
# 15-381: Artificial Intelligence

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## Dynamic Bayesian Networks

Some figures and tables are from Russell and Norvig

# Temporal models representation

- Time slices
- $X_t$ : set of state variables at time t (unobservable)
- $E_t$ : set of evidence variables at time t (observable)
- $P(X_t \mid X_{t-1})$ : transition probability
  - Markov assumption: the transition depends only on the immediately previous state
- $P(E_t \mid X_t)$ : sensor model
  - Sensor Markov assumption: the reading of evidence variables (e.g., sensors) depends only on the current state



# Inference in temporal models

- Filtering
  - Compute the posterior distribution over the most recent state, given all evidence to date: $P(X_t \mid E_1, E_2, ..., E_t)$
- Prediction
  - Compute the posterion distribution over the future state, given all evidence to date: $P(X_{t+1} \mid E_1, E_2, ..., E_t)$



# Inference in temporal models

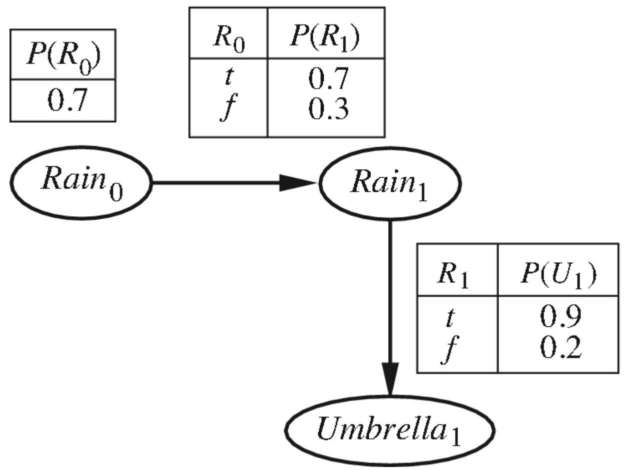
- Smoothing
  - Compute the posterior distribution over a past state, given all evidence to date: $P(X_{t-1} \mid E1, E2, ..., E_t)$
- Most likely explanation
  - Find the sequence of states that most likely generated a given sequence of observations: $\text{argmax}_{[X1,x2,...,Xt]}(P(X_1, X_2, ..., X_t \mid E_1, E_2, ..., E_t))$

# Dynamic Bayesian Networks

- $P(X_0)$ : prior distribution over the state variables
- $P(X_{t+1} \mid X_t)$ : transition model
- $P(E_t \mid X_t)$ : sensor model

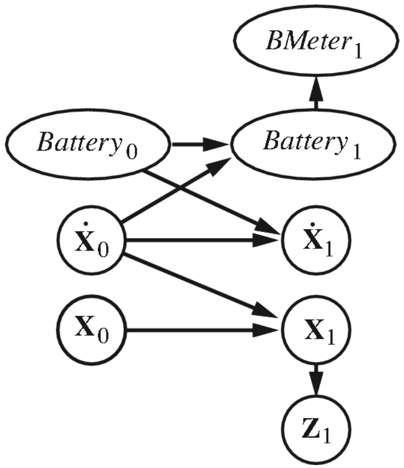


# Example: Rain and umbrella





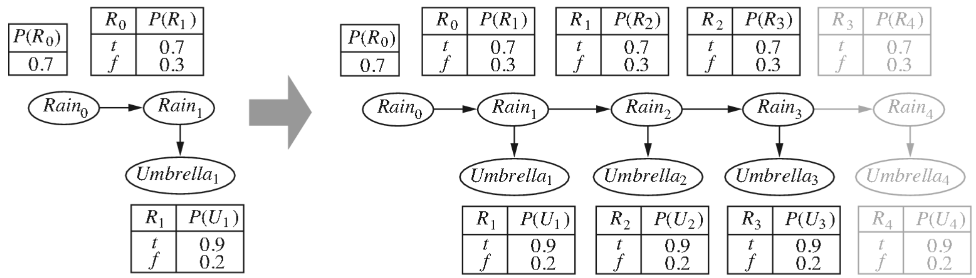

# Example: Battery-operated robot






# Inference in DBNs

- Exact inference: **unrolling**
- We can use the **variable elimination** method
- Problem: exponential growth of probability tables



# Approximate inference

- **Particle filtering**: simulate the behavior of the network using N samples
- Complexity linear in N and linear in the number of time steps
- Higher N = more accurate estimation

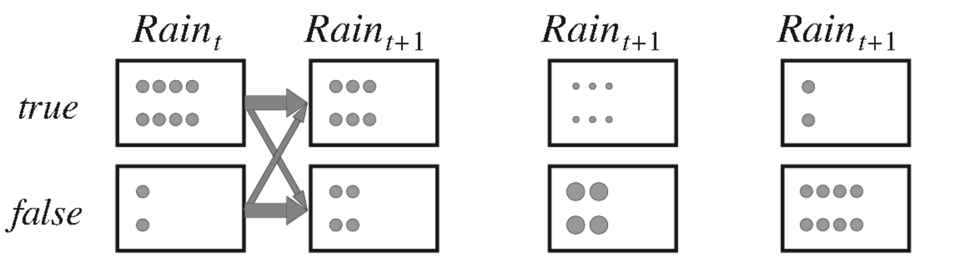


# Particle filtering

- Get N samples from the prior distribution $P(X_0)$
- For each subsequent time step:
  - **Propagate** each sample using the transition model $P(X_{t+1} \mid X_t)$
  - **Weight** each sample by the likelihood it assigns to new evidence $P(E_{t+1}, X_{t+1})$
  - **Resample** the population proportionally to the weights, then remove the weights



# Particle filtering




(a) Propagate (b) Weight (c) Resample