Computing Textual Inferences

Cleo Condoravdi
Palo Alto Research Center

University of Illinois at Urbana-Champaign
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Overview

Motivation

Recognizing textual inferences

Recognizing textual entailments

- Monotonicity Calculus
- Polarity propagation
- Semantic relations

PARC's BRIDGE system

- From text to Abstract Knowledge Representation (AKR)
- Entailment and Contradiction Detection (ECD)
- Representation and inferential properties of temporal modifiers

Comparison with MacCartney's NatLog

Motivation

Access to content: existential claims

What happened? Who did what to whom?

Microsoft managed to buy Powerset.

⟹ *Microsoft acquired Powerset.*

Shackleton failed to get to the South Pole.

⟹ *Shackleton did not reach the South Pole.*

The destruction of the file was not illegal.

⟹ *The file was destroyed.*

The destruction of the file was averted.

⟹ *The file was not destroyed.*

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Access to content: monotonicity

What happened? Who did what to whom?

Every boy managed to buy a small toy.

⟹ *Every small boy acquired a toy.*

Every explorer failed to get to the South Pole.

⟹ *No experienced explorer reached the South Pole.*

No file was destroyed.

⟹ *No sensitive file was destroyed.*

The destruction of a sensitive file was averted.

⟹ *A file was not destroyed.*

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Access to content: temporal domain

What happened when?

Ed visited us every day last week.

⟹ *Ed visited us on Monday last week.*

Ed has been living in Athens for 3 years.

Mary visited Athens in the last 2 years.

⟹ *Mary visited Athens while Ed lived in Athens.*

The deal lasted through August, until just before the government took over Freddie. (NYT, Oct. 5, 2008)

⟹ *The government took over Freddie after August.*

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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

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Knowledge about words for access to content

The verb “acquire” is a hypernym of the verb “buy”
The verbs “get to” and “reach” are synonyms

Inferential properties of “manage”, “fail”, “avert”, “not”

Monotonicity properties of “every”, “a”, “no”, “not”
Every (↓) (↑), A (↑) (↑), No(↓) (↓), Not (↓)

Restrictive behavior of adjectival modifiers “small”, “experienced”, “sensitive”

The type of temporal modifiers associated with prepositional phrases headed by “in”, “for”, “through”, or even nothing (e.g. “last week”, “every day”)

Construction of intervals and qualitative relationships between intervals and events based on the meaning of temporal expressions

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Recognizing Textual Inferences

Textual Inference Task

Does premise *P* lead to conclusion *C*?

Does text *T* support the hypothesis *H*?

Does text *T* answer the question *H*?

… without any additional assumptions

P*: Every explorer failed to get to the South Pole.*

C*: No experienced explorer reached the South Pole.*

Yes

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Local Textual Inference Initiatives

PASCAL RTE Challenge (Ido Dagan, Oren Glickman) 2005, 2006

PREMISE

CONCLUSION

TRUE/FALSE

Rome is in Lazio province and Naples is in Campania.

Rome is located in Lazio province.

TRUE (= entailed by the premise)

Romano Prodi will meet the US President George Bush in his capacity as the president of the European commission.

George Bush is the president of the European commission.

FALSE (= not entailed by the premise)

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World knowledge intrusion

Romano Prodi will meet the US President George Bush in his capacity as the president of the European commission.

George Bush is the president of the European commission.

FALSE

Romano Prodi will meet the US President George Bush in his capacity as the president of the European commission.

Romano Prodi is the president of the European commission.

TRUE

G. Karas will meet F. Rakas in his capacity as the president of the European commission.

F. Rakas is the president of the European commission.

TRUE

Inference under a particular construal

Romano Prodi will meet the US President George Bush in his capacity as the president of the European commission.

George Bush is the president of the European commission.

FALSE (= not entailed by the premise on the correct anaphoric resolution)

G. Karas will meet F. Rakas in his capacity as the president of the European commission.

F. Rakas is the president of the European commission.

TRUE (= entailed by the premise on one anaphoric resolution)

PARC Entailment and Contradiction Detection (ECD)

Text: Kim hopped.
Hypothesis: Someone moved.
Answer: TRUE

Text: Sandy touched Kim.
Hypothesis: Sandy kissed Kim.
Answer: UNKNOWN

Text: Sandy kissed Kim.
Hypothesis: No one touched Kim.
Answer: NO

Text: Sandy didn’t wait to kiss Kim.
Hypothesis: Sandy kissed Kim.
Answer: AMBIGUOUS

PARC's BRIDGE System

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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

* = now at *Powerset*

† = now at *Cuil*

Interns

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

Types of Approaches

“Shallow” approaches: many ways to approximate

- String-based (n-grams) vs. structure-based (phrases)
- Syntax: partial syntactic structures
- Semantics: relations (e.g. triples), semantic networks
- ➽ Confounded by negation, syntactic and semantic embedding, long-distance dependencies, quantifiers, *etc*.

“Deep(er)” approaches

- Syntax: (full) syntactic analysis
- Semantics: a spectrum of meaning representations depending on aspects of meaning required for the task at hand
- ➽ Scalability

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BRIDGE

Like Stanford’s NatLog system, BRIDGE is somewhere between shallow, similarity-based approaches and deep, logic-based approaches

Layered mapping from language to deeper semantic representations, Abstract Knowledge Representations (AKR)

Restricted reasoning with AKRs, a particular type of logical form derived from parsed text

BRIDGE

Subsumption and monotonicity reasoning, no theorem proving

Well-suited for particular types of textual entailments

- *p* entails *q* if whenever *p* is true, *q* is true as well, regardless of the facts of the world

Supports translation to a first-order logical formalism for interaction with external reasoners

Conventional meaning vs. speaker meaning

Not a pre-theoretic but rather a theory-dependent distinction

Multiple readings

- ambiguity of meaning?
- single meaning plus pragmatic factors?

The diplomat talked to most victims
The diplomat did not talk to all victims
UNKNOWN / YES

You can have the cake or the fruit. I don't know which.
You can have the fruit
YES
UNKNOWN

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Ambiguity management

The sheep liked the fish.

How many sheep?

How many fish?

Options multiplied out

$$\left\{\begin{array}{l} \textit{The sheep-sg liked the fish-sg.} \\ \textit{The sheep-pl liked the fish-sg.} \\ \textit{The sheep-sg liked the fish-pl.} \\ \textit{The sheep-pl liked the fish-pl.} \end{array}\right\}$$

Options packed

$$\textit{The sheep}\left\{\begin{array}{c} \textit{sg} \\ \textit{pl} \end{array}\right\} \textit{liked the fish}\left\{\begin{array}{c} \textit{sg} \\ \textit{pl} \end{array}\right\}$$

Packed representation:

- – Encodes all dependencies without loss of information
- – Common items represented, computed once
- – Key to practical efficiency with broad-coverage grammars

Packing

Calculate and represent compactly all analyses at each stage

Pass all or N-best analyses along through the stages

Mark ambiguities in a free choice space

Choice space:

$$A1 \vee A2 \leftrightarrow \mathit{true}$$

$$A1 \wedge A2 \rightarrow \mathit{false}$$

BRIDGE Pipeline

Process	Output
Text-Breaking	Delimited Sentences
NE recognition	Type-marked Entities (names, dates, etc.)
Morphological Analysis	Word stems + features
LFG parsing	Functional Representation
Semantic Processing	Scope, Predicate-argument structure
AKR Rules	Abstract Knowledge Representation
Alignment	Aligned T-H Concepts and Contexts
Entailment and Contradiction Detection	YES / NO / UNKNOWN / AMBIGUOUS

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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]
               NTYPE  NSEM [COMMON count]
    SUBJ              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)

Text → AKR

Parse text to f-structures

- Constituent structure
- Represent syntactic/semantic features (e.g. tense, number)
- Localize arguments (e.g. long-distance dependencies, control)

Rewrite f-structures to AKR clauses

- Collapse syntactic alternations (e.g. active-passive)
- Flatten embedded linguistic structure to clausal form
- Map to concepts and roles in some ontology
- Represent intensionality, scope, temporal relations
- Capture commitments of existence/occurrence

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

F-structures *vs.* AKR

- Nested structure of f-structures *vs.* flat AKR
- F-structures make syntactically, rather than conceptually, motivated distinctions
  - Syntactic distinctions canonicalized away in AKR
    - Verbal predications and the corresponding nominalizations or deverbal adjectives with no essential meaning differences
    - Arguments and adjuncts map to roles
  - Distinctions of semantic importance are not encoded in f-structures
    - Word senses
    - Sentential modifiers can be scope taking (negation, modals, *allegedly, predictably*)
    - Tense vs. temporal reference
      - Nonfinite clauses have no tense but they do have temporal reference
      - Tense in embedded clauses can be past but temporal reference is to the future

AKR representation

concept term

WordNet synsets

thematic role

```
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))
```

instantiability facts

event time

A collection of statements
Quantified terms
No variables

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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)

seeing with a telescope

girl with a telescope

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 choice spaces

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Basic structure of AKR

Conceptual Structure

- Terms representing types of individuals and events, linked to WordNet synonym sets by subconcept declarations.
- Concepts are typically further restricted by role assertions.
- Role assertions represent modified predicate-argument structures

Contextual Structure

- t is the top-level context, some contexts are headed by some 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, capturing existential commitments.

Temporal Structure

- Represents qualitative relations between time intervals and events.

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Contextual Structure

- Use of contexts enables flat representations
  - Contexts as arguments of embedding predicates
- Contexts as scope markers

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

Bill said that Ed wanted to talk.

Concepts and Contexts

- Concepts live outside of contexts.

- Still we want to tie the information about concepts to the contexts they relate to.

- Existential commitments

  Did something happen?

    e.g. Did Ed talk? Did Ed talk according to Bill?

  Does something exist?

    e.g. There is a cat in the yard. There is no cat in the yard.

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.

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

Embedded clauses

The problem is to infer whether an event described in an embedded clause is instantiable or uninstantiable at the top level.

It is surprising that there are no WMDs in Iraq.

It has been shown that there are no WMDs in Iraq.

==> **There are no WMDs in Iraq.**

Embedded examples in real text

From Google:

Song, Seoul's point man, **did not forget to persuade** the North Koreans to make a “strategic choice” of returning to the bargaining table...

Song persuaded the North Koreans…

The North Koreans made a “strategic choice”…

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Semantic relations

Presupposition (Factive predicates)

It is surprising that there are no WMDs in Iraq.

It is not surprising that there are no WMDs in Iraq.

Is it surprising that there are no WMDs in Iraq?

If it is surprising that there are no WMDs in Iraq, it is because we had good reasons to think otherwise.

Entailment (Implicative predicates)

It has been shown that there are no WMDs in Iraq.

It has not been shown that there are no WMDs in Iraq.

Has it been shown that there are no WMDs in Iraq?

If it has been shown that there are no WMDs in Iraq, the war has turned out to be a mistake.

Factives

	Class	Inference Pattern
Positive	+-/+ forget that	forget that X $\rightsquigarrow$ X, not forget that X $\rightsquigarrow$ X
Negative	+-/- pretend that	pretend that X $\rightsquigarrow$ not X, not pretend that X $\rightsquigarrow$ not X

John forgot that he had put his keys on the table.
John didn't forget that he had put his keys on the table.

Mary pretended that she had put her keys on the table.
Mary didn't pretend that she had put her keys on the table.

Implicatives

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

She managed to get a job. She didn't manage to get a job.
He failed to get a job. He didn't fail to get a job.
She forced him to leave. She didn't force him to leave.
She prevented him from leaving. She didn't prevent him from leaving.
He wasn't able to leave.
He didn't hesitate to leave.

Phrasal Implicatives

Have	+	Ability Noun	*(ability/means)*	= --Implicative
		Chance Noun	*(chance/opportunity)*	= --Implicative
		Character 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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Challenge 1: Classification

- Existing lexical resources (dictionaries, WordNet, VerbNet) do not contain the necessary information.
  - We examined 400 most frequent verbs with infinitival and that-complements (not an easy task).
  - About a third turned out to be factives or implicatives of some type and we marked them.

Classification is time-consuming

What type of construction is ***refuse to***?

Vets **refuse to forgive** Kerry for antiwar acts.

⟹ Vets don't forgive Kerry for antiwar acts.

Yet **I did not refuse to go** Saudi Arabia. **I went** because the army had attempted to make my case appear to be one of cowardice--which it certainly wasn't.

But when a customer walked up to her counter to get a refill for Micronor, Brauer **did not refuse to fill** the prescription or explain her objections. Instead, she lied. Brauer told the patient that they did not have Micronor in stock.

Conclusion: **refuse to** is **+-implicative**

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Challenge 2: Stacking

- Implicative and factive constructions may be stacked together

Ed didn’t manage to remember to open the door.

==> Ed didn’t remember to open the door.

==> Ed didn’t open the door.

Implicatives under Factives

It is surprising that Bush dared to lie.

⇓

Bush lied.

⇑

It is not surprising that Bush dared to lie.

Challenge 3: Polarity is globally determined

- The polarity of the environment of an embedding predicate depends on the chain of predicates it is in the scope of.
- We designed and implemented an algorithm that recursively computes the polarity of a context and lifts the instantiability and uninstantiability facts to the top-level 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

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Computing 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

Example: polarity propagation

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

↓

"Dave left."

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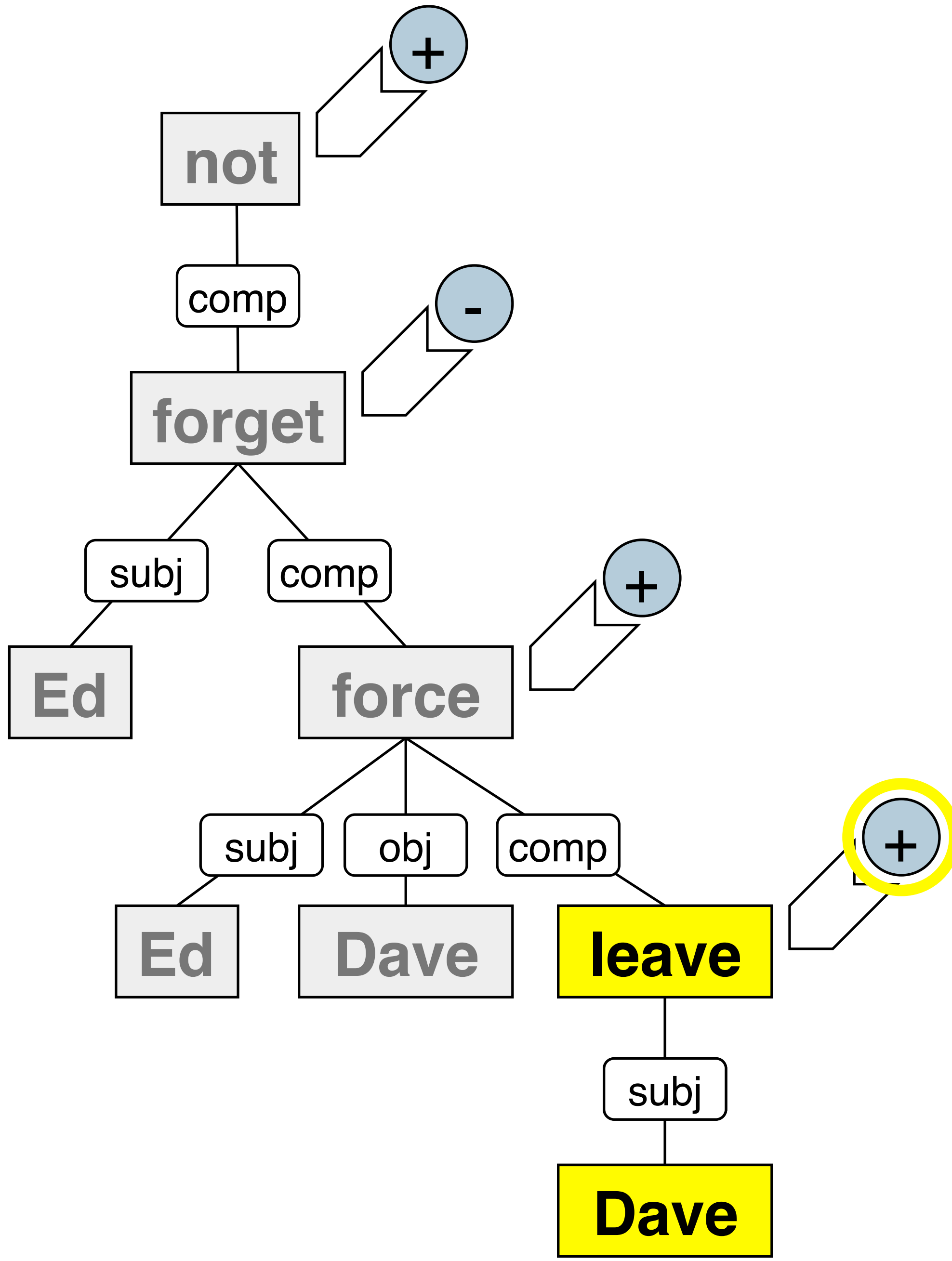

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ECD

- ECD operates on the AKRs of the passage and of the hypothesis
- ECD operates on packed AKRs, hence no disambiguation is required for entailment and contradiction detection
  - If one analysis of the passage entails one analysis of the hypothesis and another analysis of the passage contradicts some other analysis of the hypothesis, the answer returned is AMBIGUOUS
  - Else: If one analysis of the passage entails one analysis of the hypothesis, the answer returned is YES
    - If one analysis of the passage contradicts one analysis of the hypothesis, the answer returned is NO
    - Else: The answer returned is UNKNOWN

AKR (Abstract Knowledge Representation)

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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How ECD works

Context

Alignment

Text: t Kim hopped.

Hypothesis: t Someone moved.

Specificity computation

Text: t Kim hopped.

Hypothesis: t Someone moved.

Elimination of H facts that are entailed by T facts.

Text: t Kim hopped.

Hypothesis: t Someone moved.

Alignment and specificity computation

Context

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.**
Text:	**t**	**Every boy saw a small cat.**
Hypothesis:	**t**	**Every small boy saw a cat.**

Every (↓) (↑)

Some (↑) (↑)

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Elimination of entailed terms

Context

Text: t Every boy saw a small cat.

Hypothesis: t Every small boy saw a cat.

Text: t Every boy saw a small cat.

Hypothesis: t Every small boy saw a cat.

Text: t Every boy saw a small cat.

Hypothesis: t Every small boy saw a cat.

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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Stages of ECD

1. WordNet and Alias alignment for (un)instantiable concepts in conclusion

   1a Returns < = > depending on hyperlists of terms

   1b Returns < = > depending on theory of names (assuming 1a matched)

2. Make extra top contexts for special cases — e.g. Making head of question (below) interrogative a top_context

3. Context alignment

   Any top context in conclusion aligns with any top context in premise

   Any non-top_context in conclusion aligns with any non top_context in premise if their context_heads align in stage 1

4. paired_roles are saved (roles with the same role name in premise and conclusion on aligned concepts)

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Stages of ECD

6. unpaired roles in premise and conclusion (both) makes concepts not align.
7. cardinality restrictions on concepts are checked and modify alignment direction (including dropping inconsistent alignments)
8. Paired roles are checked to see how their value specificity affects alignment
9. Temporal modifiers are used to modify alignment
10. Instantiable concepts in the conclusion are removed if there is a more specific concept instantiable in an aligned context in premise.
11. Conversely for uninstantiable
12. Contradiction checked (instantiable in premise and uninstantiable in conclusion, and vice versa)

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MacCartney's Natural Logic (NatLog)

Point of departure: Sanchez Valencia's elaborations of Van Benthem's Natural Logic

Seven relevant relations:

$x \equiv y$	equivalence	couch ≡ sofa	$x = y$
$x \sqsubset y$	forward entailment	crow⊏bird	$x \subset y$
$x \sqsupset y$	reverse entailment	Asian⊐Thai	$x \supset y$
$x \wedge y$	negation	able^unable	$x \cap y = 0 \wedge x \cup y = U$
$x \mid y$	alternation	cat|dog	$x \cap y = 0 \wedge x \cup y \neq U$
$x \smile y$	cover	animal‿non-ape	$x \cap y \neq 0 \wedge x \cup y = U$
$x \# y$	independence	hungry#hippo	

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Table of joins for 7 basic entailment relations

<table>
<tr><th></th><th>≡</th><th>⊏</th><th>⊐</th><th>^</th><th>|</th><th>‿</th><th>#</th></tr>
<tr><td>≡</td><td>≡</td><td>⊏</td><td>⊐</td><td>^</td><td>|</td><td>‿</td><td>#</td></tr>
<tr><td>⊏</td><td>⊏</td><td>⊏</td><td>≡⊏⊐|#</td><td>|</td><td>|</td><td>⊏^|‿#</td><td>⊏|#</td></tr>
<tr><td>⊐</td><td>⊐</td><td>≡⊏⊐‿#</td><td>⊐</td><td>‿</td><td>⊐^|‿#</td><td>‿</td><td>⊐‿#</td></tr>
<tr><td>^</td><td>^</td><td>‿</td><td>|</td><td>≡</td><td>⊐</td><td>⊏</td><td>#</td></tr>
<tr><td>|</td><td>|</td><td>⊏^|‿#</td><td>|</td><td>⊏</td><td>≡⊏⊐|#</td><td>⊏</td><td>⊏|#</td></tr>
<tr><td>‿</td><td>‿</td><td>‿</td><td>⊐^|‿#</td><td>⊐</td><td>⊐</td><td>≡⊏⊐‿#</td><td>⊐‿#</td></tr>
<tr><td>#</td><td>#</td><td>⊏‿#</td><td>⊐|#</td><td>#</td><td>⊐|#</td><td>⊏‿#</td><td>≡⊏⊐^|‿#</td></tr>
</table>

Cases with more than one possibility indicate loss of information.
The join of # and # is totally uninformative.

Entailment relations between expressions differing in atomic edits (substitution, insertion, deletion)

Substitutions:

- open classes (need to be of the same type)
  - Synonyms: ≡ relation
  - Hypernyms: ⊏ relation (crow bird)
  - Antonyms: | relation (hot|cold) Note: not ^ in most cases, no excluded middle.
  - Other nouns: | (cat|dog)
  - Other adjectives: # (weak#temporary)
  - Verbs: ??
  - …
  - Geographic meronyms: ⊏ (in Kyoto ⊏ in Japan) but note: not without the preposition Kyoto is beautiful ⊏ Japan is beautiful

Entailment relations

Substitutions:

closed classes, example quantifiers:

all ≡ every

every ⊏ some (non-vacuity assumption)

some ^ no

no | every (non-vacuity assumption)

four or more ⊏ two or more

exactly four | exactly two

at most four ‿ at most two

most # ten or more

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Entailment relations

Deletions and insertions: default: $\sqsubset$

(upward-monotone contexts are prevalent)

- e.g. red car $\sqsubset$ car
- But doesn't hold for negation, non-subsective adjectives, implicatives.

Composition: projectivity of logical connectives

connective	≡	⊏	⊐	^	|	‿	#
Negation (not)	≡	⊐	⊏	^	‿	|	#
Conjunction (and)/intersection	≡	⊏	⊐	|	|	#	#
Disjunction (or)	≡	⊏	⊐	‿	#	‿	#

Composition: projectivity of logical connectives

connective	$\equiv$	$\sqsubset$	$\sqsupset$	$\wedge$	$\mid$	$\smile$	#
Negation (not)	$\equiv$	$\sqsupset$	$\sqsubset$	$\wedge$	$\smile$	$\mid$	#

happy $\equiv$ glad	not happy $\equiv$ not glad
kiss $\sqsubset$ touch	not kiss $\sqsupset$ not touch
human $\wedge$ nonhuman	not human $\wedge$ not nonhuman
French $\mid$ German	not French $\smile$ not German
more that 4 $\smile$ less than 6	not more than 4 $\mid$ not less than 6
swimming # hungry	not swimming # not hungry

Translating Nairn et al. classes into the MacCartney approach

	sign	del	ins	example
implicatives	++/--	≡	≡	He managed to escape ≡ he escaped
	++	⊏	⊐	He was forced to sell ⊏ he sold
	--	⊐	⊏	He was permitted to live ⊐ he did live
	+-/-+	^	^	He failed to pay ^ he paid
	+-	|	|	He refused to fight | he fought
	-+	‿	‿	He hesitated to ask ‿ he asked
factives	+-/+			
	+-/-			
Neutral		#	#	He believed he had won/ he had won

T. Ed didn’t forget to force Dave to leave

H. Dave left

i			f(e)	$g(x_{i-1},e)$ projections	$h(x_0,x_i)$ joins
0	Ed didn’t fail to force Dave to leave				
1	Ed didn’t force Dave to leave	DEL(fail)	^	Context downward monotone: ^	^
2	Ed forced Dave to leave	DEL(not)	^	Context upward monotone: ^	Join of ^,^: ≡
3	Dave left	DEL(force)	⊏	Context upward monotone: ⊏	Join of ≡,⊏: ⊏

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t: We were not able to smoke
h: We smoked Cuban cigars

i	x_i	e_i	$f(e_i)$	$g(x_{i-1},e_i)$	$h(x_0,x_i)$
0	We were not able to smoke				
1	We did not smoke	DEL (permit)	$\sqsupset$	Downward monotone: $\sqsubset$	$\sqsubset$
2	We smoked	DEL(not)	^	Upward monotone: ^	Join of $\sqsubset$,^: |
3	We smoked Cuban cigars	INS (C.cigars)	$\sqsupset$	Upward monotone: $\sqsupset$	Join of |,$\sqsupset$: |

We end up with a contradiction

Why do the factives not work?

MacCartney's system assumes that the implicatures switch when negation is inserted or deleted

But that is not the case with factives and counterfactives, they need a special treatment

Other limitations

De Morgan’s laws: Not all birds fly → some birds do not fly

Buy/sell, win/lose

Doesn’t work with atomic edits as defined.

Needs larger units

Bridge vs NatLog

NatLog	Bridge
Symmetrical between t and h	Asymmetrical between t and h
Bottom up	Top down
Local edits (more compositional?)	Global rewrites possible
Surface based	Normalized input
Integrates monotonicity and implicatives tightly	Monotonicity calculus and implicatives less tightly coupled

We need more power than NatLog allows for
Whatever that power is, it should be more limited than the one demonstrated by the current Bridge system

Inferences in the temporal domain

In 2008 Ed visited us every month.

$\Longrightarrow$ *Ed visited us in July 2008.*

Last year, in July, Ed visited us every day.

$!\Longrightarrow$ *Last year Ed visited us every day.*

Ed has been living in Athens for 3 years.
Mary visited Athens in the last 2 years.

$\Longrightarrow$ *Mary visited Athens while Ed lived in Athens.*

Ed has been living in Athens for 2 years.
Mary visited Athens in the last 3 years.

$!\Longrightarrow$ *Mary visited Athens while Ed lived in Athens.*

Temporal modification under negation and quantification

Temporal modifiers affect monotonicity-based inferences

Everyone arrived in the first week of July 2000.

⟹ *Everyone arrived in July 2000.*

No one arrived in July 2000.

⟹ *No one arrived in the first week of July 2000.*

Everyone stayed throughout the concert.

⟹ *Everyone stayed throughout the first part of the concert.*

No one stayed throughout the concert.

⟹ *No one stayed throughout the first part of the concert.*

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Quantified modifiers and monotonicity

Modifier dropping

Every boy bought a toy <u>from Ed.</u>

$\Rightarrow$ *Every boy bought a toy.*

Last year, <u>in July,</u> he visited us every day.

!$\Rightarrow$ *Last year he visited us every day.*

Modifier adding

Every boy bought a toy.

!$\Rightarrow$ *Every boy bought a toy <u>from Ed.</u>*

Last year he visited us every day.

$\Rightarrow$ *Last year he visited us every day <u>in July</u>.*

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Dependent temporal modifiers
Implicit dependencies made explicit

In 1991 Ed visited us in July.

trole(when,visit:12,interval(included_in, month(7):26))
trole(subinterval, month(7):26, year(1991):4)

In 1991 Ed visited us every week.

trole(when,visit:12,interval(included_in, week:37))
trole(subinterval,   week:37,   year(1991):4)

In 1991 in July Ed visited us every week.

trole(when,visit:12,interval(included_in, week:37))
trole(subinterval,week:37, month(7):26)
trole(subinterval, month(7):26, year(1991):4)

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From temporal modifiers to temporal relations

Inventory of temporal relations: the Allen relations plus certain disjunctions thereof

Recognize the type of temporal modifier

- e.g. bare modifiers, “in” PPs, “for” PPs
  - Ed visited us Monday/that week/every day.
  - Ed slept the last two hours.
  - Ed will arrive a day from/after tomorrow.

Represent the interval specified in the temporal modifier

Locate intervals designated by temporal expressions on time axis

Determine qualitative relations among time intervals

Allen Interval Relations

Relation	Illustration	Interpretation
X < Y Y > X	X Y	X takes place before Y
X m Y Y mi X	X Y	X meets Y (i stands for inverse
X o Y Y oi X	X Y	X overlaps Y
X s Y Y si X	X Y	X starts Y
X d Y Y di X	X Y	X during Y
X F Y Y fi X	X Y	X finishes Y
X = Y	X Y	X is equal to Y (X is cotemporal with Y)

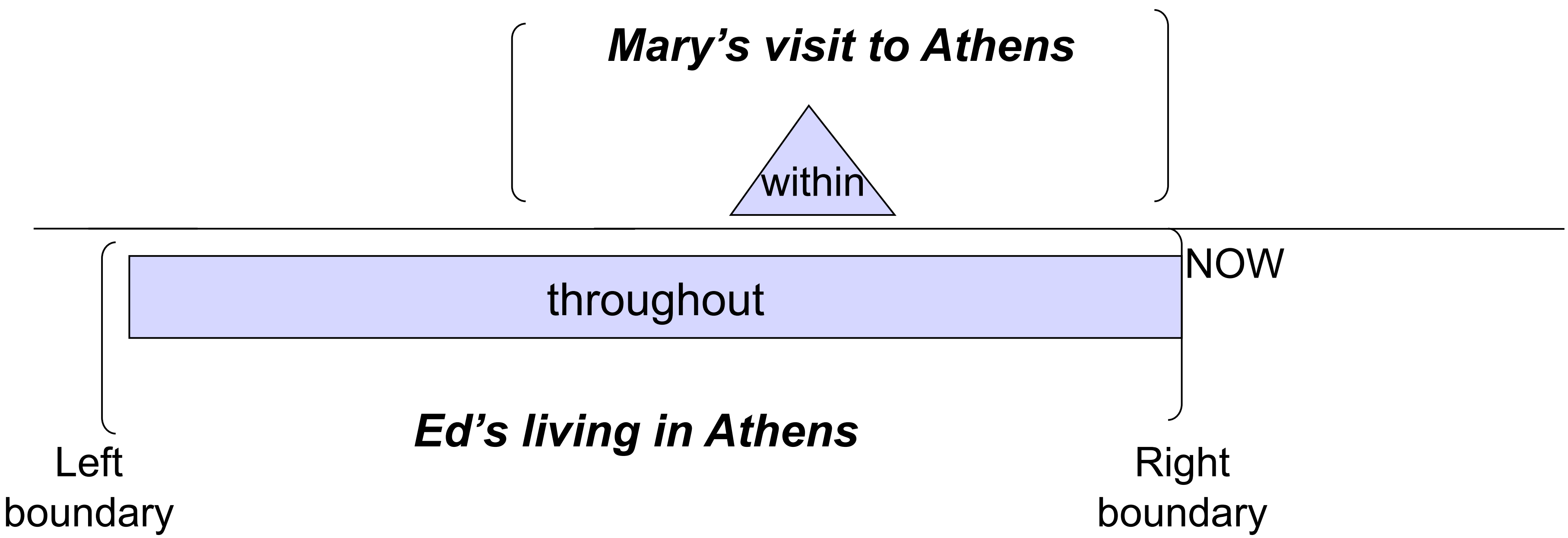
From language to qualitative relations of intervals and events

Ed has been living in Athens for 3 years.
Mary visited Athens in the last 2 years.

⇒ *Mary visited Athens*
while Ed lived in Athens.

Construct interval boundaries using

- Aspect
- Tense
- Preposition meaning



Inference from interval relations

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From English to AKR

Ed has been living in Athens for 3 years.

trole(duration,extended_now:13,interval_size(3,year:17))

trole(when,extended_now:13,interval(finalOverlap,Now))

trole(when,live:3,interval(includes,extended_now:13)

Mary visited Athens in the last 2 years.

trole(duration,extended_now:10,interval_size(2,year:11))

trole(when,extended_now:10,interval(finalOverlap,Now))

trole(when,visit:2,interval(included_in,extended_now:10))

Mary visited Athens while Ed lived in Athens.

trole(ev_when,live:22,interval(includes,visit:6))

trole(ev_when,visit:6,interval(included_in,live:22))

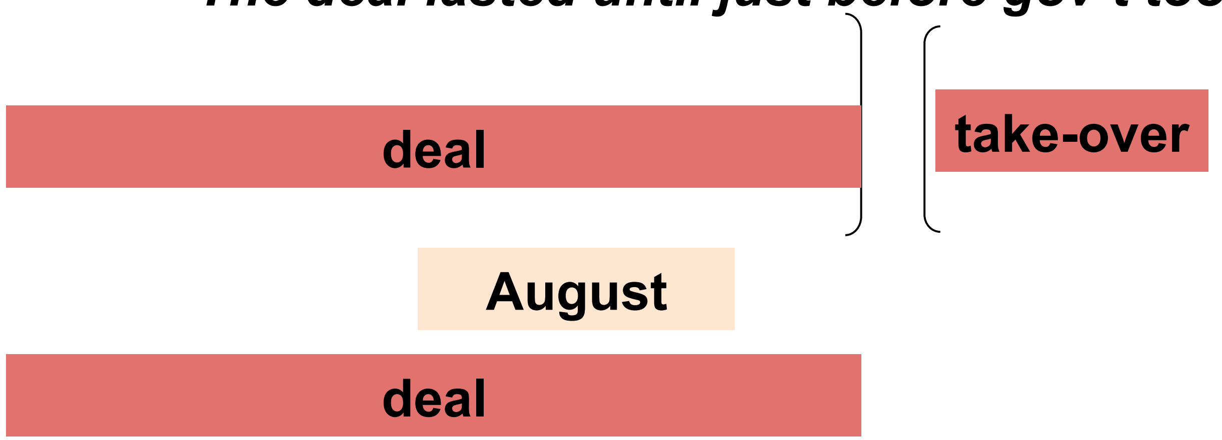
Independent temporal modifiers

The deal lasted through August, until just before the government took over Freddie.

=> *The deal lasted through August.*

The deal lasted until just before the gov't took over Freddie.

The deal lasted until just before gov't took over …



The deal lasted through August.

The government took over after August

Thank you