From Syntax to Knowledge Representation: Parc’s Bridge System

Lauri Karttunen and Annie Zaenen
Boulder, CO
Aug 2, 2011
Toward NL Understanding

Local Textual Inference
   A measure of understanding a text is the ability to make inferences based on the information conveyed by it.

Veridicality reasoning
   Did an event mentioned in the text actually occur?

Temporal reasoning
   When did an event happen? How are events ordered in time?

Spatial reasoning
   Where are entities located and along which paths do they move?

Causality reasoning
   Enablement, causation, prevention relations between events
Overview

PARC's Bridge system
  LFG and XLE
  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!
LFG (Lexical Functional Grammar)

One of two “Bay-Area Unification-based Grammar Formalisms” (frenemies)

LFG -- Joan Bresnan, Ronal M. Kaplan (≈ 1980)
HPSG - (Head-Driven Phrase Structure Grammar)
   Ivan Sag, Carl Pollard (≈ 1984)

Rejection of transformations: no movement, use constraints (unification) to enforce non-local dependencies. (Recall Ivan’s talk on last week.)

Unlike anything coming from MIT, LFG and HPSG had computational implementations and comprehensive hand-written grammars for many languages from the very beginning.
The early computational implementations of LFG (and HPSG) were seen as an aid for grammar writers. The XLE (Xerox Linguistic Environment) system started out as a “Grammar Writer’s Workbench” for LFG linguists. Practical applications came later.

The current XLE is differs from the other systems we have looked at in that it constructs a special representation to assist reasoning. This is called AKR (abstract knowledge representation). It is a “flat” collection of statements, no complex nesting as you have in syntactic trees, no lambdas.
XLE parser

Broad coverage, domain independent, ambiguity enabled dependency parser

Robustness: fragment parses

From Powerset: .3 seconds per sentence for 125 Million Wikipedia sentences

Maximum entropy learning to find weights to order parses

Accuracy: 80-90% on PARC 700 gold standard
System Overview

string

“A girl hopped.”
System Overview

“A girl hopped.”

string

LFG Parser

syntactic F-structure

PRED 'hop<44:girl>
   PRED 'girl'
   CHECK [LEX-SOURCE countnun-lg]
SUBJ NTYPE [NSEM [COMMON count]]
   NSYN common
   SPEC [DET [PRED 'a']]
   CASE nom, NUM sg, PERS 3
   CHECK [SUBCAT-FRAME V-SUB]
TNS-ASP [MODO indicative, PERF _, PROG _, TENSE past]
CLAUSE-TYPE decl, PASSIVE _, VTYPE main
System Overview

string
“A girl hopped.”

LFG Parser

syntactic F-structure

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)
AKR representation

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))

A collection of statements.
AKR representation

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))

A collection of statements.
AKR representation

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))

A collection of statements.
AKR representation

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))

A collection of statements.
AKR representation

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))

A collection of statements.
AKR representation

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))

A collection of statements.
John saw the girl with a telescope.

Choice Space:
\text{xor}(A1, A2) \text{ iff } 1

Conceptual Structure:
\text{definite}(\text{girl}:10) \\
\text{definite}(\text{John}:1) \\
\text{subconcept}(\text{see}:6,[\text{see}-1,\text{understand}-2,\text{witness}-2,\text{visualize}-1,\text{see}-5,\text{learn}-:)
\text{A1: role}(\text{prep}(\text{with}),\text{see}:6,\text{telescope}:17) \\
\text{role}(\text{sb},\text{see}:6,\text{John}:1) \\
\text{role}(\text{ob},\text{see}:6,\text{girl}:10) \\
\text{subconcept}(\text{John}:1,[\text{male}-2]) \\
\text{alias}(\text{John}:1,[\text{John}]) \\
\text{role}(\text{cardinality}_\text{restriction},\text{John}:1,\text{sg}) \\
\text{subconcept}(\text{girl}:10,[\text{girl}-1,\text{female}_\text{child}-1,\text{daughter}-1,\text{girlfriend}-2,\text{girl}-5])
\text{A2: role}(\text{prep}(\text{with}),\text{girl}:10,\text{telescope}:17) \\
\text{role}(\text{cardinality}_\text{restriction},\text{girl}:10,\text{sg}) \\
\text{subconcept}(\text{telescope}:17,[\text{telescope}-1]) \\
\text{role}(\text{cardinality}_\text{restriction},\text{telescope}:17,\text{sg})

Contextual Structure:
\text{context}(t) \\
\text{top}_\text{context}(t) \\
\text{instantiable}(\text{John}:1,t) \\
\text{instantiable}(\text{girl}:10,t) \\
\text{instantiable}(\text{see}:6,t) \\
\text{instantiable}(\text{telescope}:17,t)

Temporal Structure:
\text{trole}(\text{when},\text{see}:6,\text{interval}(\text{before},\text{Now}))
Basic structure of AKR
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.
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.
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.
Temporal Structure
Temporal Structure

\[ \text{trole}(\text{when}, \text{talk}:6, \text{interval}(\text{before}, \text{Now})) \]

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

\[ \text{trole(when, talk:6, interval(before, Now))} \]

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

“Bill will say that Ed talked.”

\[ \text{trole(when, say:45, interval(after, Now))} \]
\[ \text{trole(ev\_when, talk:68, interval(before, say:45))} \]
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.”
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.
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
Equivalence

The earth is wet.

The ground is wet.

Answer: YES: [ground=earth]

Answer: YES: [earth=ground]
**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
One-way entailment

Passage: The plane is dry.

Question: The level is dry.

Answer: YES: [level=plane]

Passage: The level is dry.

Question: The plane is dry.

Answer: UNKNOWN
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.

\[
\text{context}(t) \\
\text{context}(\text{ctx(talk:29)}) \\
\text{context}(\text{ctx(want:19)}) \\
\text{top_context}(t) \\
\text{context_relation}(t,\text{ctx(want:19)},\text{crel(comp,say:6)}) \\
\text{context_relation}(\text{ctx(want:19)},\text{ctx(talk:29)},\text{crel(ob,want:19)})
\]

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

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

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

\[ \text{instantiable(girl:13, t) – girl:13 exists in t} \]
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.

\[
\text{instantiable}(\text{girl}:13, t) \quad \text{– girl:13 exists in } t \\
\text{instantiable}(\text{see}:7, t) \quad \text{– see:7 is true in } t
\]
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
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
Negation

“Ed did not talk”

**Contextual structure**

- context(t)
- context(ctx(talk:12))
- context_relation(t, ctx(talk:12), not:8)
- antiveridical(t,ctx(talk:12))

**Local and lifted instantiability assertions**

- instantiable(talk:12, ctx(talk:12))
- uninstantiable (talk:12, t)
Relations between contexts
Relations between contexts

Generalized entailment: veridical

If $c_2$ is \textit{veridical} with respect to $c_1$,
the information in $c_2$ is part of the information in $c_1$
Lifting rule: instantiable$(\text{Sk, } c_2)$ $\Rightarrow$ instantiable$(\text{Sk, } c_1)$
Relations between contexts

Generalized entailment: veridical

If $c_2$ is \textit{veridical} with respect to $c_1$,
the information in $c_2$ is part of the information in $c_1$
Lifting rule: $\text{instantiable}(Sk, c_2) \Rightarrow \text{instantiable}(Sk, c_1)$

Inconsistency: antiveridical

If $c_2$ is \textit{antiveridical} with respect to $c_1$,
the information in $c_2$ is incompatible with the info in $c_1$
Lifting rule: $\text{instantiable}(Sk, c_2) \Rightarrow \text{uninstantiable}(Sk, c_1)$

Consistency: averidical

If $c_2$ is \textit{averidical} with respect to $c_1$,
the info in $c_2$ is compatible with the information in $c_1$
No lifting rule between contexts
Determinants of context relations
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
Relative Polarity
Relative Polarity

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

Veridicality relations between contexts determined on the basis of a recursive calculation of the relative polarity of a given “embedded” context
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
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
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.
## Factives and Counterfactives

<table>
<thead>
<tr>
<th>Class</th>
<th>Inference Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive</strong></td>
<td></td>
</tr>
<tr>
<td>forget that</td>
<td>forget that $X \not\models X$, not forget that $X \models X$</td>
</tr>
<tr>
<td>pretend that</td>
<td>pretend that $X \models \neg X$, not pretend that $X \not\models \neg X$</td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td></td>
</tr>
</tbody>
</table>

Abraham pretended that Sarah was his sister. $\neg$ Sarah was not his sister
Howard did not pretend that it did not happen. $\neg$ It happened.
## Implicatives

<table>
<thead>
<tr>
<th>Class</th>
<th>Inference Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>++/-- manage to</td>
<td>manage to X ( \vdash ) X, not manage to X ( \vdash ) not X ( \vdash ) not X, not fail to X ( \vdash ) X</td>
</tr>
<tr>
<td>+/+- fail to</td>
<td></td>
</tr>
<tr>
<td>++ force to</td>
<td>force X to Y ( \vdash ) Y</td>
</tr>
<tr>
<td>+/ prevent from</td>
<td>prevent X from Ying ( \vdash ) not Y</td>
</tr>
<tr>
<td>-- be able to</td>
<td>not be able to X ( \vdash ) not X</td>
</tr>
<tr>
<td>--+ hesitate to</td>
<td>not hesitate to X ( \vdash ) X</td>
</tr>
</tbody>
</table>

### Two-way implicatives
- ++/-- manage to
- +/+- fail to

### One-way implicatives
- ++ force to
- +/ prevent from
- -- be able to
- --+ hesitate to
Example: polarity propagation

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

$$\Rightarrow$$ Dave left.
Ed

Dave

not

force

forget

Ed

Dave

leave

Ed

Dave

Wednesday, August 3, 2011
Ed

Dave

not

+-/-+ Implicative

forget

force

Ed

Dave

leave

Ed

Dave

 subj

 comp

 subj

 obj

 comp

 subj

 Wednesday, August 3, 2011
Ed
not

forget

force

Ed

Dave

leave

Dave

Wednesday, August 3, 2011
Ed

Dave

subj

obj

leave

comp

not

+-/-+ Implicative

forget

+-/-+ Implicative

force

++ Implicative

Ed

Dave

subj

comp

subj

Dave

Wednesday, August 3, 2011
not

forget

Ed

force

Ed

Dave

leave

Dave

+-/-+ Implicative

+-/-+ Implicative

++ Implicative

Wednesday, August 3, 2011
Ed not (+-/-+ Implicative)
  comp
 forgot (+-/-+ Implicative)
    subj
    comp
      Ed
      force (++ Implicative)
        subj
        obj
        comp
          Ed
          Dave
          leave
            subj
              Dave
Ed

Dave

subj

obj

comp

not

force

forget

subj

comp

Ed

Dave

leave

subj

Dave

++ Implicative

+-/- Implicative

+-/- Implicative

Wednesday, August 3, 2011
Ed

Dave

sb

comp

not

comp

forget

sb

comp

force

sb

ob

comp

Ed

Dave

leave

subj

Dave

t

veridical

ctx(leave:7)
Ed + not force leave Dave

Dave force

Ed + sb

Dave ob

leave subj

Dave

veridical

t

ctx(leave:7)
Overview

PARC’s Bridge system
   Process pipeline
   LFG and XLE
   Abstract Knowledge Representation (AKR)
      Conceptual, contextual and temporal structure
      Instantiability
Entailment and Contradiction Detection (ECD)
   Concept alignment, specificity calculation, entailment as subsumption
Demo!
NatLog vs. Bridge
Kim hopped => Someone moved

Kim hopped.

Conceptual Structure:
subconcept(hop:2,[hop-1,hop-2,hop-3,hop-4],
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,move-5],
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)
More specific entails less specific

**Passage:** Kim hopped.

**Question:** Someone moved.

**Answer:** YES: [person=Kim,move=hop]
How ECD works
How ECD works

Alignment

Text: \( t \)  
Hypothesis: \( t \)  
Context  
Kim hopped.  
Someone moved.
How ECD works

Alignment

Text: \texttt{t}
Hypothesis: \texttt{t}

Specificity computation

Text: \texttt{t}
Hypothesis: \texttt{t}

Context

Kim hopped.
Someone moved.

Hypothesis:
Kim hopped.
Someone moved.
How ECD works

Context

Alignment

Specificity computation

Elimination of H facts that are entailed by T facts.

Text: \( t \)

T facts

Kim hopped.

Hypothesis: \( t \)

Someone moved.

Text: \( t \)

T facts

Kim hopped.

Hypothesis: \( t \)

Someone moved.

Text: \( t \)

T facts

Kim hopped.

Hypothesis: \( t \)

Someone moved.
Alignment and specificity computation
Alignment and specificity computation

Context

Text: Every boy saw a small cat.

Hypothesis: Every small boy saw a cat.
## Alignment and Specificity Computation

<table>
<thead>
<tr>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text:</td>
</tr>
<tr>
<td>Hypothesis:</td>
</tr>
</tbody>
</table>

### Specificity Computation

<table>
<thead>
<tr>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text:</td>
</tr>
<tr>
<td>Hypothesis:</td>
</tr>
</tbody>
</table>

### Alignment

<table>
<thead>
<tr>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text:</td>
</tr>
<tr>
<td>Hypothesis:</td>
</tr>
</tbody>
</table>
Alignment and specificity computation

**Context**

Text: \( t \) Every boy saw a small cat.

Hypothesis: \( t \) Every small boy saw a cat.

**Alignment**

Text: \( t \) Every boy saw a small cat.

Hypothesis: \( t \) Every small boy saw a cat.

**Specificity computation**

Text: \( t \) Every boy saw a small cat.

Hypothesis: \( t \) Every small boy saw a cat.

Every (↓) (↑) Some (↑) (↑)
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)
From English to AKR

Ed has been living in Athens for 3 years.
\[\text{trole(duration, extended\_now: 13, interval\_size(3, year: 17))}\]
\[\text{trole(when, extended\_now: 13, interval(finalOverlap, Now))}\]
\[\text{trole(when, live: 3, interval(includes, extended\_now: 13))}\]

Mary visited Athens in the last 2 years.
\[\text{trole(duration, extended\_now: 10, interval\_size(2, year: 11))}\]
\[\text{trole(when, extended\_now: 10, interval(finalOverlap, Now))}\]
\[\text{trole(when, visit: 2, interval(included\_in, extended\_now: 10))}\]

Mary visited Athens while Ed lived in Athens.
\[\text{trole(ev\_when, live: 22, interval(includes, visit: 6))}\]
\[\text{trole(ev\_when, visit: 6, interval(included\_in, live: 22))}\]
From language to qualitative relations of intervals and events

\textit{Ed has been living in Athens for 3 years.}  
\textit{Mary visited Athens in the last 2 years.}  
\implies \textit{Mary visited Athens while Ed lived in Athens.}

\begin{itemize}
  \item \textit{Mary’s visit to Athens}
  \item \textit{Ed’s living in Athens}
\end{itemize}

Construct interval boundaries using
Aspect  
Tense  
Preposition meaning

Inference from interval relations
AKR modifications

Oswald killed Kennedy => Kennedy died.

The situation improved.

— normalize — ⊤ ∇ → AKR0

The situation became better.

Kim managed to hop. => Kim hopped.
Overview

PARC’s Bridge system

LFG and XLE

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!

NatLog vs. Bridge
### Bridge vs. NatLog

<table>
<thead>
<tr>
<th>NatLog</th>
<th>Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetrical</td>
<td>Asymmetrical</td>
</tr>
<tr>
<td>between $t$ and $h$</td>
<td>between $t$ and $h$</td>
</tr>
<tr>
<td>Bottom up</td>
<td>Top down</td>
</tr>
<tr>
<td>Local edits, more compositional</td>
<td>Global rewrites possible</td>
</tr>
<tr>
<td>Surface based</td>
<td>Normalized input</td>
</tr>
<tr>
<td>Integrates monotonicity and implicatives tightly</td>
<td>Monotonicity calculus and implicatives less tightly</td>
</tr>
</tbody>
</table>

We need more power than NatLog allows but it needs to be deployed in a more constrained way than the current Bridge system demonstrates.