

# Constructive Hybrid Logics and Contexts

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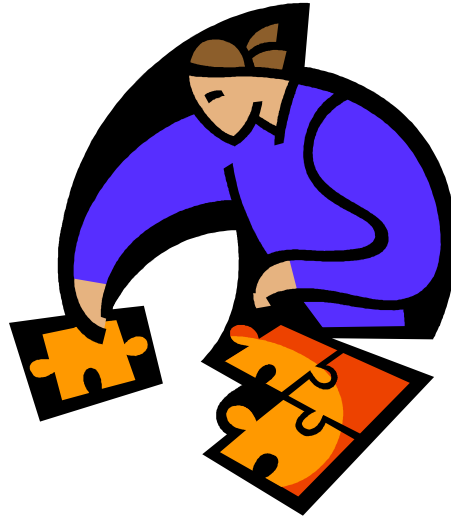
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# Outline

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

# 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...

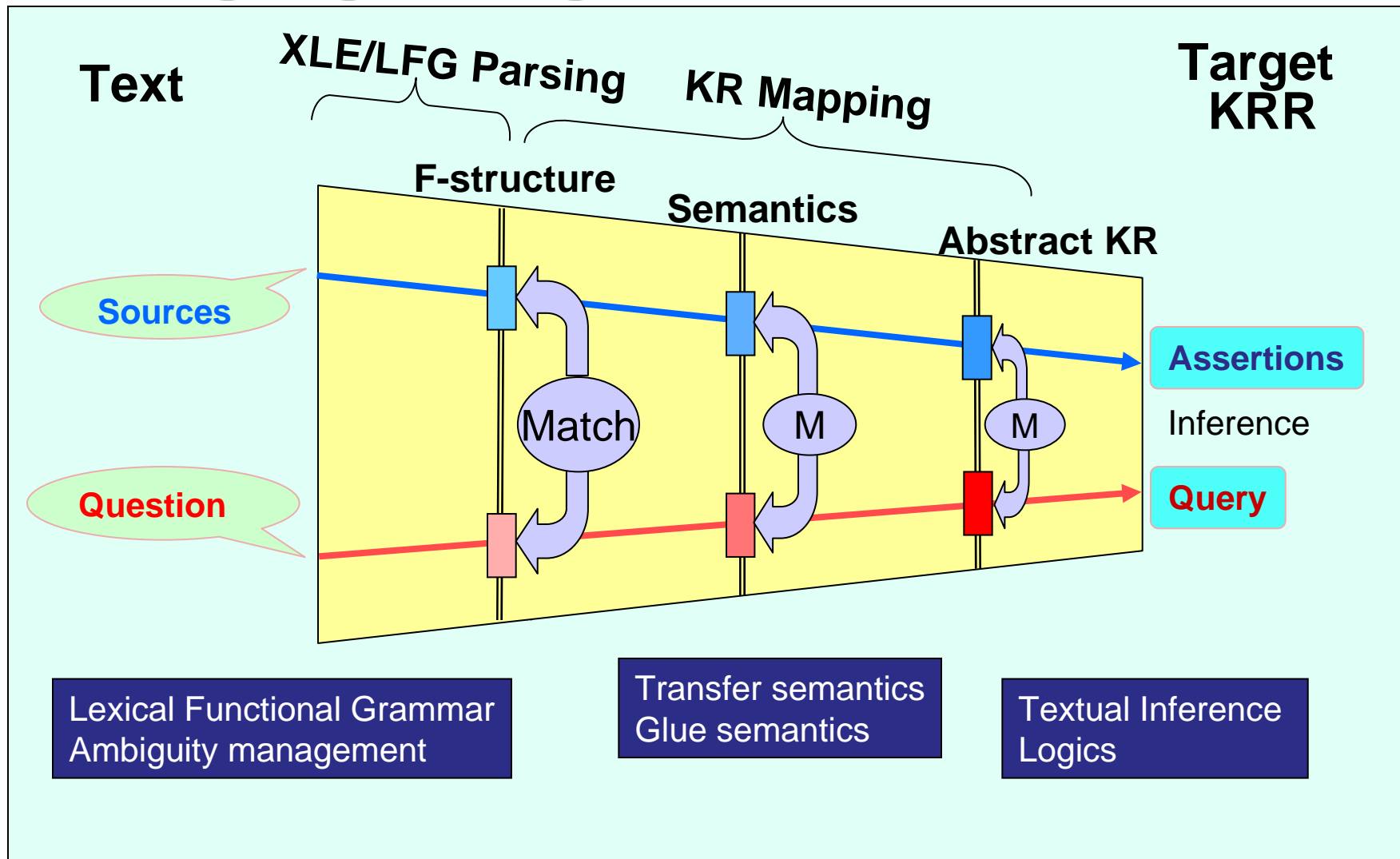
# Motivation: Logic for Text Understanding

- 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  
(thanks PARC Aquaint team: Dick Crouch, Danny Bobrow, Cleo Condoravdi, Tracy King, Ron Kaplan, Annie Zaenen, Lauri Karttunen)

# 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?

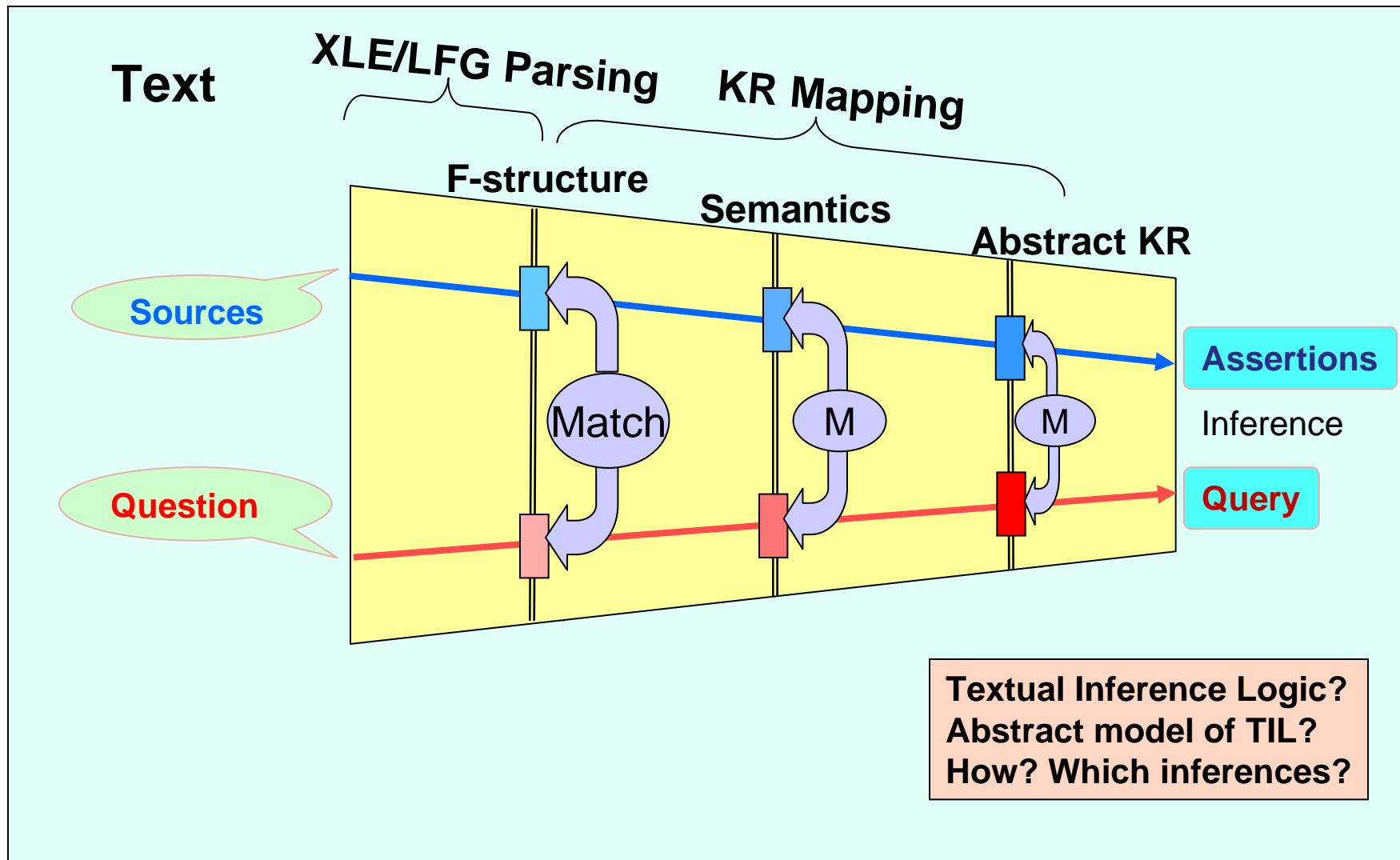
# Canonicalization helps matching

- 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)

PRED	fire<Ed, boy>
TENSE	past
SUBJ	[ PRED Ed ]
OBJ	[ PRED boy ] DEF +

```
(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

# 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

# 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.

# 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],[9500  
236] ),),  
cf(A1, subconcept('fire##1',[[1124984],[1123061],[1123474]])),  
cf(A2, subconcept('fire##1',[[2379472]])),  
cf(1, temporalRel(startsAfterEndingOf,'Now','fire##1'))
```

# 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...

# 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

$$\diamond(A \vee B) \rightarrow (\diamond A \vee \diamond B) \text{ nor } \neg \diamond \perp$$

# 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, Karttunen2005), 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?
- ...

# 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 Dhabi. Alcohol is forbidden.* → *In Abu Dhabi, 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  $\text{Holds\_at}(c, A)$ , 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) 1<sup>st</sup> 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

# (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

# References

- [Natural Deduction for Hybrid Logic](#). Torben Braüner [J. Log. Comput.](#) 14(3): 329-353 (2004)
- [Intuitionistic Hybrid Logic](#). Torben Braüner and Valeria de Paiva: *J. Applied Log.* To appear. Also in M4M-3.
- [The Logic of Correct Description](#) Jerry Seligman In M. de Rijke, et al (ed.) *Advances in Intensional Logic*. Dordrecht, Kluwer Academic Publishers, 107-136, 1997.
- [A binary modality for reasoning about conjoined situations in a hybrid logic](#). 2003. David D. Ahn and Lenhart K. Schubert. Proceedings of Methods for Modalities 3 (M4M-3).
- [A Basic Logic for Textual Inference](#) ( D. Bobrow, C. Condoravdi, R. Crouch, R. Kaplan, L. Karttunen, T. King, V. de Paiva and A. Zaenen), In Procs. of the AAAI Workshop on Inference for Textual Question Answering, Pittsburgh PA, July 2005.
- [Modal Proofs As Distributed Programs](#) (Limin Jia and David Walker) In the European Symposium on Programming, LNCS 2986, David Schmidt (Ed.), pp. 219--233, Springer, April, 2004. ([pdf](#))
- [A binary modality for reasoning about conjoined situations in a hybrid logic](#). 2003. David D. Ahn and Lenhart K. Schubert. Proceedings of Methods for Modalities 3 (M4M-3).

Thanks!