Estimating the range of a Tracking Device using Markov Chain

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Understanding Markov Chain

Definition

- A **Markov Chain** is a mathematical system that undergoes transitions from one state to another, within a finite or countable number of possible states.
- It is based on the Markov Property, which states that the future state depends only on the current state, not on the sequence of events that preceded it

Key Characteristics

States - States are the distinct positions or conditions the system can be in.

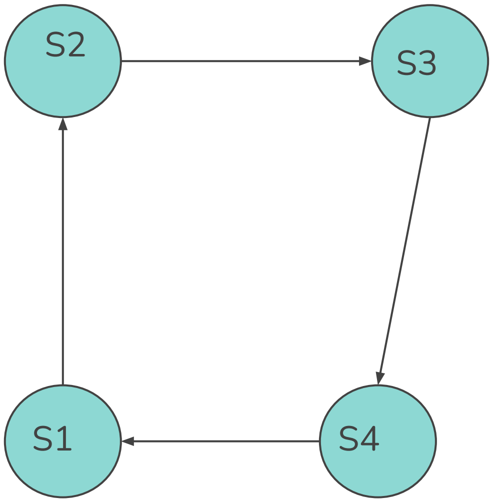
Memorylessness - The Markov Property implies memorylessness, meaning the next state depends only on the current state.

Transitions - Transitions are the changes from one state to another, with each transition having a certain probability.

Visual Representation (An Example)

Time = T = {0, 1, 2, 3, 4, 5, 6, 7} : Time Space

S = {1, 2, 3, 4}



Tracking Devices - An Overview

About

Tracking devices are technologies used to monitor the movement or location of objects or people.

Common examples include GPS trackers, RFID tags and mobile tracking apps.

Key Functionalities

- Real-time location tracking
- Historical movement data analysis
- Geofencing and movement alerts.

Importance of Range Estimation

- Determining the range of a tracking device is crucial for understanding its effective monitoring capacity.
- Range estimation affects accuracy, reliability, and application potential.
- In logistics, precise range estimation can lead to improved route planning and asset management.

Visual Aid

This visual represents different types of tracking devices and their typical use cases.

Let’s talk more….

Problem Statement

We aim to show, how the range of tracking device can be estimated using the Markov Chain.

Effective range system is critical for optimizing the performance and reliability of tracking systems.

Challenges

Challenge 1

Challenge 2

Challenge 3

Accurate Range Estimation

- Develop a method to accurately estimate the range within which a tracking device can reliably operate.
- Focus on specific types of tracking devices, such as GPS trackers or RFID tags.

Modeling Signal Variability

- Incorporate factors like signal strength variability and environmental influences into the model.
- Consideration of various environmental conditions that can affect tracking range, like urban vs. rural settings.

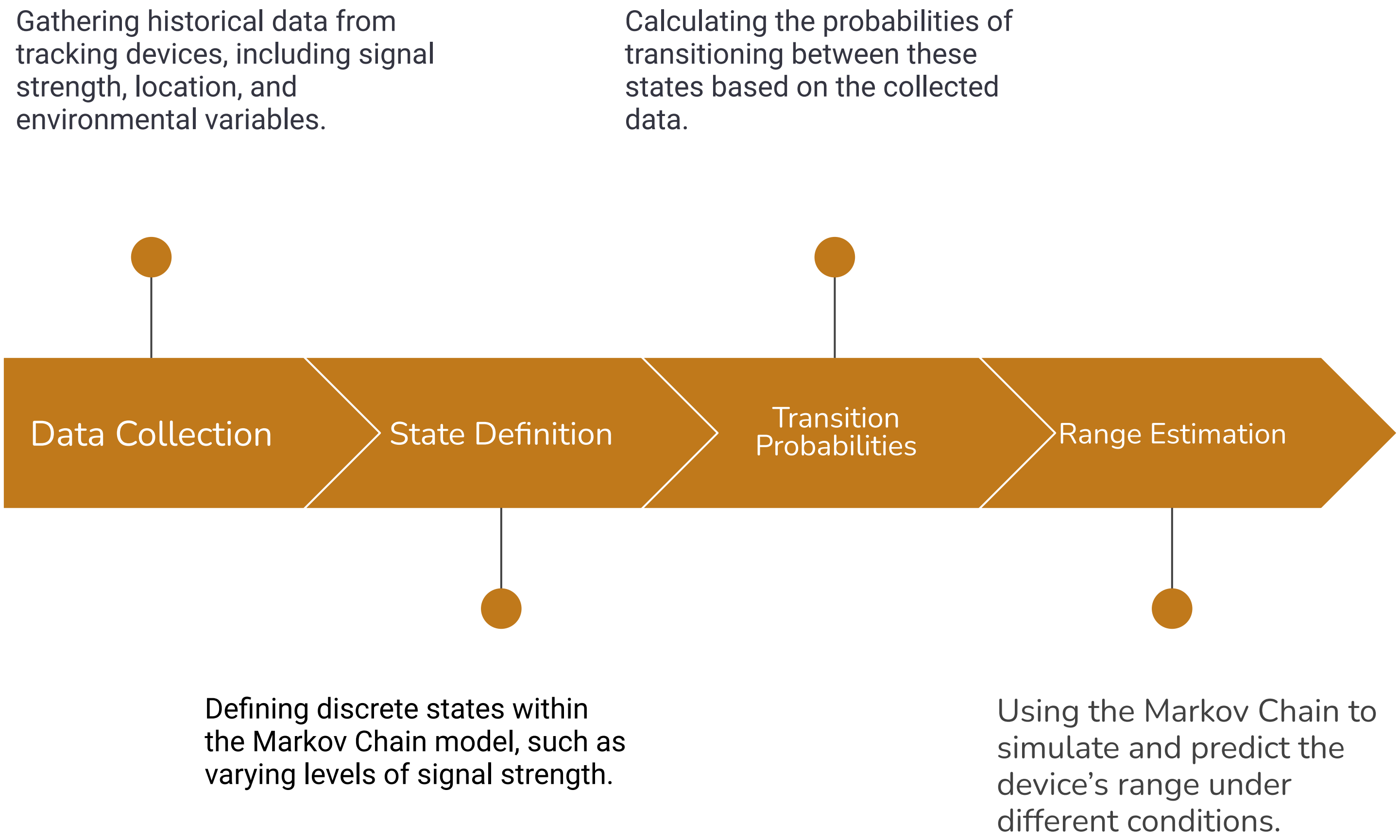
Practical Application

- Ensure the model is adaptable for different types of tracking devices and real-world scenarios.
- Utilize historical data from tracking devices to inform and validate the model.

Overview of the Methodology

Methodology steps in the next slide

- Our approach involves developing a Markov Chain model to estimate the effective range of tracking devices.
- The model is based on analyzing state transitions that represent different signal strength levels and environmental conditions.


Gathering historical data from tracking devices, including signal strength, location, and environmental variables.
Calculating the probabilities of transitioning between these states based on the collected data.
Data Collection
State Definition
Transition Probabilities
Range Estimation
Defining discrete states within the Markov Chain model, such as varying levels of signal strength.
Using the Markov Chain to simulate and predict the device’s range under different conditions.

An Example: Estimating the Range of GPS Trackers in Wildlife Monitoring

Objective
To estimate the effective range of GPS tracking devices used in monitoring wildlife in a national park.
The park includes diverse environments such as dense forests, open grasslands, and rocky terrain.

Data Requirements and Collections

We will be using the Discrete Time Markov Chain for calculating the transition probabilities for this case study.

Types of Data:

- **GPS Signal Strength:** Collected from GPS trackers attached to a sample population of animals.
- **Environmental Data:** Classified as Forest (F), Grassland (G), and Rocky Terrain (R).
- **Device Transitions:** Recorded when devices move between different signal strengths and environments.

Data collected and to be used

	Signal Strength	Environment
0	Medium Signal	Forest
1	No Signal	Grassland
2	Low Signal	Rocky Terrain
3	Medium Signal	Rocky Terrain
4	High Signal	Rocky Terrain
5	High Signal	Grassland
6	High Signal	Grassland
7	Low Signal	Rocky Terrain
8	Medium Signal	Forest
9	Low Signal	Grassland

These are the first 10 entries of the data.

States Defined

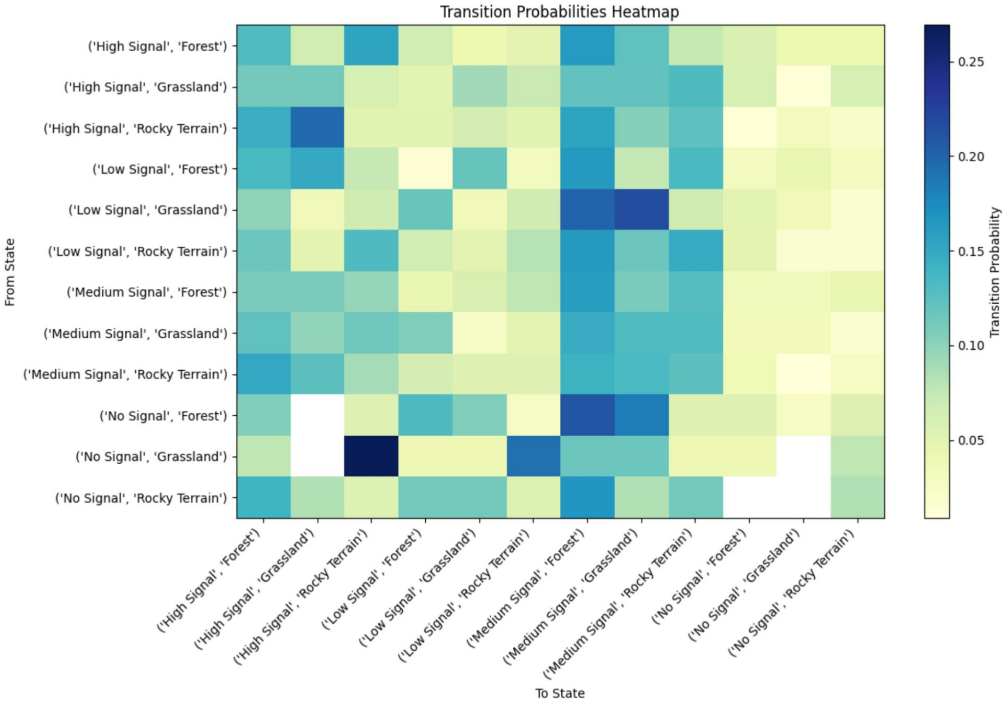
Signal Strength Levels: High Signal, Medium Signal, Low Signal, and No Signal.

Environmental Conditions: Forest, Grassland, and Rocky Terrain.

Calculated Transition Probabilities for combined states

From/To	High Signal, Forest	High Signal, Grassland	High Signal, Rocky Terrain	...	Medium Signal, Rocky Terrain	No Signal, Forest
High Signal, Forest	0.1301	0.0650	0.1545	...	0.0732	0.0569
High Signal, Grassland	0.1111	0.1111	0.1959	...	0.1313	0.0606
High Signal, Rocky Terrain	0.1443	0.0606	0.0515	...	0.1237	0.0103
Low Signal, Forest	0.1343	0.1493	0.0746	...	0.1343	0.0299
Low Signal, Grassland	0.1000	0.0333	0.0667	...	0.0667	0.0500
Low Signal, Rocky Terrain	0.1148	0.0492	0.1311	...	0.1475	0.0492
Medium Signal, Forest	0.1090	0.1090	0.0962	...	0.1282	0.0321
Medium Signal, Grassland	0.1220	0.0976	0.1138	...	0.1301	0.0325
Medium Signal, Rocky Terrain	0.1504	0.1239	0.0885	...	0.1239	0.0354
No Signal, Forest	0.1053	0.0000	0.0526	...	0.0526	0.0526
...	...	...	...	...	...	...

Results and Analysis



Estimated Range is proportion of time an animal spends in each state.
You can simulate the Python code as many times as you want.
The output value will be different for a given signal strength and environmental condition.

Challenges and Limitations

- Challenges in obtaining complete and accurate data from tracking devices, especially in remote or densely covered areas like forests.
- Difficulty in accounting for all environmental factors that can influence signal strength, like weather changes or unforeseen obstacles.
- The simplification of signal strength and environmental conditions into discrete states may not capture the full complexity of real-world scenarios.
- The assumption that the future state depends only on the current state (memorylessness) might not hold true in all situations, especially in dynamically changing environments

Conclusion

Our application of Discrete-Time Markov Chains effectively estimates the range of tracking devices in varied environments, as demonstrated in the wildlife monitoring example. The model provides valuable insights into how signal strength and environmental factors interact, affecting the device's operating range.

#**Reference**

The code used for generating data will be submitted along with this presentation document.

Thank You