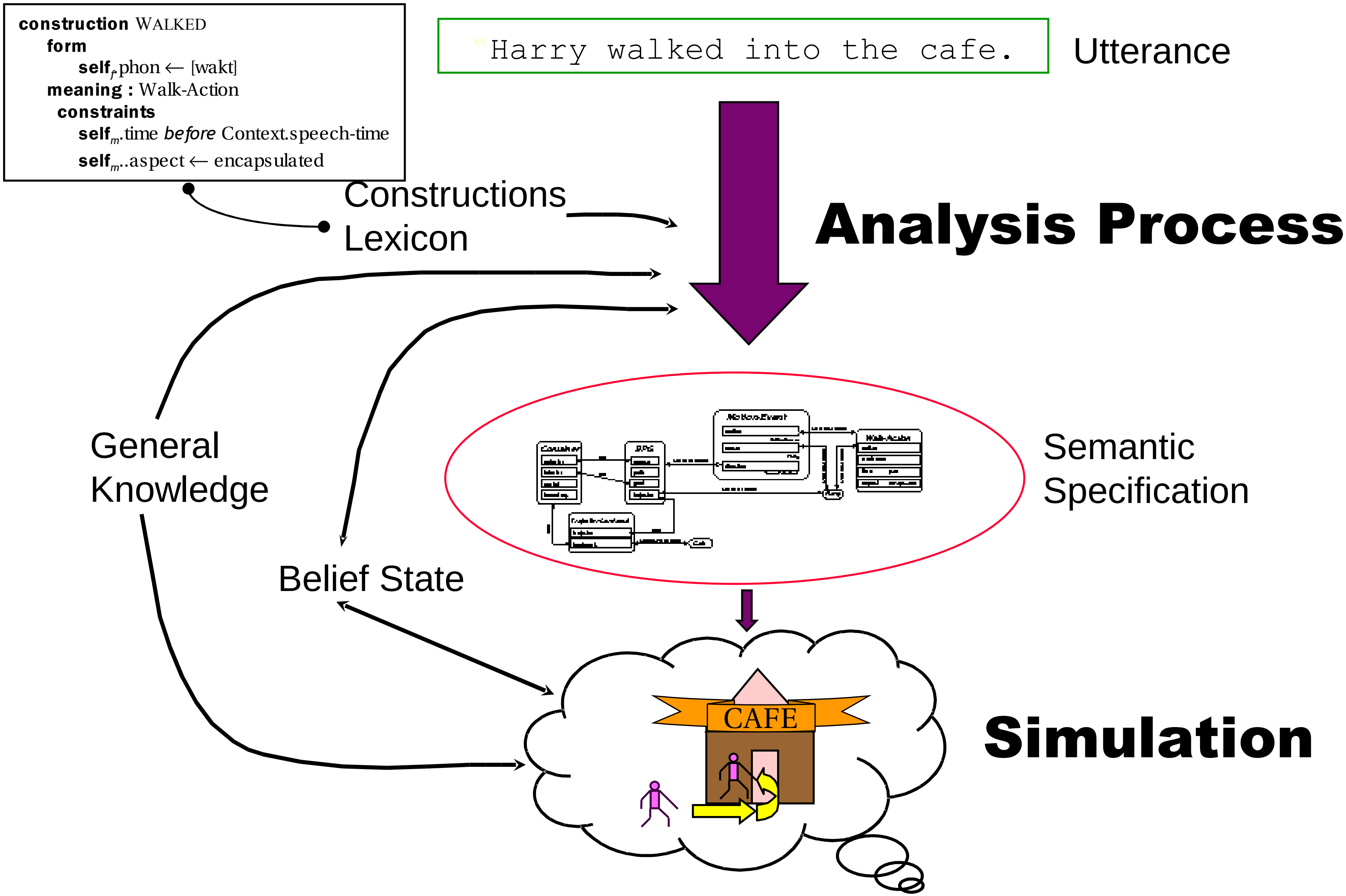
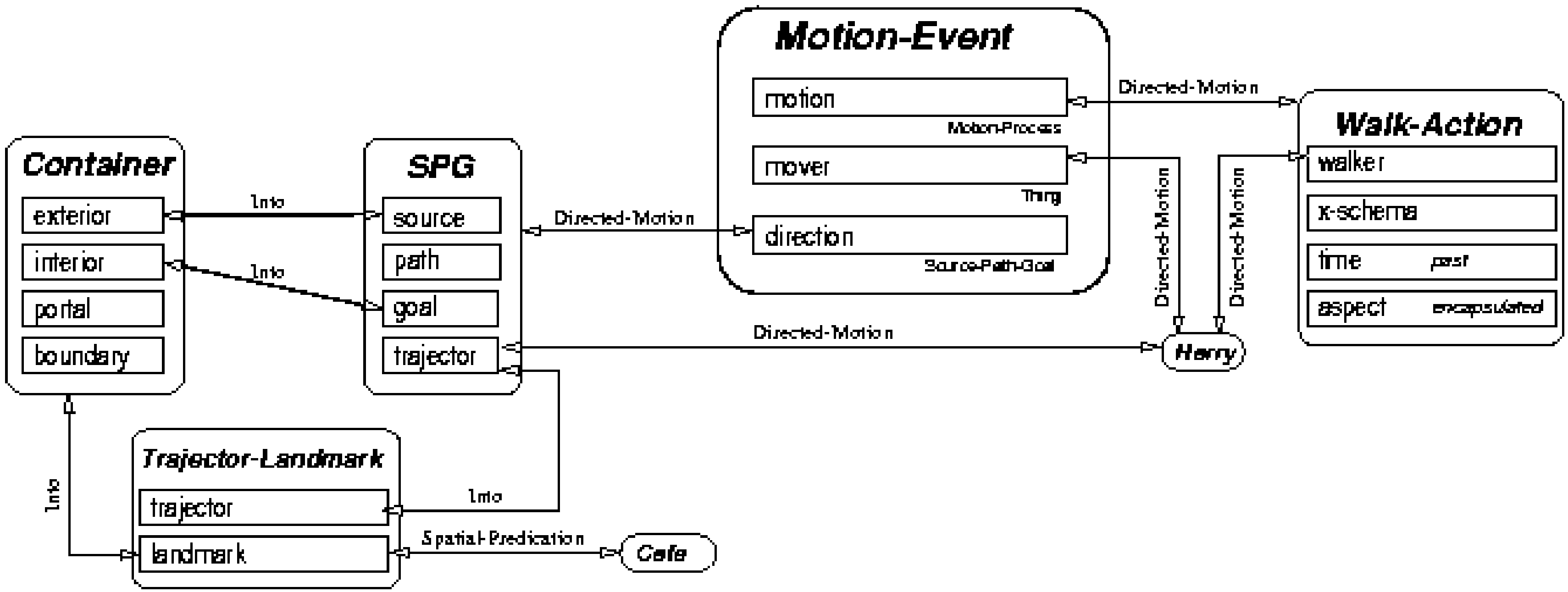
Lecture Overview

- Metaphors
  - Primary Metaphors
  - Complex Metaphors
- A computational Model of Event Structure
- Applying the Model to understanding newspaper articles.
  - Demo
- Extensions and Scalable Inference

Language : analysis & simulation



Simulation specification



The analysis process produces a **simulation specification** that

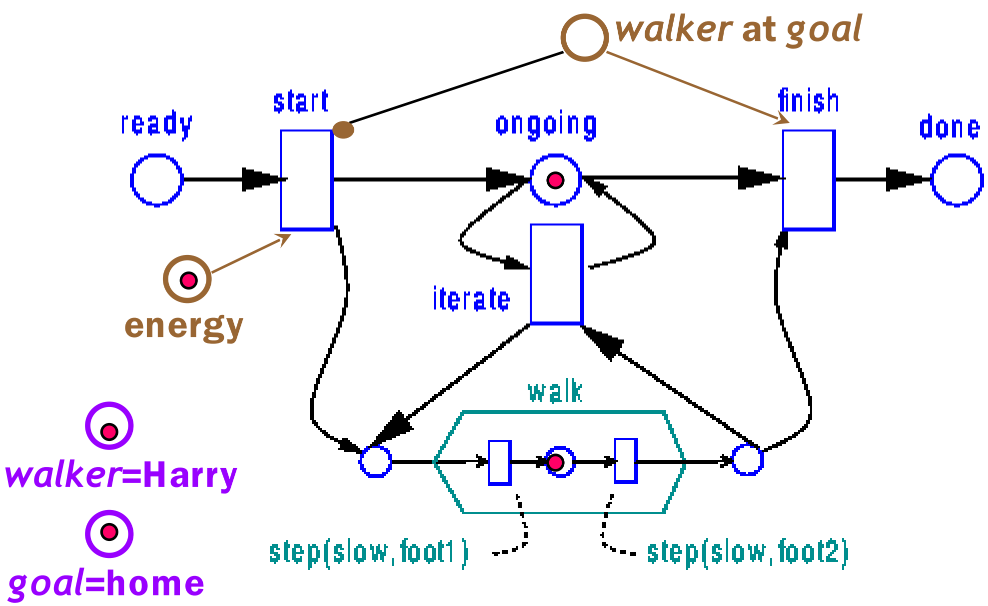
- includes image-schematic, motor control and conceptual structures
- provides parameters for a mental simulation

Simulation Semantics

- *BASIC ASSUMPTION*: ***SAME REPRESENTATION FOR PLANNING AND SIMULATIVE INFERENCE***
  - Evidence for common mechanisms for recognition and action (mirror neurons) in the F5 area (Rizzolatti et al (1996), Gallese 96, Boccino 2002) and from motor imagery (Jeannerod 1996)
- *IMPLEMENTATION*:
  - x-schemas affect each other by ***enabling, disabling or modifying execution trajectories***. Whenever the ***CONTROLLER*** schema makes a *transition* it may *set, get,* or *modify state* leading to *triggering or modification* of other x-schemas. State is completely distributed (a graph marking) over the network.
- *RESULT*: INTERPRETATION IS IMAGINATIVE SIMULATION!

Active representations

- Many inferences about actions derive from what we know about executing them
- Representation based on stochastic Petri nets captures dynamic, parameterized nature of actions



Walking:

bound to a specific *walker* with a direction or *goal*

consumes resources (e.g., energy)

may have termination condition (e.g., *walker* at *goal*)

ongoing, iterative action

X-Schema Extensions to Petri Nets

- Parameterization
  - x-schemas take parameter values (speed, force)
    - Walk(speed = slow, dest = store1)
- Dynamic Binding
  - X-schemas allow run-time binding to different objects/entities
    - Grasp(cup1), push(cart1)
- Hierarchical control and durative transitions
  - Walk is composed of steps which are composed of stance and swing phases
- Stochasticity and Inhibition
  - Uncertainties in world evolution and in action selection

Task

- Interpret simple discourse fragments/blurbs
  - France fell into recession. Pulled out by Germany
  - Economy moving at the pace of a Clinton jog.
  - US Economy on the verge of falling back into recession after moving forward on an anemic recovery.
  - Indian Government stumbling in implementing Liberalization plan.
  - Moving forward on all fronts, we are going to be ongoing and relentless as we tighten the net of justice.
  - The Government is taking bold new steps. We are loosening the stranglehold on business, slashing tariffs and removing obstacles to international trade.

Event Structure for semantic QA

Srini Narayanan

- Reasoning about dynamics
  - Complex event structure
    - Multiple stages, interruptions, resources, framing
  - Evolving events
    - Conditional events, presuppositions.
  - Nested temporal and aspectual references
    - Past, future event references
  - Metaphoric references
    - Use of motion domain to describe complex events.
- Reasoning with Uncertainty
  - Combining Evidence from Multiple, unreliable sources
  - Non-monotonic inference
    - Retracting previous assertions
    - Conditioning on partial evidence

Event Structure in Language

- Fine-grained
- Rich Notion of Contingency Relationships.
  - Phenomena: Aspect, Tense, Force-dynamics, Modals, Counterfactuals
- Event Structure Metaphor:
  - Phenomena: Abstract Actions are conceptualized in Motion and Manipulation terms.
  - Schematic Inferences are preserved.

Aspect

- Aspect is the name given to the ways languages describe the structure of events using a variety of lexical and grammatical devices.
  - Viewpoints
    - is walking, walk
  - Phases of events
    - Starting to walk, walking, finish walking
  - Inherent Aspect
    - run vs cough vs. rub
  - Composition with
    - Temporal modifiers, tense..
    - Noun Phrases (count vs. mass) etc..

Frames

- Frames are conceptual structures that may be culture specific
- Words evoke frames
  - The word "talk" evokes the Communication frame
  - The word buy (sell, pay) evoke the Commercial Transaction (CT) frame.
  - The words journey, set out, schedule, reach etc. evoke the Journey frame.
- Frames have roles and constraints like schemas.
  - CT has roles vendor, goods, money, customer.
- Words bind to frames by specifying binding patterns
  - Buyer binds to Customer, Vendor binds to Seller.

I/O as Feature Structures

- ***Indian Government stumbling in implementing liberalization plan***

Input

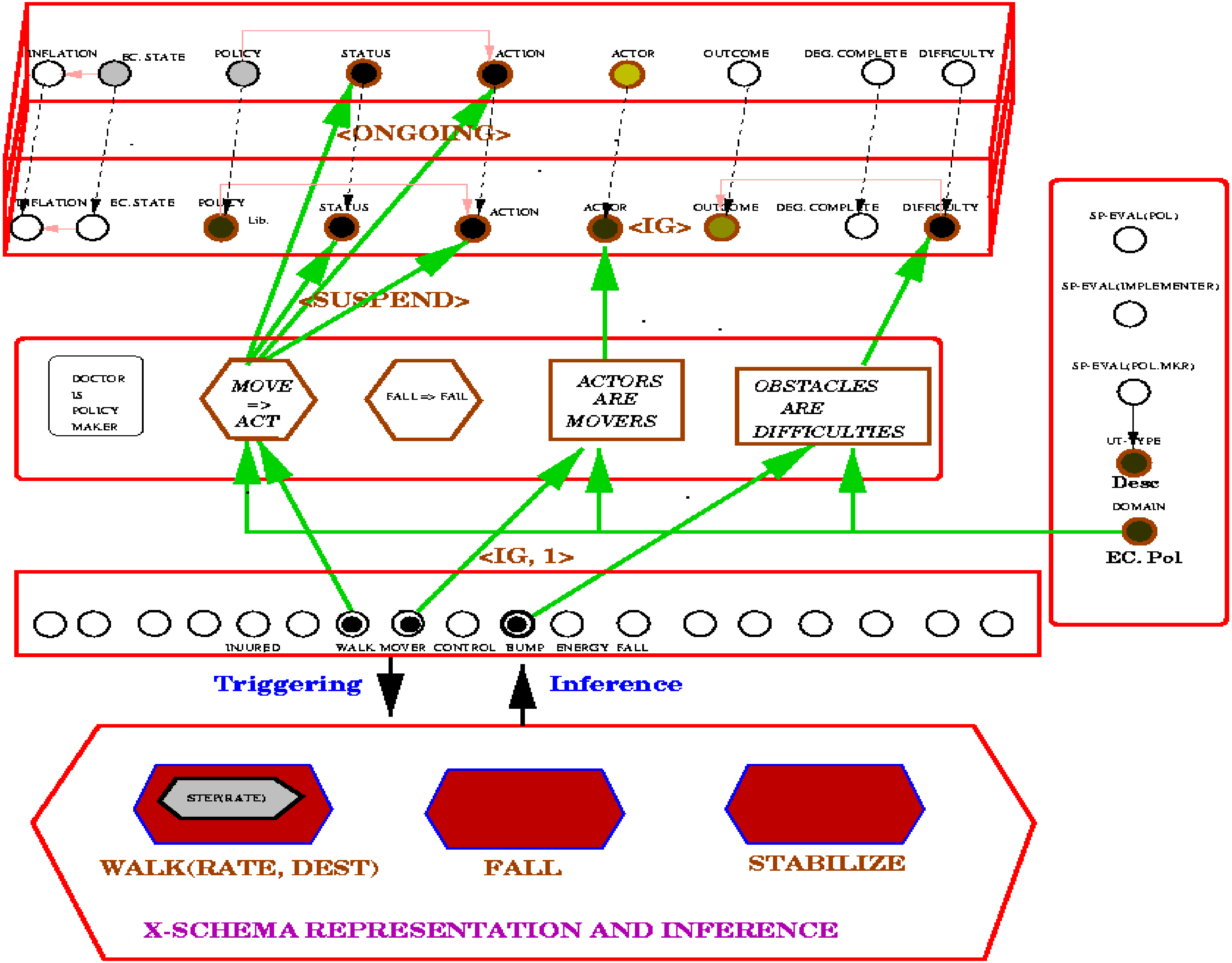
Event	Domain	Actor	Aspect
stumble(IG)	Liberalization Plan	Indian Gov. (IG)	present-progressive

Output

Event	Domain	*Context*	*Status*	*Outcome*	*Goal*
stumble (IG)	Liberaliza-tion Plan	Ongoing plan, **difficulty**	**inter-rupted(.8)**	**failure (.7)**	***free-trade, deregula-tion***

Basic Components

- An fine-grained executing model of action and events (X-schemas).
- A simulation of connected embodied x-schemas using a controller x-schema
- A representation of the domain/frames (DBN's) that supports spreading activation
- A model of metaphor maps that project bindings from source to target domains.


INFLATION
EC. STATE
POLICY
STATUS
ACTION
ACTOR
OUTCOME
DEG. COMPLETE
DIFFICULTY
<ONGOING>
INFLATION
EC. STATE
POLICY
Lib.
STATUS
ACTION
ACTOR
<IG>
OUTCOME
DEG. COMPLETE
DIFFICULTY
<SUSPEND>
SP-EVAL(POL)
SP-EVAL(IMPLEMENTER)
SP-EVAL(POL.MKR)
UT-TYPE
Desc
DOMAIN
EC. Pol
DOCTOR IS POLICY MAKER
MOVE => ACT
FALL => FALL
ACTORS ARE MOVERS
OBSTACLES ARE DIFFICULTIES
<IG, 1>
INJURED
WALK
MOVER
CONTROL
BUMP
ENERGY
FALL
Triggering
Inference
STEP(RATE)
WALK(RATE, DEST)
FALL
STABILIZE
X-SCHEMA REPRESENTATION AND INFERENCE

The Target Domain

- ***Simple knowledge about Economics***
  - Factual (US is a market economy)
  - Correlational (High Growth => High Inflation)
- ***Key Requirement***:
  - Must combine background knowledge of economics with inherent structure and constraints of the target domain with inferential products of metaphoric (and other) projections from multiple source domains.
  - Must be able to compute the global impact of new observations (from direct input as well as metaphoric inferences)

Bayes Nets and Human Probabilistic Inference

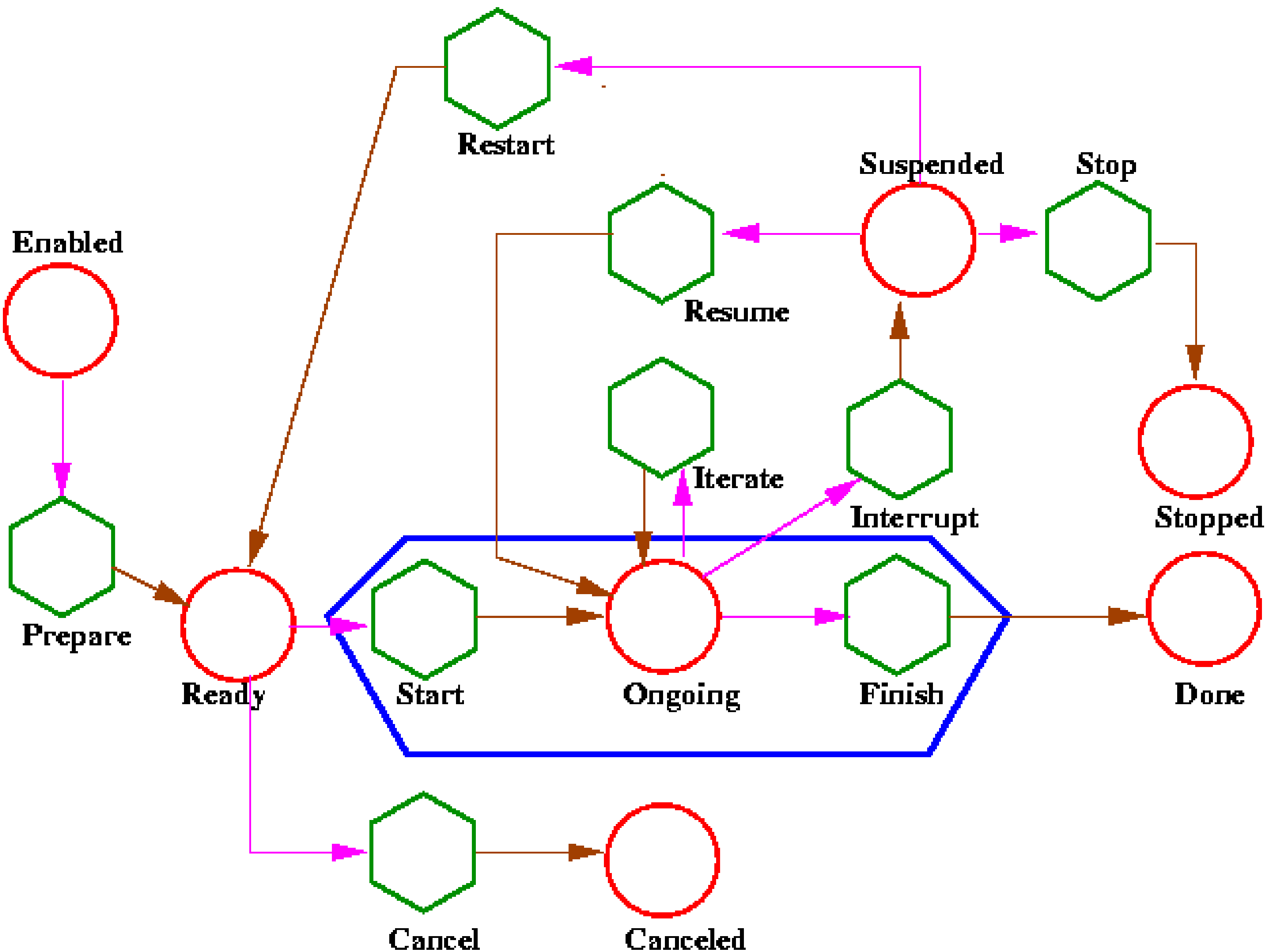
- Our use of Bayes Networks will be to model how people reason about uncertain events, such as those in economics and politics.
- We know that people do reason probabilistically, but also that they do not always act in accord with the formal laws of probability.
  - Daniel Kahneman won the 2002 Nobel Prize largely for his work with Amos Tversky explaining many of the limitations of human probabilistic reasoning. Some of the limitations are obvious, e.g. the calculations might be just too complex.
- But some are much deeper involving the way a question is stated, a preference for avoiding loss, and some basic misperceptions about large and small probabilities.
- Bayes nets only approximate the underlying evidential neural computation, but they are by far the best available model.

Metaphor Maps

- Static Structures that project bindings from source domain f- struct to target domain Belief net nodes by setting evidence on the target network.
- Different types of maps
  - PMAPS project X- schema Parameters to abstract domains
  - OMAPS connect roles between source and target domain
  - SMAPS connect schemas from source to target domains.
- ASPECT is an invariant in projection.

An Active Model of Events

- Computationally, actions and events are coded in active representations called x-schemas which are extensions to Stochastic Petri nets.
- x-schemas are fine-grained action and event representations that can be used for monitoring and control as well as for inference.
- The controller schema provides a compositional mechanism to compose events through activation, inhibition, and modification

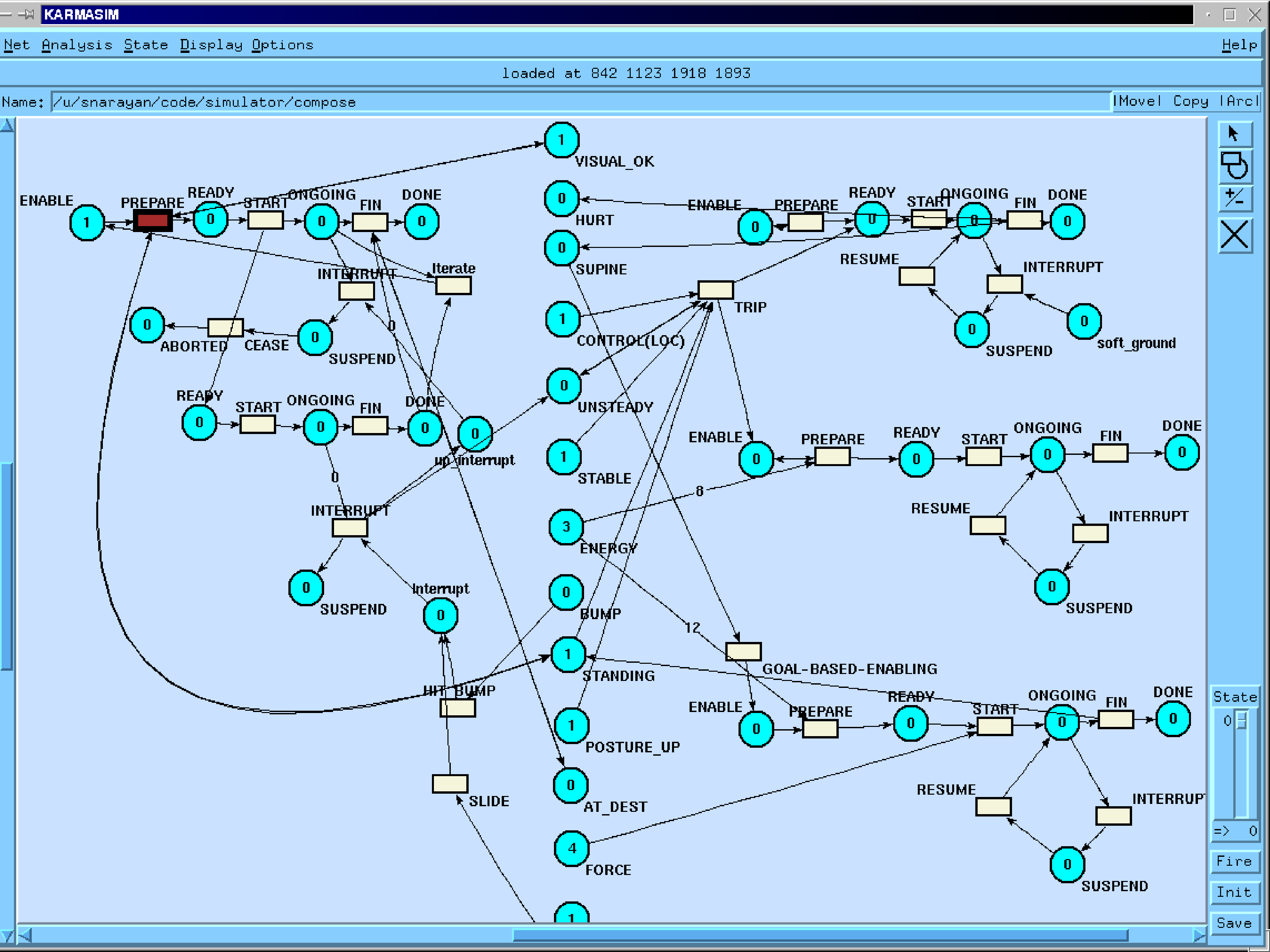


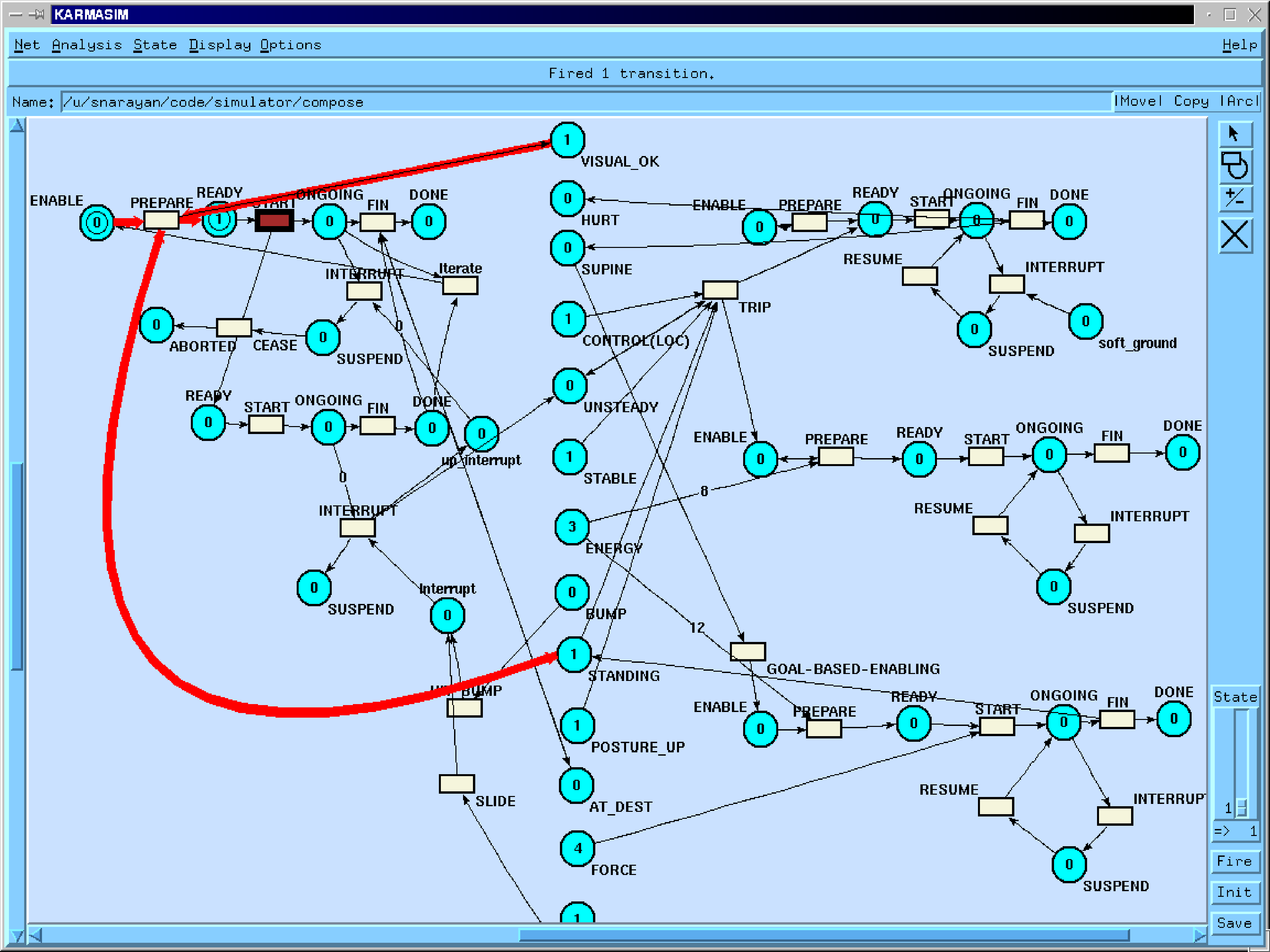
Restart
Suspended
Stop
Enabled
Resume
Iterate
Interrupt
Stopped
Prepare
Ready
Start
Ongoing
Finish
Done
Cancel
Canceled

Simulation hypothesis

We understand utterances by mentally simulating their content.

- Simulation exploits some of the **same neural structures** activated during performance, perception, imagining, memory…
- Linguistic structure **parameterizes** the simulation.
  - Language gives us enough information to simulate


KARMASIM
Net Analysis State Display Options
Help
loaded at 842 1123 1918 1893
Name: /u/snarayan/code/simulator/compose
|Move| Copy |Arc|
VISUAL_OK
HURT
SUPINE
CONTROL(LOC)
UNSTEADY
STABLE
ENERGY
BUMP
STANDING
POSTURE_UP
AT_DEST
FORCE
ENABLE
PREPARE
READY
START
ONGOING
FIN
DONE
INTERRUPT
Iterate
ABORTED
CEASE
SUSPEND
RESUME
up_interrupt
Interrupt
HIT_BUMP
SLIDE
TRIP
soft_ground
GOAL-BASED-ENABLING
State
Fire
Init
Save



KARMASIM
Net Analysis State Display Options
Help
Fired 1 transition.
Name: /u/snarayan/code/simulator/compose
|Move| Copy |Arc|
VISUAL_OK
ENABLE
PREPARE
READY
START
ONGOING
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DONE
HURT
SUPINE
INTERRUPT
Iterate
ABORTED
CEASE
SUSPEND
RESUME
soft_ground
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STABLE
ENERGY
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SLIDE
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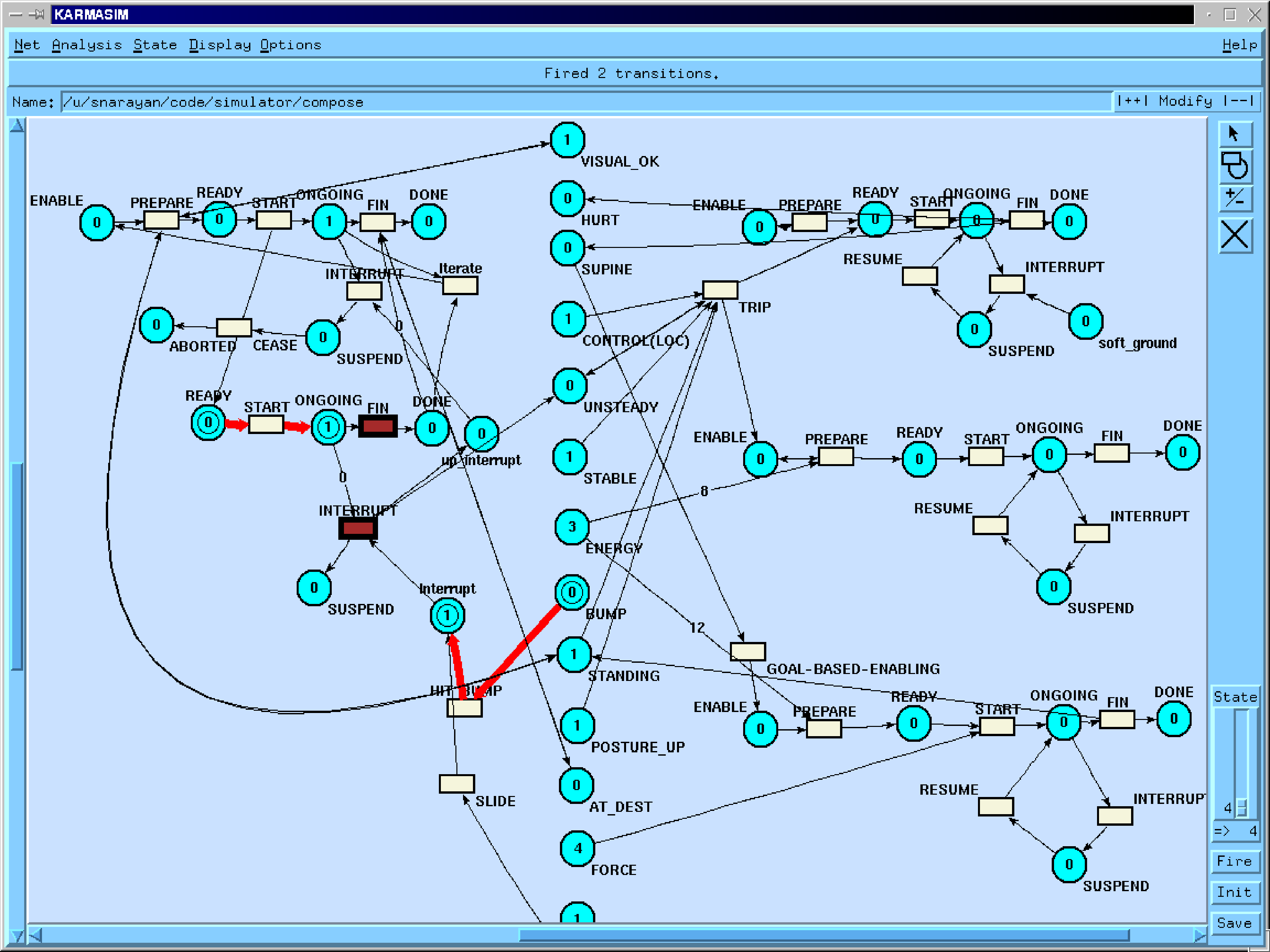
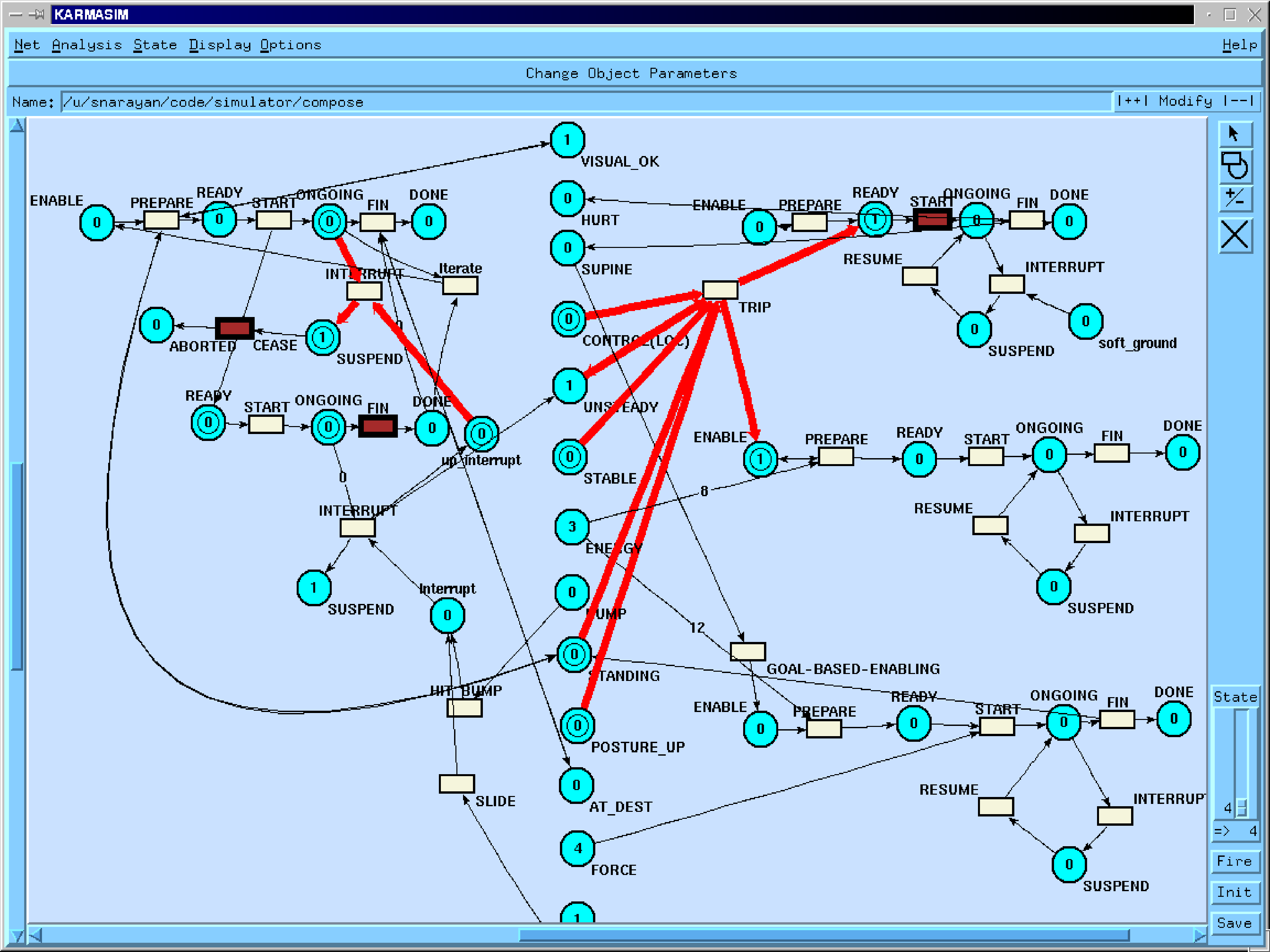
State
=> 1
Fire
Init
Save


KARMASIM
Net Analysis State Display Options
Help
Fired 2 transitions.
Name: /u/snarayan/code/simulator/compose
|++| Modify |--|
VISUAL_OK
ENABLE
PREPARE
READY
START
ONGOING
FIN
DONE
HURT
SUPINE
INTERRUPT
Iterate
ABORTED
CEASE
SUSPEND
TRIP
RESUME
soft_ground
CONTROL(LOC)
UNSTEADY
up_interrupt
STABLE
ENERGY
Interrupt
BUMP
GOAL-BASED-ENABLING
STANDING
HIT_BUMP
POSTURE_UP
SLIDE
AT_DEST
FORCE
State
Fire
Init
Save



KARMASIM
Net Analysis State Display Options
Help
Change Object Parameters
Name: /u/snarayan/code/simulator/compose
|++| Modify |--|
VISUAL_OK
ENABLE
PREPARE
READY
START
ONGOING
FIN
DONE
HURT
SUPINE
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Fire
Init
Save

Inference from Domain knowledge

- Language understanding never occurs in a vacuum –
  - in making sense of an utterance we use both our general experience of the world and our beliefs about the current situation.
  - X-schemas describe our embodied knowledge of action and of processes are used in comprehending language.
  - The programs that interpret news stories must also make inferences from descriptive (Frame and Domain) knowledge.

General and Domain Knowledge

- Conceptual Knowledge and Inference
  - Embodied
  - Language and Domain Independent
  - Powerful General Inferences
  - Ubiquitous in Language
- Domain Specific Frames and Ontologies
  - FrameNet, OWL ontologies
- Metaphor links domain specific to general
  - E.g., France slipped into recession.

The Target Domain

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  - Correlational (High Growth => High Inflation)
- ***Key Requirement***:
  - Must combine background knowledge of economics with inherent structure and constraints of the target domain with inferential products of metaphoric (and other) projections from multiple source domains.
  - Must be able to compute the global impact of new observations (from direct input as well as metaphoric inferences). Such inference should model spreading activation (parallel, top-down and bottom up)

Modeling Spreading Activation

- Traditional theories of meaning have focused entirely on logical deduction as a model of understanding.
  - Although much has been learned from this approach, it only covers a small fraction of the kinds of inferences that people draw when understanding language.
- From our neural perspective, inference is better seen as a process of quantitatively combining evidence in context to derive the most likely conclusions.
- When you hear or read something new, your brain's spreading activation mechanisms automatically connect it to related information.
  - Strength of connection
  - Strength of activation

A computational model: Bayes Nets

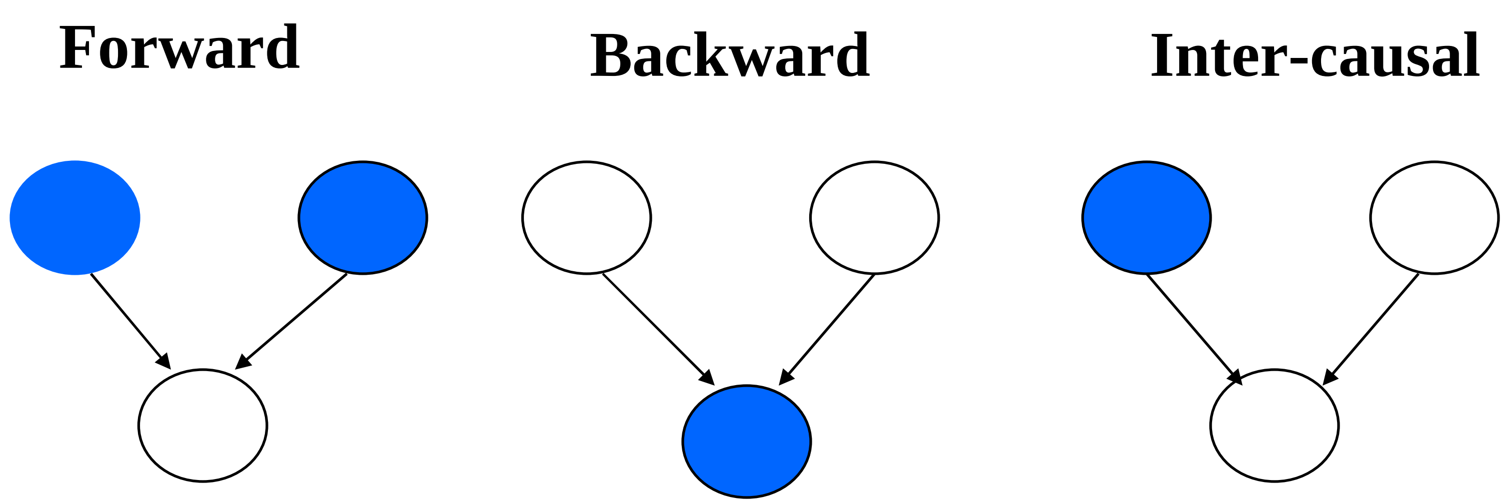
- At the computational level, *Bayes Networks* capture the *best fit* character of neural inference
  - allows us to model a much wider range of language behavior.
- BN are a computational formalism that is the best available approximation to neural spreading activation.
- In this lecture, we will combine
  - bayes networks
  - active schemas
- in a computational model of how people understand the meaning of news stories about economics.

Bayes Networks

Expoits conditional independence requiring only local conditional beliefs.

Basic operation is *conditioning* in the presence of evidence.

Supports Multiple inference types

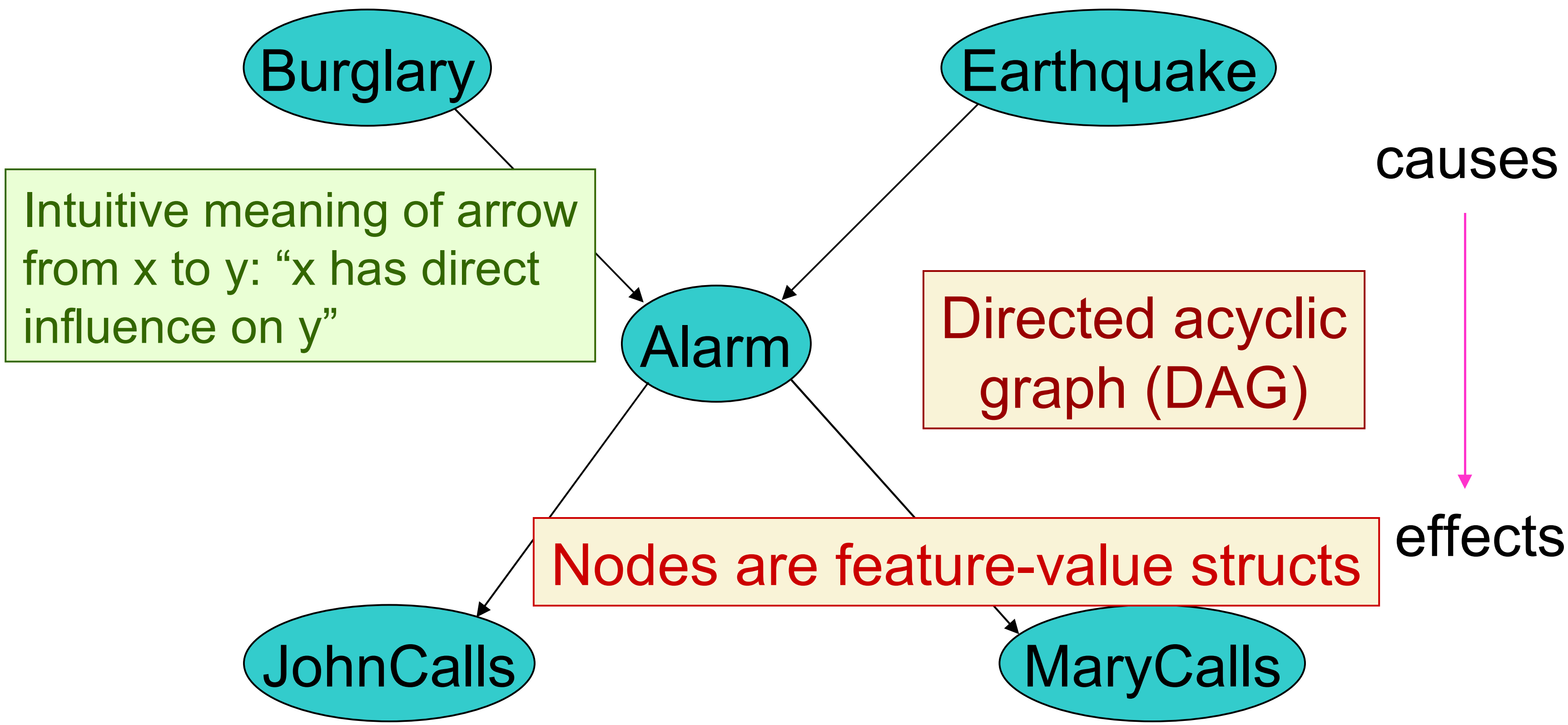


Example: Alarm

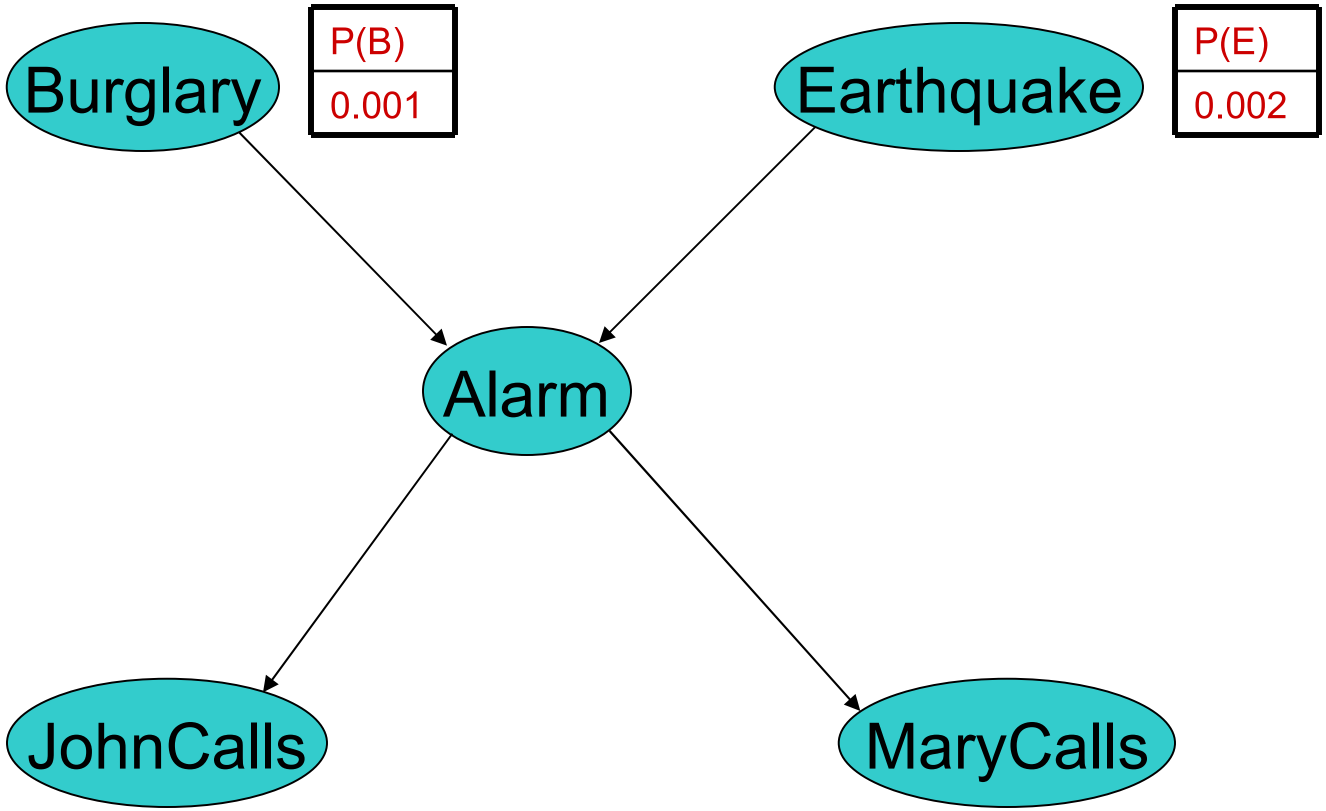
Five state features

- A: Alarm
- B: Burglary
- E: Earthquake
- J: JohnCalls
- M: MaryCalls

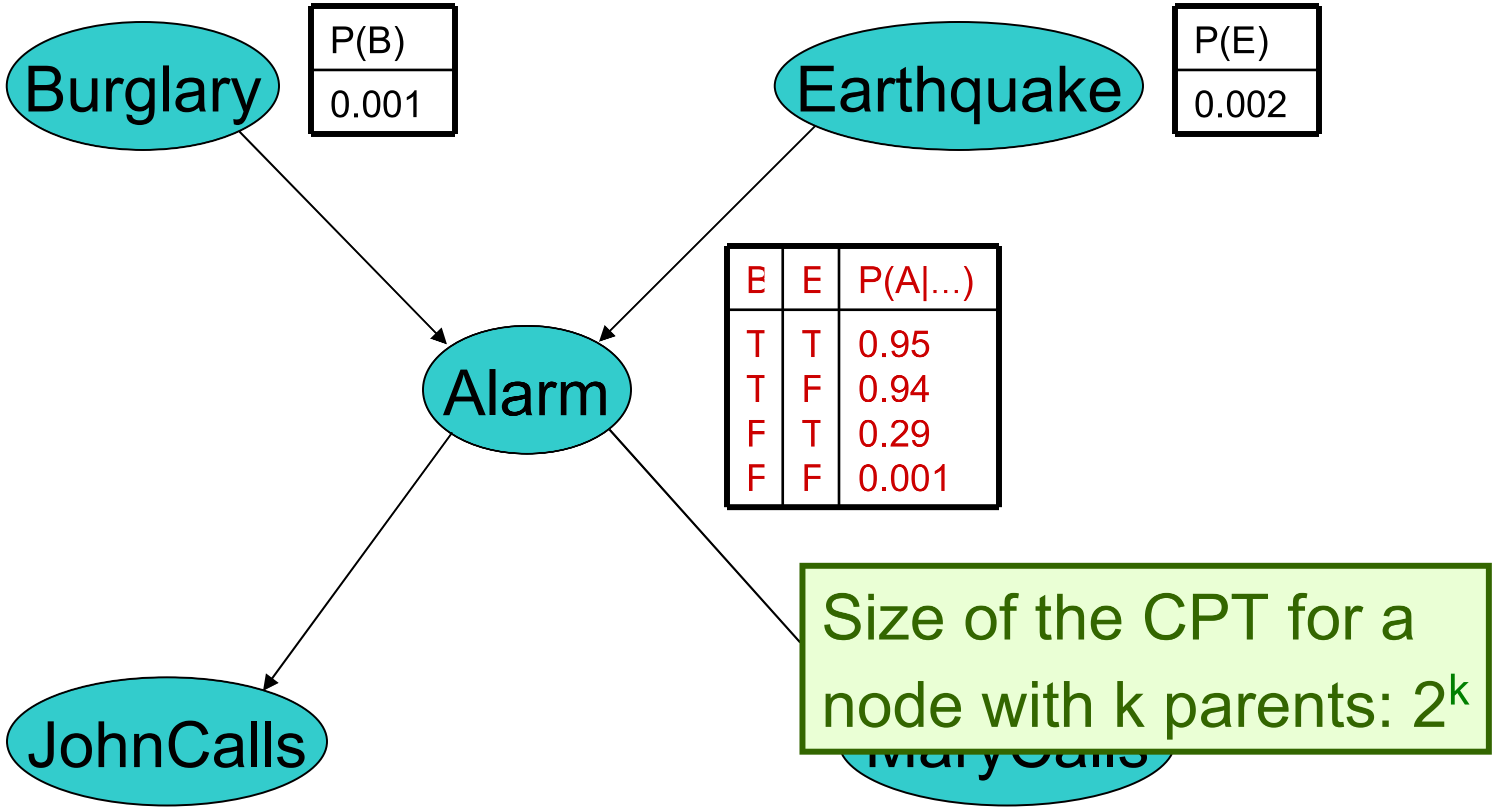
A Simple Bayes Net



Assigning Probabilities to Roots



Conditional Probability Tables



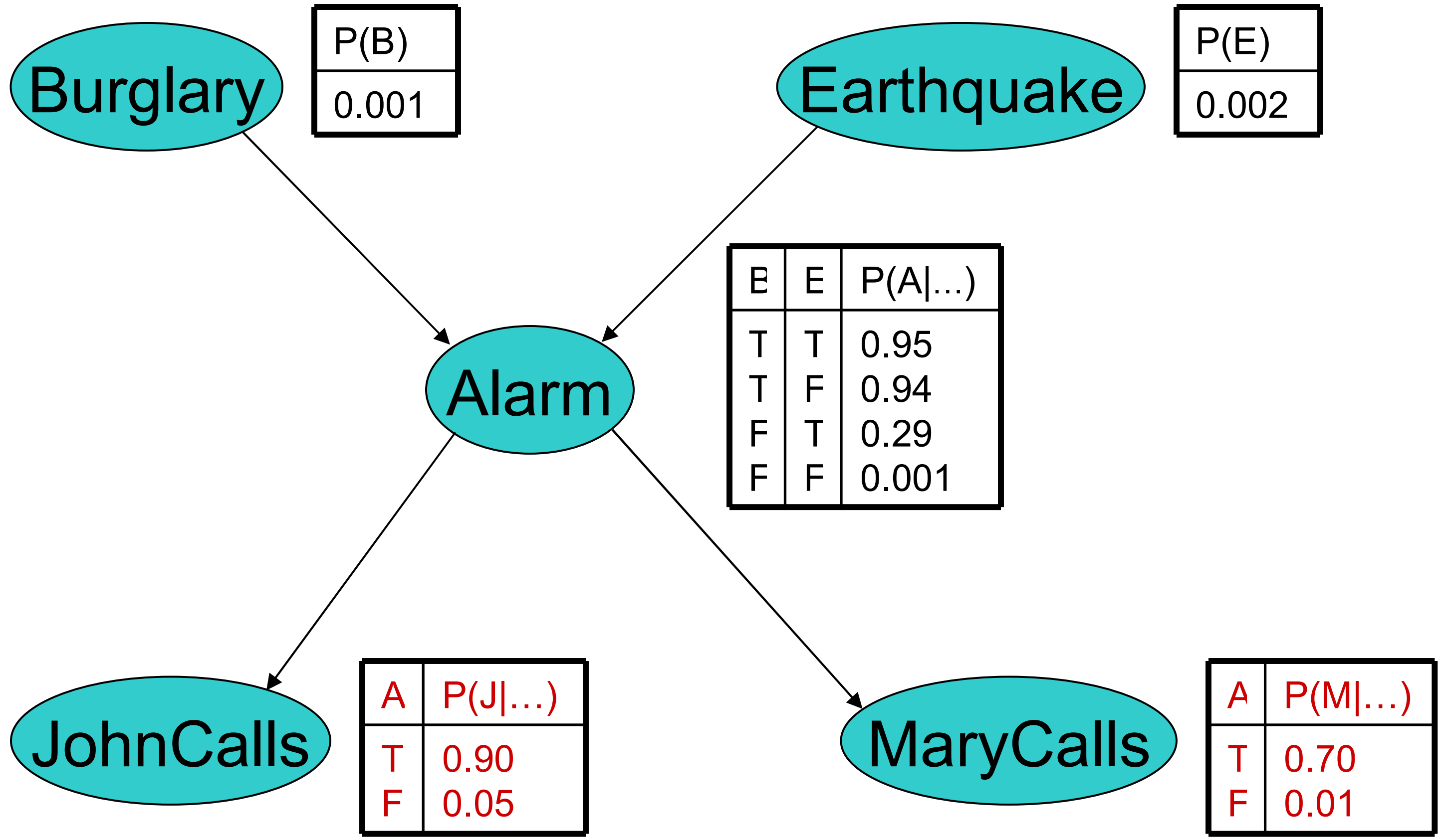
P(B)
0.001

P(E)
0.002

B	E	P(A|…)
T	T	0.95
T	F	0.94
F	T	0.29
F	F	0.001

Size of the CPT for a node with k parents: 2^k

Conditional Probability Tables



P(B)
0.001

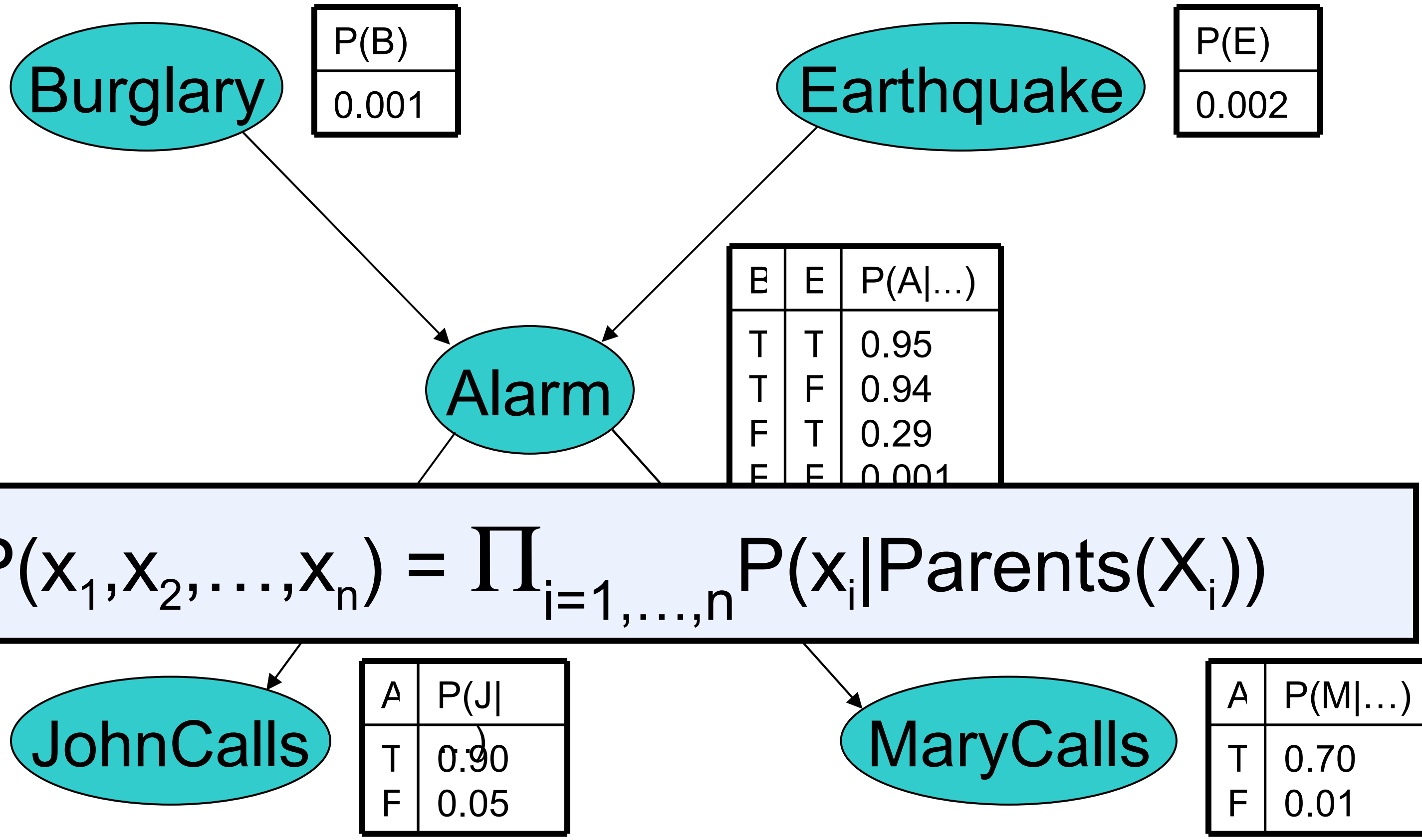
P(E)
0.002

B	E	P(A|…)
T	T	0.95
T	F	0.94
F	T	0.29
F	F	0.001

A	P(J|…)
T	0.90
F	0.05

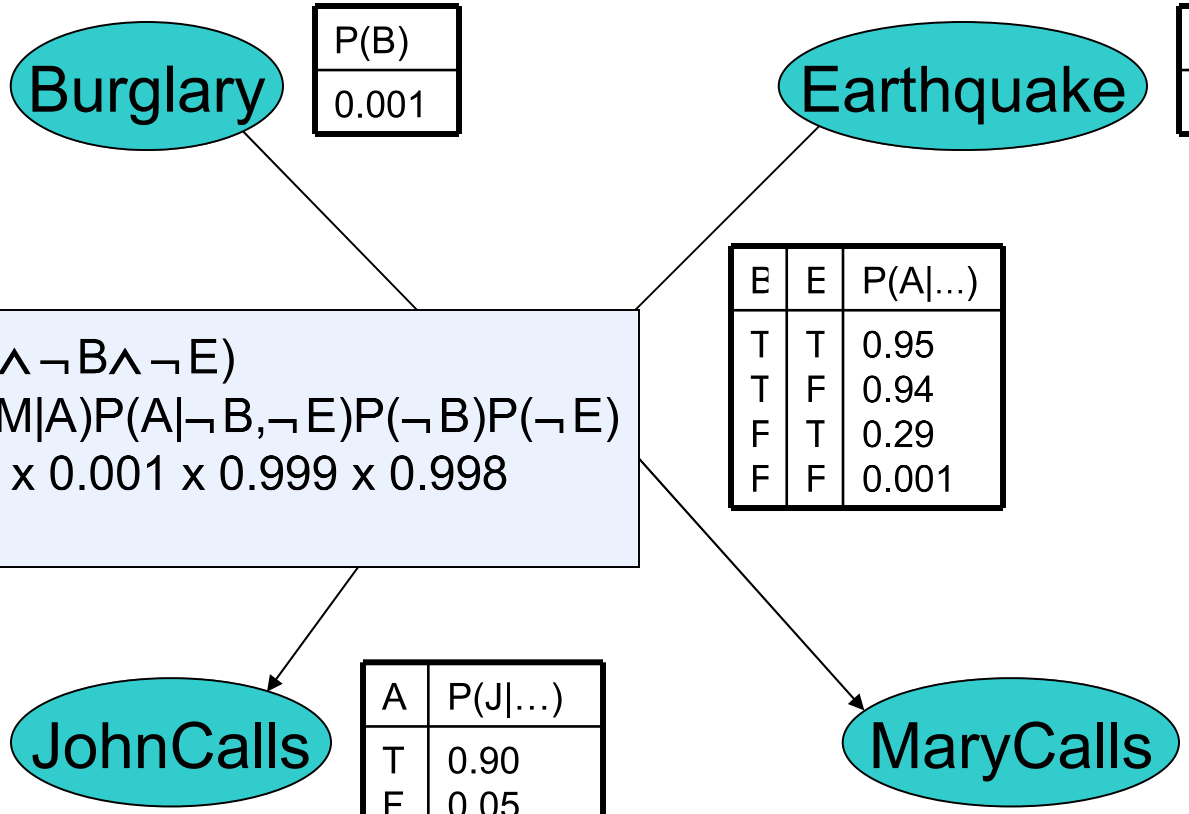
A	P(M|…)
T	0.70
F	0.01

What the BN Means



$$P(x_1,x_2,\ldots,x_n) = \prod_{i=1,\ldots,n} P(x_i|Parents(X_i))$$

Calculation of Joint Probability



P(B)
0.001

P(E)
0.002

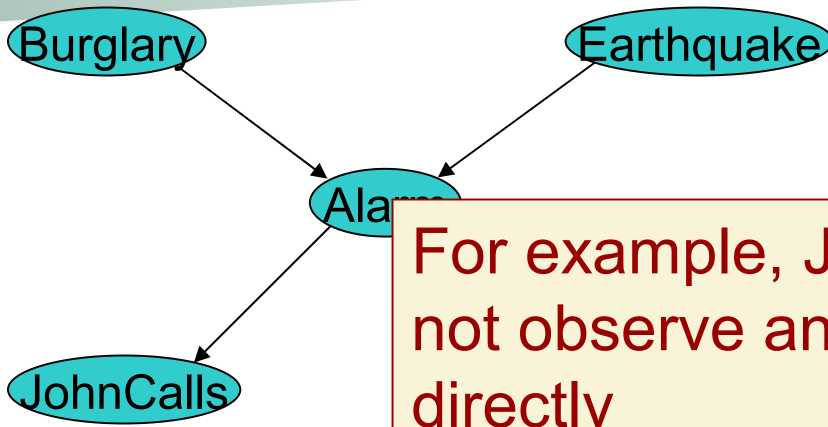
$P(J \wedge M \wedge A \wedge \neg B \wedge \neg E)$
$= P(J|A)P(M|A)P(A|\neg B,\neg E)P(\neg B)P(\neg E)$
$= 0.9 \times 0.7 \times 0.001 \times 0.999 \times 0.998$
$= 0.00062$

B	E	P(A|…)
T	T	0.95
T	F	0.94
F	T	0.29
F	F	0.001

A	P(J|…)
T	0.90
F	0.05

A	P(M|…)
T	0.70
F	0.01

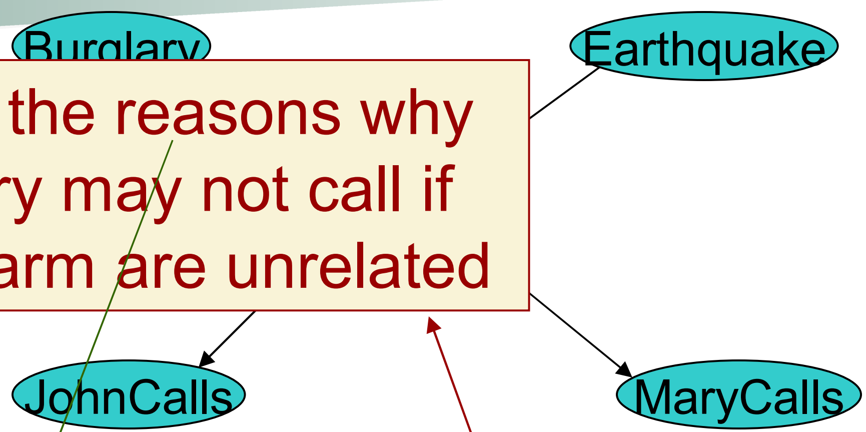
What the BN Encodes



For example, John does not observe any burglaries directly

- Each of the beliefs JohnCalls and MaryCalls is independent of Burglary and Earthquake given Alarm or ¬ Alarm
- The beliefs JohnCalls and MaryCalls are independent given Alarm or ¬ Alarm

What the BN Encodes



For instance, the reasons why John and Mary may not call if there is an alarm are unrelated

- Each of the beliefs

Note that these reasons could be other beliefs in the network. The probabilities summarize these non-explicit beliefs

Alarm or ¬ Alarm

- The beliefs JohnCalls nd MaryCalls are ndependent given larm or ¬ Alarm

D-Separation

- Say we want to know the probability of some variable (e.g. JohnCalls) given evidence on another (e.g. Alarm). What variables are relevant to this calculation?
- I.e.: Given an arbitrary graph G = (V,E), is X_A independent of $X_B | X_C$ for some A,B, and C?
- The answer can be read directly off the graph, using a notion called D-separation

What can Bayes nets be used for?

- **Posterior probabilities**
  - Probability of any event given any evidence
- Most likely explanation
  - Scenario that explains evidence
- Rational decision making
  - Maximize expected utility
  - Value of Information
- Effect of intervention
  - Causal analysis

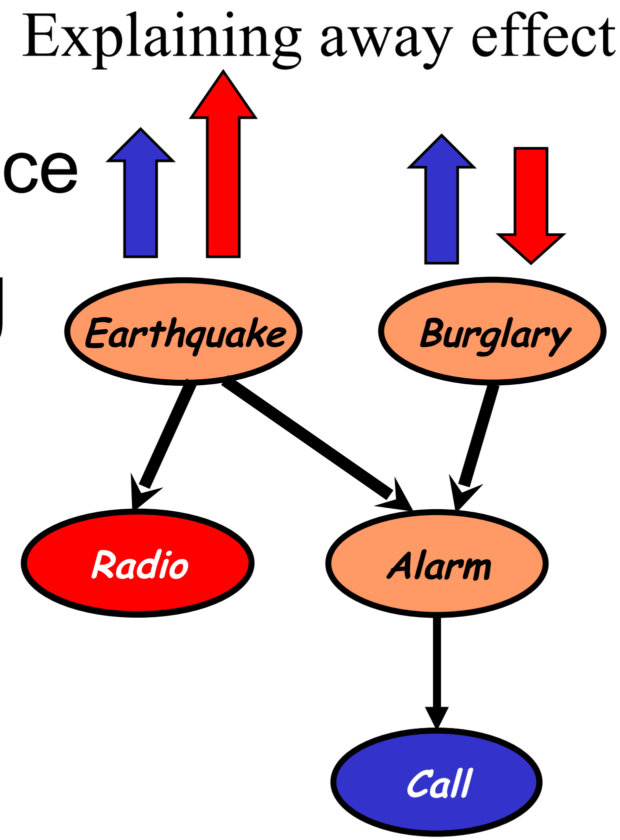
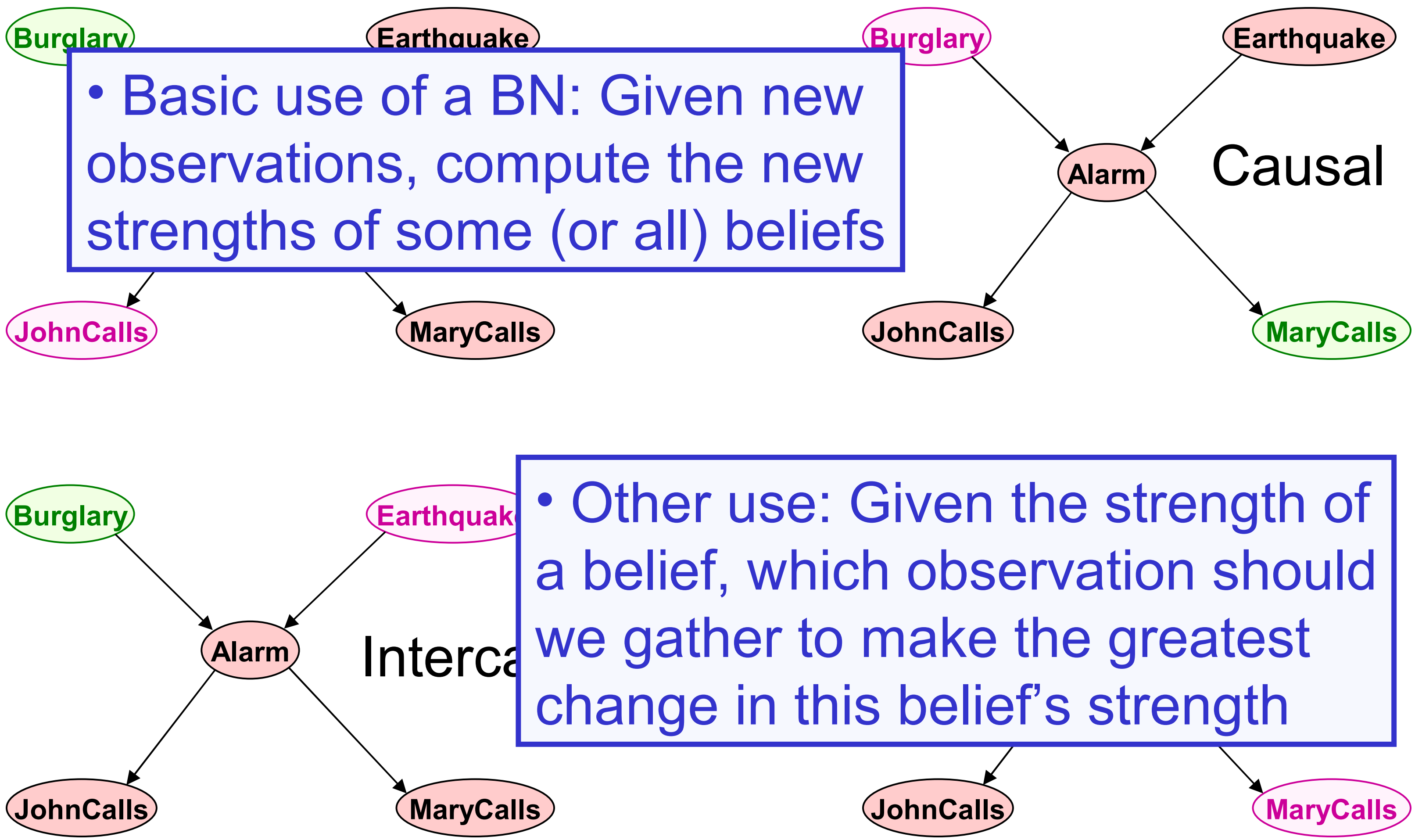


Figure from N. Friedman

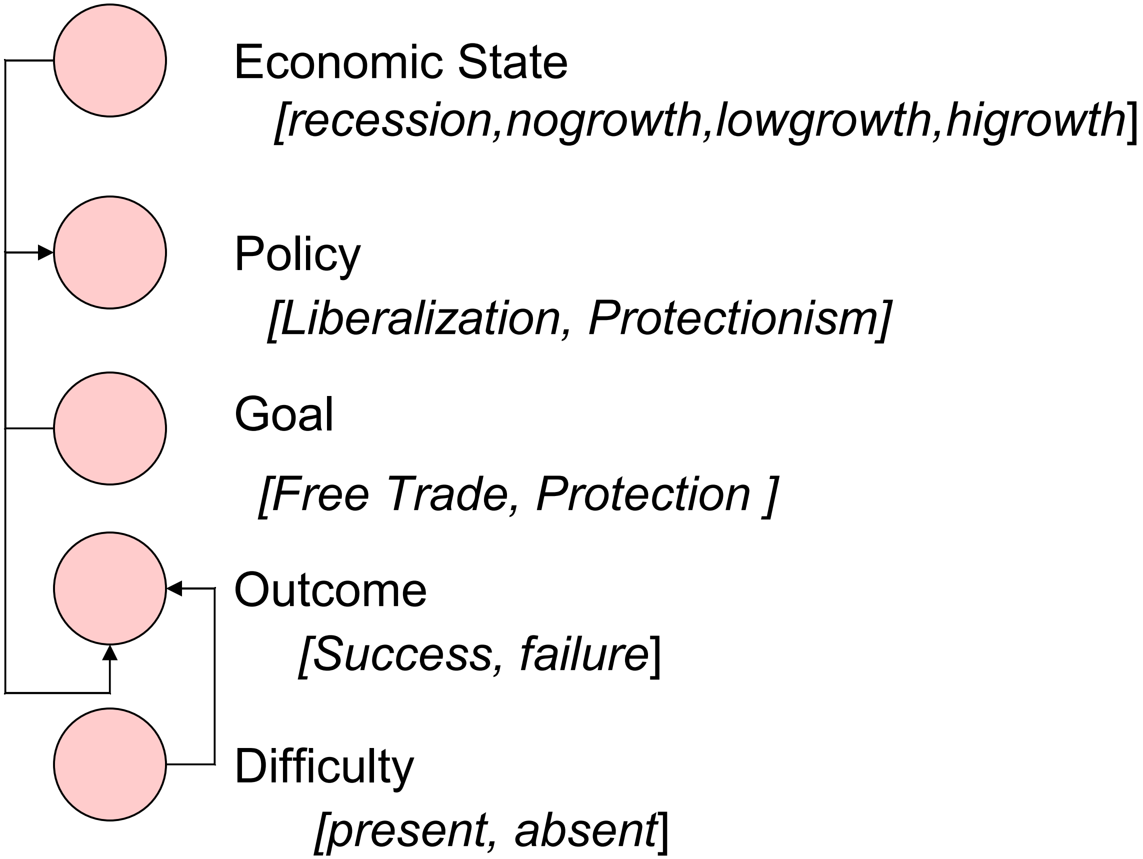
Inference Patterns

- Basic use of a BN: Given new observations, compute the new strengths of some (or all) beliefs

- Other use: Given the strength of a belief, which observation should we gather to make the greatest change in this belief's strength



A Simple Bayes Net for the target domain



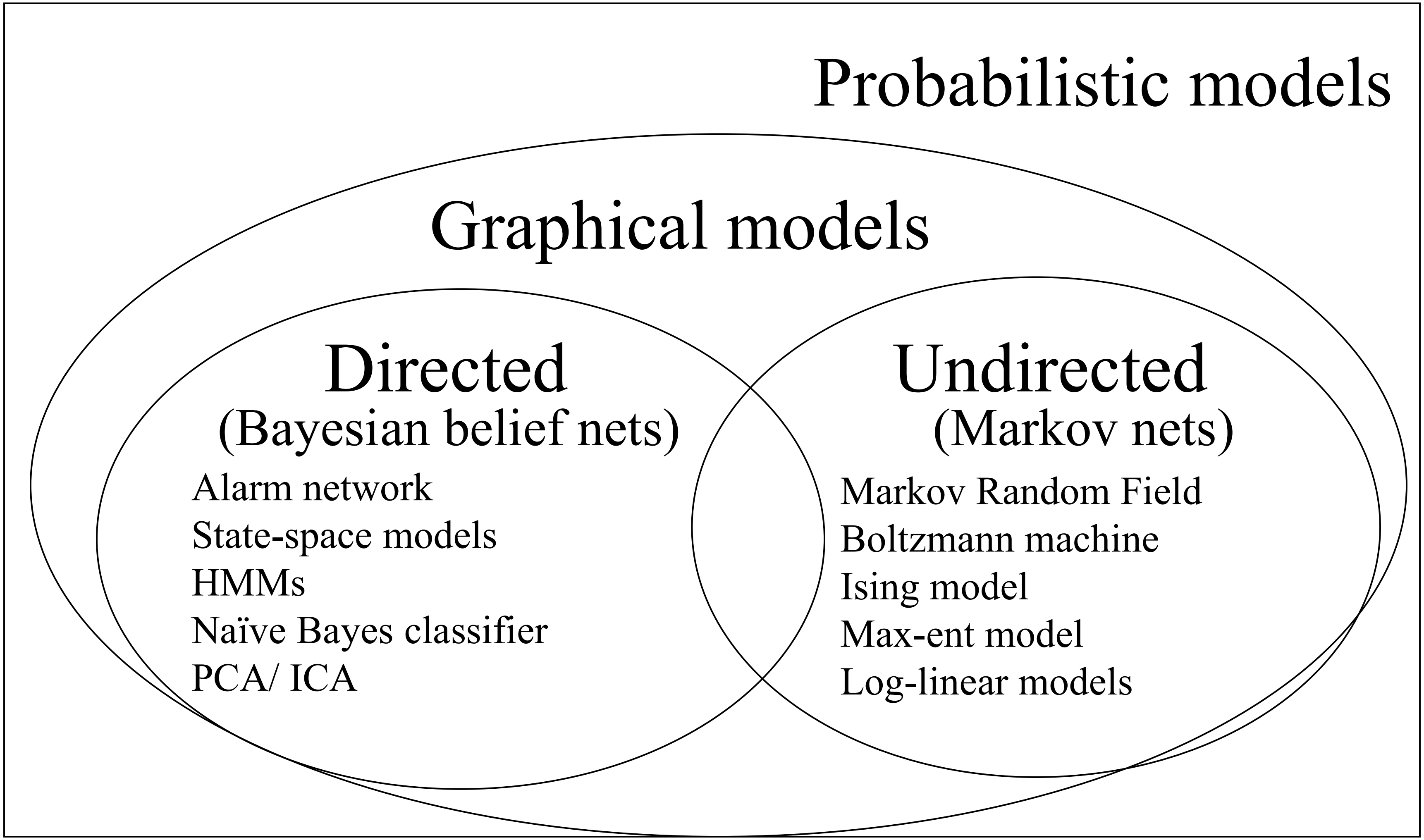
A Simple Bayes Net for the target domain of Economic Policy

G/P	L	P
F	.9	.1
P	.1	.9

Approaches to inference

- Exact inference
  - Inference in Simple Chains
  - Variable elimination
  - Clustering / join tree algorithms
- **Approximate inference**
  - Stochastic simulation / sampling methods
  - Markov chain Monte Carlo methods
  - Mean field theory

Probabilistic graphical models



Dynamic Bayes Nets

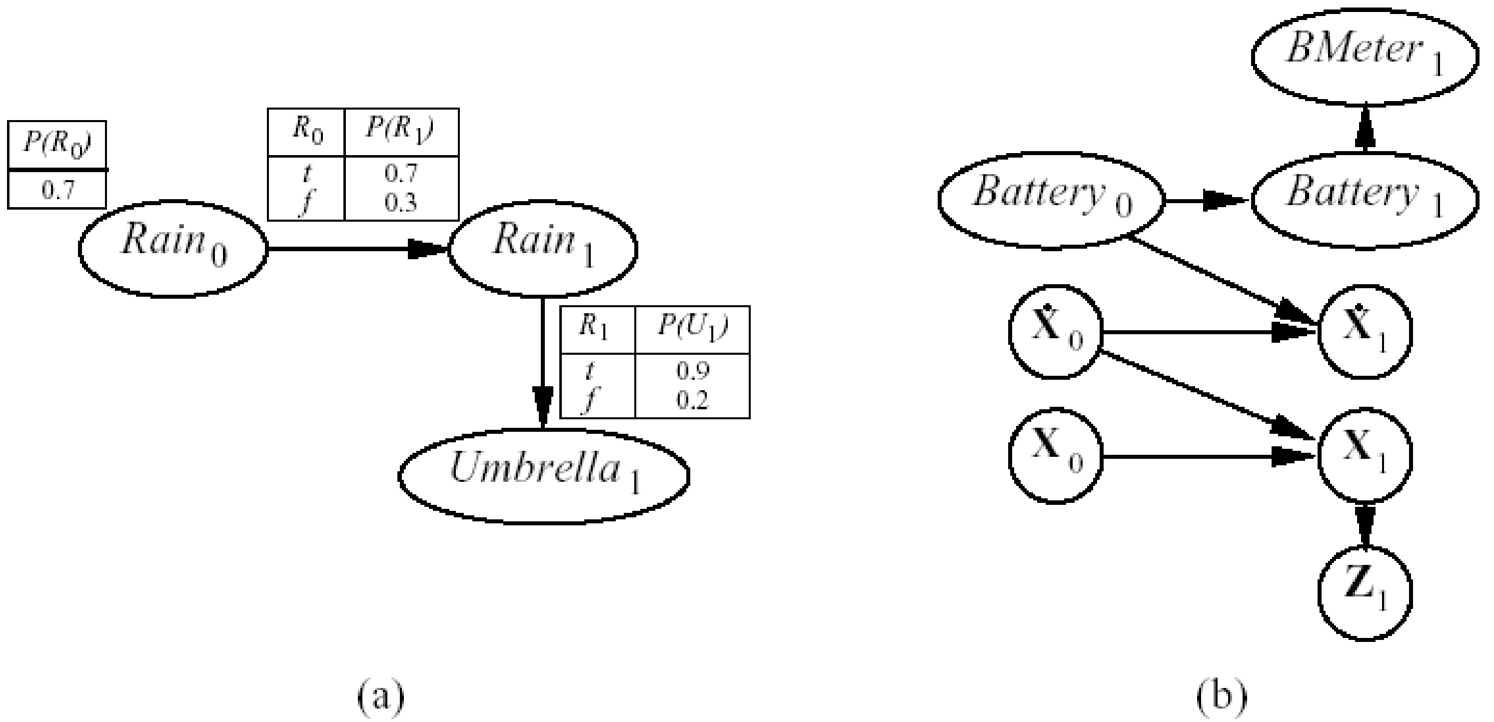
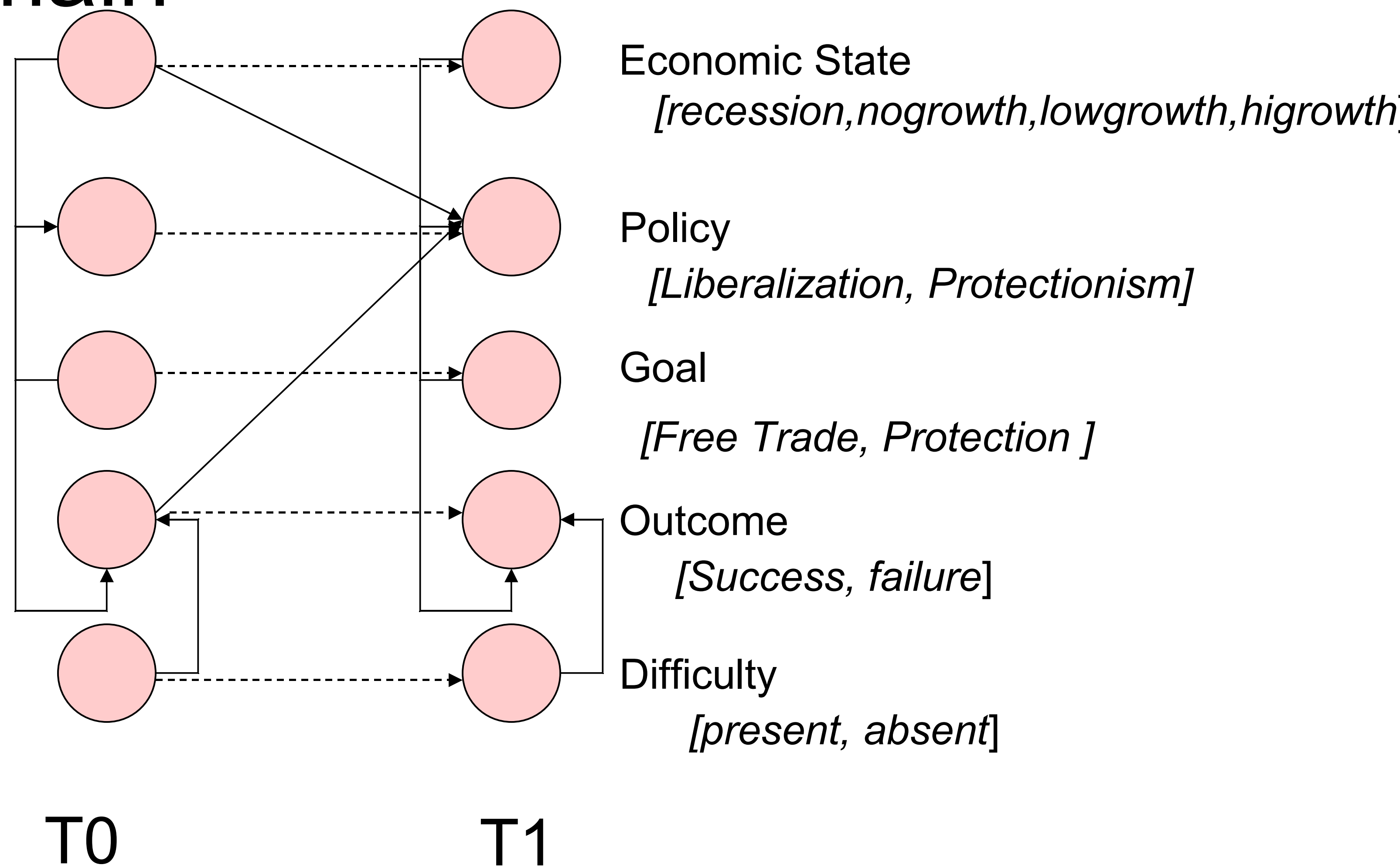


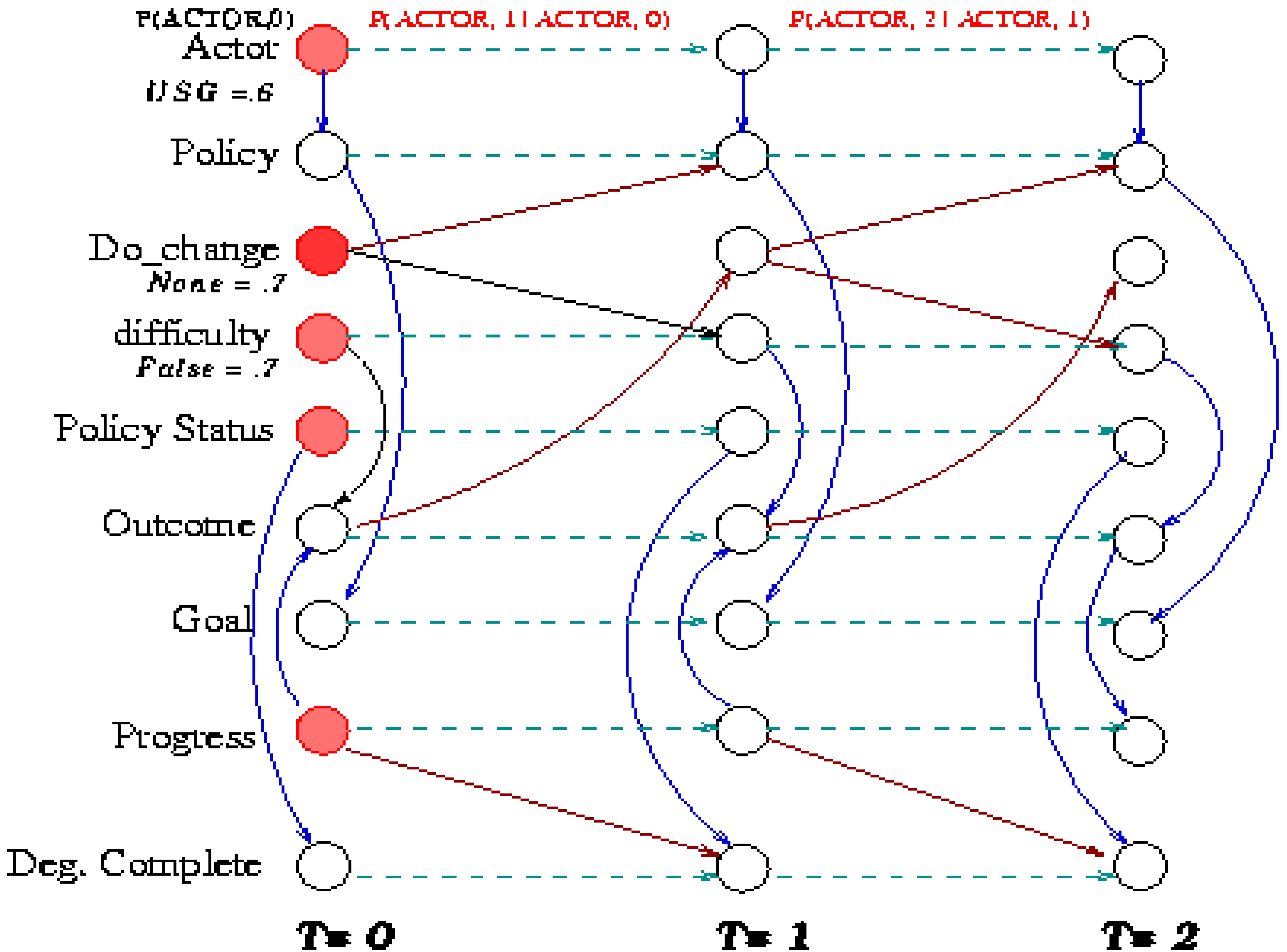
Figure 15.11 (a) Specification of the prior, transition model, and sensor model for the umbrella DBN. All subsequent slices are assumed to be copies of slice 1. (b) A simple DBN for robot motion in the X–Y plane.

States

- Factorized Representation of State uses Dynamic Belief Nets (DBN's)
  - Probabilistic Semantics
  - Structured Representation

A Simple DBN for the target domain





P(ACTOR,0)
P(ACTOR, 1 | ACTOR, 0)
P(ACTOR, 2 | ACTOR, 1)
Actor
USG =.6
Policy
Do_change
None = .7
difficulty
False = .7
Policy Status
Outcome
Goal
Progress
Deg. Complete
T= 0
T= 1
T= 2

Probabilistic inference

- Filtering
  - P(X_t | o_1…t,X_1…t)
  - Update the state based on the observation sequence and state set
- MAP Estimation
  - $\text{Argmax}_{h1\ldots hn}$P(X_t | o_1…t, X_1…t)
  - Return the best assignment of values to the hypothesis variables given the observation and states
- Smoothing
  - P(X_t-k | o_1…t, X_1…t)
  - modify assumptions about previous states, given observation sequence and state set
- Projection/Prediction/Reachability
  - P(X_t+k | o_1..t, X_1..t)

Metaphor Maps

- Static Structures that project bindings from source domain f- struct to target domain Bayes net nodes by setting evidence on the target network.
- Different types of maps
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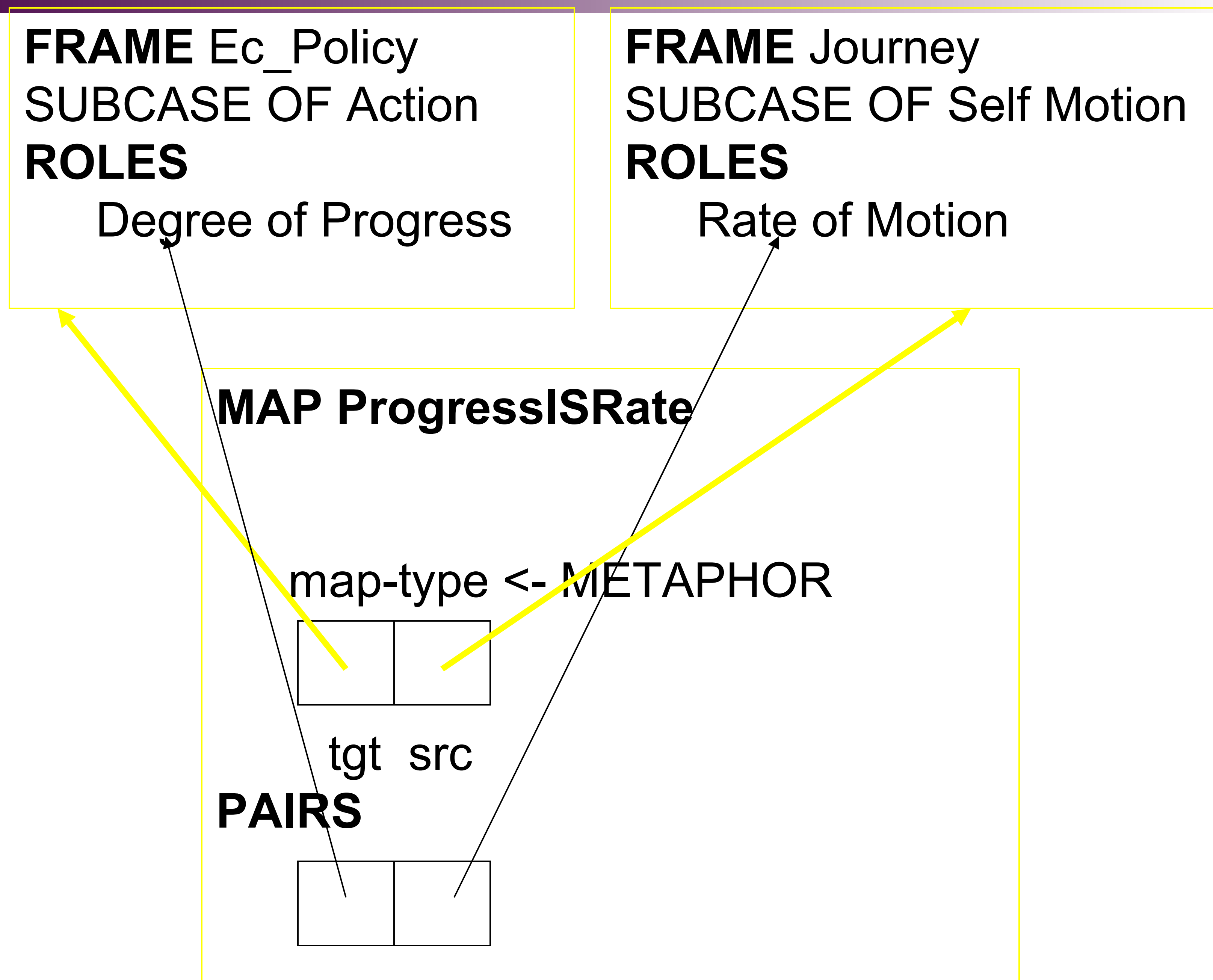
- ASPECT is an invariant in projection.



FRAME Ec_Policy
SUBCASE OF Action
ROLES
Degree of Progress
FRAME Journey
SUBCASE OF Self Motion
ROLES
Rate of Motion
MAP ProgressISRate
map-type <- METAPHOR
tgt
src
PAIRS

Lecture Overview

- Metaphors
  - Primary Metaphors
  - Complex Metaphors
- A computational Model of Event Structure
- Applying the Model to understanding newspaper articles.
  - Demo
- Extensions and Scalable Inference

Task: Interpret simple discourse fragments

- France fell into recession. Pulled out by Germany
- US Economy on the verge of falling back into recession after moving forward on an anemic recovery.
- Indian Government stumbling in implementing Liberalization plan.
- Moving forward on all fronts, we are going to be ongoing and relentless as we tighten the net of justice.
- The Government is taking bold new steps. We are loosening the stranglehold on business, slashing tariffs and removing obstacles to international trade.

I/O as Feature Structures

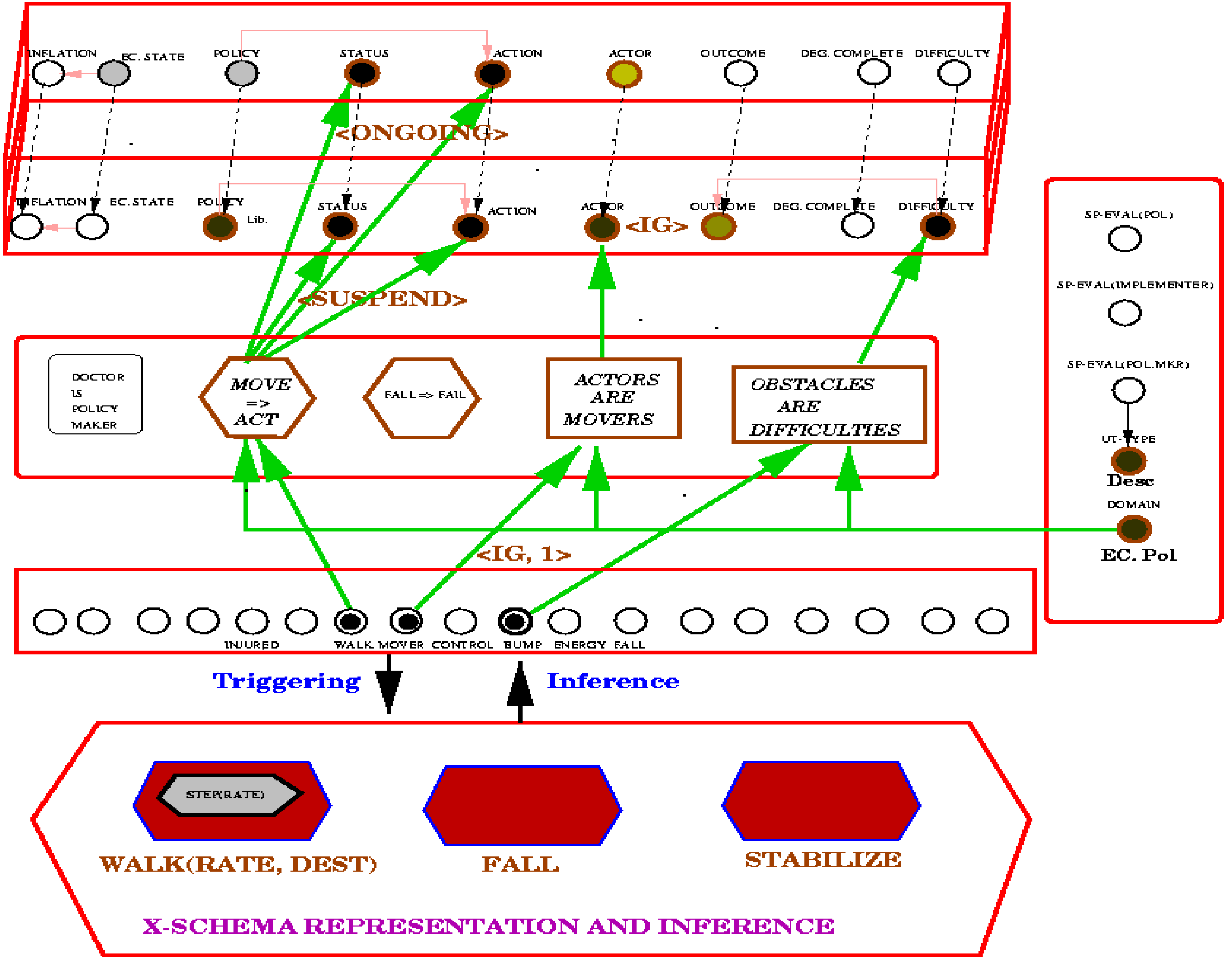
- ***Indian Government stumbling in implementing liberalization plan***

Input

Event	Domain	Actor	Aspect
stumble(IG)	Liberalization Plan	Indian Gov. (IG)	present-progressive

Output

Event	Domain	*Context*	*Status*	*Outcome*	*Goal*
stumble (IG)	Liberalization Plan	Ongoing plan, **difficulty**	**inter-rupted(.8)**	**failure (.7)**	***free-trade, deregula-tion***



INFLATION
EC. STATE
POLICY
STATUS
ACTION
ACTOR
OUTCOME
DEG. COMPLETE
DIFFICULTY
<ONGOING>
Lib.
<IG>
<SUSPEND>
DOCTOR IS POLICY MAKER
MOVE => ACT
FALL => FAIL
ACTORS ARE MOVERS
OBSTACLES ARE DIFFICULTIES
SP-EVAL(POL)
SP-EVAL(IMPLEMENTER)
SP-EVAL(POL.MKR)
UT-TYPE
Desc
DOMAIN
EC. Pol
<IG, 1>
INJURED
WALK
MOVER
CONTROL
BUMP
ENERGY
FALL
Triggering
Inference
STEP(RATE)
WALK(RATE, DEST)
FALL
STABILIZE
X-SCHEMA REPRESENTATION AND INFERENCE

KARMA DEMO

- **SOURCE DOMAINS: MOTION, HEALTH**
- **TARGET DOMAINS: INTERNATONAL ECONOMICS**
- **METAPHOR MAPS: EVENT STRUCTURE METAPHOR**

Results

- Model was implemented and tested on discourse fragments from a database of 50 newspaper stories in international economics from standard sources such as WSJ, NYT, and the Economist. Results show that motion terms are often the most effective method to provide the following types of information about abstract plans and actions.
  - Information about uncertain events and dynamic changes in goals and resources. (sluggish, fall, off-track, no steam)
  - Information about evaluations of policies and economic actors and communicative intent (strangle-hold, bleed).
  - Communicating complex, context-sensitive and dynamic economic scenarios (stumble, slide, slippery slope).
  - Communicating complex event structure and aspectual information (on the verge of, sidestep, giant leap, small steps, ready, set out, back on track).
- ALL THESE BINDINGS RESULT FROM REFLEX, AUTOMATIC INFERENCES PROVIDED BY X-SCHEMA BASED INFERENCES.

Psycholinguistic evidence

- Embodied language impairs action/perception
  - Sentences with **visual components** to their meaning can interfere with performance of visual tasks (Richardson et al. 2003)
  - Sentences describing motion can interfere with performance of **incompatible motor actions** (Glenberg and Kashak 2002)
  - Sentences describing **incompatible visual imagery** impedes decision task (Zwaan et al. 2002)
  - Verbs associated with particular effectors activates corresponding areas of motor cortex (Pulvermuller et al. 2001, Hauk et al. 2004
  - Effector-specific Interference Effects with **visual priming** (Narayan,Bergen,Feldman 2002)

- Simulation effects from fictive motion sentences
  - Fictive motion sentences describing paths that require **longer time**, span a **greater distance**, or involve **more obstacles** impede decision task (Matlock 2000, Matlock et al. 2003)

Discussion

- Language acquisition and use is a hallmark of being human
  - Language seems to rely on fine-grained aspects of embodied (sensory-motor and social cognition) primitives and brain-like computation (massively parallel, distributed, spreading activation, temporal binding).
  - Understanding requires imaginative simulation!
  - We have built a pilot system that demonstrates the use of motor control representations in grounding the language of abstract actions and policies.
    - Sensory-Motor imagination and simulation is crucial in interpretation!
- Coming Attractions
  - How could a neural net bind variables
  - Grammar
  - Grammar and Analysis
  - Learning Grammar

Language understanding: analysis & simulation