Constructive Hybrid Logics and Contexts

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Outline

- Motivation
- Textual Inference Logic
- Contexts as Modalities
- Contexts as @-operators
- The experiment
- Discussion

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An applied logician's job is never done…

- When modeling a system as a logic you can start from the system

- Or you can start from logics that could fit it
- Hopefully the two meet up…

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Motivation: Logic for Text Understanding

- A logic for reasoning about questions and answers using formulae automatically created from texts in English
- Logic used both to describe the logical representation of information and to answer/solve/infer questions
- How?
- Build upon decades of work on NLP at PARC

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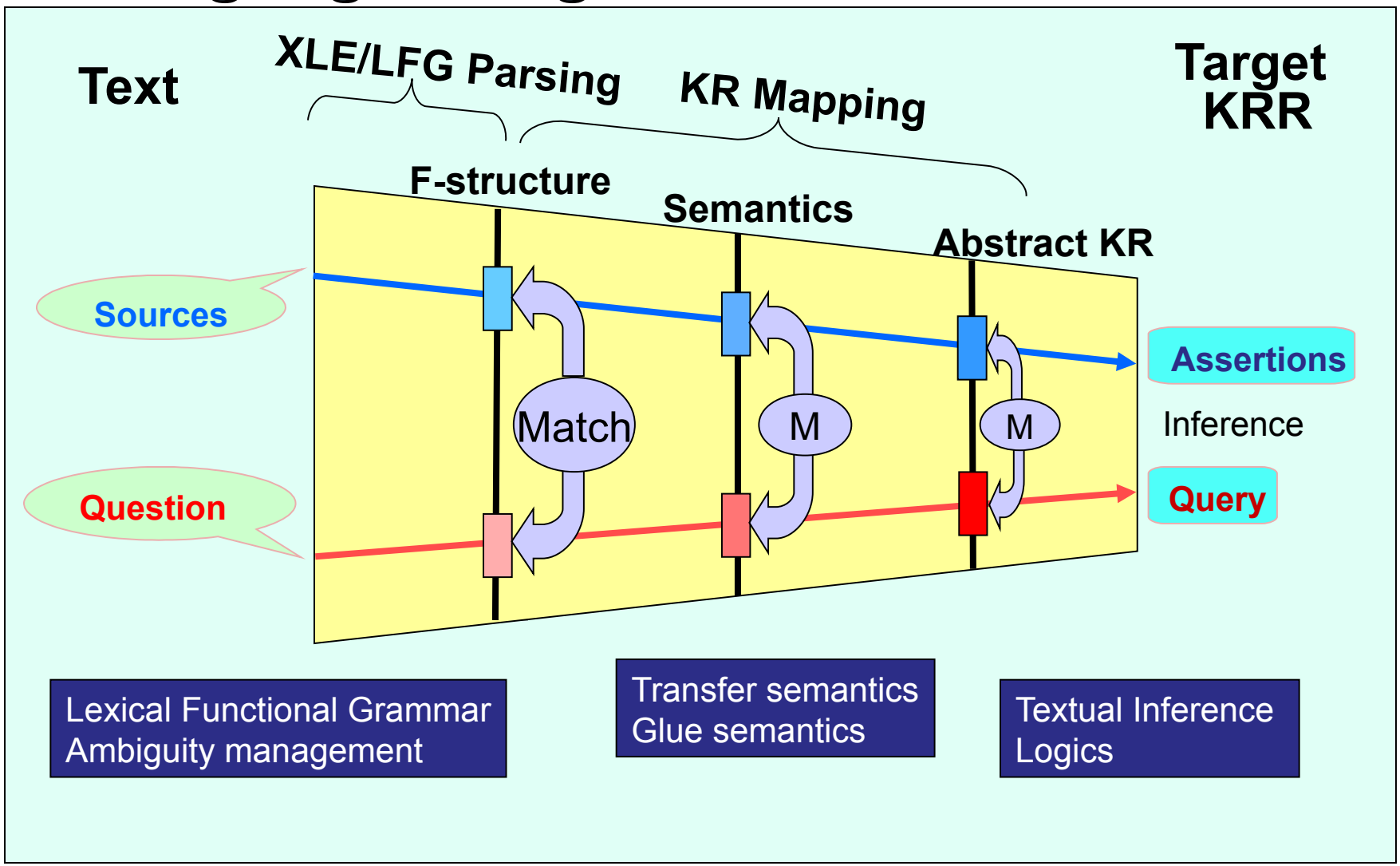
Motivation: PARC's approach

- Knowledge-based question answering
  - Deep/logical representations allow high precision and recall, but
  - Typically on restricted domains
  - Hard for users to pose KR questions and interpret KR answers
  - Very hard for system to build up knowledge

- Shallow, open-domain question answering
  - Broad-coverage
  - Lower precision and recall
  - Easy to pose questions but sensitive to question form

- Question answering at PARC
  - Layered mapping from language to deeper semantic representations
  - Broad-coverage: Matching for answers as light reasoning
  - Expresses KRR answers in real English -- eventually

Architecture: 2-way bridge between language & logic



Key Process: Canonicalization of representations

- Sentences are parsed into f(unctional)-structures using XLE
- F-structures are (somewhat) semantic representations
- Transform f-structures into (flat and contexted) transfer semantic structures

  (inspired by Glue and need to 'pack' semantics)
- Transform transfer sem-structures into (flat and contexted) AKR structures
- Today: Discuss logics for AKR structures
- but before that, what do these layers of representation buy you?

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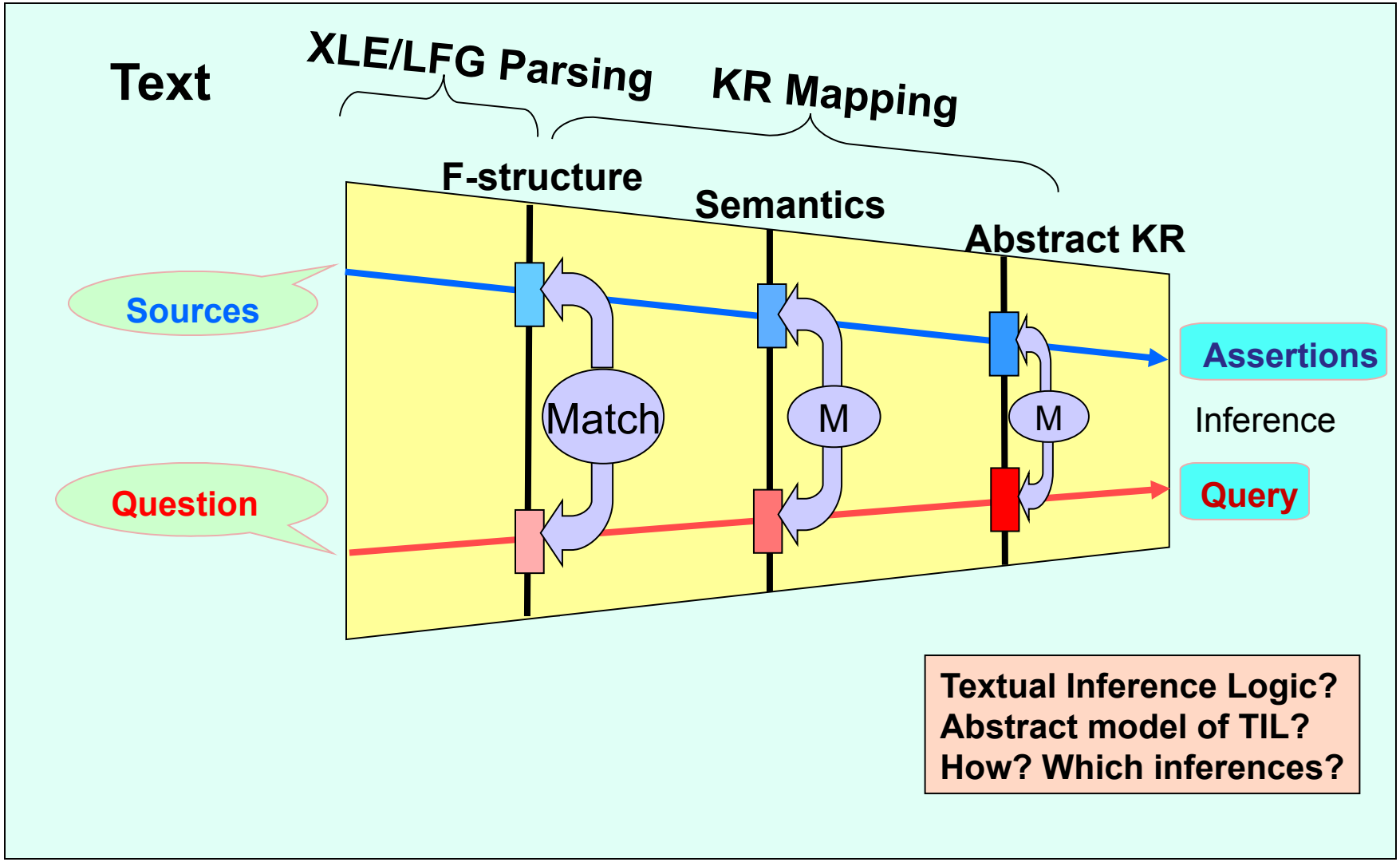
Canonicalization helps matching

- Argument structure:
  - Mary bought an apple/An apple was bought by Mary.
- Synonyms and hypernyms:
  - Mary bought/purchased/acquired an apple.
- Factivity and contexts:
  - Mary bought an apple/Mary did not buy an apple.
  - Mary managed/failed to buy an apple.
  - Ed prevented Mary from buying an apple.
  - We know/said/believe that Mary bought an apple.
  - Mary didn't wait to buy an apple.

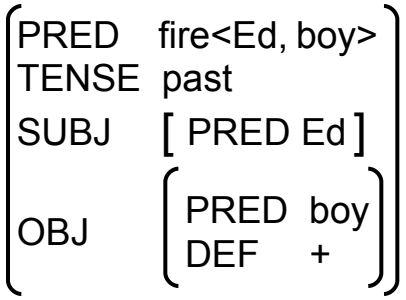
Layers to overcome language/KR misalignments:

- Language
  - Generalizations come from the structure of the language
  - Representations compositionally derived from sentence structure
- Knowledge representation and reasoning
  - Generalizations come from the structure of the world
  - Representations to support reasoning
- Layered architecture helps with different constraints
- But boundaries are not fixed (like beads in a string?)

This talk: Logics for Abstract KR only



Abstract KR: "Ed fired the boy." (Cyc version)




```
(subconcept Ed3 Person)
(subconcept boy2 MaleChild)
(subconcept fire_ev1 DischargeWithPrejudice)
(role fire_ev1 performedBy Ed3)
(role fire_ev1 objectActedOn boy2)
```

Conceptual

```
(context t)
(instantiable Ed3 t)
(instantiable boy2 t)
(instantiable fire_ev1 t)
```

Contextual

```
(temporalRel startsAfterEndingOf Now
  fire_ev1)
```

Temporal

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Abstract Knowledge Representation

- Encode different aspects of meaning
  - Asserted content
    - » **concepts and arguments, relations among objects**
  - Contexts
    - » **author commitment, belief, report, denial, prevent, …**
  - Temporal relations
    - » **qualitative relations among time intervals, events**
- Translate to various target KR's

  e.g. CycL, Knowledge Machine, AnsProlog
- Capture meaning ambiguity
  - Mapping to KR can introduce and reduce ambiguity
  - Need to handle ambiguity efficiently
- A Basic Logic for Textual Inference (Bobrow et al, July 05)

Textual Inference Logic (TIL)
Cyc version (Bobrow et al 2005)

- A contexted version of a description logic of concepts
- Static Cyc concepts: **`Person`**, **`MaleChild,`**, **`DischargeWithPrejudice`**, etc..
- Cyc Roles: **`objectActedOn`**, **`performedBy`**, **`infoTransferred`**, etc
- Dynamic concepts like **`Ed3, boy2`** and **`fire_ev1`**
- WordNet/VerbNet as fallback mechanisms
- Sortal restrictions from Cyc disambiguate

  e.g, Ed fired the boy/Ed fired the gun.
- Limitation: raggedness of Cyc

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Textual Inference Logic (TIL)
WN/VN version 2006

- A contexted version of a description logic of concepts
- Concepts from WordNet: e.g. [1740] synset for **`Thing`**
- VerbNet Roles: **`Agent`**, **`Theme`**, **`Experiencer`**, etc
- Sortal restrictions not used to disambiguate

  e.g, Ed fired the boy/the gun ➔ packed version of 'fire'.
- Contexts as black boxes/boundaries, e.g "Mary knows that Ed fired the boy", two contexts t and what is known, named by firing event.

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Ed fired the boy.

```
cf(1, context(t)),
cf(1, instantiable(‘Ed##0',t)),
cf(1, instantiable('boy##3',t)),
cf(1, instantiable('fire##1',t)),
cf(1, role('Agent','fire##1',‘Ed##0')),
cf(1, role('Theme','fire##1','boy##3')),
cf(1,subconcept(‘Ed##0',[[7626,4576]])),
cf(1,subconcept('boy##3',[[10131706],[9725282],[10464570],
    [9500236] ),),
  cf(A1, subconcept('fire##1',[[1124984],[1123061],[1123474]])),
  cf(A2, subconcept('fire##1',[[2379472]])),
  cf(1, temporalRel(startsAfterEndingOf,'Now','fire##1'))
```

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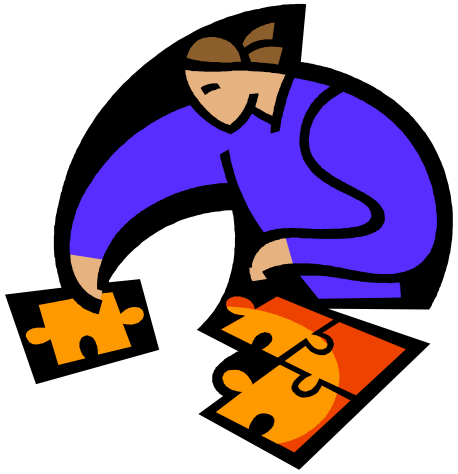
So far starting from the system…



Now for off-the-shelf logical systems:

- Modal logic
- Hybrid logic
- Description logic
- Situation Semantics
- MCS/LMS
- FOL/HOL
- Intensional Logic
- Etc…

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TIL Contexts

- **Contexts** introduced by syntactical items such as verbs, adverbs and adjectives
- Contexts in TIL like nano-theories to Cyc's microtheories
- How do we analyze the logic of contexts?
- If instead of concepts and roles we had traditional propositional logic formulae, then contexts could be thought of as modalities in
- **McCarthy's logic of contexts**
- Slogan: contexts as constructive modalities

Contexts as Constructive Modalities

- Abstract version of TIL has contexts that behave like **black boxes**
- Similar to McCarthy's 'Logic of Contexts', as formalized by Buvac and Mason
- Can be seen as a multimodal system K
- Paper in Context2003 proposes a **constructive** version of multimodal K
- Several constructive versions of K in literature. ours doesn't satisfy
  § (A _ B) ! (§ A _ § B) nor : § ?

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Contexts as Constructive Modalities

- Pros: well-understood syntax,
  - traditional Kripke semantics (2005),
  - categorical semantics (2001)
  - Curry-Howard Isomorphism (2001)
- Cons: modeling too abstract, cannot capture work on factives and implicatives (Nairn, Condoravdi, Karttunen), as it stands
  - Need to be extended to deal with temporal phenomena.
- Maybe should try another notion of context?..

Which contexts for NL?

Literature vast, many conceptions, many formalisms

- Theories?
- Viewpoints?
- Situations?
- Indexicals?
- Propositional Attitudes?
- …

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Contexts as @-Operators?

- Can we use Hybrid Logic instead of Modal Logic for our contexts?
- How easy it is to do it?
- Should we do it?
- Which possible way should we do it?
- What do we gain?

Contexts as @-Operators?

- Clearly can do it: HL is a generalization of ML
- Could use the boxes in HL as contexts (if motivation was simply better proof theory)
- Or could use @ operators as contexts
- This seems intuitive: a context looks like a possible world that one wants to get to, reason within and move out, when convenient
- Surely this has been tried before?...

Hybrid logic for Situation Theory
@-Operators for situations

- Two examples: Seligman's "Logic of Correct Description" and Ahn-Schubert's HLC**
- Both logics model relations between sentences and situations, in the Barwise-Perry meaning of the term.
- Seligman's logic has an operator for "phi is a correct description of s", call his system SHL
- Schubert and Ahn have two such operators relating sentences to situations, one where sentences 'characterize' situations and where they 'support' situations

@-Operators for situations: SHL

- Seligman's operator for correct description: phi is a correct description of s
- Cut-free sequent calculus, one of the sources for Brauner and de Paiva intuitionistic hybrid logic
- Omniscient situations (either phi or not phi is a correct description of s) oversimplification
- Analogy to spatial reasoning: in location loc, phi holds. Exemple: *This is Abu Dabi. Alcohol is forbidden.➔ In Abu Dabi, alcohol is forbidden.*
- Intuitively a good notion of context
- But not what we're doing at PARC

@-Operators for situations: HLC**

- Based on Schubert's FOL**, episodic logic
- Alternative to (generalization of) Davidsonian theory: for atoms Davidsonian
- partial situations,satisfaction/characterization relation between situations and formulas
- Adds binary modality for conjoined situations
- Sound and complete tableau system
- HLC** is modal reconstruction of propositional fragment of FOL**
- Positive and negative characterizations

@-operators as contexts

- Neither SHL or HLC** works well for us
- Our contexts are not about indexicals
- Negation introduces a context for us, in HLC** it's an orthogonal mechanism
- If temporal information were to introduce a context, then we could use a hybrid logic
- Then the ability to say Holds_at(c, A), where c is a temporal context, would be useful
- To do it constructively, could use Brauner and de Paiva's Intuitionistic Hybrid Logic (IHL)

Digression: Intuitionistic Hybrid Logics

- (Brauner & de Paiva 2003) 1st intuitionistic proposal based on Simpson's ND formulation for modal logic
- IHL = HL(@) over a intuitionistic basis
- ND rules for nominals simple, but all rules are satisfaction statements,
- Main results: normalization + ability to extend to geometric theories
- **Robust**: extended by Brauner to first-order, and to N4 (Nelson's constructible falsity) system
- Applied work on variations of IHL going strong: Walker and Jia 2003/4, Sassone et al 2004/5, J. Moody, etc

The experiment: not done, yet?

- ONE: Use @ operators of IHL for temporal contexts and usual boxes for contexts

  (How different from system envisaged by semanticists?)
- TWO: Build Constructive HL by using ND rules for CK plus nominal rules of SHL
- Reduction rules of CK plus ones for nominals?
- Prove soundness and completeness using new models (Mendler and de Paiva 2005) & normalization
- Problem: counterexample to subformula property in Brauner's comparison paper

The experiments: why not?

- For implemented system need temporal relations
- Semanticists say they don't look like contexts: no use for hybrid logic?
- No obvious need for A-boxes in our application
- At the level of `contexted description logic' things not brilliant: yes, we do have concepts, roles and subsumption of concepts, but not clear if TIL+ really is/can be thought of/ as multimodal ALC or not

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(More) Discussion

- For TIL+ not clear whether to use hybrid logic
- Need to see which kinds of temporal features the linguists want
- For type theory/logic would like to see what CHL would look like
- Also want to play with the very impoverished version of HL that has no modalities, only nominals and satisfaction operators: distributed propositional logic ‘a la Ghidini and Serafini?
- Proposed application: distributed sensors network

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Thanks!

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ND for Hybrid Logics

- Brauner2003 comparison between IHL and SHL
- IHL has reduction rules & satisfies normalization
- SHL doesn't have reduction rules, so provide translations to and from IHL and induce reductions via the reductions in IHL
- Does it work? No, can't prove normalization with induced rules
- Problem: SHL doesn't have subformula property

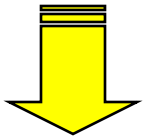
Local Textual Inference

- Broadening and Narrowing
  - Ed went to Boston by bus → Ed went to Boston
  - Ed didn't go to Boston → Ed didn't go to Boston by bus
- Positive implicative
  - Ed managed to go → Ed went
  - Ed didn't manage to go → Ed didn't go
- Negative implicative
  - Ed forgot to go → Ed didn't go
  - Ed didn't forget to go → Ed went
- Factive
  - Ed forgot that Bill went
  - Ed didn't forget that Bill went

  } → Bill went

Verbs differ as to speaker commitments

"Bush **realized that** the US Army had to be transformed to meet new threats"



"The US Army had to be transformed to meet new threats"

"Bush **said that** Khan sold centrifuges to North Korea"

"Khan sold centrifuges to North Korea"

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