ANIMAL MOVEMENT in Foraging

Model applied
Random Walk

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Mexican Ground Squirrel Foraging For Berries

Background

Animal foraging movement is how animals search for food, balancing exploration and efficiency, often influenced by environmental factors and memory.

Animal foraging movement is often studied **using random walk models**, which simulate step lengths and turning angles to represent exploratory behavior.

However, animals may **not always** move randomly - memory can influence their paths, leading to more efficient foraging by revisiting resource-rich areas or avoiding previously explored regions.

This **analysis** checks if the movement follows a random walk or is influenced by memory, using step lengths, turning angles, and displacement over time.

The dataset

The dataset

The dataset, acquired from PLOS ONE (from the article *Memory Effects on Movement Behavior in Animal Foraging* by Bracis, Gurarie, Van Moorter, and Goodwin (2015)), tracks animal movement during foraging, focusing on step lengths, turning angles, and displacement over time

The key metrics for analysis are:

Turning Angles: Mean Cosine/Sine Turning Angle: Determines directional consistency (goal-oriented vs. random movement).
Distance Traveled: Stepwise and average distances by resource regeneration rate to assess how resource availability impacts movement.
Resource Regeneration Rate: Analyzes the effect of resource availability on foraging behavior.

SimulationIndex	ResourceRegenerationRate	TotalConsumption0	StdDevConsumption0	DistanceTraveled0	Sinuosity0	AverageSpeed0	AverageSpeedSearch0	AverageSpeedFeeding0	MeanSinTurningAngle0	MeanCosTurningAngle0	TimeSearching0
0	0.05	0.52284875	6.63E-05	1216.724883	50.44833184	1.21731921	2.307784966	0.506255549	9.05E-05	0.988300121	39470
1	0.05	0.252914301	2.09E-05	1152.288475	51.41605808	1.152869196	2.148015212	0.496818904	-0.003477357	0.988433557	39780
2	0.05	0.223131951	9.5E-06	1093.139726	63.48157911	1.093710273	2.343353763	0.508610715	0.002799106	0.986405808	31890
3	0.05	0.917822463	1.3E-04	1167.697764	59.95498879	1.16828945	2.231566389	0.512722324	-0.001472813	0.988521464	38140
0	0.01	0.329285136	4.43E-05	1308.849731	80.91620502	1.309431369	2.188365191	0.487641852	-0.001862518	0.989653364	48320
4	0.05	0.339077247	2.44E-05	901.25434	39.32341073	0.901829031	1.958156353	0.527981262	0.002695104	0.989181829	26140
1	0.01	0.299710344	2.57E-05	1116.220074	47.03767214	1.116790768	2.239091011	0.52826747	-0.001105517	0.988654414	34400
5	0.05	0.197277229	1.06E-05	1185.808629	66.29665079	1.186408628	2.121047965	0.505143164	0.003523072	0.98603195	42160
2	0.01	0.208264143	8.41E-06	1084.333498	123.3055779	1.084916272	2.167298871	0.523589532	-0.001015127	0.988850753	34150
6	0.05	0.518409531	8.34E-05	1322.492763	72.04563062	1.323067193	2.372413059	0.492538701	0.004152014	0.987810621	44180
0	0.005	0.360977733	5.01E-05	1257.46162	69.86564474	1.258032753	2.154098012	0.459572182	3.89E-04	0.98817665	47120

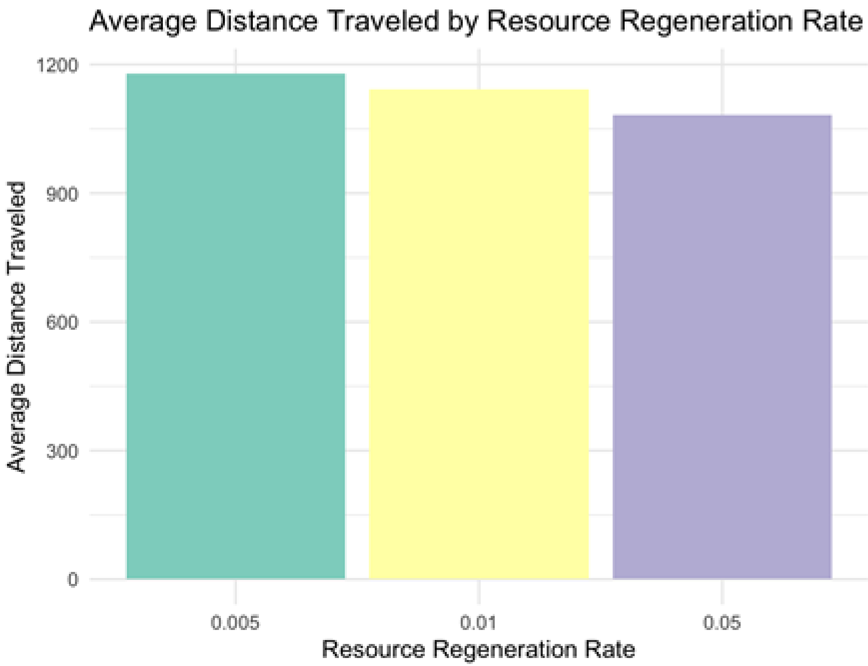
Dataset

R Code

```r
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))

# 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()
```

```r
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")
```

Average Distance Traveled by Resource Regeneration Rate

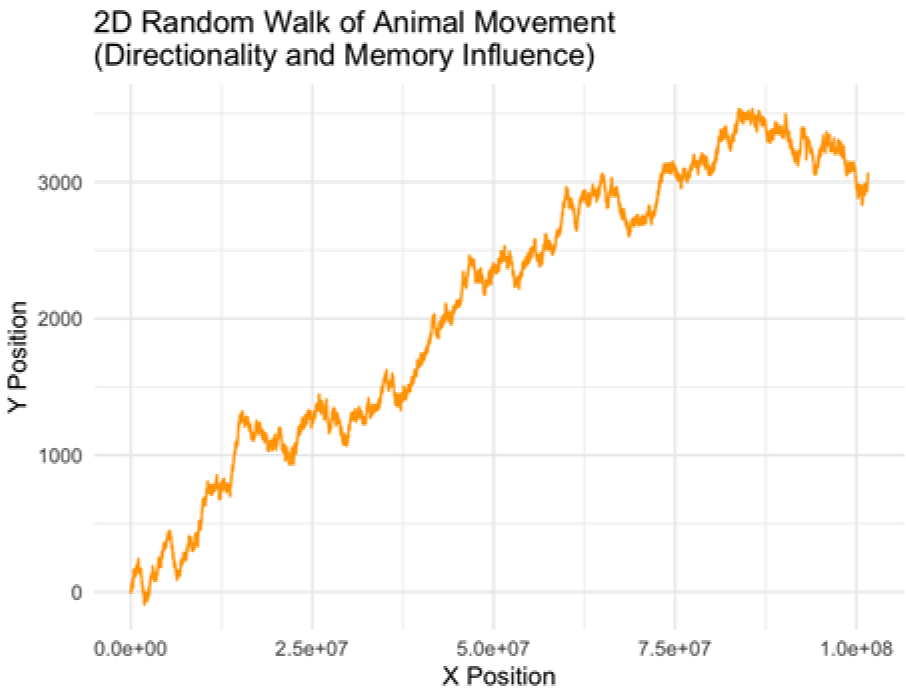


This chart shows that at **low** resource regeneration rates (0.005), animals travel the **longest**, while **higher rates** (0.01 and 0.05) result in **shorter distances**.

Inefficient resources require animals to **explore further**, while faster regeneration allows them to forage more efficiently in localized areas

This reflects how **resource availability** impacts **movement patterns.**

Random Walk of Animal Movement



This graph shows a **2D random walk of animal movement,** with a **smooth upward trend** indicating directional consistency
The **lack of sharp turns** or looping suggests **memory-influenced foraging**, where the animal avoids redundant paths and balances exploration with **goal-oriented movement.**

Random Walk of Animal Movement

```
> # 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"
```

The turning angle analysis shows

- a near-zero mean sine value (2.95e-05), indicating no significant left or right bias
- a high mean cosine (0.9879), reflecting strong directional persistence.

The 2D movement graph supports this, showing an upward trajectory with consistent forward motion and a lack of sharp turns.

Combined with the bar chart, the results suggest **memory-driven foraging:** traveling farther when resources regenerate slowly and staying closer to the source when regeneration is faster.

Conclusion:

This shows that movement is **shaped by memory and resource availability** instead of being completely random.

THANKS!

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