From Syntax to Knowledge Representation: Parc's Bridge System

Lauri Karttunen and Annie Zaenen
Boulder, CO
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Credits for the Bridge System

NLTT (Natural Language Theory and Technology) group at PARC

- Daniel Bobrow
- Bob Cheslow
- Cleo Condoravdi
- Dick Crouch
- Ronald Kaplan
- Lauri Karttunen
- Tracy King
- John Maxwell
- Valeria de Paiva
- Annie Zaenen

Interns

- Rowan Nairn
- Matt Paden
- Karl Pichotta
- Lucas Champollion

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Who's still there?

KLI (Knowledge Language Interaction) group at PARC

- Daniel Bobrow
- (Bob Cheslow)
- Cleo Condoravdi
- Dick Crouch*
- Ronald Kaplan*
- (Lauri Karttunen)
- Tracy King**
- John Maxwell
- Valeria de Paiva***
- (Annie Zaenen)

Interns

- Rowan Nairn****
- Matt Paden
- Karl Pichotta
- Lucas Champollion*****

() = retired

* = at *Powerset/Microsoft*

** = at *eBay*

*** = at *Rearden*

**** = at *Google*

***** = at NYU

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Overview

- PARC's Bridge system
  - Process pipeline
  - Abstract Knowledge Representation (AKR)
    - Conceptual, contextual and temporal structure
    - Instantiability
- Entailment and Contradiction Detection (ECD)
  - Concept alignment, specificity calculation, entailment as subsumption
- Demo!
  - Case studies
    - phrasal implicatives (*have the foresight to Y*, *waste a chance to Y*)
    - converse and inverse relations (*buy/sell*, *win/lose*)
- Reflections

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System Overview

string

"A girl hopped."

LFG Parser

syntactic F-structure

```
PRED     'hop<[44:girl]>'
         PRED   'girl'
         CHECK  [_LEX-SOURCE countnoun-lex]
SUBJ     NTYPE  [NSEM [COMMON count]
                 NSYN common        ]
         SPEC   [DET [PRED     'a'  ]
                     [DET-TYPE indef]]
      44 CASE nom, NUM sg, PERS 3
CHECK    [_SUBCAT-FRAME V-SUBJ]
TNS-ASP  [MOOD indicative, PERF -_, PROG -_, TENSE past]
104 CLAUSE-TYPE decl, PASSIVE -, VTYPE main
```

rewrite rules

Conceptual Structure:

subconcept(hop:7,[hop-1,hop-2,hop-3,hop-4,hop-5,hop-6])
role(sb,hop:7,girl:5)
subconcept(girl:5,[girl-1,female_child-1,daughter-1,girlfriend-2,girl-5])
role(cardinality_restriction,girl:5,sg)

Contextual Structure:

context(t)
top_context(t)
instantiable(girl:5,t)
instantiable(hop:7,t)

Temporal Structure:

trole(when,hop:7,interval(before,Now))

AKR (Abstract Knowledge Representation)

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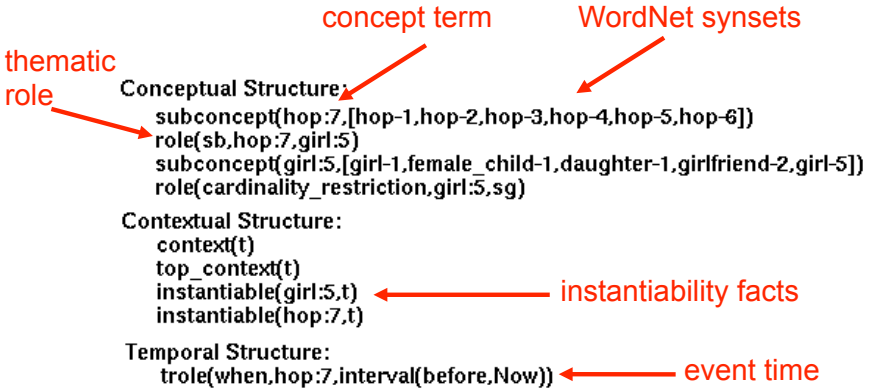
AKR representation



A collection of statements.

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John saw the girl with a telescope.

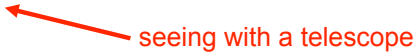
Choice Space:
xor(A1, A2) iff 1

Conceptual Structure:
definite(girl:10)
definite(John:1)
subconcept(see:6,[see-1,understand-2,witness-2,visualize-1,see-5,learn-
A1: role(prep(with),see:6,telescope:17)
role(sb,see:6,John:1)
role(ob,see:6,girl:10)
subconcept(John:1,[male-2])
alias(John:1,[John])
role(cardinality_restriction,John:1,sg)
subconcept(girl:10,[girl-1,female_child-1,daughter-1,girlfriend-2,girl-5])
A2: role(prep(with),girl:10,telescope:17)
role(cardinality_restriction,girl:10,sg)
subconcept(telescope:17,[telescope-1])
role(cardinality_restriction,telescope:17,sg)

Contextual Structure:
context(t)
top_context(t)
instantiable(John:1,t)
instantiable(girl:10,t)
instantiable(see:6,t)
instantiable(telescope:17,t)

Temporal Structure:
trole(when,see:6,interval(before,Now))

Ambiguity management with choices



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Basic structure of AKR

Conceptual Structure

- concept terms represent individuals and events, linked to WordNet synonym sets by subconcept declarations.
- concepts typically have roles associated with them.
- Syntactic ambiguity is encoded in a space of alternative choices.

Contextual Structure

- t is the top-level context, some contexts are headed by an event term.
- Clausal complements, negation and sentential modifiers also introduce contexts.
- Contexts can be related in various ways such as veridicality.
- Instantiability declarations link concepts to contexts.

Temporal Structure

- Locating events in time.
- Temporal relations between events.

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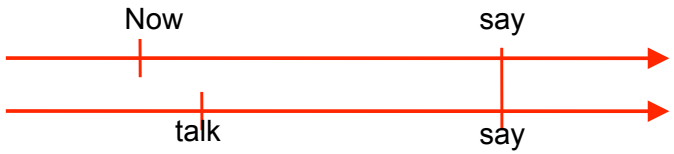
Temporal Structure

trole(when, talk:6,interval(before,Now))

Shared by “Ed talked.” and “Ed did not talk.”

“Bill will say that Ed talked.”



trole(when,say:45,interval(after,Now))
trole(ev_when,talk:68,interval(before, say:45))

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Conceptual Structure

- Captures basic predicate-argument structures
- Maps words to WordNet synsets
- Assigns thematic roles

```
subconcept(talk:4, [talk-1,talk-2,speak-3,spill-5,spill_the_beans-1,lecture-1])
role(sb, talk:4, Ed:1)
subconcept(Ed:1, [male-2])
alias(Ed:1, [Ed])
role(cardinality_restriction,Ed:1,sg)
```

Shared by “Ed talked”, “Ed did not talk” and “Bill will say that Ed talked.”

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Prime semantics vs. Wordnet semantics

What is the meaning of life?

Montague 1970:

life'

WordNet:

a cloud of synonym sets (14) in an ontology of hypernyms

In prime semantics, lexical reasoning requires axioms (meaning postulates).

In Wordnet semantics, some lexical reasoning can be done with the synsets and hypernyms.

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earth and ground intersect

earth
Sense 3
earth, ground
=> material, stuff
=> substance, matter
=> physical entity
=> entity

ground
Sense 3
land, dry land, earth, ground, solid ground, terra firma
=> object, physical object
=> physical entity
=> entity

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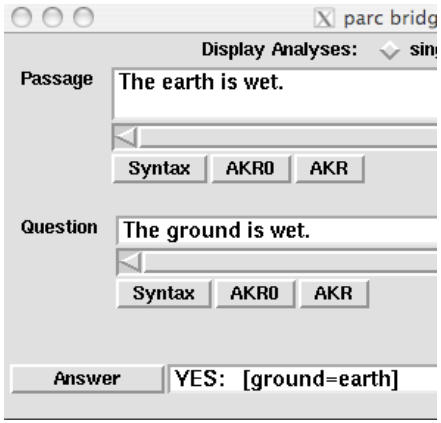
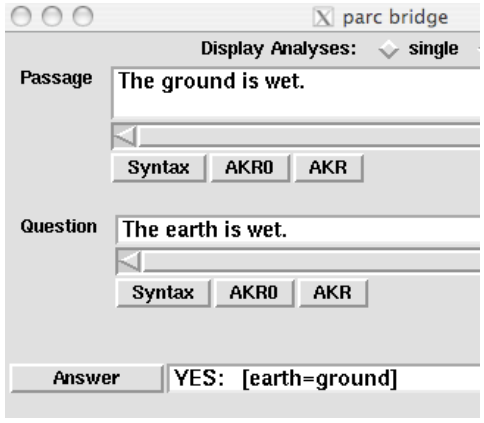
Equivalence





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$level_3$ is a hypernym of $plane_3$

level

1. degree, grade, level => property
2. grade, level, tier => rank
3. **degree, level, stage, point => state**
4. level => altitude, height => altitude
5. level, spirit level => indicator
6. horizontal surface, level => surface
7. floor, level, storey, story => structure
8. level, layer, stratum => place

plane

1. airplane, aeroplane, plane => heavier-than-air craft
2. plane, sheet => shape, form
3. **plane => degree, level, stage, point**
4. plane, planer, planing machine => power tool, => tool
5. plane, carpenter's plane, woodworking plane => edge tool, => hand tool

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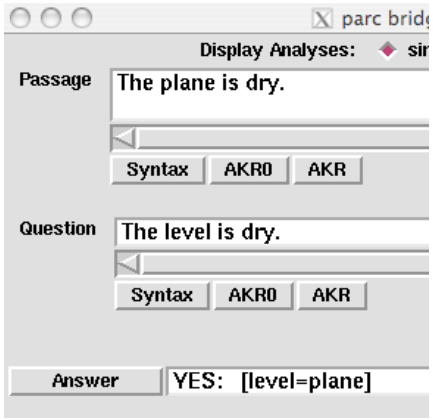
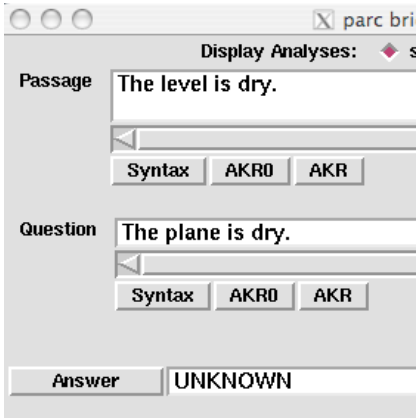
One-way entailment





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Contextual Structure

- t is the top-level context
- the head of the context is typically an event concept
- contexts can serve as roles such as object

Bill said that Ed wanted to talk.

```
context(t)
context(ctx(talk:29))
context(ctx(want:19))
top_context(t)
context_relation(t,ctx(want:19),crel(comp,say:6))
context_relation(ctx(want:19),ctx(talk:29),crel(ob,want:19))
```

ctx(want:19) is the object of say:6 in t

The head of the context, want:19, is used to name the context.

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Instantiability

An instantiability assertion of a concept-denoting term in a context implies the existence of an instance of that concept in that context.

An uninstantiability assertion of a concept-denoting term in a context implies there is no instance of that concept in that context.

If the denoted concept is of type *event*, then existence/nonexistence corresponds to truth or falsity.

instantiable(girl:13, t) – girl:13 exists in t

instantiable(see:7, t) – see:7 is true in t

uninstantiable(girl:13, t) – there is no girl:13 in t

uninstantiable(see:7, t) – see:7 is false in t

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Negation

"Ed did not talk"

Contextual structure

context(t)
context(ctx(talk:12)) **new context triggered by negation**
context_relation(t, ctx(talk:12), not:8)
antiveridical(t,ctx(talk:12)) **interpretation of negation**

Local and lifted instantiability assertions

instantiable(talk:12, ctx(talk:12))
uninstantiable (talk:12, t) **entailment of negation**

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Relations between contexts

Generalized entailment: veridical

If c2 is **veridical** with respect to c1,
the information in c2 is part of the information in c1

Lifting rule: instantiable(Sk, c2) => instantiable(Sk, c1)

Inconsistency: antiveridical

If c2 is **antiveridical** with respect to c1,
the information in c2 is incompatible with the info in c1

Lifting rule: instantiable(Sk, c2) => uninstantiable(Sk, c1)

Consistency: averidical

If c2 is **averidical** with respect to c1,
the info in c2 is compatible with the information in c1

No lifting rule between contexts

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Determinants of context relations

Relation depends on complex interaction of

- Concepts
- Lexical entailment class
- Syntactic environment

Example

1. He didn't remember to close the window.
2. He doesn't remember that he closed the window.
3. He doesn't remember whether he closed the window.

He closed the window.

- Contradicted by 1
- Implied by 2
- Consistent with 3

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Relative Polarity

Veridicality relations between contexts determined on the basis of a recursive calculation of the relative polarity of a given “embedded” context

Globality: The polarity of any context depends on the sequence of potential polarity switches stretching back to the top context

Top-down each complement-taking verb or other clausal modifier, based on its parent context's polarity, either switches, preserves or simply sets the polarity for its embedded context.

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Factives and Counterfactives

	Class	Inference Pattern
Positive	forget that	forget that X $\models$ X, not forget that X $\models$ X
Negative	pretend that	pretend that X $\models$ not X, not pretend that X $\models$ not X

Abraham pretended that Sarah was his sister. $\rightsquigarrow$ Sarah was not his sister

Howard did not pretend that it did not happen. $\rightsquigarrow$ It happened.

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Implicatives

	Class	Inference Pattern
Two-way implicatives	++/-- *manage to* +-/-+ *fail to*	manage to X ⊩ X, not manage to X ⊩ not X fail to X ⊩ not X, not fail to X ⊩ X
	++ *force to*	force X to Y ⊩ Y
One-way implicatives	+- *prevent from*	prevent X from Ying ⊩ not Y
	-- *be able to*	not be able to X ⊩ not X
	-+ *hesitate to*	not hesitate to X ⊩ X

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Example: polarity propagation

Ed did **not forget to force** Dave to leave.

==> Dave left.

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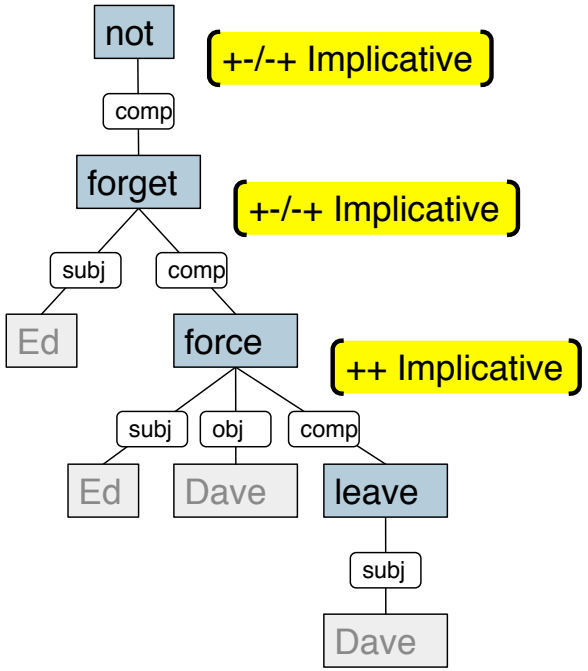
It's all very well classifying the implications of words in certain sentences. What makes this interesting is that these things can nest and still carry implications. As always in semantics, you want to distill out the properties of various words and hope that you cover all the possible sentence combinations of these words with how they interact. Here's a simple example.



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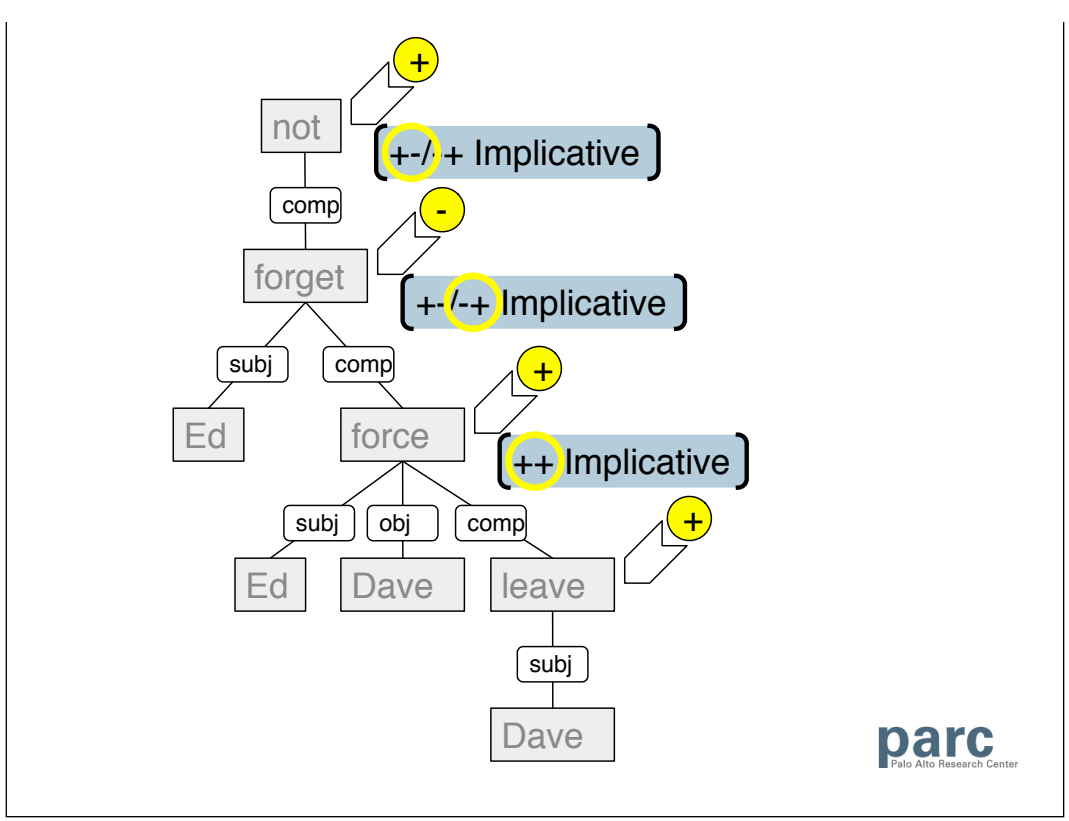
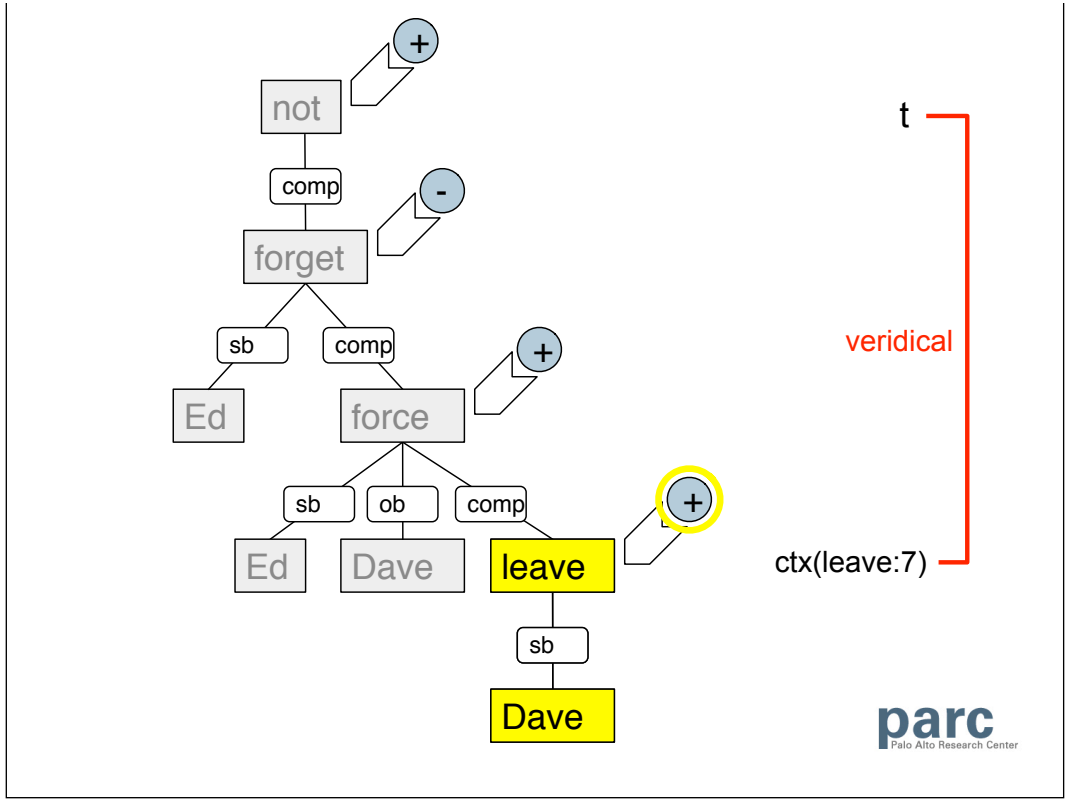


Stress Combinatorics: Found a way to label these clausal verbs independantly so that the


+
not
comp
-
forget
sb
comp
+
Ed
force
sb
ob
comp
+
Ed
Dave
leave
sb
Dave
t
veridical
ctx(leave:7)
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Overview

- Introduction
  - Motivation
  - Local Textual Inference
- PARC's Bridge system
  - Process pipeline
  - Abstract Knowledge Representation (AKR)
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Kim hopped => Someone moved

Kim hopped.

Conceptual Structure:
subconcept(hop:2,[hop-1,hop-2,hop-3,hop-4,h
role(Theme,hop:2,Kim:0)
subconcept(Kim:0,[person-1])
alias(Kim:0,[Kim])
role(cardinality_restriction,Kim:0,sg)

Contextual Structure:
context(t)
top_context(t)
instantiable(Kim:0,t)
instantiable(hop:2,t)

Temporal Structure:
temporalRel(startsAfterEndingOf,Now,hop:2)

Someone moved.

Conceptual Structure:
subconcept(move:5,[travel-1,move-2,move-3,mov
role(Theme,move:5,person:0)
subconcept(person:0,[person-1])
role(cardinality_restriction,person:0,some(sg))

Contextual Structure:
context(t)
top_context(t)
instantiable(move:5,t)
instantiable(person:0,t)

Temporal Structure:
temporalRel(startsAfterEndingOf,Now,move:5)

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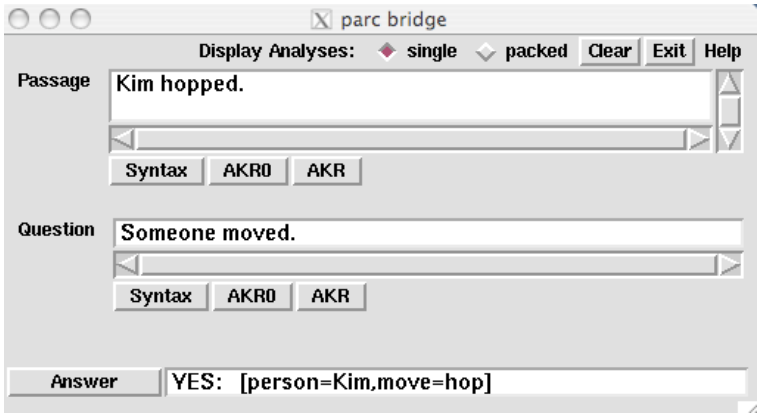
More specific entails less specific



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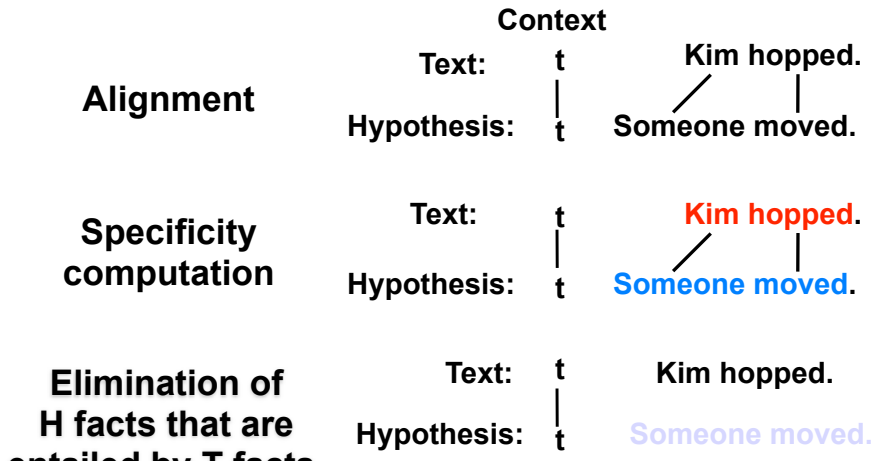
How ECD works



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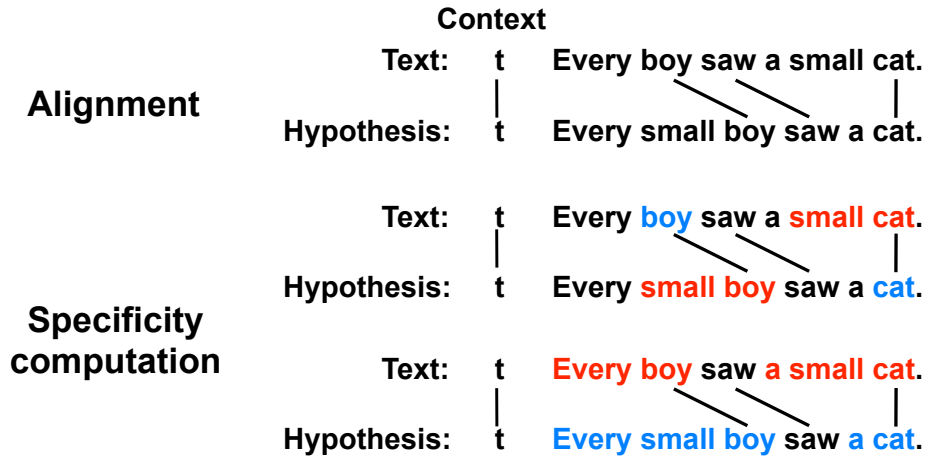
Alignment and specificity computation



Every (↓) (↑)

Some (↑) (↑)

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Contradiction: instantiable --- uninstantiable

```
No one moved.

Conceptual Structure:
    subconcept(not:12,[not-1])
    role(degree,not:12,normal)
    subconcept(move:2,[travel-1,move-2,move-3,move-4,go-2,be_active-
    role(Theme,move:2,person:0)
    subconcept(person:0,[person-1])
    role(cardinality_restriction,person:0,no)

Contextual Structure:
    context(t)
    context(ctx(move:2))
    top_context(t)
    context_lifting_relation(antiveridical,t,ctx(move:2))
    context_relation(t,ctx(move:2),not:12)
    uninstantiable(move:2,t)
    instantiable(move:2,ctx(move:2))
    instantiable(person:0,ctx(move:2))

Temporal Structure:
    temporalRel(startsAfterEndingOf,Now,move:2)
```

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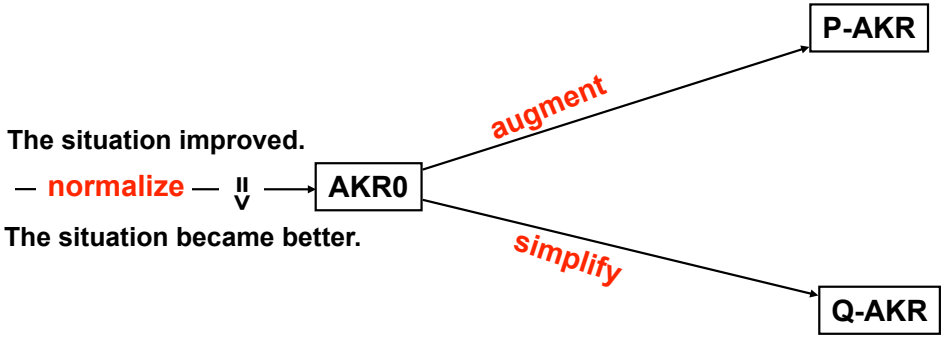
AKR modifications

Oswald killed Kennedy => Kennedy died.



Kim managed to hop. => Kim hopped.

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Phrasal Implicatives

Have	+	Ability Noun	*(ability/means)*	= --Implicative
		Chance Noun	*(chance/opportunity)*	= --Implicative
		Bravery Noun	*(courage/nerve)*	= ++/--Implicative
Take	+	Chance Noun	*(chance/opportunity)*	= ++/--Implicative
		Asset Noun	*(money)*	= ++/--Implicative
		Effort Noun	*(trouble/initiative)*	= ++/--Implicative
Use	+	Chance Noun	*(chance/opportunity)*	= ++/--Implicative
		Asset Noun	*(money)*	= ++/--Implicative
Waste	+	Chance Noun	*(chance/opportunity)*	= +-/-+Implicative
		Asset Noun	*(money)*	= ++/--Implicative
Miss	+	Chance Noun	*(chance/opportunity)*	= +-/-+Implicative
Seize	+	Chance Noun	*(chance/opportunity)*	= ++/--Implicative

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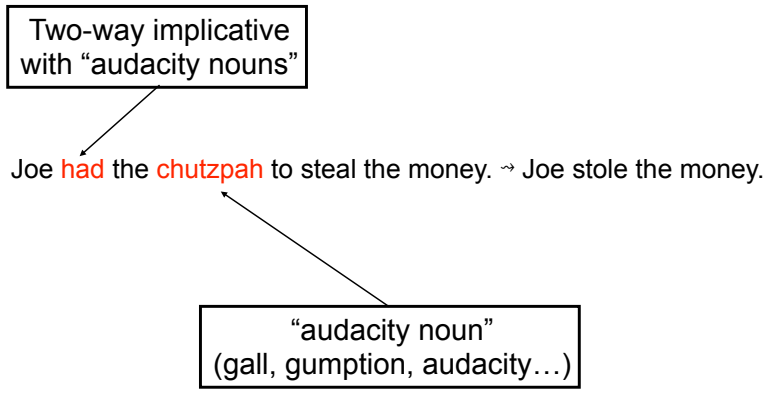
Conditional verb classes



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Conditional verb classes

(cat(V), word(have), subcat(V-SUBJ-OBJ),
…
xfr:lex_class(%1,conditional(impl_nn,Theme,ability_noun)),
xfr:lex_class(%1,conditional(impl_nn,Theme,chance_noun)),
xfr:lex_class(%1,conditional(impl_pp_nn,Theme,audacity_noun)),
…)

(cat(V), word(chutzpah), subcat(NOUN-XCOMP),
…
xfr:lex_class(%1,audacity_noun)),
…)

Joe had the chutzpah to steal the money.

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wasting time vs. wasting a chance

I regret having wasted the time to read it and even more, wasted the money to buy it.

==> I read it. I bought it.

I would not waste the money to buy Vista for a computer that has XP on it.

==> I would not buy Vista…

lex_class(waste, conditional(impl_pp_nn, ob, asset_noun))

Mr. Spitzer wasted the opportunity to drive a harder bargain.

==> Mr. Spitzer did not drive a harder bargain.

Galileo did not waste the chance to aim a funny mock-syllogism at Grassi's flying eggs.

==> Galileo aimed a funny mock-syllogism…

lex_class(waste, conditional(impl_pn_np, ob, chance_noun))

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Stacking phrasal implicatives

Leona Helmsley **managed to have the gumption to** leave most of her estate to her,.. wait for it,... dog!

=> Leona Helmsley left most of her estate to her dog.

The patent attorney **did not bother to take the time to** understand the slightly angled feature.

=> The patent attorney did not understand the slightly angled feature.

The Arab leaders **didn't have the courage to take the decisive step to** bring about peace.

=> The Arab leaders did not bring about peace.

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Reflections

Textual inference is a good test bed for computational semantics.

- It is task-oriented. It abstracts away from particular meaning representations and inference procedures.
- It allows for systems that make purely linguistic inferences, others may bring in world knowledge and statistical reasoning.

This is a good time to be doing computational semantics.

- Purely statistical approaches have plateaued.
- There is computing power for parsing and semantic processing.

There are enough of unsolved problems to keep us busy and funded for many years to come.

- Invited inferences
- Presuppositions

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