Textual Entailment: Bridging Logic and Language

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Ron Kaplan “Beyond the GUI: It’s Time for a Conversational User Interface”, Wired 2013

http://www.wired.com/2013/03/conversational-user-interface/
Siri and other personal assistants
The Future is Meaning...
Recent Past...
PARC’s Bridge System (1999-2008)
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Powerset

Acquired by Microsoft, 2008
and Cuil...
Another story

Nowadays: redoing PARC work in Portuguese...
Goals in 2010

A Bridge
Goals in 2010
Goals in 2010...

In fact we want...

- Content analysis
- Large-scale intelligent information extraction, access and retrieval
- Text understanding
- Text generation
- Text simplification
- Automatic summarization
- Dialogue systems
- Question answering
- Machine Translation
- Named Entity Recognition,
- Anaphora/co-reference resolution,
- Reading, writing, grammar aids, etc...
Goals in 2014…

- The same!
- But we’ve done LOTS…
- Only in 2014, more than 9 papers (5 to be presented next month, in DHandES, PROPOR and TorPorEsp) on systems for Portuguese
- TO RECAP:
What can we do?
Logic and Lexical Ontologies

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Improving Lexical Resources and Inferential Systems to work with Logic coming from free form text.
PARC’s Bridge System (1999-2008)

Text

Parsing

F-structure

KR Mapping

semantics

Inference Engines

KR

Sources

Question

Grammar
Stanford Parser

Term rewriting
OpenWN-PT
SUMO-PT
KR mapping rules

Textual Inference logics

Assertions

Query

Idea: Simplify and reproduce components in PORTUGUESE
A Generic Architecture

All require a host of pre & post-processing: text segmenters, POS taggers, Lexica, Named Entity Recognizers, Gazetteers, Temporal Modules, Coreference Resolution, WSD, etc

Pipeline Envisaged in 2010

Grammar

• LFG
• CCG
• HPSG
• ...

Semantics

• Transfer
• MRS
• DRS
• ...

Knowledge Representation

• AKR
• Episodic Log
• Triples
• ...

Pipeline Envisaged in 2010
Reality Check...

- What PARC considered pre-processing is MOST of the processing...

- Got the XLE research license, but hard to use it, needed several lexicons that DO NOT exist in Portuguese, notably WordNet

- There are several open toolkits that can be used instead: FREELING, OpenNLP, StanfordNLP, NLTK

  More usable, more community, less expertise required
Textual entailment methods recognize, generate, and extract pairs \( \langle T, H \rangle \) of natural language expressions, such that a human who reads (and trusts) \( T \) would infer that \( H \) is most likely also true (Dagan, Glickman & Magnini, 2006)

Example:

\( T \): The drugs that slow down Alzheimer’s disease work best the earlier you administer them.

\( H \): Alzheimer’s disease can be slowed down using drugs.

\( T \Rightarrow H \)

A series of competitions since 2004, ACL “Textual Entailment Portal”, many different systems...
RTE Competitions


- A BIG area, lots of research: tutorials, books, courses…

- 8th Recognizing Textual Entailment Challenge at SemEval 2013

- [...] NIST and PASCAL

All Logic?...

- By no means
- Mostly NO Logic...
- Graphs, alignments, transformations, stats
- Some logic though: Stanford (MacCartney&Manning, Bos, etc..)
- Today: Inference using theorem proving
- Vivek Nigam, UF Paraiba
BlackBox Inference: outline

- Use Xerox’s PARC Bridge system as a black box to produce NL representations of sentences in KIML (Knowledge Inference Management Language).

- KIML + inference rules = TIL (version of) Textual Inference Logic

- Translate TIL formulas to a theory in Maude, the SRI rewriting system.

- Use Maude rewriting to prove Textual Entailment “theorems”.
An example: a crow slept

Conceptual Structure:
role(cardinality restriction,crow-1,sg)
role(sb,sleep-4,crow-1)
subconcept(crow-1,
[crow#n#1,crow#n#2,brag#n#1])
subconcept(sleep-4,
[sleep#v#1,sleep#v#2])

Contextual Structure:
instantiable(crow-1,t)
instantiable(sleep-4,t)
top context(t)
Temporal Structure:
trole(when,sleep-4,interval(before,Now))
KIML (Knowledge Inference Management Language)

- A representation language based on events (neo-Davidsonian), concepts, roles and contexts, McCarthy-style

- Using events, concepts and roles is traditional in NL semantics

- Usually equivalent to FOL (first-order logic), ours a small extension, contexts are like modalities.
  Language based on linguists’ intuitions!

- Exact formulation still being decided: e.g. not considering temporal assertions, yet…
KIML versus FOL

- In FOL could write $\exists \text{Crow} \exists \text{Sleep} \cdot \text{Sleep}(\text{crow})$
- Instead we will use basic concepts from a parameter ontology

- $O$ (could be Cyc, SUMO, UL, KM, etc...)

- Instead of FOL have Skolem constant crow-1 a subconcept of an ambiguous list of concepts:
  \[ \text{subconcept(crow-1, [crow#n#1,crow#n#2,brag#n#1])} \]

- Same for sleep-2 and have roles relating concepts
  \[ \text{role(sb,sleep-4,crow-1)} \]
  meaning that the sb=subject of the sleeping event is a crow concept
What is Different?

- Corresponding to formulas in FOL, KIML has a collection of assertions that, read conjunctively, correspond to the semantics of a (fragment of a) sentence in English.

- Concepts in KIML – similar to Description Logic
  concepts primitive concepts from an idealized version of the chosen

- Ontology on-the-fly concepts, always sub-concepts of some primitive concept. concepts are as fine or as coarse as needed by the application

- Roles connect concepts: deciding which roles with which concepts a big problem... for linguists

- Roles assigned in a consistent, coherent and maximally informative way by the NLP module
Contexts for Quantification

- Using contexts for modelling negation, implication, as well as propositional attitudes and other intensional phenomena. There is a first initial context (written as t), roughly what the author of the sentence takes the world to be.

- Contexts used for making existential statements about the existence and non-existence in specified possible worlds of entities that satisfy the intensional descriptions specified by our concepts. Propositional attitudes predicates (knowing, believing, saying,...) relate contexts and concepts in our logic.

- Concepts like knowing, believing, saying introduce context that represents the proposition that is known, believed or said.

COMMONSENSE 2013
Ed knows that the crow slept

- alias(Ed-0,[Ed])
  role(prop,know-1,ctx(sleep-8))
  role(sb,know-1,Ed-0)
  role(sb,sleep-8,crow-6)
- subconcept(Ed-0,[male#n#2])
- subconcept(crow-6, [crow#n#1,crow#n#2,brag#n#1])
- subconcept(know-1,[know#v#1,...,sleep-together#v#1])
- subconcept(sleep-8, [sleep#v#1,sleep#v#2])
- context(ctx(sleep-8)), context(t) context-lifting-relation(veridical,t,ctx(sleep-8)) context-relation(t,ctx(sleep-8),crel(prop,know-1))
- instantiable(Ed-0,t)
- instantiable(crow-6,ctx(sleep-8))
- instantiable(sleep-8,ctx(sleep-8))
Inference to build reps and to reason with them

- In previous example can conclude: 
  instantiable(sleep-8,t)  
  if knowing X implies X is true.  
  (Can conclude instantiable(crow-6,t) too, for definitiveness reasons..)

- Happening or not of events is dealt with by the instantiability/uninstantiability predicate that relates concepts and contexts  
  e.g. Negotiations prevented a strike

- Contexts can be: 
  veridical, antiveridical or averidical with respect to other contexts.

- Have ‘context lifting rules’ to move instantiability assertions between contexts.
Inference Rules

The totally obvious

\[
\begin{align*}
    s & \rightarrow s \\
\end{align*}
\]

\[
\begin{align*}
    s & \rightarrow t \\
    s & \rightarrow r \\
    \hline
    r & \rightarrow t
\end{align*}
\]
Inference Rules

Inheritance rules

Nina has a canary, canary ⊆ bird

Nina has a bird

Ed kissed Nina, kiss ⊆ touch

Ed touched Nina

Every carp is a fish, carp ⊆ koi

Every koi is a fish

She didn’t give him a bird, bird ⊆ canary

She didn’t give him a canary
Modifiers Inference Rules

Ed arrived in the city by bus

\[ \text{Ed arrived in the city} \]

Ed did not arrive in the city

\[ \text{Ed did not arrive in the city by bus} \]

Ed arrived in the city, Ed ⊆ person

A person arrived in the city

Ed arrived in Rome, Rome ⊆ city

Ed arrived in a city

Note that *Ed did not arrive in the city by bus* does not entail that
*Ed did not arrive in the city*. 
Implicative Commitment Rules

- Preserving polarity:
  “Ed managed to close the door” → “Ed closed the door”
  “Ed didn’t manage to close the door” → “Ed didn’t close the door”.

- The verb “forget (to)” inverts polarities:
  “Ed forgot to close the door” → “Ed didn’t close the door”
  “Ed didn’t forget to close the door” → “Ed closed the door”.

- There are six such classes, depending on whether positive environments are taken to positive or negative ones.

- Accommodating this fine-grained analysis into traditional logic description is further work. (Nairn et al 2006 presents an implemented recursive algorithm for composing these rules)
Towards a Rewriting Framework

- A implementation of TIL, using the traditional rewriting system Maude to reason about the logical representations produced by the blackbox NLP module

- Hand-correct the representations given by the NLP module: the goal here is not to obtain correct representations, but to work logically with correct representations.

- Maude system is an implementation of rewriting logic developed at SRI International.

- Maude modules (rewrite theories) consist of a term-language plus sets of equations and rewrite-rules. Terms in rewrite theory are constructed using operators (functions taking 0 or more arguments of some sort, which return a term of a specific sort).
A Rewriting Framework

- A rewrite theory is a triple $(\Sigma, E, R)$, with $(\Sigma, E)$ an equational theory with $\Sigma$ a signature of operations and sorts, and $E$ a set of (possibly conditional) equations, and with $R$ a set of (possibly conditional) rewrite rules.

- A few logical predicates for our natural languages representations: (sub)concepts, roles, contexts and a few relations between these.

- But the concepts that the representations would use in a minimally working system in the order of 135 thousand, concepts in WordNet. Scaling issues?
Maude Rewriting

- Basic rewriting sorts: Relations, SBasic and UnifSet

- TIL basic assertions such as canary ⊑ bird belong to Relations.

- Concept and contextual assertions, such as instantiable(drink-0,t) belong to the SBasic basic statements sort.

- The third basic sort, UnifSet, contains unification of skolem constants, such as crow-6 := bird-1. This last sort is necessary for unifying skolem constants.
Experimental Results: a few theorems

1. a crow was thirsty ⊢ a thirsty crow

2. a thirsty crow ⊢ a crow

3. ed arrived and the crow flew away. ⊢ the crow flew away

4. ed knew that the crow slept ⊢ the crow slept

5. ed did not forget to force the crow to fly ⊢ the crow flew

6. the crow came out in search of water ⊢ the crow came out

7. a crow was thirsty ⊢ a bird was thirsty
Conclusions

- Proof-of-concept framework

- Introduced a general rewriting framework, using KIML assertions and TIL inference system for textual entailment

- Demonstrated by example that framework can be implemented in Maude and used it to prove in an semi-automated fashion whether a sentence follows from another

- ‘shallow theorem proving’ for common sense applications?

- Many problems: black box, ambiguity, temporal information, etc..
Thanks!
Thanks!
References


References

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Logical and Semantic Frameworks with Applications, LSFA'10, Natal, Brazil, 2010.

How do we get about it?

Totally unbaked ideas…

- The future seems easier if it’s Open Source (see Ann Copestake’s page)
- And collaborative (that too!)
- Translation and comparison of results is necessary
- Many more lexical resources need to be created and shared
- Machine learning of semantics/kr is required
- Logics, building up from ECD, using probabilistic component need to be in place
- Looking on the bright side… LOTS of FUN WORK!
A bridge between language and logic

Wish List:

- translation compositional and principled,
- meaning preserving, at least truth value preserving…
- a reasonable fragment of all language
- generic texts
- “logical forms” obtained are useful for reasoning.

Questions:

- which kind of logic on the target?
- how do we know when we’re done?
- how do we measure quality of results?
Simplifying the PARC’s Bridge Architecture

Idea: Simplify and reproduce components in PORTUGUESE