From Arguments to Constraints on a Bayesian Network

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Introduction

- Decision support for reasoning with evidence
  - Legal cases
  - Risk assessment
  - Intelligence
- Analysts and decision-makers work with natural language text (or semi-structured arguments, scenarios)
- They miss the reasoning power of more mathematical approaches
  - Formal argumentation
  - Logical model-based reasoning
  - Bayesian networks

Introduction

Semi-structured or unstructured text ⇄ Structured arguments and scenarios ⇄ Bayesian networks

Introduction

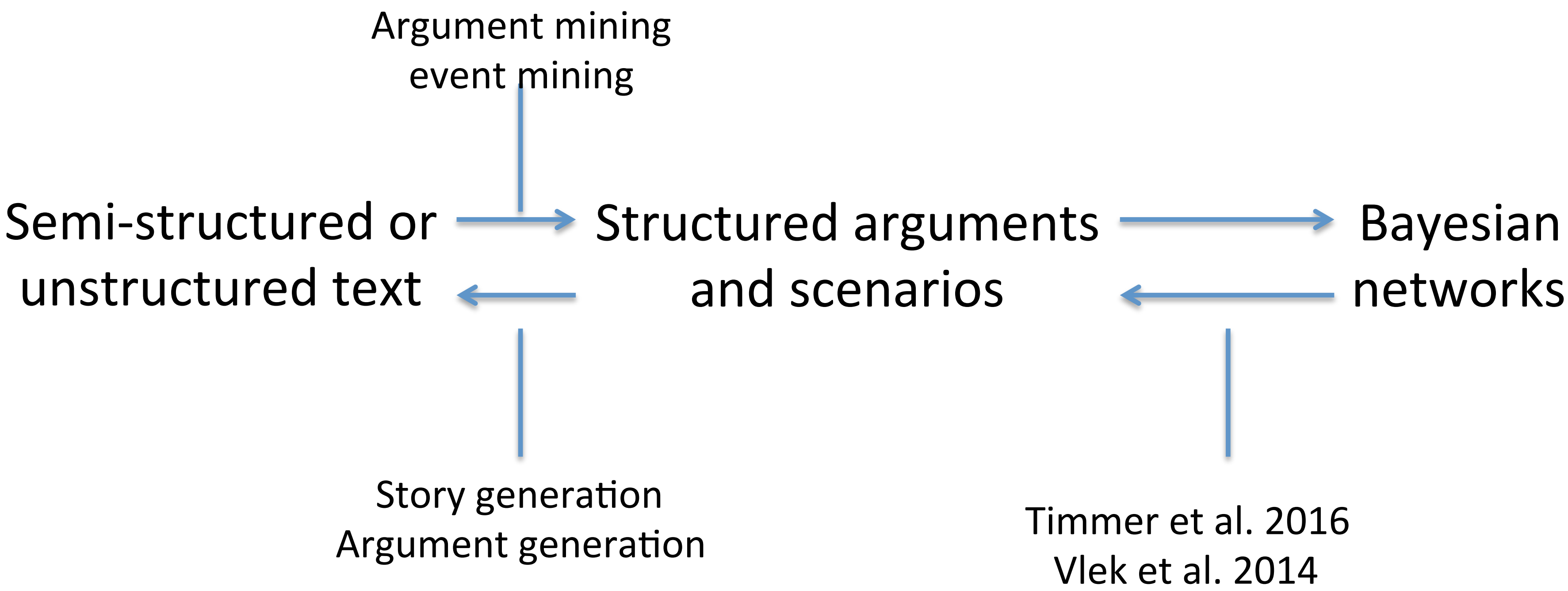
Reports, transcripts, etc — Semi-structured or unstructured text

Wigmore graphs, AIF argument graphs — Structured arguments and scenarios

(Qualitative) structured argumentation — Structured arguments and scenarios

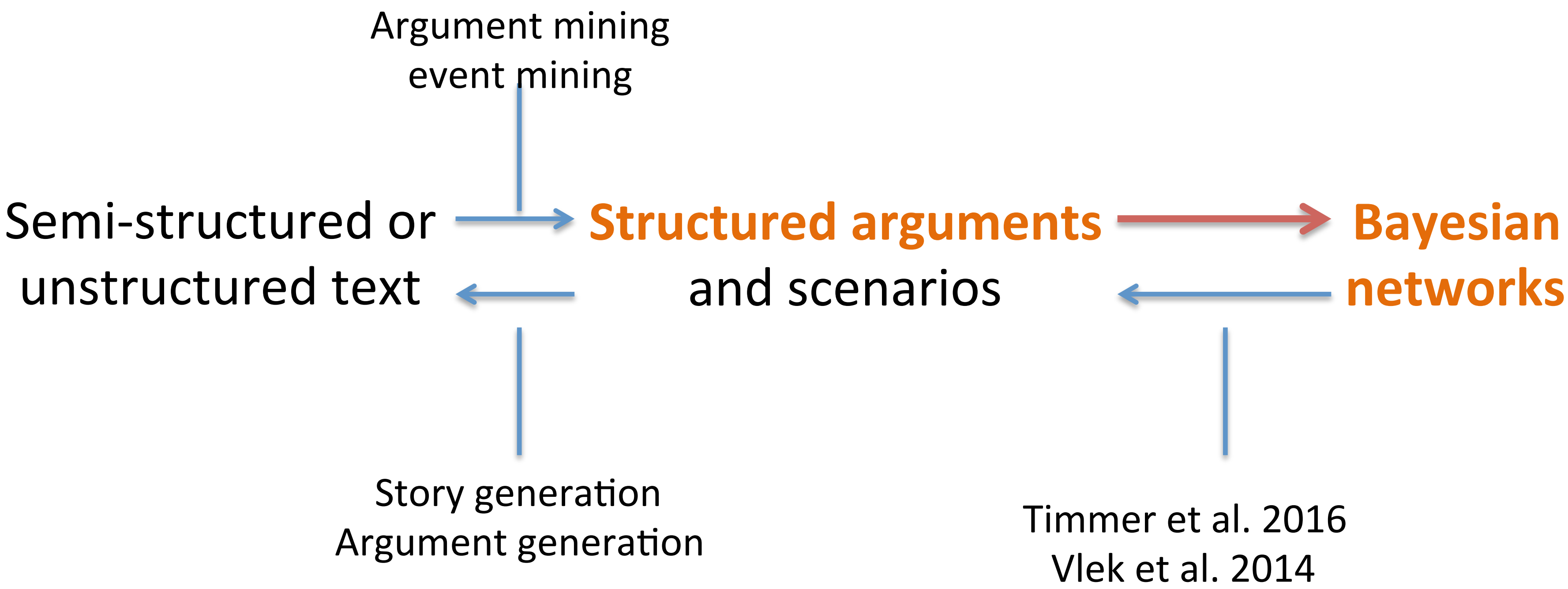
Semi-structured or unstructured text ⇄ Structured arguments and scenarios ⇄ Bayesian networks

Introduction



Introduction

- A formal account of constraints on a BN imposed by structured arguments

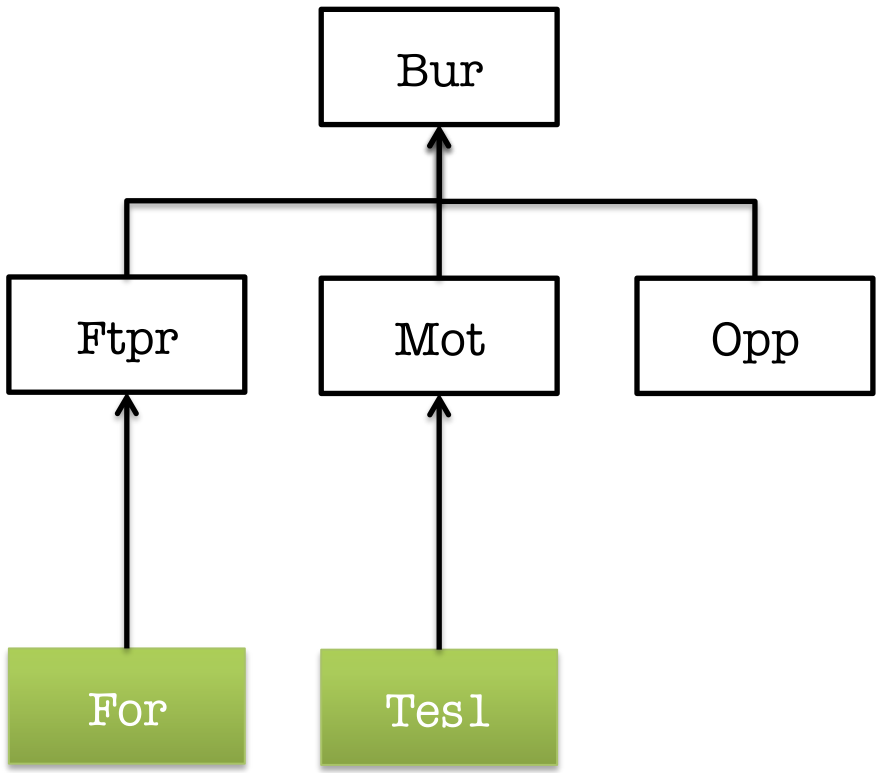


Structured argumentation: ASPIC+

- Arguments are Directed Acyclic graphs
  - Nodes are statements in a logical language with neg.
  - Links are applications of inference rules (strict or defeasible)
- Arguments constructed from knowledge base
  - $\mathcal{K}_e$ (evidence, certain premises), $\mathcal{K}_p$ (assumptions, uncertain premises)
- Attack
  - On uncertain premises, on defeasible inferences, on conclusions

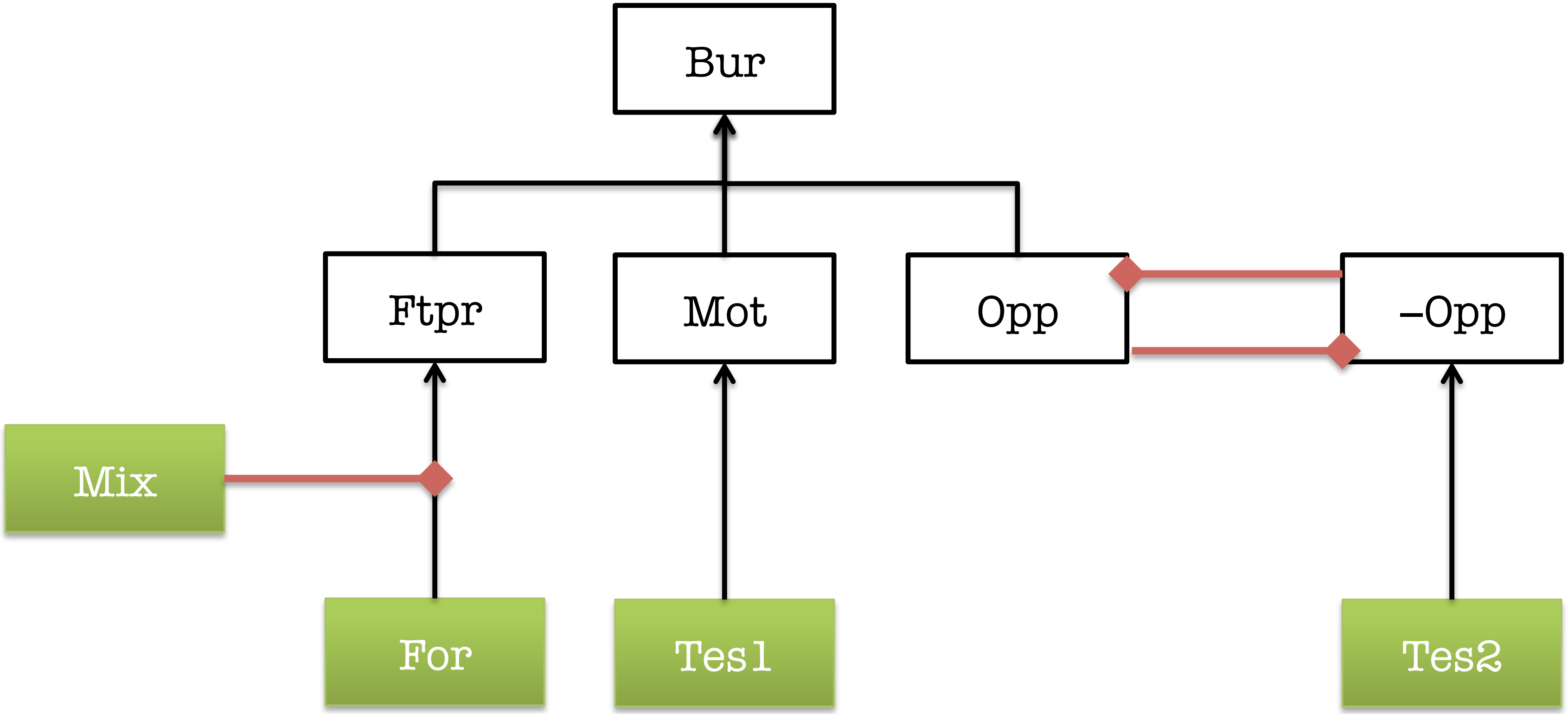
Structured arguments

- The burglary (Bur) was committed by the suspect, because there is a footprint match (Ftpr) and a motive (Mot) backed by a report (For) and a testimony (Tes1), and the suspect has no alibi, so Opp.



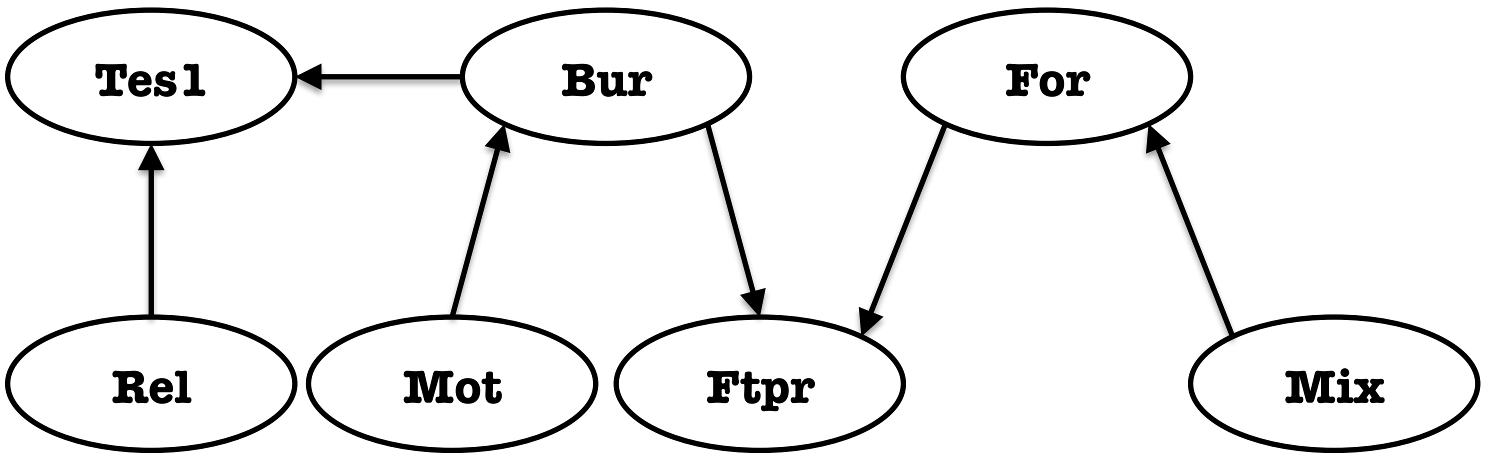
Structured arguments

- However, there is evidence of a mixup in the lab (Mix), which means the footprint match is not really backed by evidence. Furthermore, the suspect later gave a testimony (Tes2) with an alibi, so –Opp.



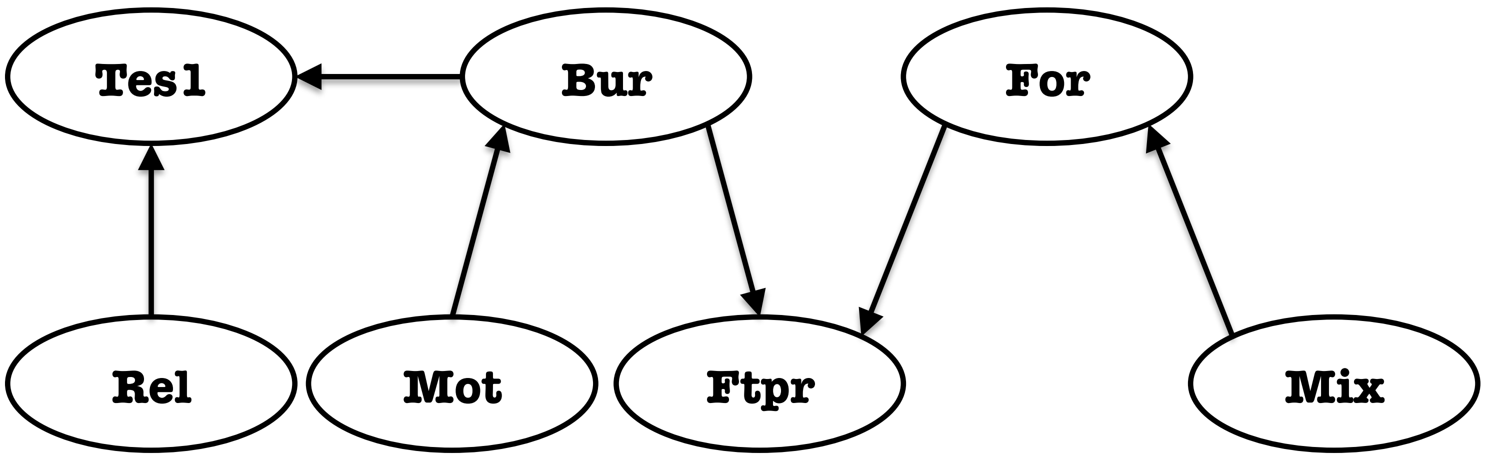
Bayesian Networks

- Represent joint probability distribution as DAG + CPT
- Directed Acyclic Graph
  - Nodes are variables **Bur** = [Bur, –Bur]
  - Arcs represent probabilistic dependencies between nodes (**Mot**, **Bur**)



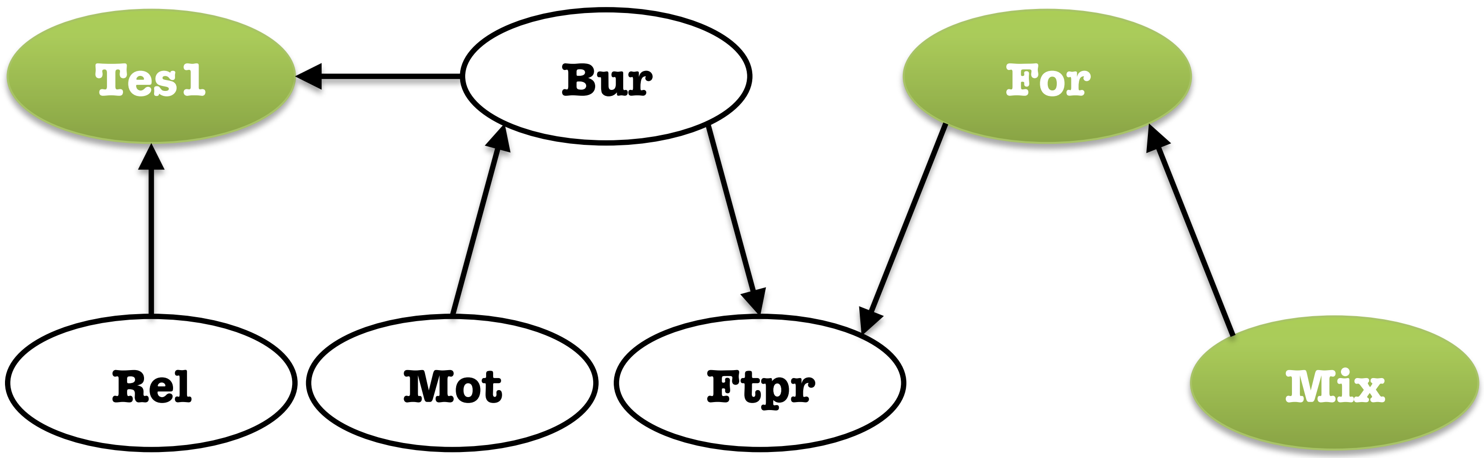
Bayesian Networks

- (Conditional) probabilities
  - Pr(Mot)=0.4; Pr(–Mot)=0.6;
  - Pr(Bur | Mot)=0.6; Pr(–Bur | Mot)=0.4
    Pr(Bur | –Mot)=0.01; Pr(–Bur | –Mot)=0.99
  - Conditional Probability Tables (CPT) give all probabilities for Pr(V | *Par*(V)).



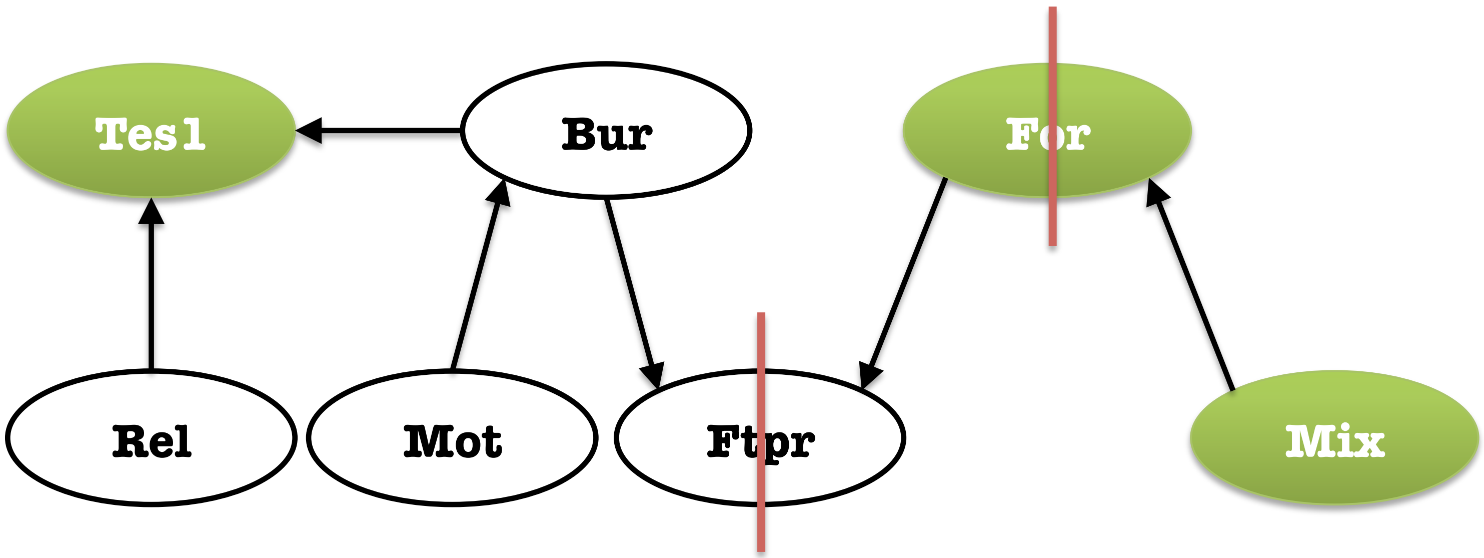
Bayesian Networks

- Observations $\mathcal{E}$
  - If a mixup has been observed then Pr($\mathtt{Mix}$)=1, Pr(–$\mathtt{Mix}$)=0



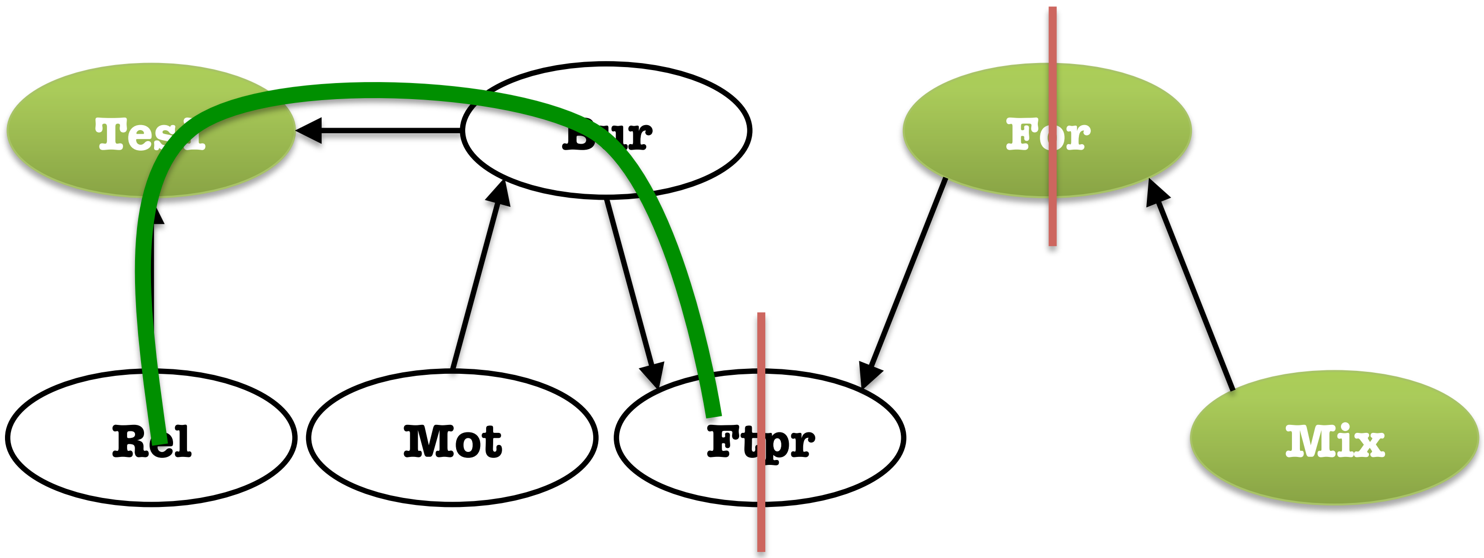
Bayesian Networks

- Chain s is said to be *blocked*, or *inactive*, given $\mathcal{E}$ if
  - s contains node with two incoming arcs which is not in $\mathcal{E}$ and has no descendants in $\mathcal{E}$; or
  - s contains node in $\mathcal{E}$ that has at most one incoming arc on the chain.



Bayesian Networks

- Active chains are not blocked



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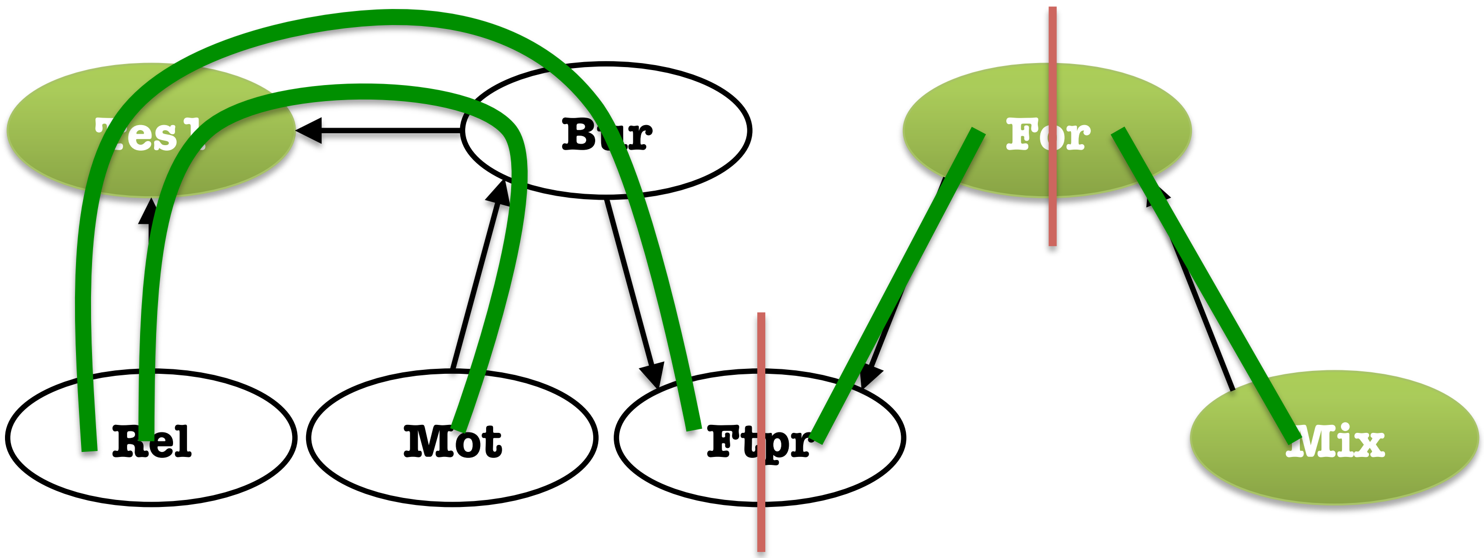
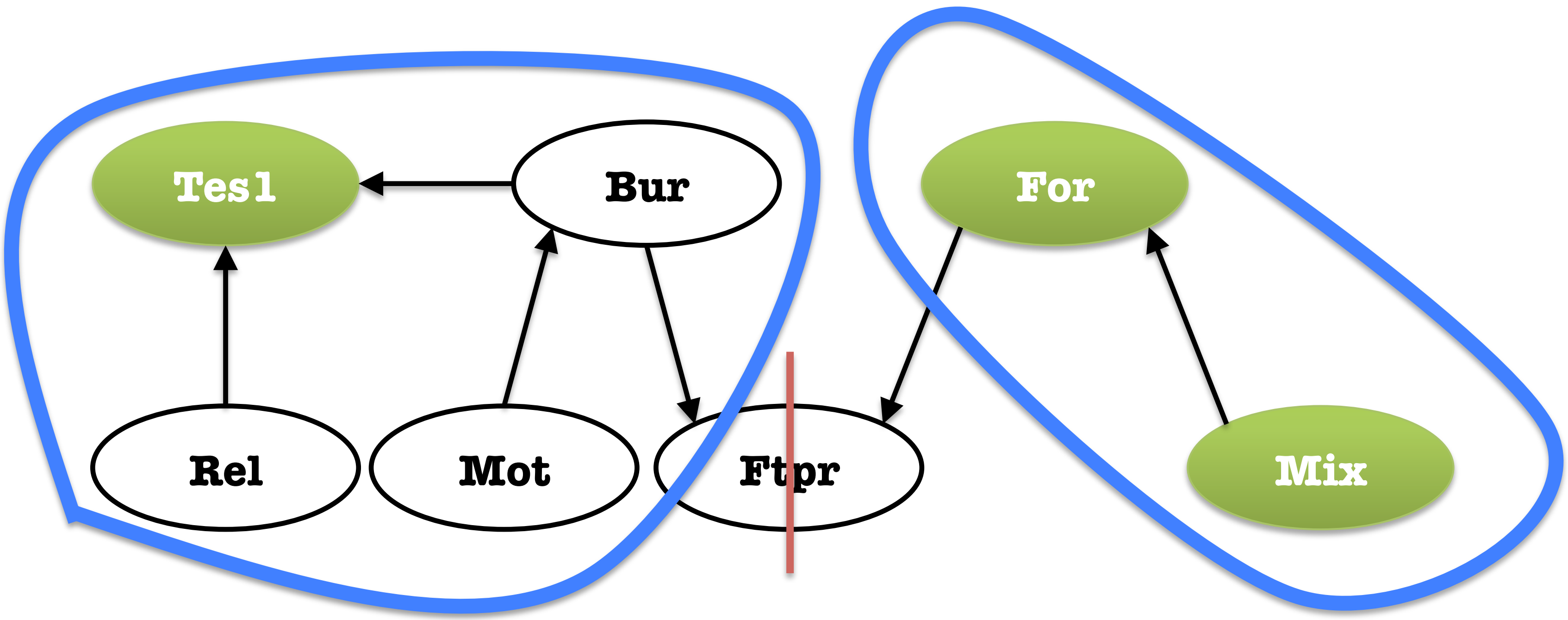


Bayesian Networks

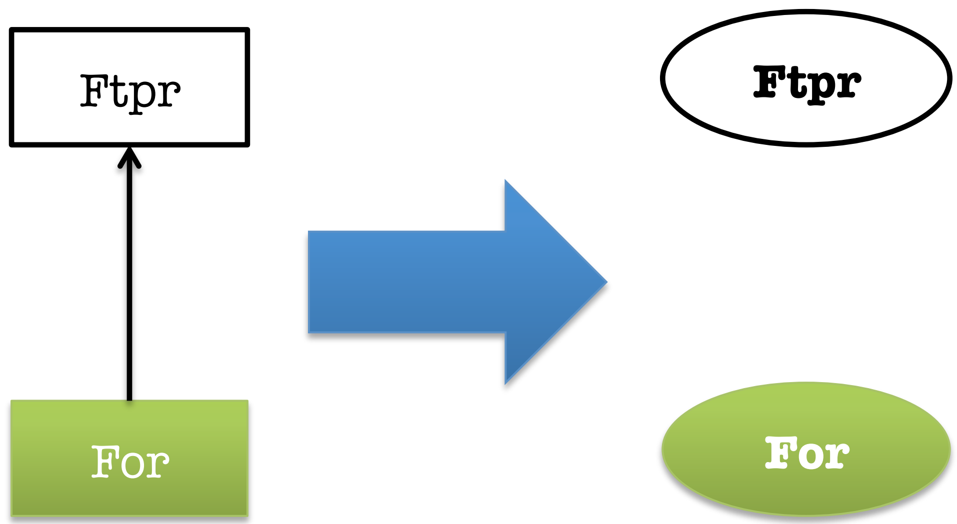
- Sets of variables X and Y are independent given $\mathcal{E}$ iff there is no active chain from X to Y



From arguments to constraints on BN

Nodes

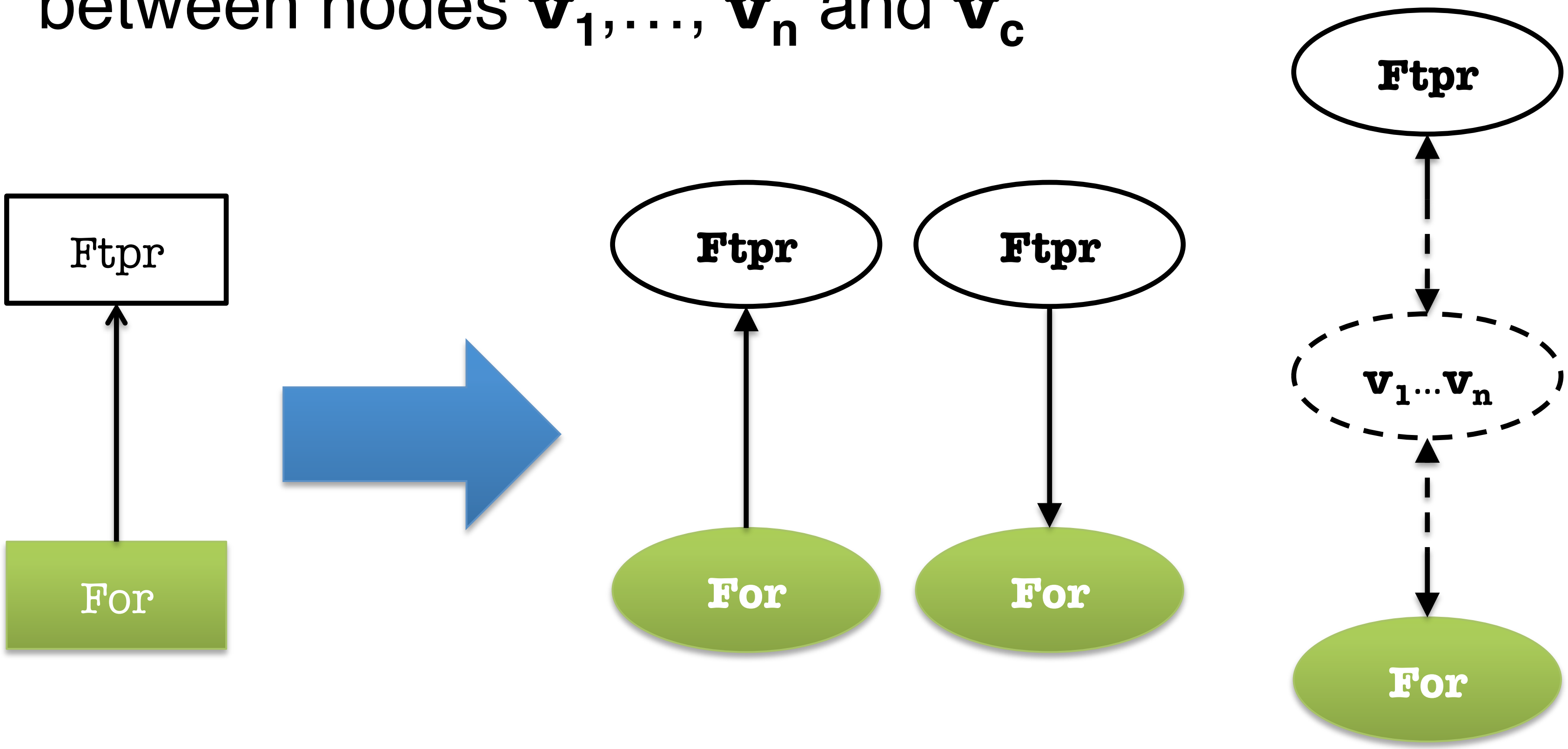
- Every proposition v or $-\mathrm{v}$ in the argument is a node representing variable $\mathbf{v}$ in the BN
- Every proposition v in $\mathcal{K}_e$ is the observed value of $\mathbf{v}$



From arguments to constraints on BN

Inference chains

- For every rule $v_1, \ldots, v_n \Rightarrow v_c$ / $v_1, \ldots, v_n \rightarrow v_c$ used in an argument there is an active chain between nodes $\mathbf{v_1}, \ldots, \mathbf{v_n}$ and $\mathbf{v_c}$



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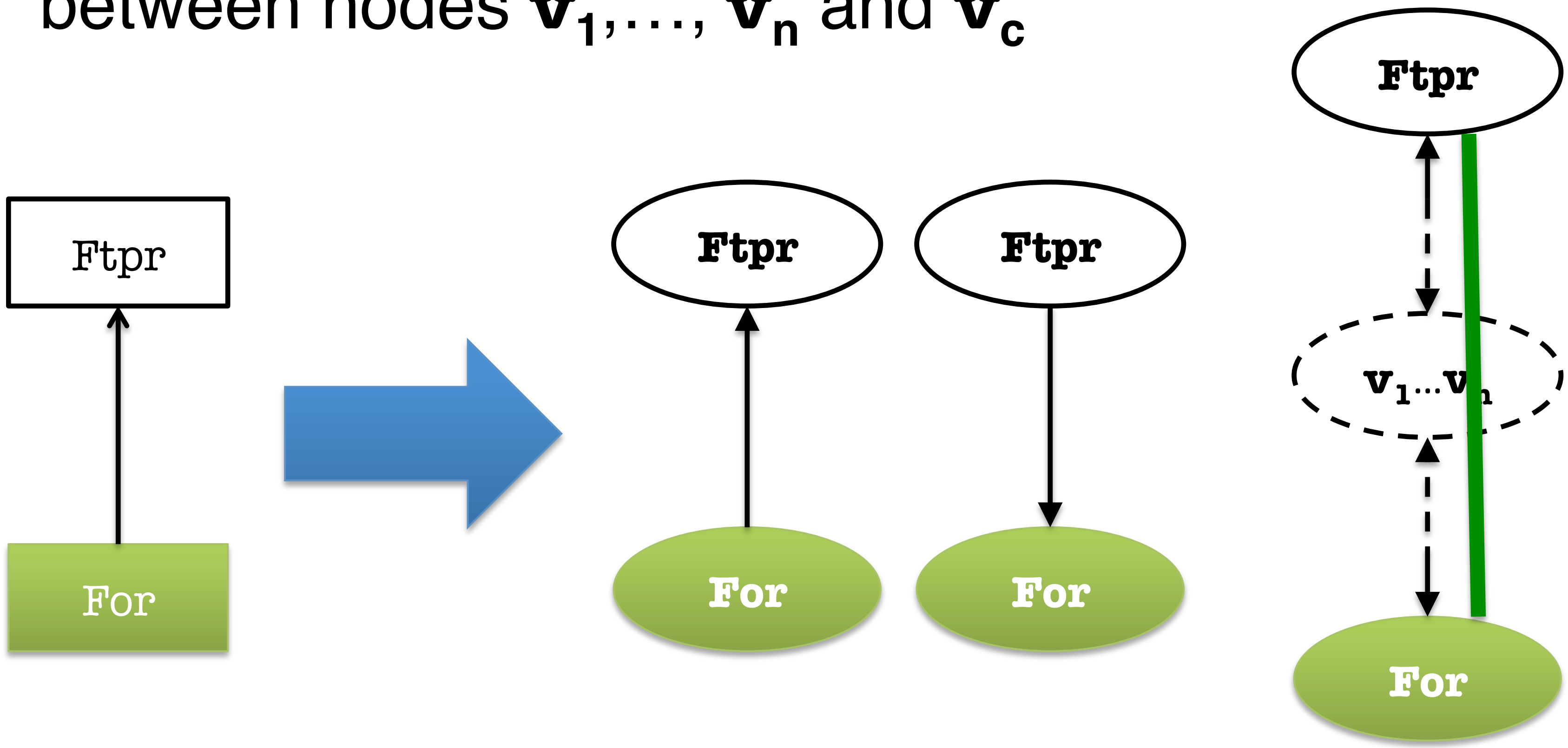
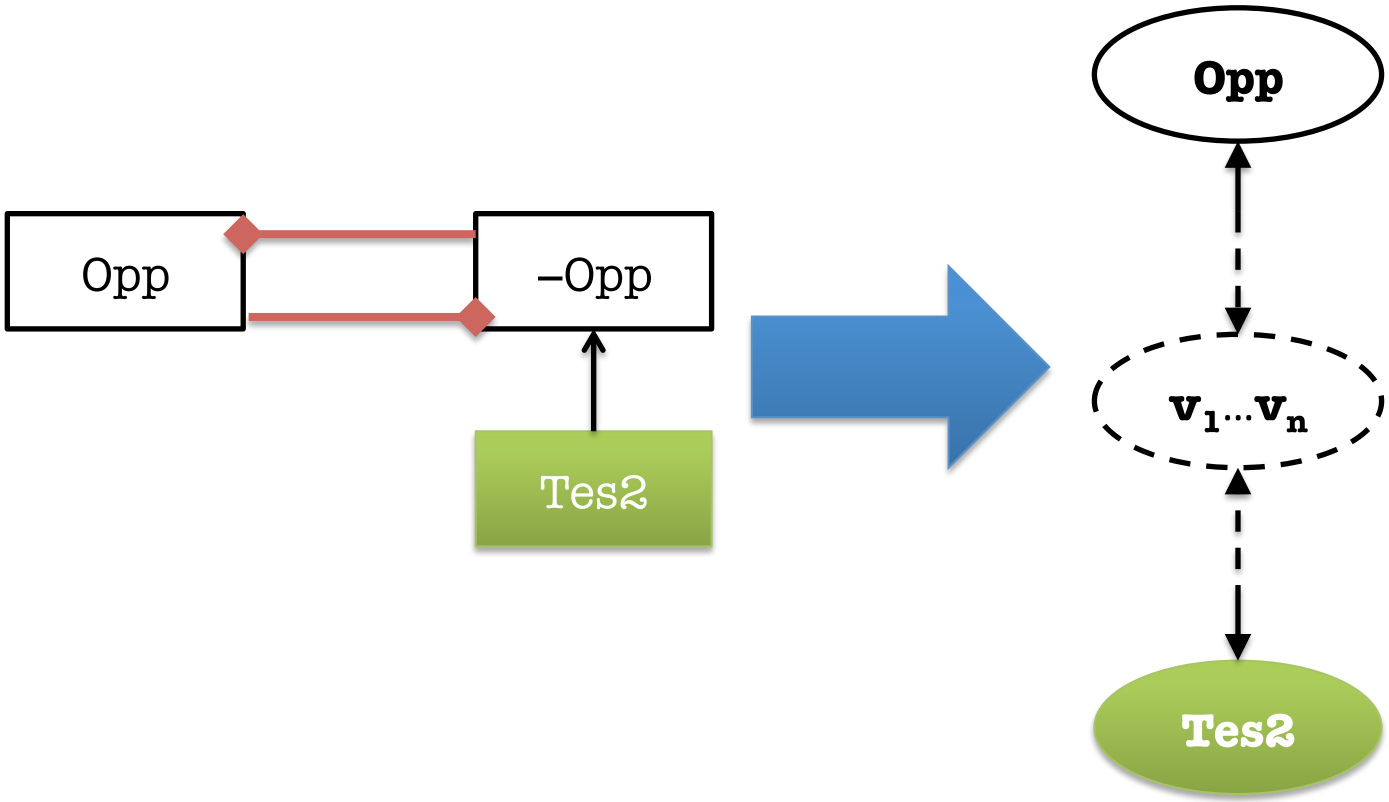


From arguments to constraints on BN

Attack chains

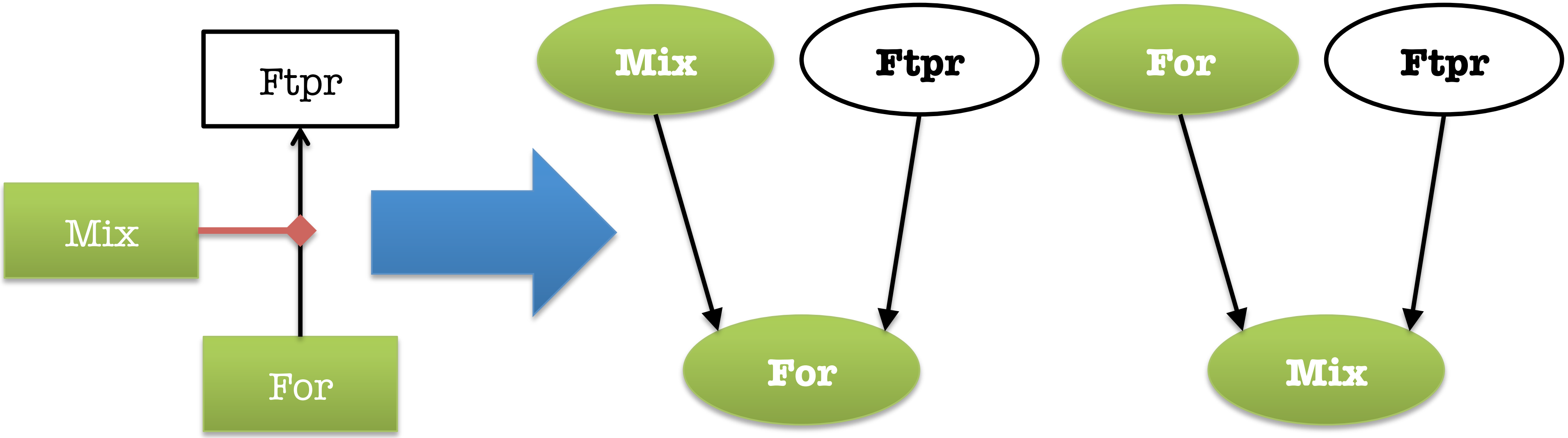
- For contradictory (i.e. Opp and –Opp) propositions, this is captured by inference chains



From arguments to constraints on BN

Attack chains

- If v_u undercuts the application of rule $v_p \Rightarrow v_c$, then there are active chains from $\mathbf{v_p}$, $\mathbf{v_c}$ to $\mathbf{v_u}$



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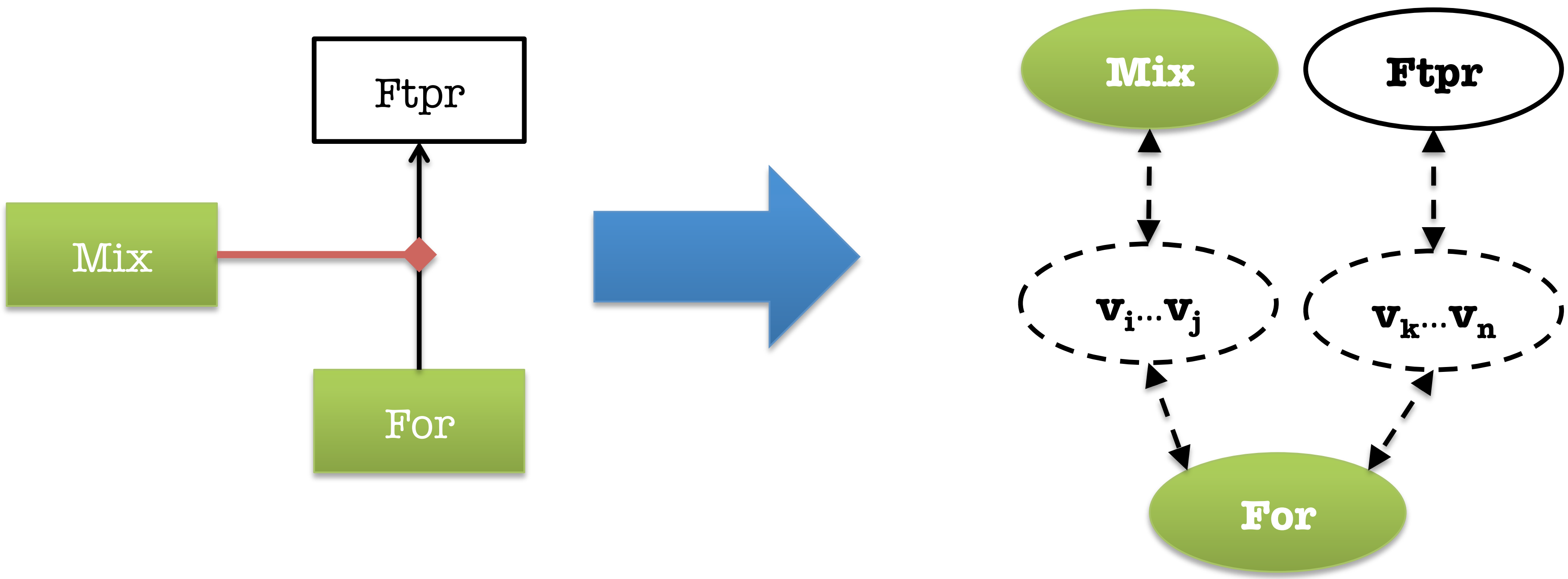

From arguments to constraints on BN

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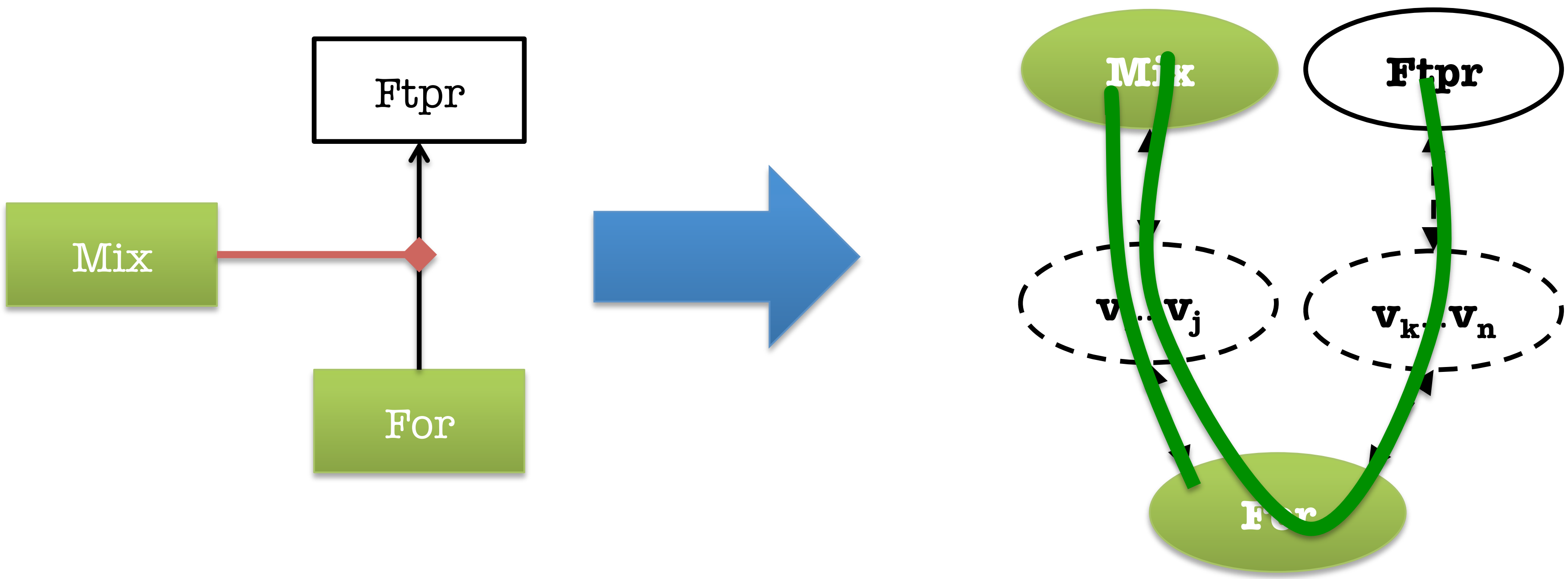
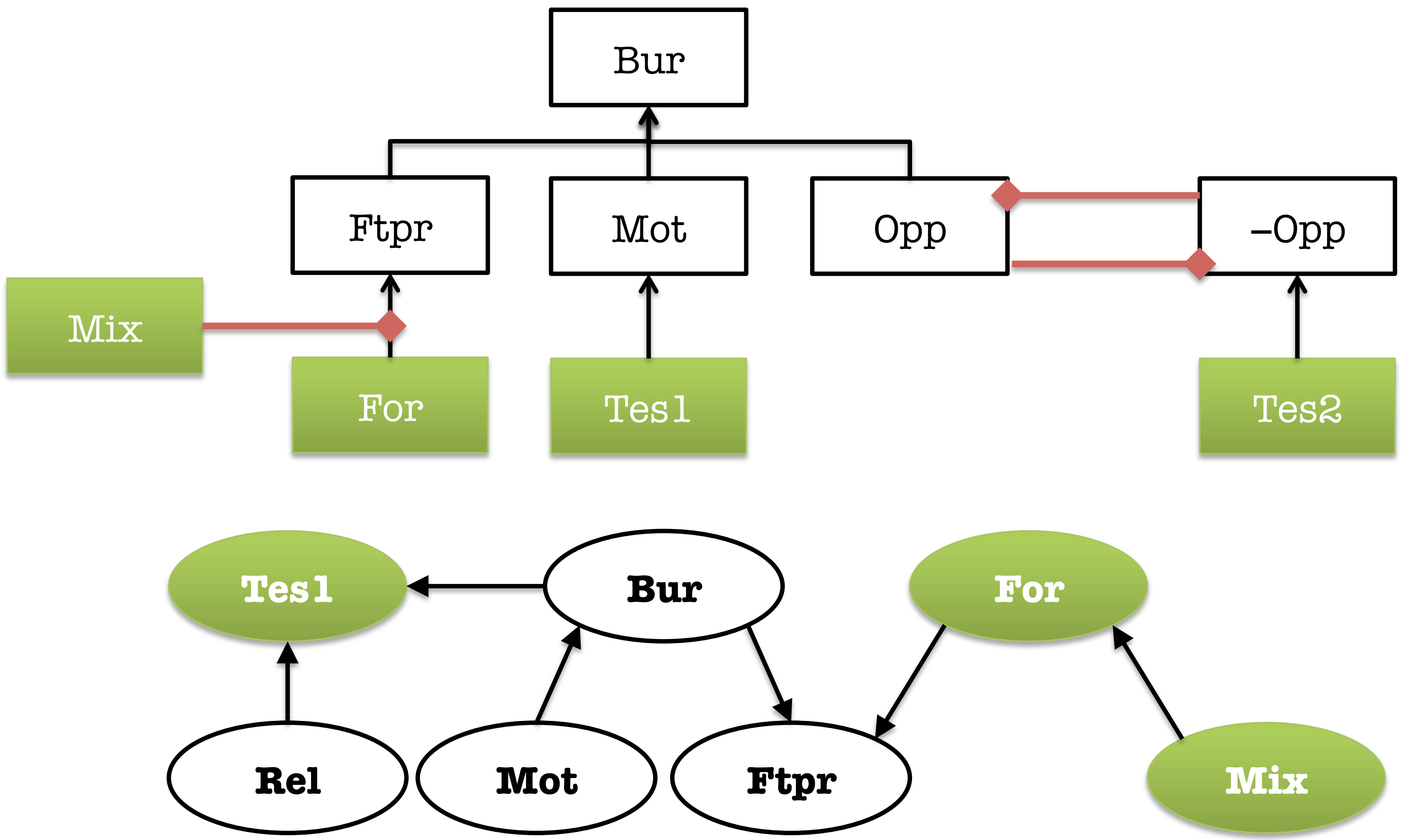
- If v_u undercuts the application of rule v_p => v_c, then there are active chains from $\mathbf{v_p}$, $\mathbf{v_c}$ to $\mathbf{v_u}$

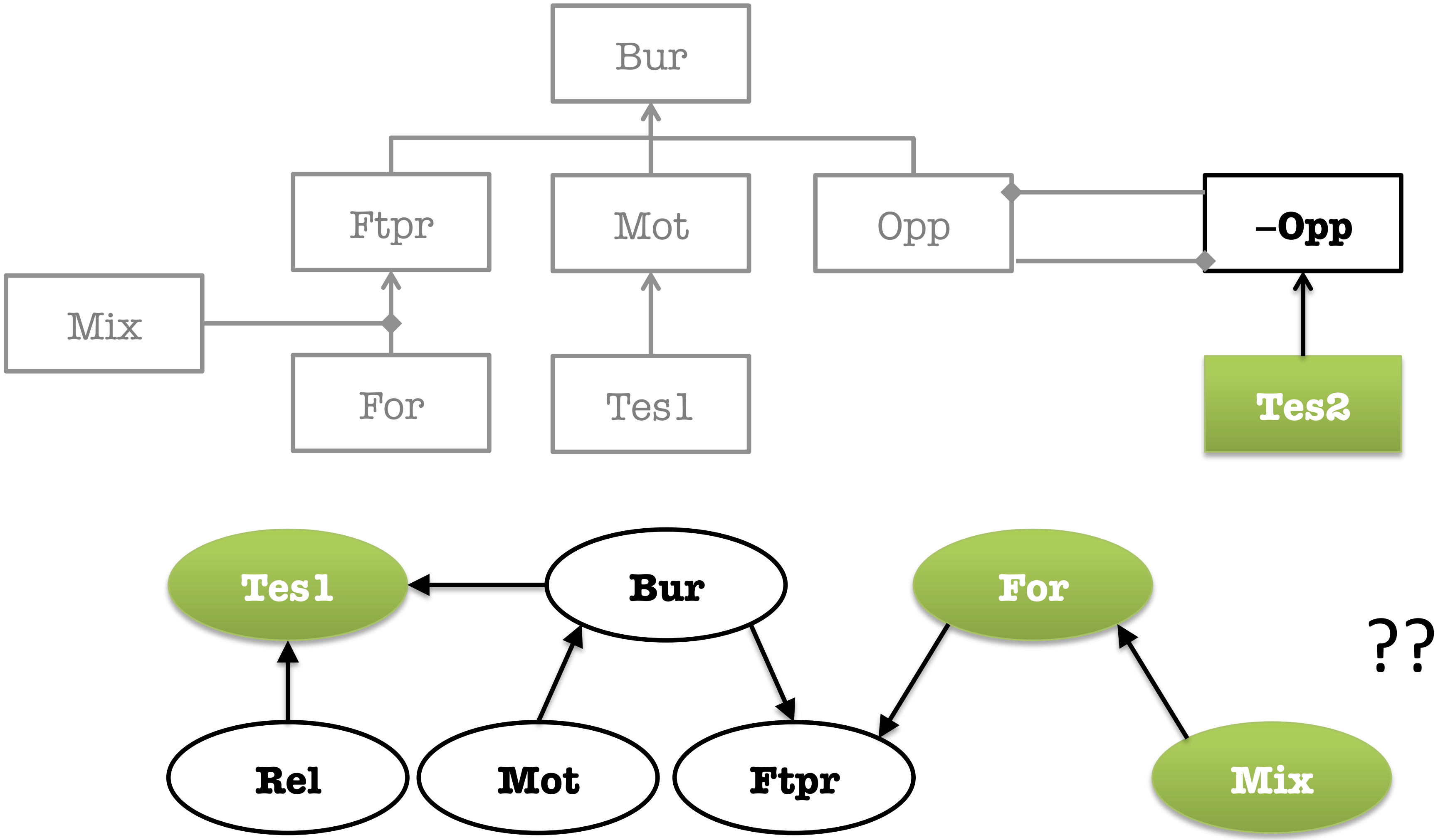


Using arguments to check BNs



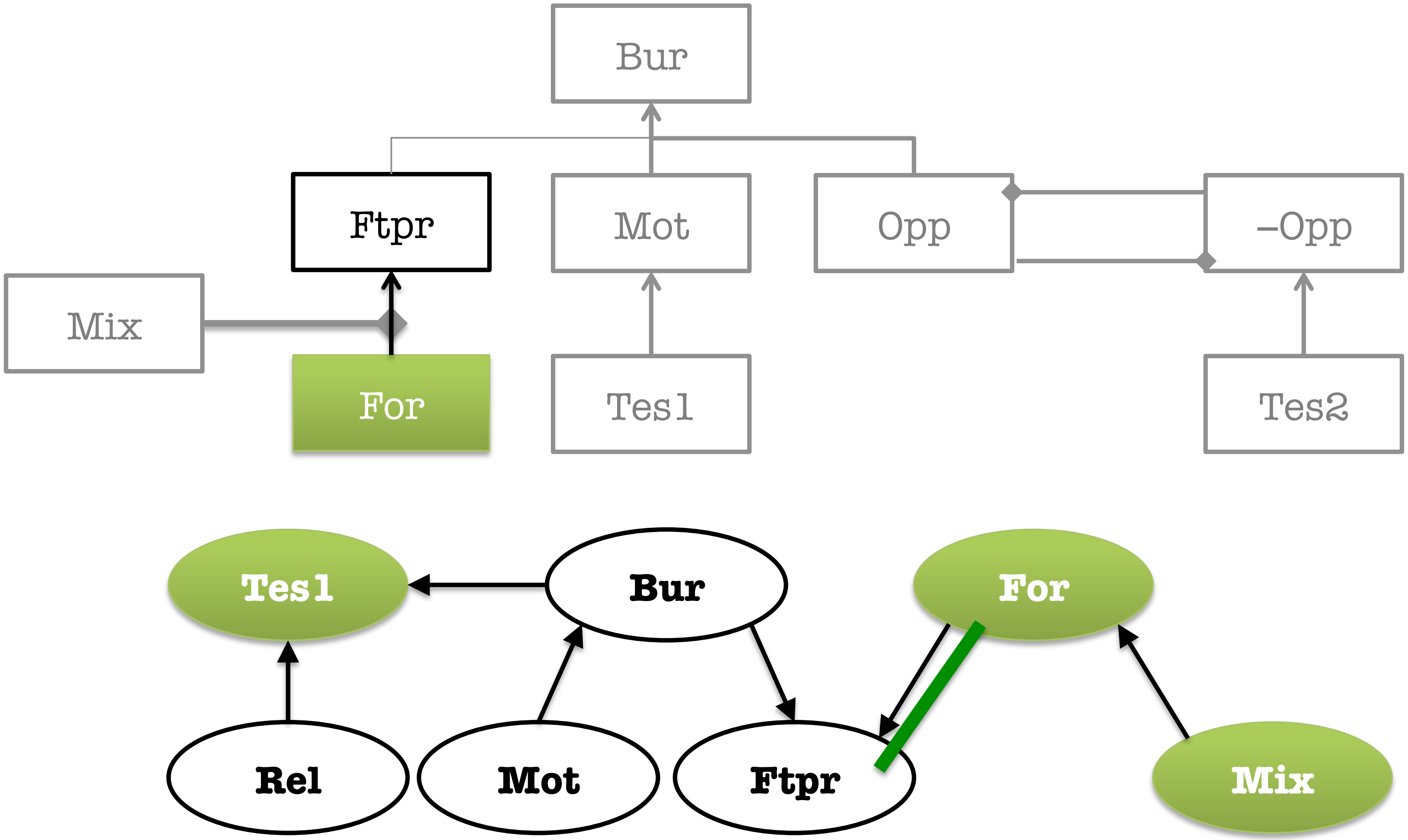
Using arguments to check BNs

- Missing variables



Using arguments to check BNs

- Active inference chains



Using arguments to check BNs

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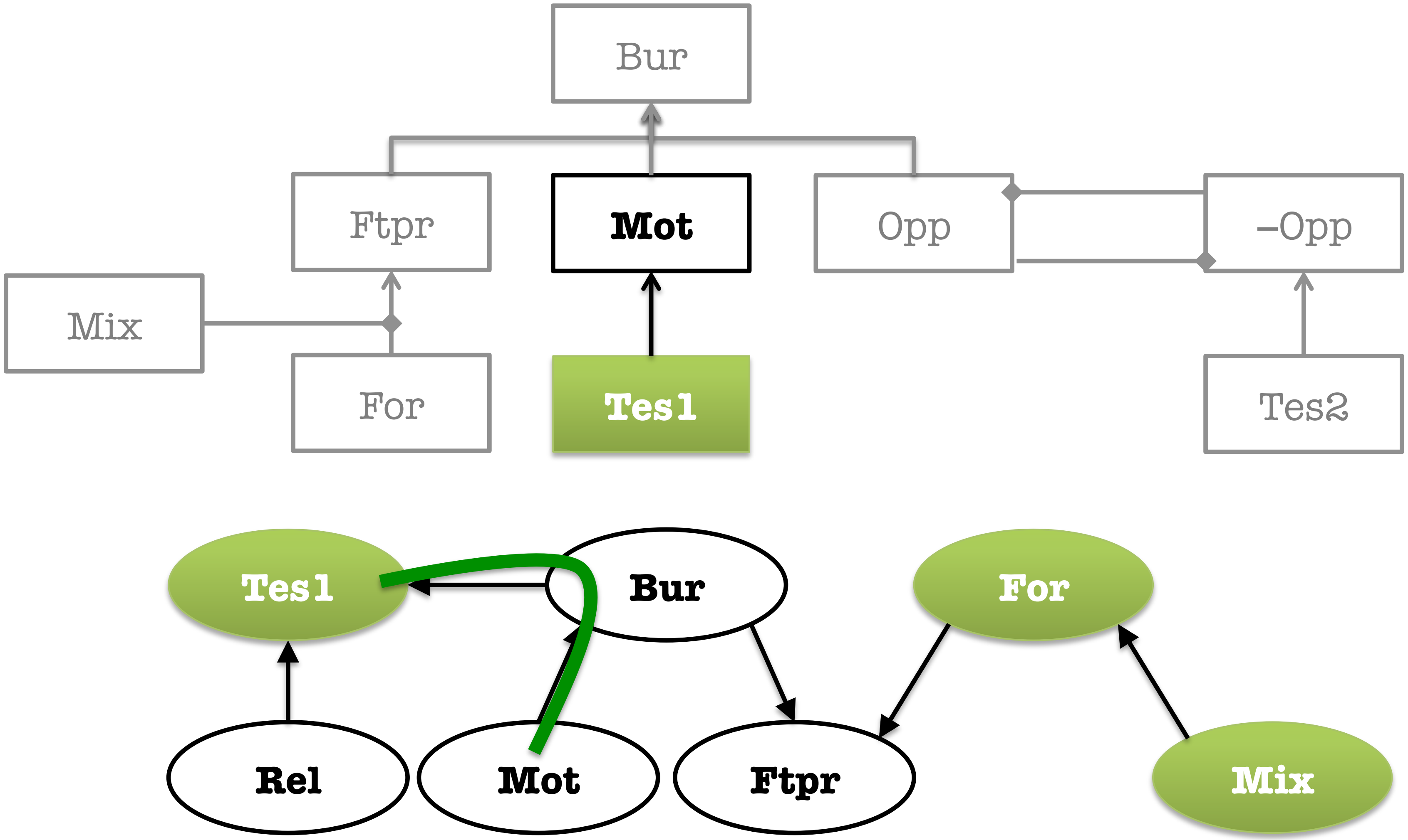
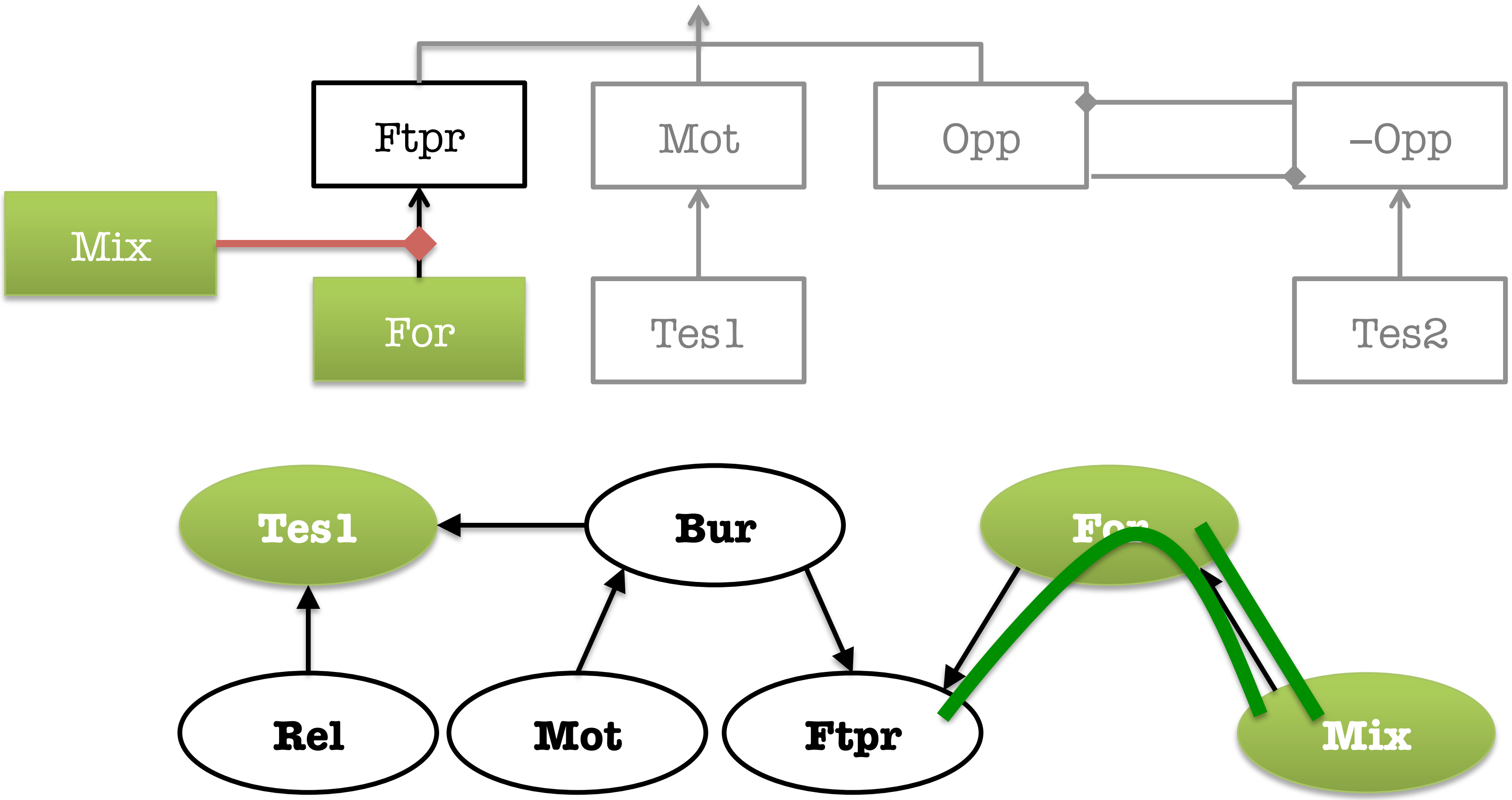


Using arguments to check BNs

- Active attack chains
  - If Mix undercuts the application of rule For => Ftpr, then there are active chains from **For**, **Ftpr** to **Mix**



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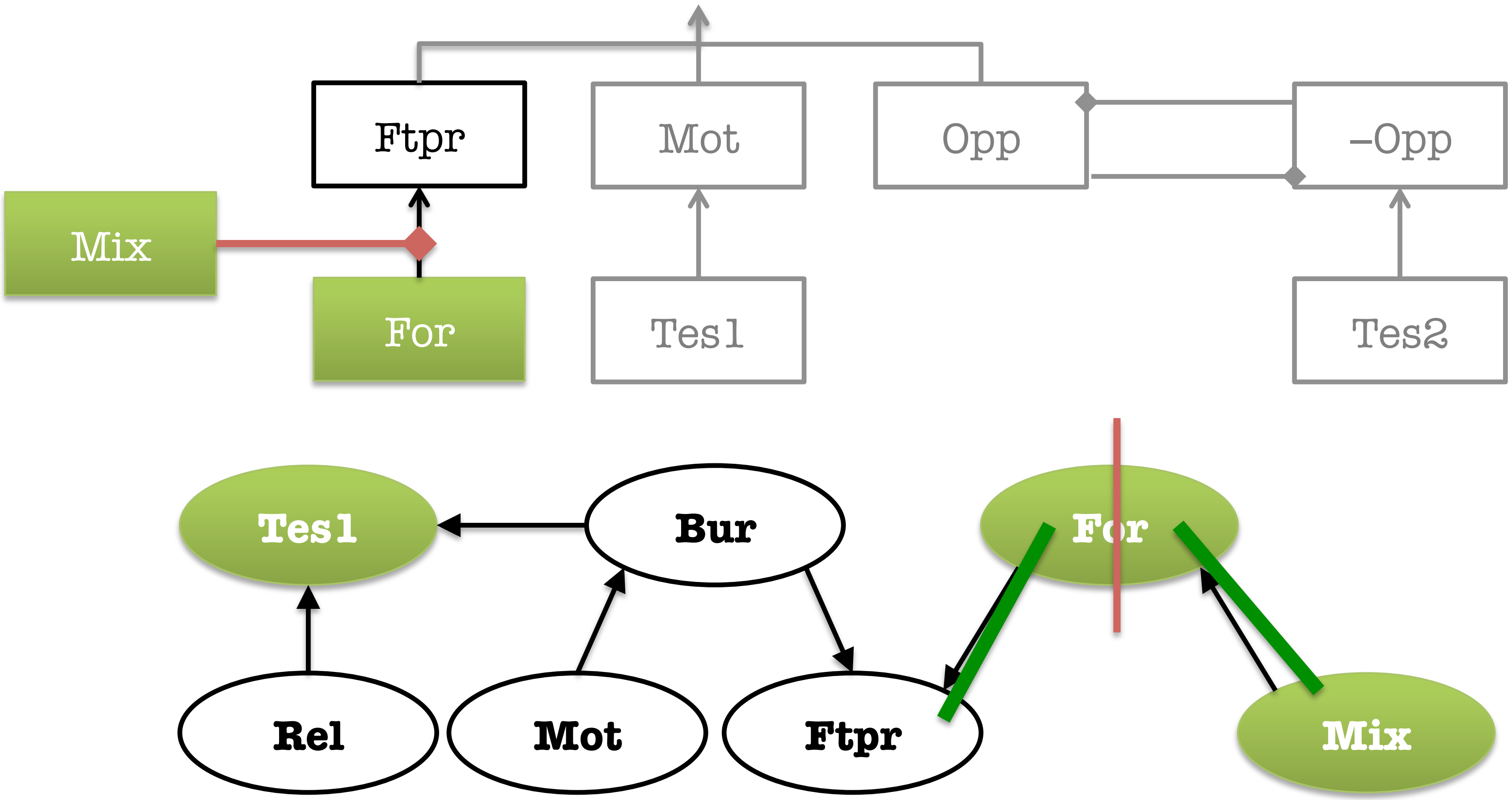
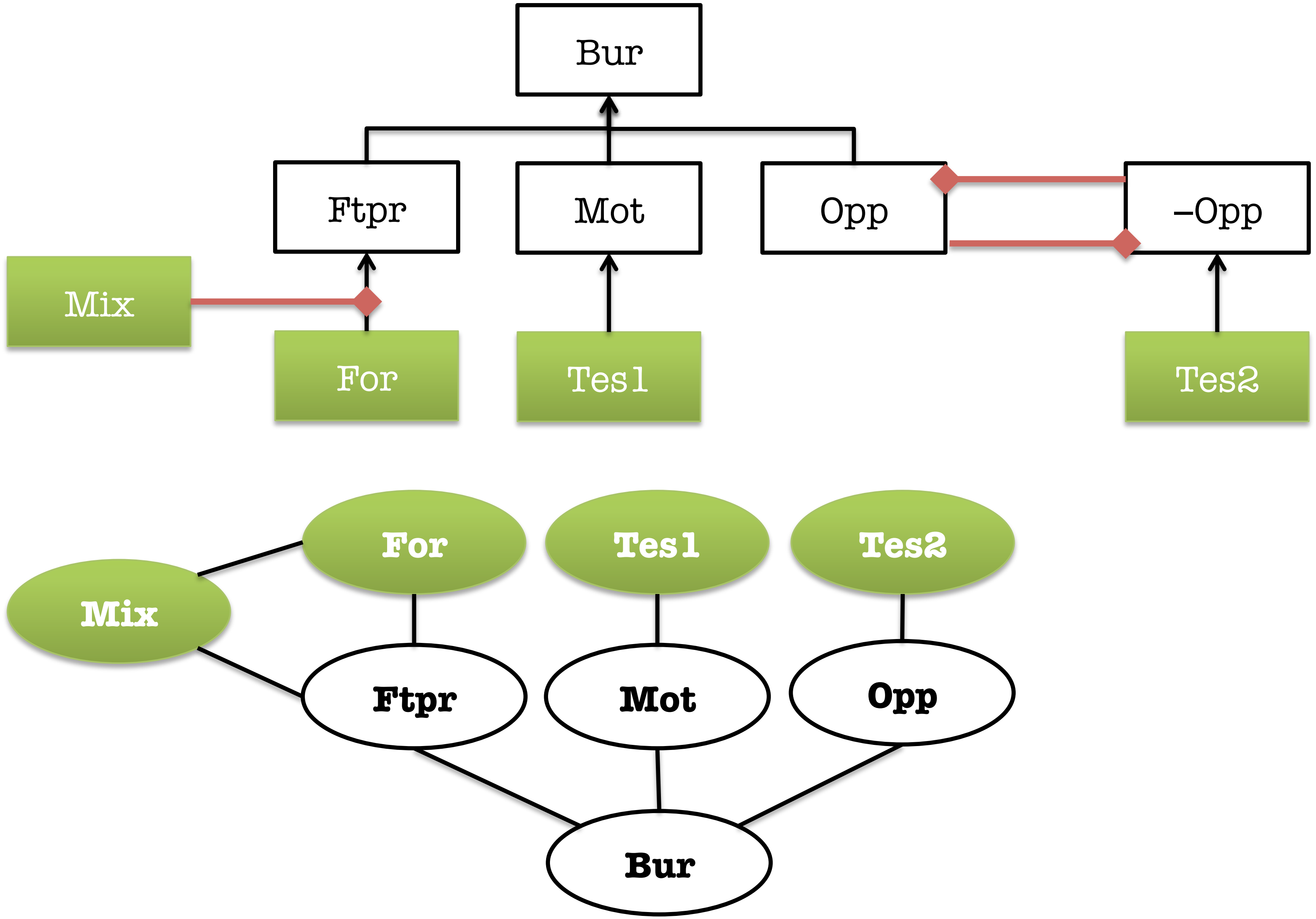
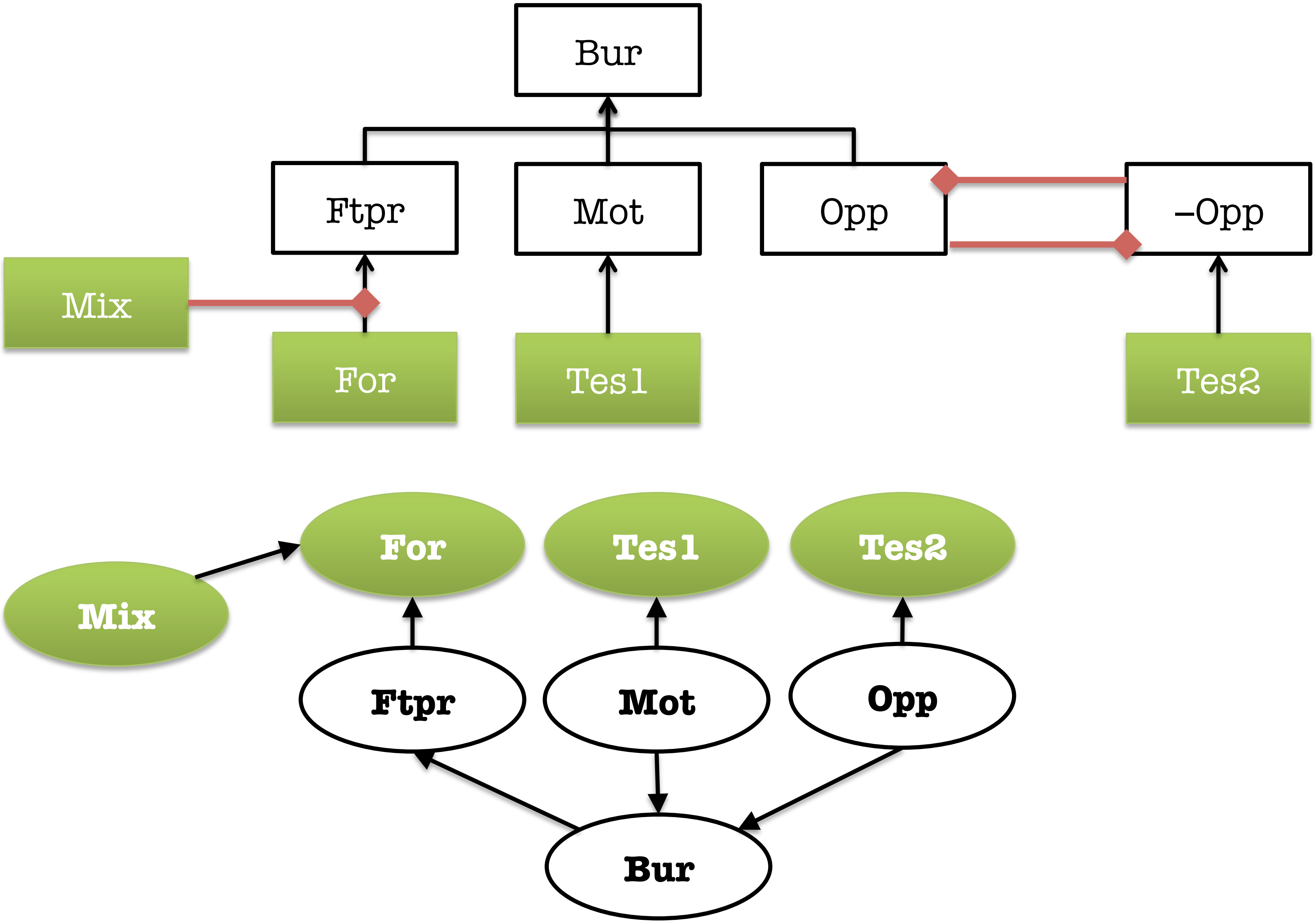


Using arguments to build BNs



Using arguments to build BNs



From arguments to constraints on BN

Probability constraints

- For every strict rule $v_1,\ldots, v_n$ –> v_c in an argument, we have $Pr(v_c | v_1,\ldots, v_n) = 1$
- For every defeasible rule $v_1,\ldots, v_n$ => v_c in an argument, we have $Pr(v_c | v_1,\ldots, v_n) > 0$
  - Above interpretation was proposed by Verheij (2014)
  - $Pr(v_c | v_1,\ldots, v_n) > 0.5$ (Pollock 1995)
  - $Pr(v_c | v_1,\ldots, v_n) > Pr(v_c)$ (Hahn & Hornikx 2015)
  - …

From arguments to constraints on BN

Probability constraints

- If v_i attacks (rebuts, undermines) v_j, we have $Pr(v_j \mid v_i) = 0$
- If v_u undercuts the application of rule $v_p \Rightarrow v_c$, we have $Pr(v_c \mid v_p, v_u) < Pr(v_c \mid v_p)$
  - Explaining away: chances of `Ftpr` given `For` and `Mix` are smaller than chances of `Ftpr` given just `For`.
  - $Pr(v_c \mid v_p, v_u) = 0$ (Verheij 2014)

Conclusions

- We can go from structured arguments to BN structures
  - Conditional Probability Tables need more assumptions

- (Semi-structured) arguments used by decision-makers can be compared with BNs built by forensic experts
- (Semi-structured) arguments used by decision-makers can be used to build initial BNs