart, which demonstrated that at low resource regeneration rates (0.005), animals traveled the longest distances. In contrast, at higher regeneration rates (0.01 and 0.05), the animals moved shorter distances.

This suggests that when resources regenerate slowly, animals need to travel farther to find food, while faster resource regeneration allows them to forage more efficiently within a smaller area. This supports the idea that the availability of resources plays a key role in shaping animal movement behavior.

The findings highlight how resource abundance or scarcity can influence the distance traveled during foraging, reflecting the animals' strategies for efficient food acquisition.

B. Random Walk of Animal Movement

I also looked at the animal's movement using a 2D random walk graph. From R output, it shows a smooth upward trend indicating that the animals move in a consistent direction. There are no sharp turns or looping paths, which suggests that the animals are using memory to guide their movement. This means they avoid going in circles and instead focus on exploring new areas while also being goal-oriented, likely remembering where resources are located. This shows how memory helps animals forage more efficiently.

C. Turning Angle

The turning angle analysis shows a near-zero mean sine value (2.95e-05), indicating that there is no significant left or right bias in the animal's movement. The high mean cosine value (0.9879) reflects strong directional persistence, suggesting that the animals tend to move in a consistent direction. This is further supported by the 2D movement graph, which shows an upward trajectory with steady forward motion and no sharp turns, indicating a lack of random movement.

V. Conclusion

The analysis of animal foraging movement, through the bar chart, 2D movement graph, and turning angle metrics, highlights that the animals' movements are not purely random but are influenced by memory and resource availability. The bar chart reveals that animals travel farther when resource regeneration is slow, while they remain closer to the source when regeneration is faster, indicating efficient foraging based on available resources. The 2D movement graph further supports this by showing consistent forward motion and a smooth upward trajectory, without sharp turns, suggesting that the animals use memory to avoid redundant paths. Additionally, the turning angle analysis, with a near-zero sine value and a high cosine value, confirms strong directional persistence, further emphasizing memory-driven movement.

Together, these results show that animal movement is shaped by both memory and the surrounding environment, allowing for more effective foraging rather than purely random exploration.

VI. Appendix

A. R code

```
library(ggplot2)
library(tidyverse)
data = read.csv("/Users/christinenguyen/Downloads/S2_Appendix/ForagerMemory.csv")

# Analysis 2: Turning Angle and Directionality Analysis
mean_sin_turn = mean(data$MeanSinTurningAngle0, na.rm = TRUE)
mean_cos_turn = mean(data$MeanCosTurningAngle0, na.rm = TRUE)
# Print the results
print(paste("Mean Sin Turning Angle:", mean_sin_turn))
print(paste("Mean Cos Turning Angle:", mean_cos_turn))
```

Picture 1: R code for the Turning Angle and Directional Analysis

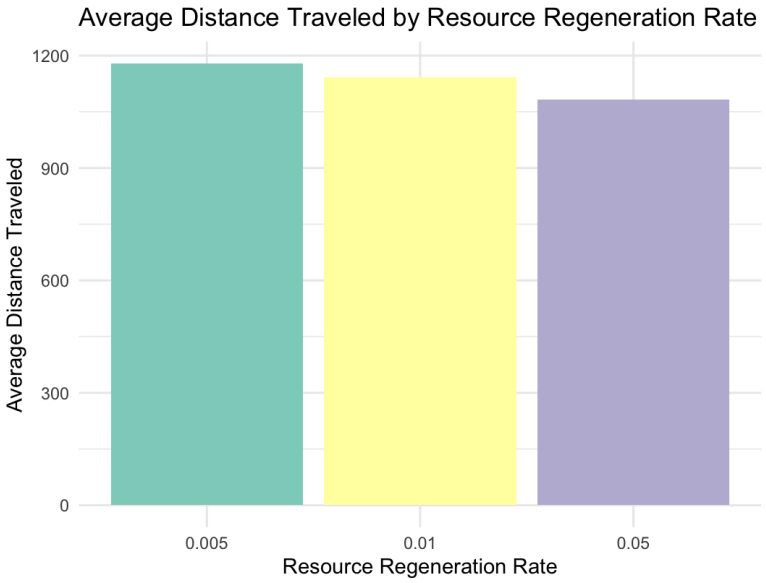
```
# Set up initial position (X0, Y0) for path plotting
x = c(0)
y = c(0)
# Loop through each time step, using distance and angle to calculate new positions
for (i in 2:nrow(data)) {
  # Use the distance and turning angle to calculate new position
  dx = data$DistanceTraveled0[i] * data$MeanCosTurningAngle0[i]  # Change in X
  dy = data$DistanceTraveled0[i] * data$MeanSinTurningAngle0[i]  # Change in Y

  x[i] = x[i-1] + dx
  y[i] = y[i-1] + dy
}
# Combine the positions into a data frame for plotting
positions = data.frame(x = x, y = y)

# Plot the 2D random walk path
ggplot(positions, aes(x = x, y = y)) +
  geom_path(color = "orange") +
  labs(title = "2D Random Walk of Animal Movement
(Directionality and Memory Influence)",
       x = "X Position", y = "Y Position") +
  theme_minimal()
```

Picture 2: R code for 2D random walk path

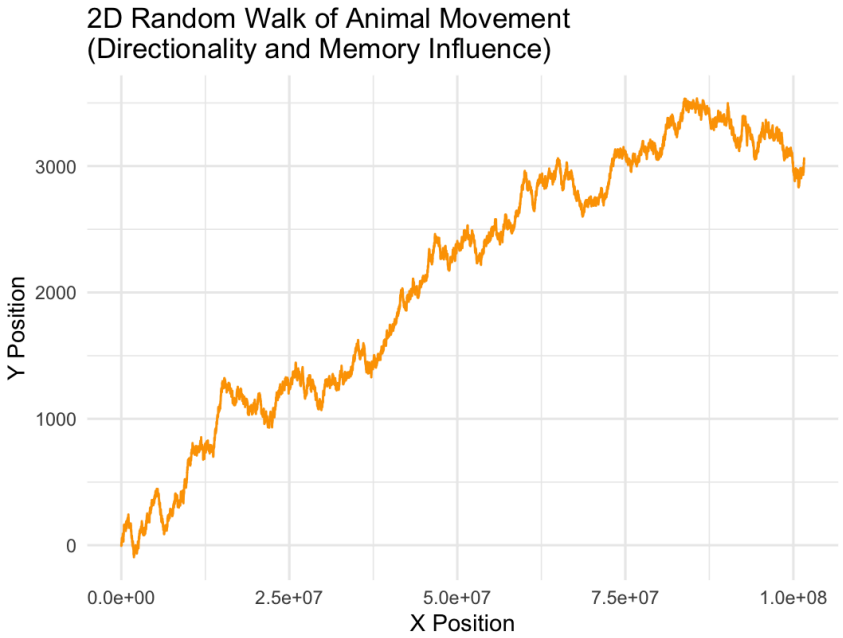
```
avg_distance_by_resource = data %>%
    group_by(ResourceRegenerationRate) %>%
    summarise(AverageDistance = mean(DistanceTraveled0, na.rm = TRUE))

 # Plot the bar chart
 ggplot(avg_distance_by_resource,
        aes(x = as.factor(ResourceRegenerationRate),
            y = AverageDistance,
            fill = as.factor(ResourceRegenerationRate))) +
   geom_bar(stat = "identity") +
   labs(title = "Average Distance Traveled by Resource Regeneration Rate",
        x = "Resource Regeneration Rate",
        y = "Average Distance Traveled") +
   theme_minimal() +
   scale_fill_brewer(palette = "Set3") +
   theme(legend.position = "none")
```

Picture 3: R code for Bar chart for Average Distance Traveled by Resource Regeneration Rate

B. R output



Picture 4: R output for Bar chart for Average Distance Traveled by Resource Regeneration Rate



Picture 5: R output for a 2D random walk path

```
> # Print the results
> print(paste("Mean Sin Turning Angle:", mean_sin_turn))
[1] "Mean Sin Turning Angle: 2.95471943992504e-05"
> print(paste("Mean Cos Turning Angle:", mean_cos_turn))
[1] "Mean Cos Turning Angle: 0.987913360966259"
```

Picture 6: R output for the Turning Angle and Directional Analysis

VII. Reference

Bracis, Chloe, et al. "Memory Effects on Movement Behavior in Animal Foraging." *PLOS ONE*, vol. 10, no. 8, 2015, e0136057. *PLOS ONE*, https://doi.org/10.1371/journal.pone.0136057.