The method behind:
Mobile device tracking and transportation mode detection

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Introduction

Method applicable for:

- Observations at time steps
- Noisy observations of locations
- Different transportation models

Applications

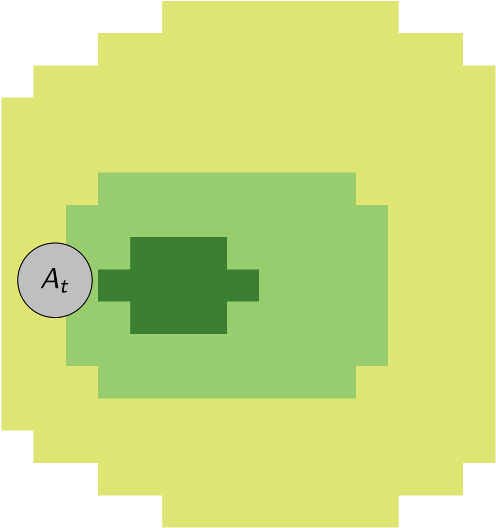
Examples:

- Object tracking in video
- Mobile Network connections
- Radar observations

Particle filter

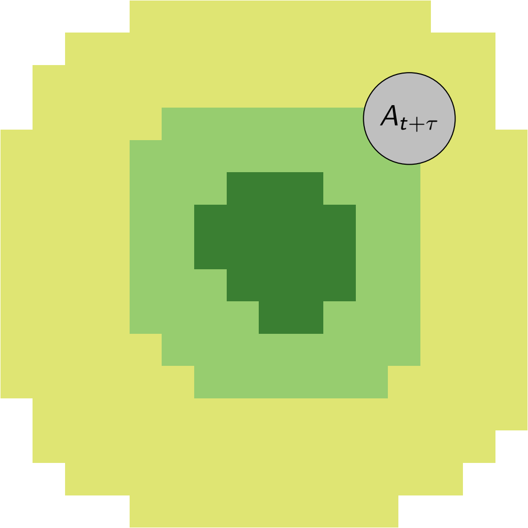
- Two observations: A_t, $A_{t+\tau}$

Particle filter



- Two observations: A_t, $A_{t+\tau}$
- Each with different $\mathbb{P}(\text{location}|A)$

Particle filter



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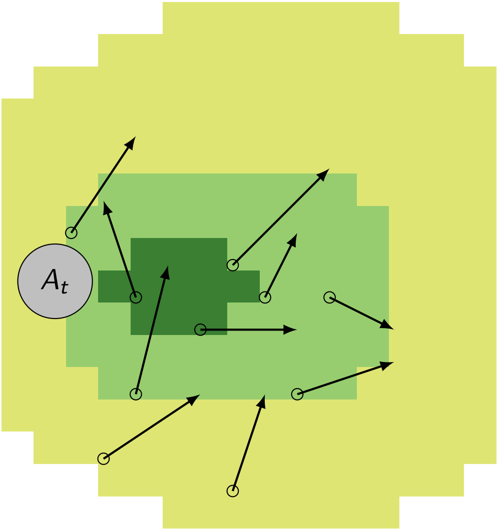
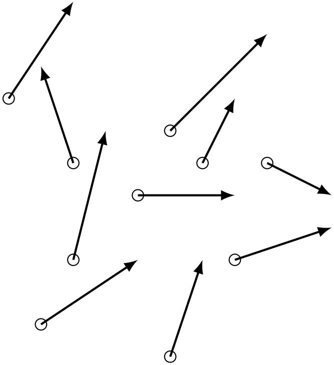


- Two observations: A_t, $A_{t+\tau}$
- Each with different $\mathbb{P}(\text{location}|A)$
- Particles $p_1(t), \dots, p_{10}(t)$

Particle filter

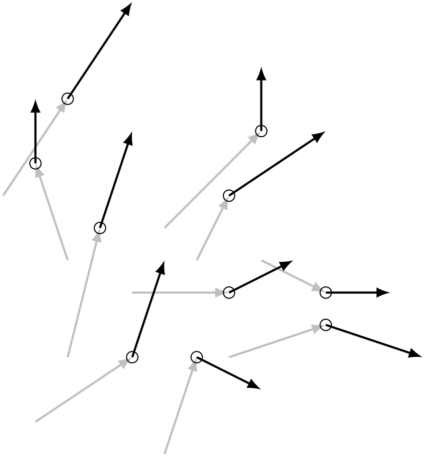


- Particles $p_1(t), \ldots, p_{10}(t)$

$$p_i(t) = \begin{pmatrix} x_i(t) \\ y_i(t) \\ v_i(t) \\ \theta_i(t) \end{pmatrix}$$

- Horizontal position: $x_i(t)$
- Vertical position: $y_i(t)$
- Velocity: $v_i(t)$
- Direction: $\theta_i(t)$

Particle filter

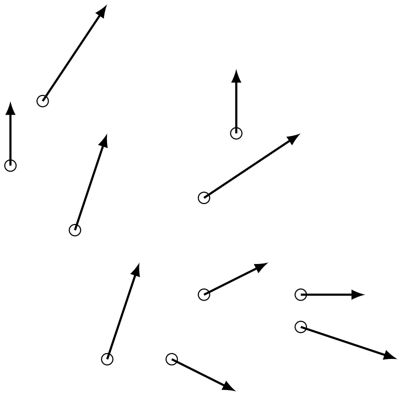


- Prediction step
- Time step duration: τ

$$\tilde{p}_i(t+\tau) = \begin{pmatrix} x_i(t) + \tau \cdot \cos(\theta) \cdot v_i(t) \\ y_i(t) + \tau \cdot \sin(\theta) \cdot v_i(t) \\ v_i(t) + u_v \\ \theta_i(t) + u_\theta \end{pmatrix}$$

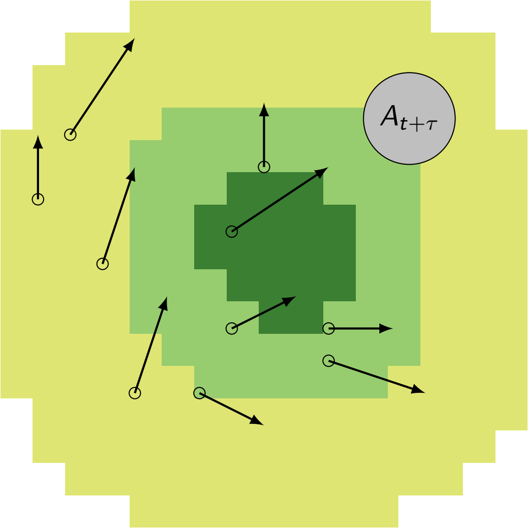
- u_v (stabilising) random update
- u_θ random update

Particle filter



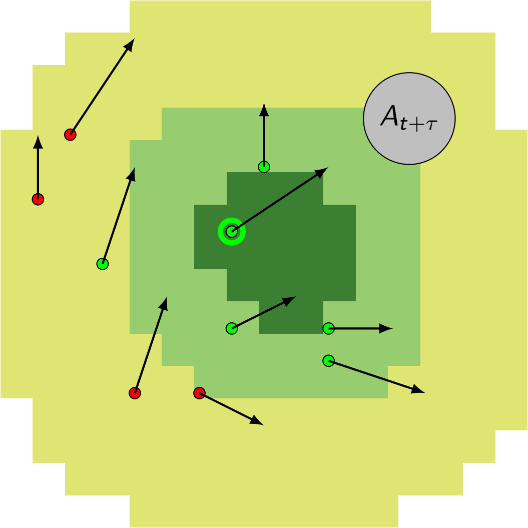
- Particles $\tilde{p_1}(t+\tau), \ldots, \tilde{p_{10}}(t+\tau)$

Particle filter



- Observation $A_{t+\tau}$

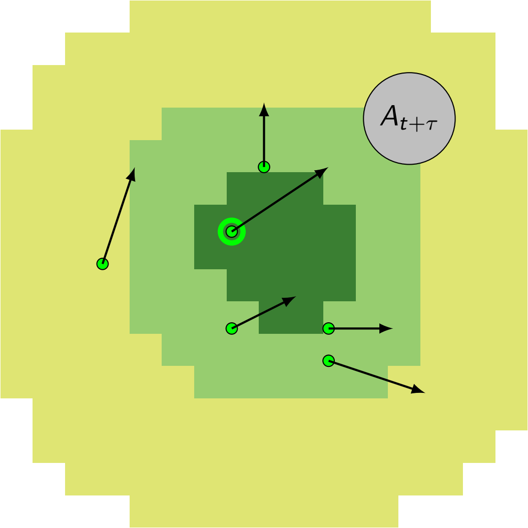
Particle filter



- Observation $A_{t+\tau}$
- Sample $p_1(t+\tau), \ldots, p_7(t+\tau)$

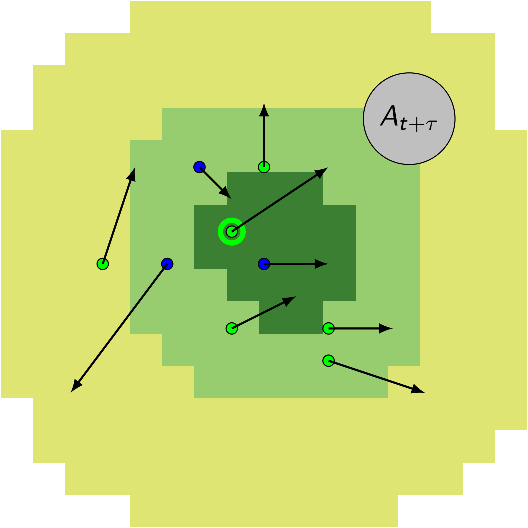
$$p_1(t+\tau), \ldots, p_7(t+\tau)$$
$$\in \{\tilde{p_1}(t+\tau), \ldots, \tilde{p_{10}}(t+\tau)\}$$

Particle filter



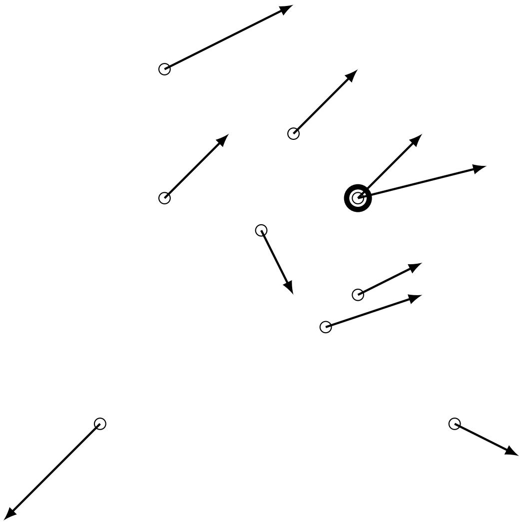
- Observation $A_{t+\tau}$
- Sample $p_1(t+\tau), \ldots, p_7(t+\tau)$
- Drop $\tilde{p}_i(t+\tau)$

Particle filter



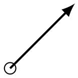
- Observation $A_{t+\tau}$
- Sample $p_1(t+\tau), \ldots, p_7(t+\tau)$
- Drop $\tilde{p}_i(t+\tau)$
- Sample $p_8(t+\tau)$, $p_9(t+\tau)$ and $p_{10}(t+\tau)$ from observed probabilities $\mathbb{P}(\text{location}|A_{t+\tau})$

Particle filter



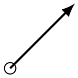
- Set $t \leftarrow t + \tau$
- Repeat cycle

Summarising particles



- Particles $p_1(t), ..., p_{10}(t)$
- Horizontal position: $x_i(t)$
- Vertical position: $y_i(t)$
- Velocity: $v_i(t)$
- Direction: $\theta_i(t)$

Summarising particles



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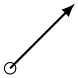
- Direction: $\theta_i(t)$

- Summarise
-
-
-
-

Summarising particles: path



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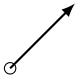
- Horizontal position: $x_i(t)$
- Vertical position: $y_i(t)$
- Velocity: $v_i(t)$
- Direction: $\theta_i(t)$

- Summarise
- Position
- Position

Summarising particles: transportation mode



- Particles $p_1(t), \ldots, p_{10}(t)$
- Horizontal position: $x_i(t)$
- Vertical position: $y_i(t)$
- Velocity: $v_i(t)$
- Direction: $\theta_i(t)$

- Summarise
- Position
- Position
- Transportation mode
- Transportation mode

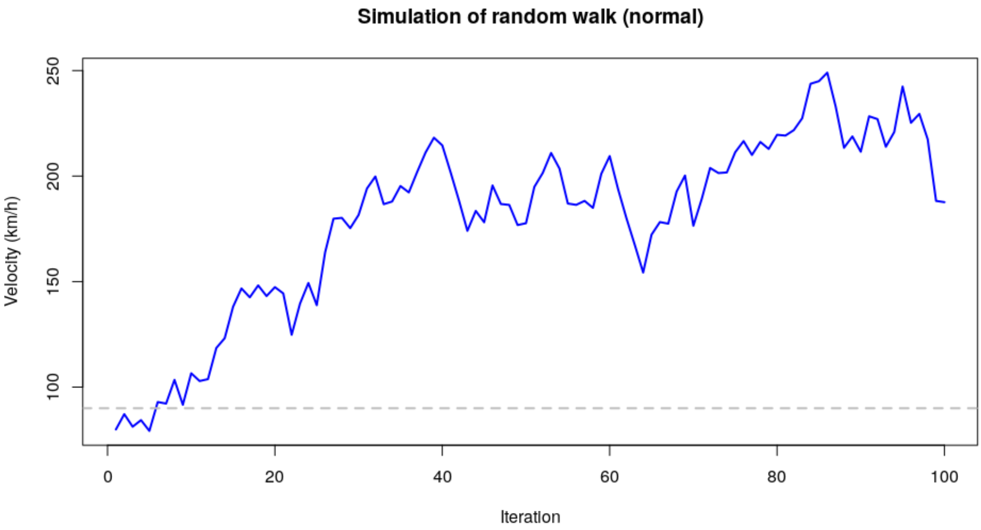
Transportation mode detection

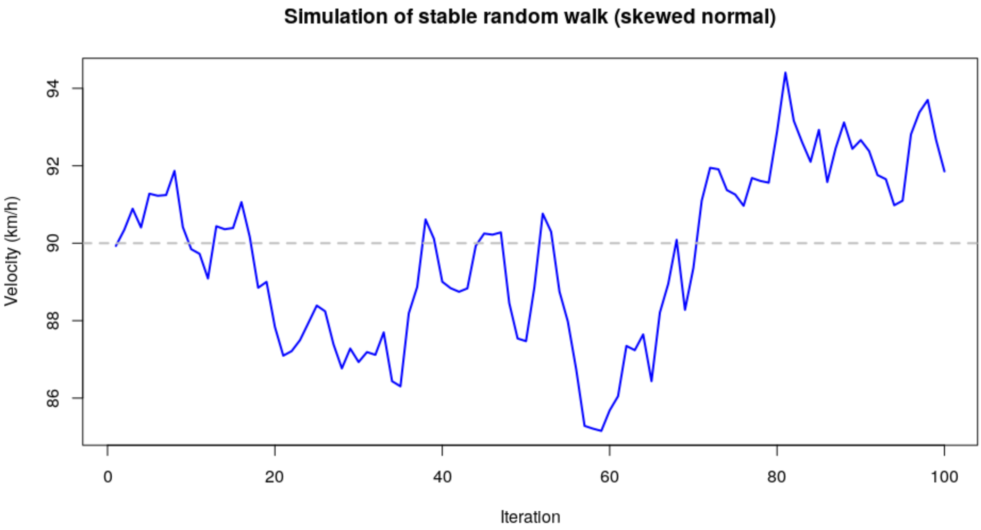
Updating velocity and direction

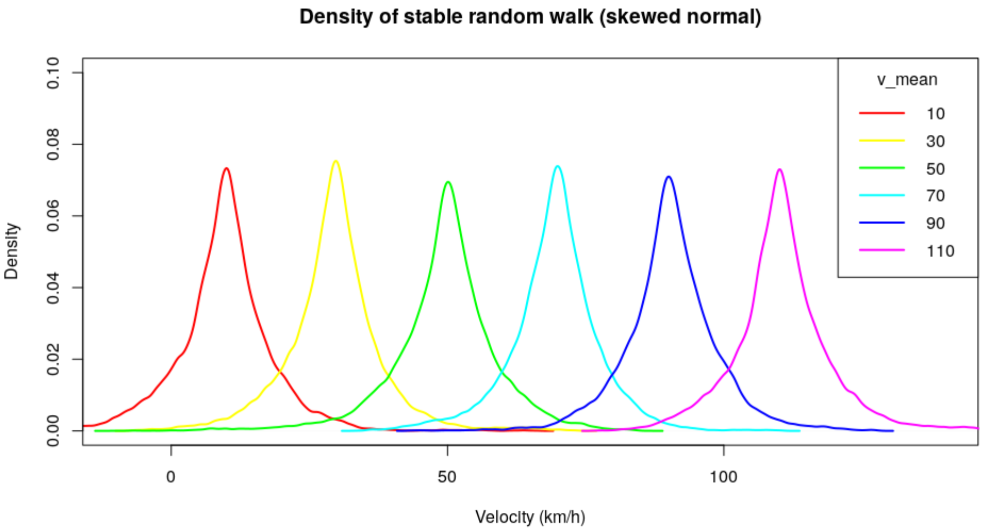
Transportation mode detection

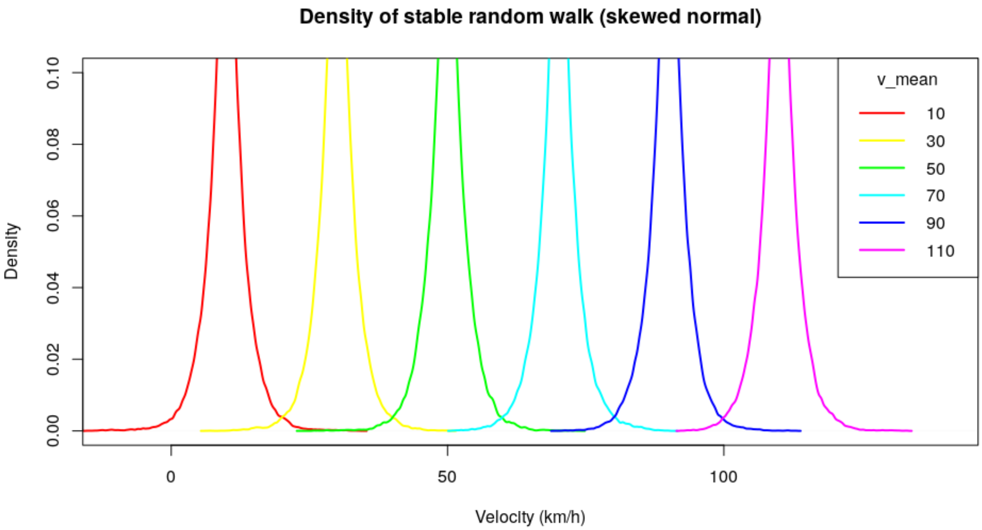
Updating velocity and direction

- Focus: velocity


Simulation of random walk (normal)
Velocity (km/h)
Iteration
250
200
150
100
0
20
40
60
80
100


Simulation of stable random walk (skewed normal)
Velocity (km/h)
86
88
90
92
94
0
20
40
60
80
100
Iteration


Density of stable random walk (skewed normal)
v_mean
10
30
50
70
90
110
Density
0.00
0.02
0.04
0.06
0.08
0.10
0
50
100
Velocity (km/h)



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0.00
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0.04
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0.10
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50
100
Velocity (km/h)
v_mean
10
30
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70
90
110

Transportation mode detection

- Modelled mode: velocity and direction updates
- Mode profile: survival ratio of modelled modes over time
- Designed to resemble transportation mode
- Transportation mode detection: based on mode profile

Conclusion

Building block between raw data and further analysis.

Advantages:

- Compatible with any observation model
- Use information over time
- Transportation mode detection

Disadvantages:

- Simulation dependent
- Computational costs