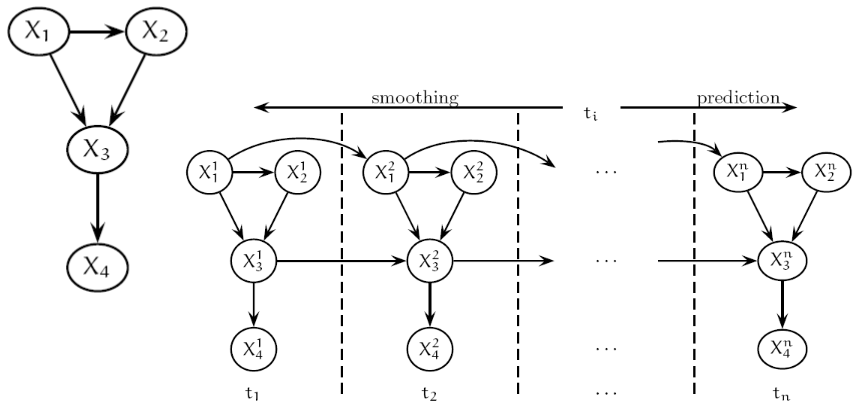
Probabilistic Reasoning

Unit # 16

Dynamic Models

- The graph of a probabilistic network is restricted to be a finite acyclic directed graph.
- This seems to imply that probabilistic networks as such do not support models with feedback loops or models of dynamic systems changing over time. This is not the case.
- A common approach to representing and solving dynamic models or models with feedback loops is to unroll the dynamic model for the desired number of time steps and treat the resulting network as a static network.
- The unrolled static network is then solved using a standard algorithm applying evidence at the appropriate time steps.

Static vs. Dynamic Model



Temporal Links

- The *temporal links of a time-slice t_i is the set of links from variables of* time-slice t_{i-1} into variables of time-slice t_i .
- The temporal links of time slice t_i define the conditional distribution of the variables of time slice t_i given the variables of time slice t_{i-1}.
- The temporal links connect variables of adjacent time slices. For instance, the temporal links of time-slice t2 on previous slide is the set $\{(X_1^1, X_1^2), (X_3^1, X_3^2)\}$.

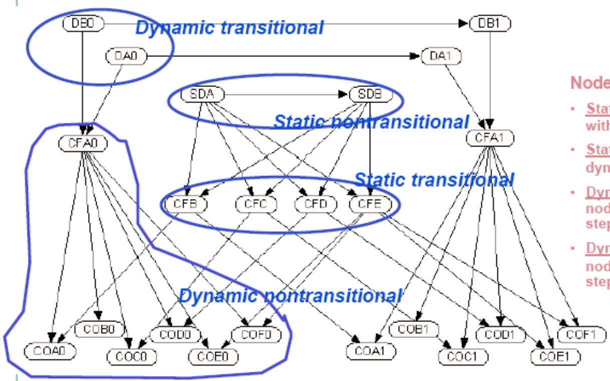
Important Concepts

- Let i be the current time step, then
  - *smoothing* is the process of querying about the state of the system at a previous time step j < i given evidence about the system at time i,
  - *filtering* is the process of querying about the state of the system at the current time step, and
  - *prediction* is the process of querying about the state of the system at a future time step j > i.

Important Concepts (Cont'd)

- A dynamic Bayesian network is *stationary when the transition probability* distributions are invariant between time steps.
- A dynamic Bayesian network is first-order Markovian when the variables at time step i+1 are d-separated from the variables at time step i −1 given the variables at time step i.
- When a system is stationary and Markovian, the state of the system at time i + 1 only depends on its state at time i, and the probabilistic dependence relations are the same for all i.
- The Markovian property implies that arcs between time slices only go from one time slice to the subsequent time slice.

Partially Dynamic Bayesian Networks

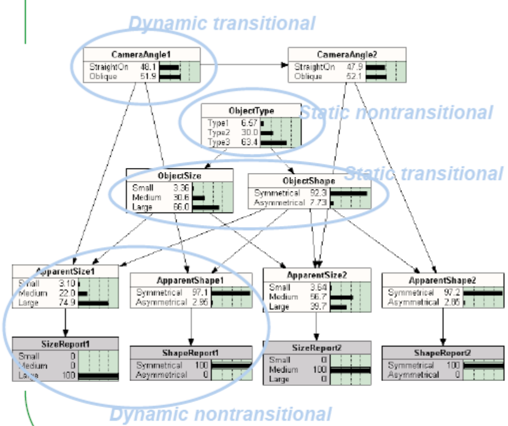


Node types:

- Static nontransitional - static nodes with no dynamic children
- Static transitional - static nodes with dynamic children
- Dynamic nontransitional - dynamic nodes with no children in next time step
- Dynamic transitional - dynamic nodes with children in next time step

- PDBN has static as well as dynamic nodes
- Most DBN theory and algorithms assume all variables are dynamic
- Static nodes can be exploited for efficiency but may degrade accuracy in algorithm not specialized to handle static nodes

Example PDBN



- There are 3 types of objects
  - Type 1 objects are usually small and asymmetrical
  - Type 2 objects are usually medium-sized and may be symmetrical or asymmetrical
  - Type 3 objects are usually large and symmetrical
- Objects can be viewed straight on or obliquely
  - Camera angle is unknown and changes with time
- Asymmetrical objects viewed obliquely may look smaller than actual size and may appear symmetrical

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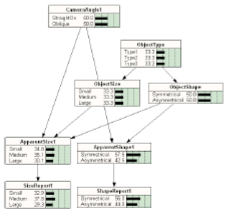
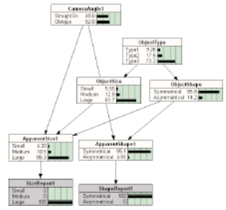
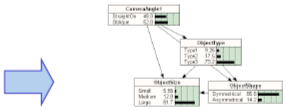
Example: Exact Rollup
(First Evidence)

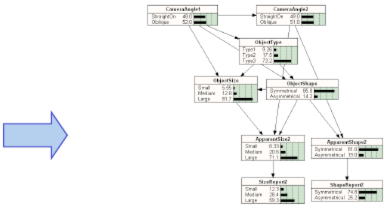


Initialize PDBN at Time Step 1



1. Apply evidence at current time step
2. Update beliefs on all unobserved RVs





3. Absorb all RVs not part of past expression

4. Extend to next time step

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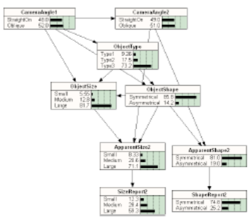
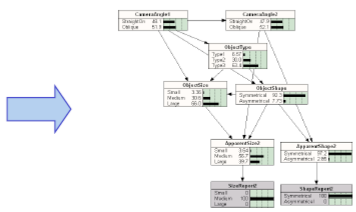
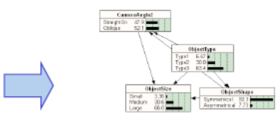
Example: Exact Rollup
(Next Evidence)

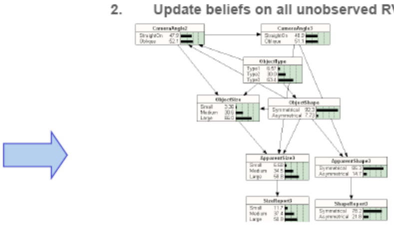


Begin with current 2-PDBN



1. Apply evidence at current time step
2. Update beliefs on all unobserved RVs





3. Absorb all RVs not part of past expression

4. Extend to next time step

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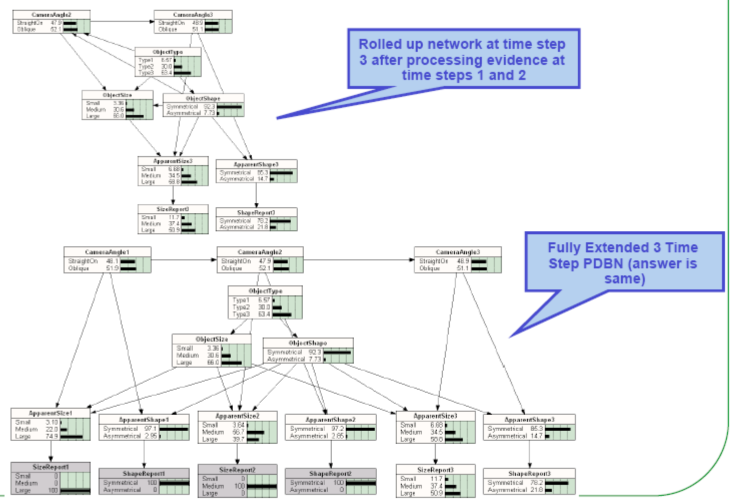
Comparison



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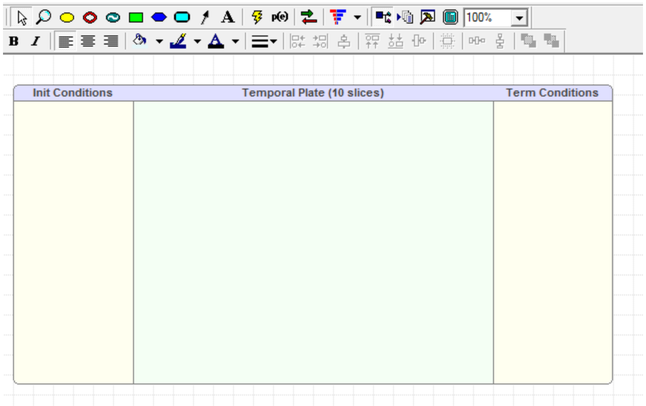
GeNIe Demo for Temporal Models

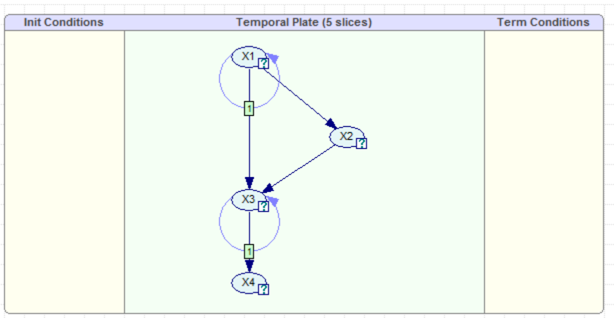
GeNIe Demo (Cont'd)

- You can bring the "Temporal Plate" by clicking Network -> Enable Temporal Plate



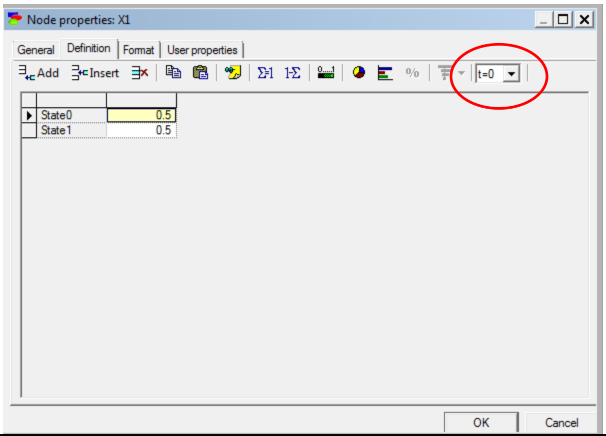
GeNIe Demo (Cont'd)

- Dependence of a node on its previous state is modeled by drawing a self-loop.



GeNIe Demo (Cont'd)

- Prior probability for Node X1 is defined in the usual manner. The only difference is the presence of t=0.



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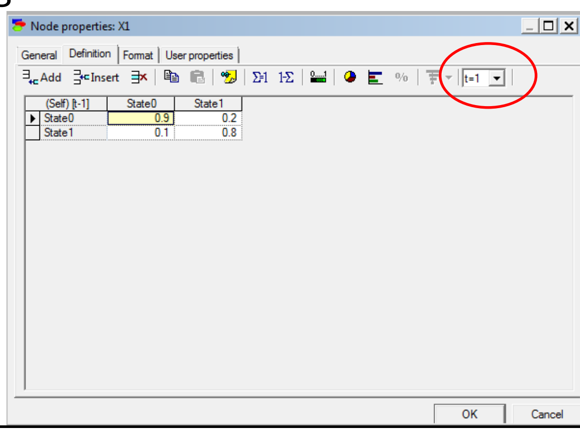
GeNIe Demo (Cont'd)

- Temporal dependence is captured by specifying the transitional probabilities after setting t=1



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GeNIe Demo (Cont'd)

- DBN can be unrolled by selecting Network → Unroll option.