# Dynamic Networks

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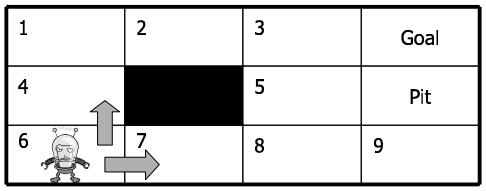
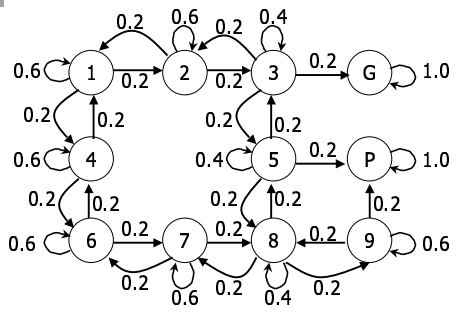
## Overview

- Markov Models
- Hidden Markov Models
- Kalman Filters
- Inference in Temporal Networks
- Dynamic Bayesian Network
- MDP
- POMDP
- Dynamic Decision Networks

## Robot in Maze




## Robot Markov Model

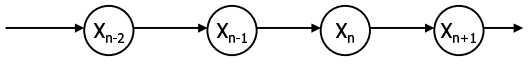



## Markov Models

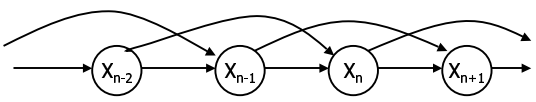
- First order Markov Models
  - To next state only depends on the current state.
  - $P(x_{n+1} | x_n x_{n-1} x_{n-2} \ldots) = P(x_{n+1} | x_n)$
- Second order Markov Models
  - $P(x_{n+1} | x_n x_{n-1} x_{n-2} \ldots) = P(x_{n+1} | x_n x_{n-1})$
- $K^{th}$ order Markov Models
  - $P(x_{n+1} | x_n x_{n-1} x_{n-2} \ldots) = P(x_{n+1} | x_n x_{n-1} \ldots x_{n-k+1})$

## Bayesian Models

First Order Markov Model

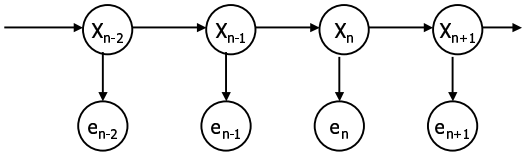



Second Order Markov Model



## Robot in Maze

- Now suppose the robot cannot tell which room it is in.
- However, it can use it's imperfect sensors to determine how many walls there are.




## Hidden Markov Models

- A Hidden Markov Model is a temporal probabilistic model in which the state is hidden and described by a single discrete random variable.
- Problem 1: Compute the probability of a sequence of states given a sequence of corresponding observations:
  - Solution: Forward-backward algorithm.
- Problem 2: Find the most likely sequence of states given a corresponding sequence of observations:
  - Solution: Viterbi algorithm.

## Kalman Filters

- A Kalman Filter is a temporal probabilistic model in which:
  - The state is hidden and described by continuous random variables.
  - The joint distribution of the state and the observation variables is a multivariable Gaussian distribution.

## Dynamic Belief Networks

*A Bayesian Network which represents a temporal probability model.*

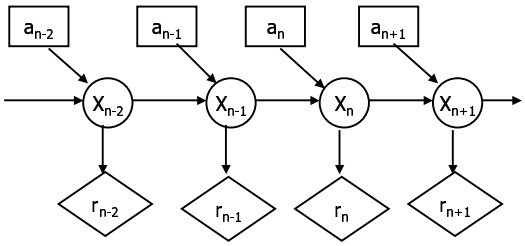
## Inference in Temporal Networks

- Filtering
  - Computing the belief of the current state given all the evidence to date.
- Prediction
  - Computing the belief of future states given all the evidence to date.
- Smoothing
  - Computing the belief of a past state given all the evidence to date.
- Most likely explanation
  - Finding the sequence of states *most likely* to have generated the evidence to date.

## Markov Decision Process

- A fully observable environment with a Markovian transition model and additive rewards.
- Contains:
  - Initial state: $x_0$
  - Transition Model: $P(x_{n+1} | x_n a_n)$
  - Reward function: $R(x_n)$

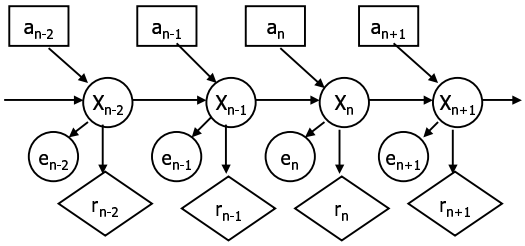
## Decision Network for MDP




## Partially Observable Markov Decision Process

- A fully observable environment with a Markovian transition model and additive rewards.
- Contains:
  - Initial state: $x_0$
  - Transition Model: $P(x_{n+1} | x_n a_n)$
  - Reward function: $R(x_n)$
  - Observation model: $P(e_n | x_n)$

## Decision Network for POMDP




## Dynamic Decision Network

- A Dynamic Bayesian Network together with
  - Decision nodes, and
  - Utility nodes.
- Handle uncertainty and can make decisions.
- Deal with continuous streams of sensor input.
- Handle noisy sensors and sensor failure.
- Handle relatively large state spaces.
- Support approximation algorithms.