

The Neural Basis of Thought and Language

Week 11

Metaphor and Automatic
Reasoning



Schedule

- Assignment 7 extension, due Tuesday in class
- Last Week
 - Aspect and Tense
 - Event Structure Metaphor
- This Week
 - Inference, KARMA: Knowledge-based Action Representations for Metaphor and Aspect
 - The binding theory, automatic inference, and SHRUTI
- Next Week
 - Grammar

Last few lectures

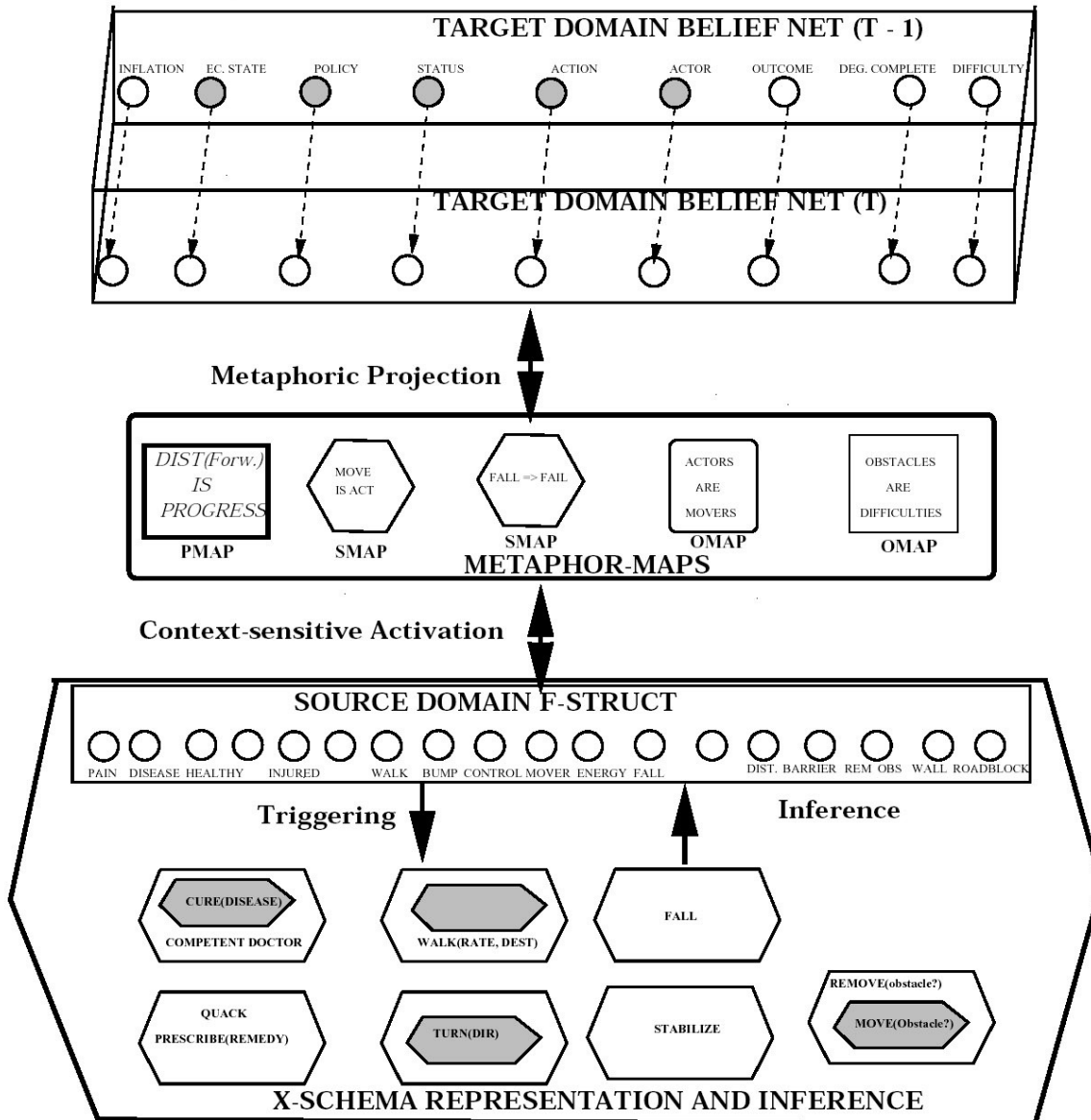
- What topics do you want to go over in the last few lectures?

Questions

1. How are the source and target domains represented in KARMA?
2. How does the source domain information enter KARMA? How should it?
3. What does SHRUTI buy us?
4. How are bindings propagated in a structured connectionist framework?

KARMA

- DBN to represent target domain knowledge
- Metaphor maps link target and source domain
- X-schema to represent source domain knowledge

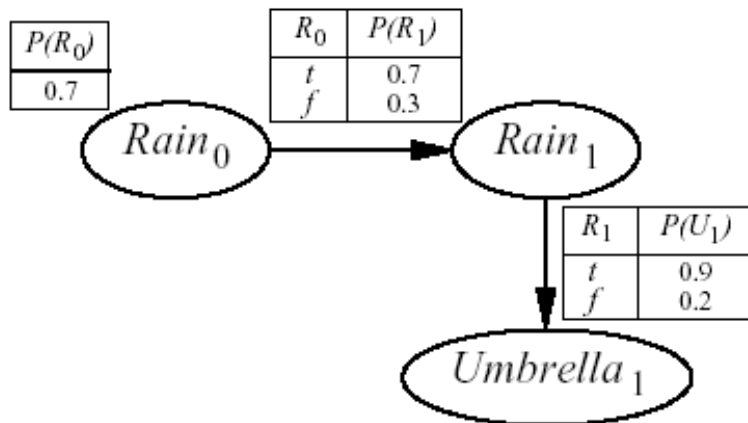


DBNs

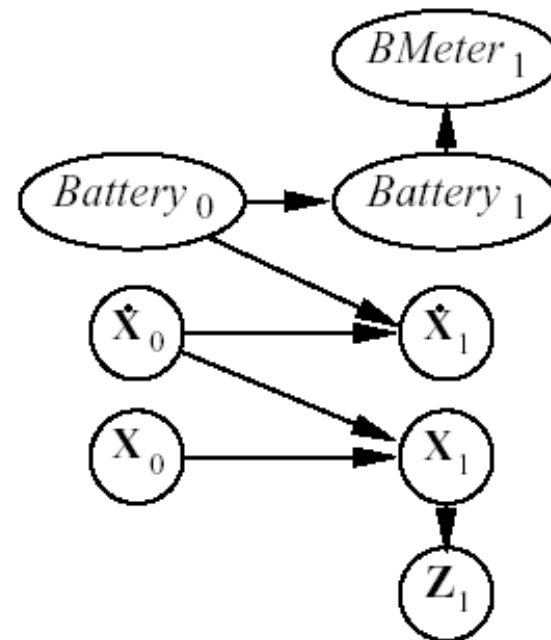
- Explicit causal relations + full joint table \rightarrow Bayes Nets
- Sequence of full joint states over time \rightarrow HMM
- HMM + BN \rightarrow DBNs

- DBNs are a generalization of HMMs which capture sparse causal relationships of full joint

Dynamic Bayes Nets



(a)



(b)

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.

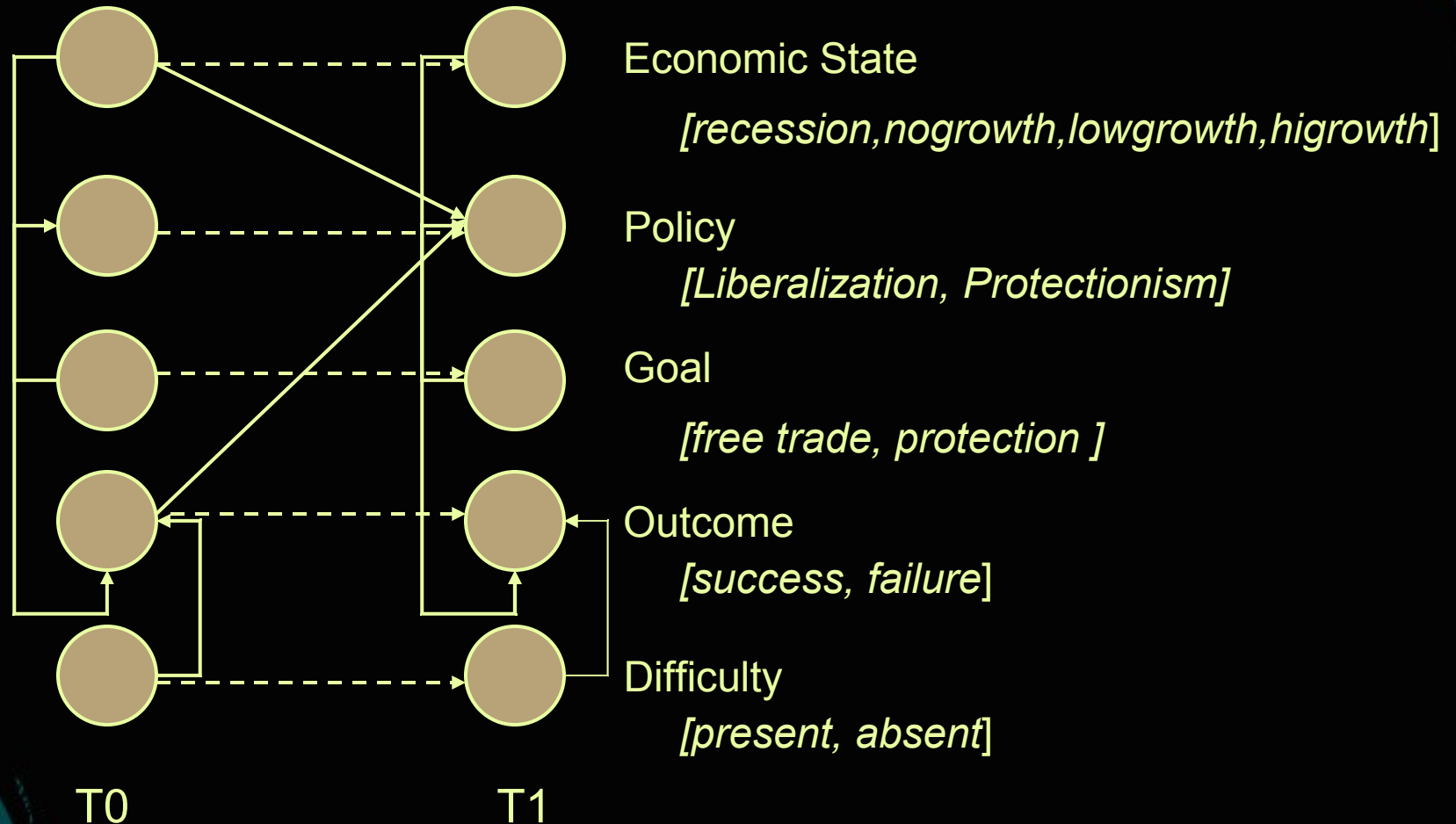
Metaphor Maps

- map **entities and objects** between embodied and abstract domains
- invariantly map the **aspect** of the embodied domain event onto the target domain
by setting the evidence for the status variable based on controller state (event structure metaphor)
- project x-schema **parameters** onto the target domain

Where does the domain knowledge come from?

- Both domains are structured by frames
- Frames have:
 - List of roles (participants, frame elements)
 - Relations between roles
 - Scenario structure

DBN for the target domain



Let's try a different domain

- I didn't quite *catch* what he was saying
- His slides are *packed* with information
- He *sent* the audience a clear message

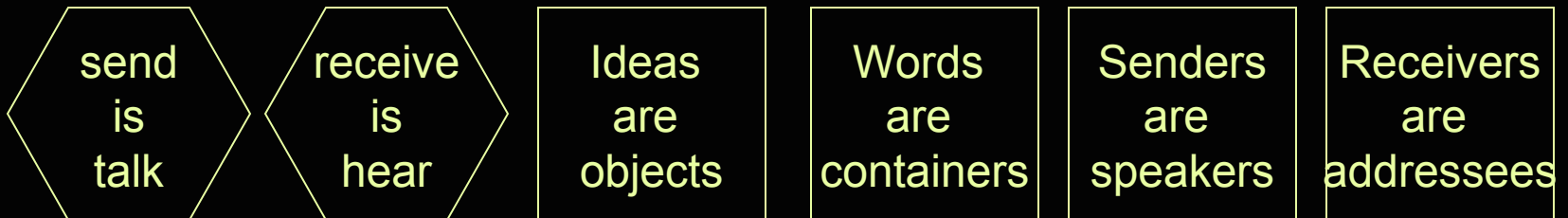
When we can get a good *flow* of information from the streets of our cities *across* to, whether it is an investigating magistrate in France or an intelligence operative in the Middle East, and begin to *assemble* that kind of information and analyze it and *repackage* it and *send* it back out to users, whether it's a policeman on the beat or a judge in Italy or a Special Forces Team in Afghanistan, then we will be getting close to the kind of capability we need to deal with this kind of problem. That's going to take a couple, a few years.

Target domain belief net (T-1)

Target domain belief net (T) (communication frame)



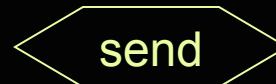
Metaphor Map (conduit metaphor)



Source domain f-structs (transfer)



X-Schema representation



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How do the source domain f-structs get parameterized?

- In the KARMA system, they are hand-coded.
- In general, you need analysis of sentences:
 - syntax
 - semantics



Syntax captures:

- constraints on word order
- constituency (units of words)
- grammatical relations (e.g. subject, object)
- subcategorization & dependency (e.g. transitive, intransitive, subject-verb agreement)

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SHRUTI

- A connectionist model of **reflexive processing**

Reflexive reasoning

automatic, extremely fast (~300ms), ubiquitous

- computation of coherent explanations and predictions
- gradual learning of causal structure
- episodic memory
- understanding language

Reflective reasoning

conscious deliberation, slow
overt consideration of alternatives
external props (pencil + paper)

- solving logic puzzles
- doing cryptarithmic
- planning a vacation

SHRUTI

- synchronous activity without using global clock
- An episode of reflexive processing is a **transient** propagation of **rhythmic** activity
- An “entity” is a **phase** in the above rhythmic activity.
- **Bindings** are synchronous firings of **role** and **entity** cells
- **Rules** are interconnection patterns mediated by coincidence detector circuits that allow selective propagation of activity
- Long-term memories are coincidence and coincidence-failure detector circuits
- An affirmative answer / explanation corresponds to reverberatory activity around closed loops

focal cluster

- provides locus of coordination, control and decision making
- enforce sequencing and concurrency
- initiate information seeking actions
- initiate evaluation of conditions
- initiate conditional actions
- link to other schemas, knowledge structures

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dynamic binding example

entity



type



predicate



- asserting that `get(father, cup)`

- father fires in phase with agent role
- cup fires in phase with patient role

Active Schemas in SHRUTI

- active schemas require control and coordination, dynamic role binding and parameter setting
- schemas are interconnected networks of **focal clusters**
- bindings are encoded and propagated using **temporal synchrony**
- scalar parameters are encoded using **rate-encoding**