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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

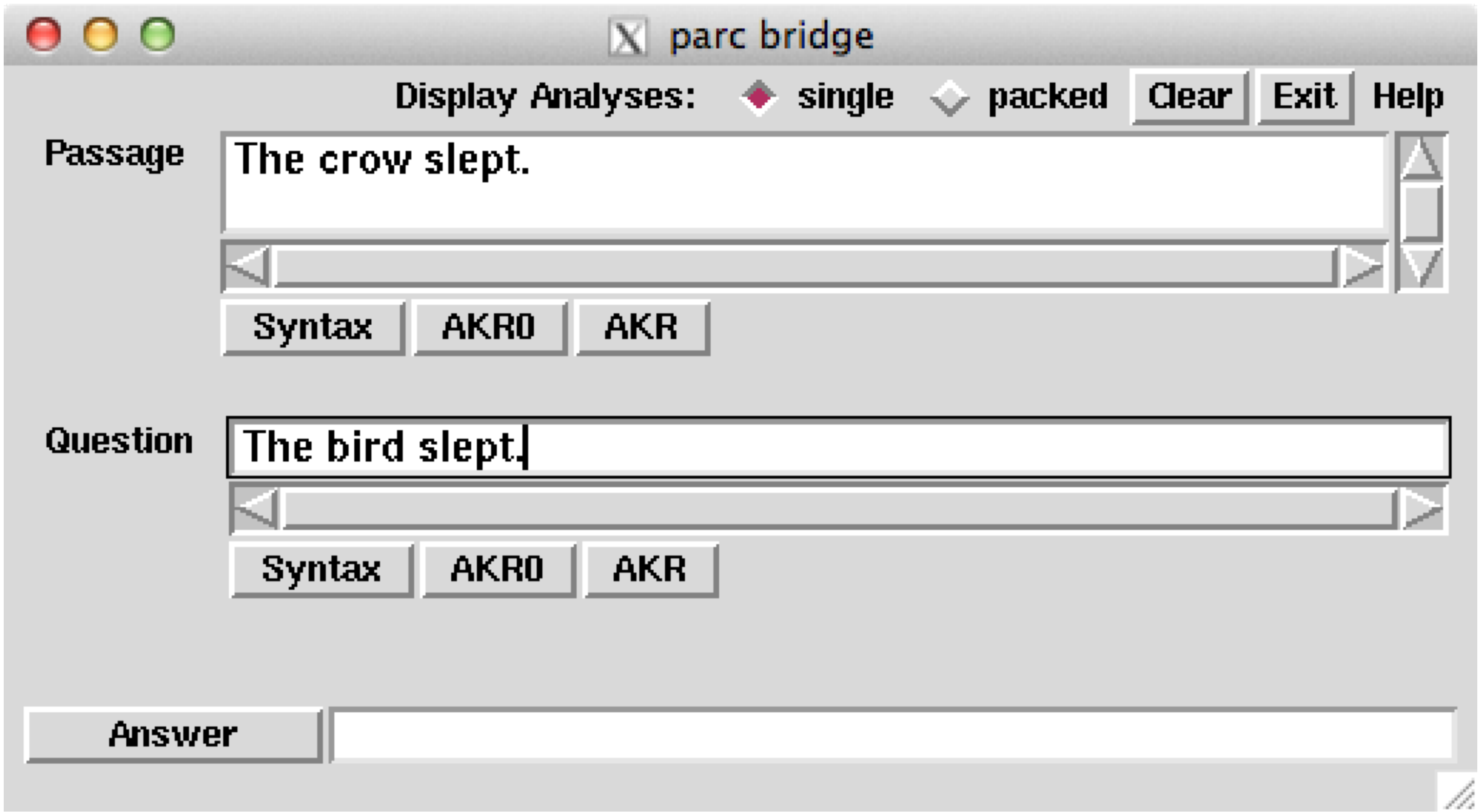
http://www.wired.com/2013/03/conversational-user-interface/

Siri and other personal assistants

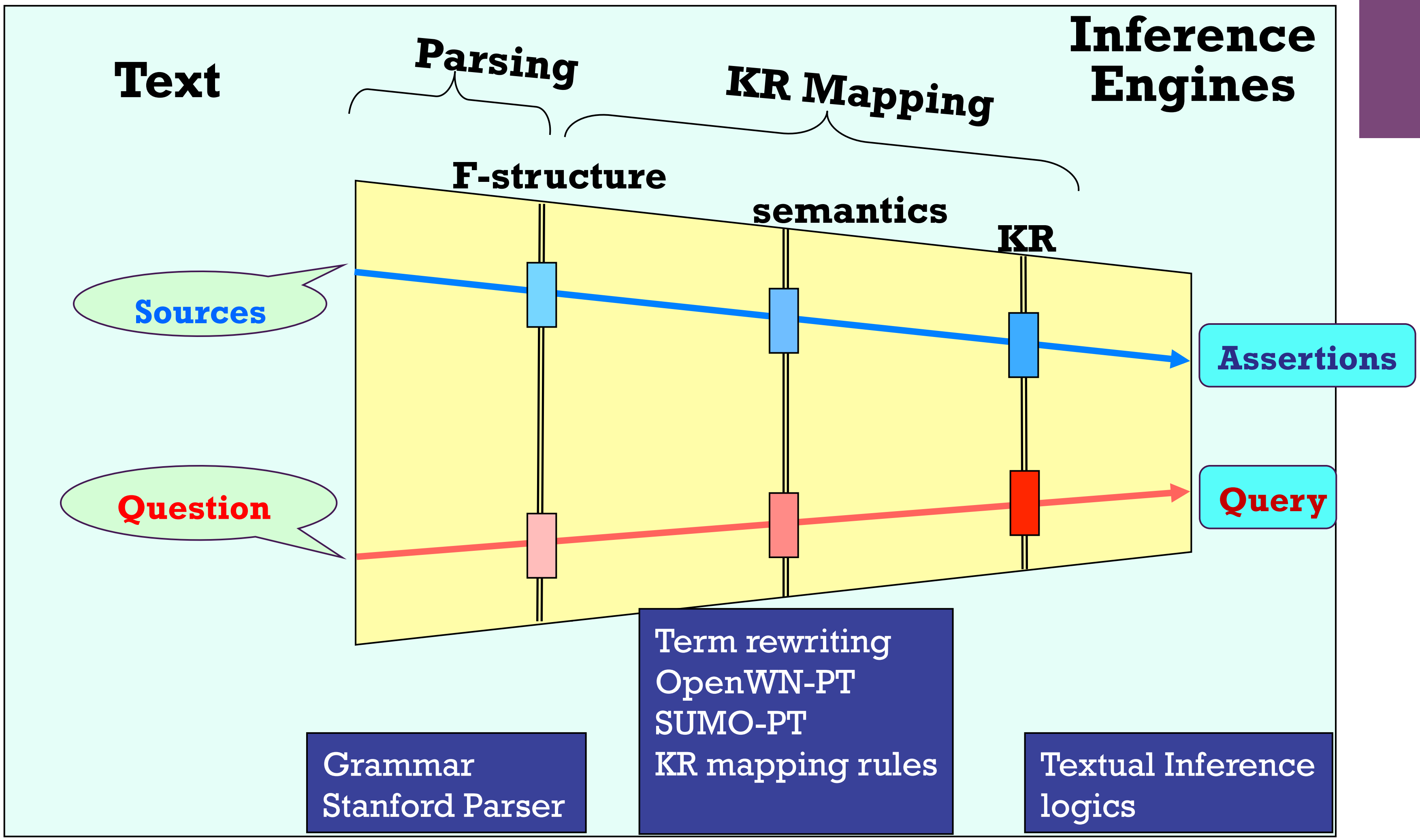
The Future is Meaning…

Recent Past…

PARC's Bridge System (1999-2008)



+ PARC's Bridge System (1999-2008)



Powerset

Acquired by Microsoft, 2008

and Cuil…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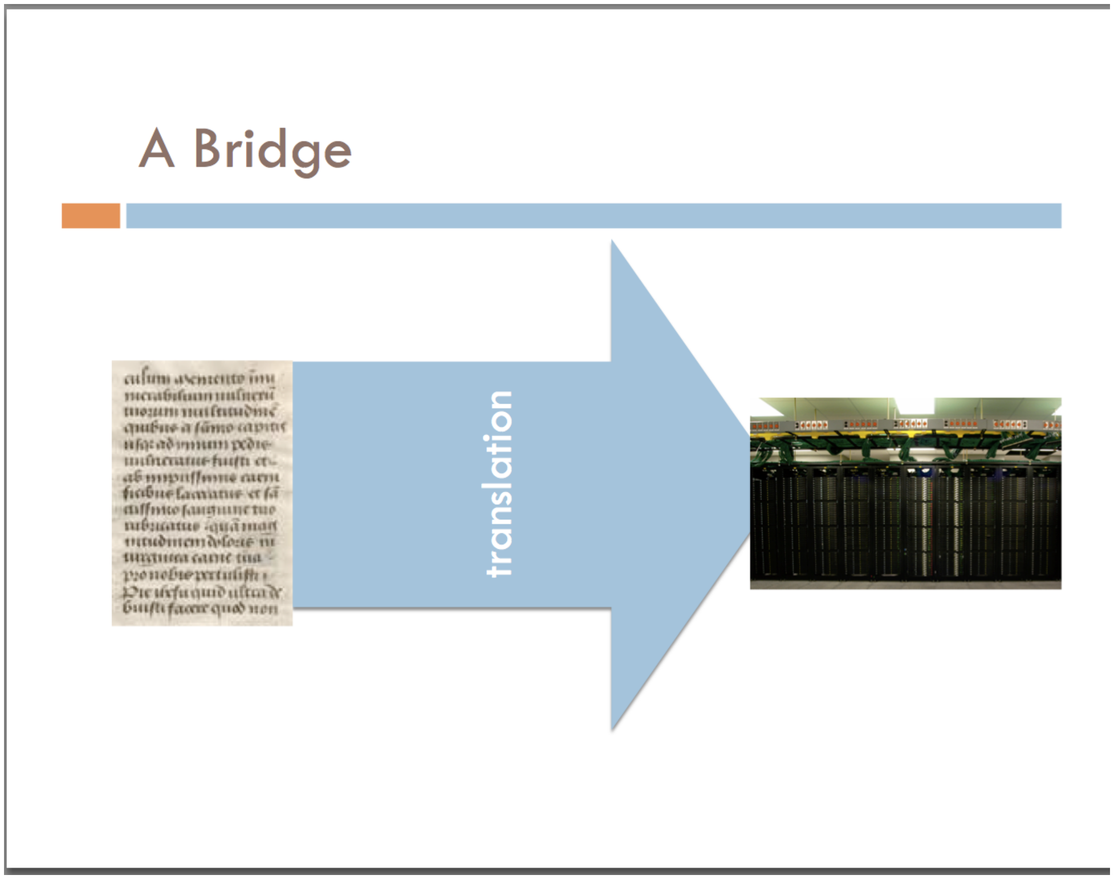
Another story

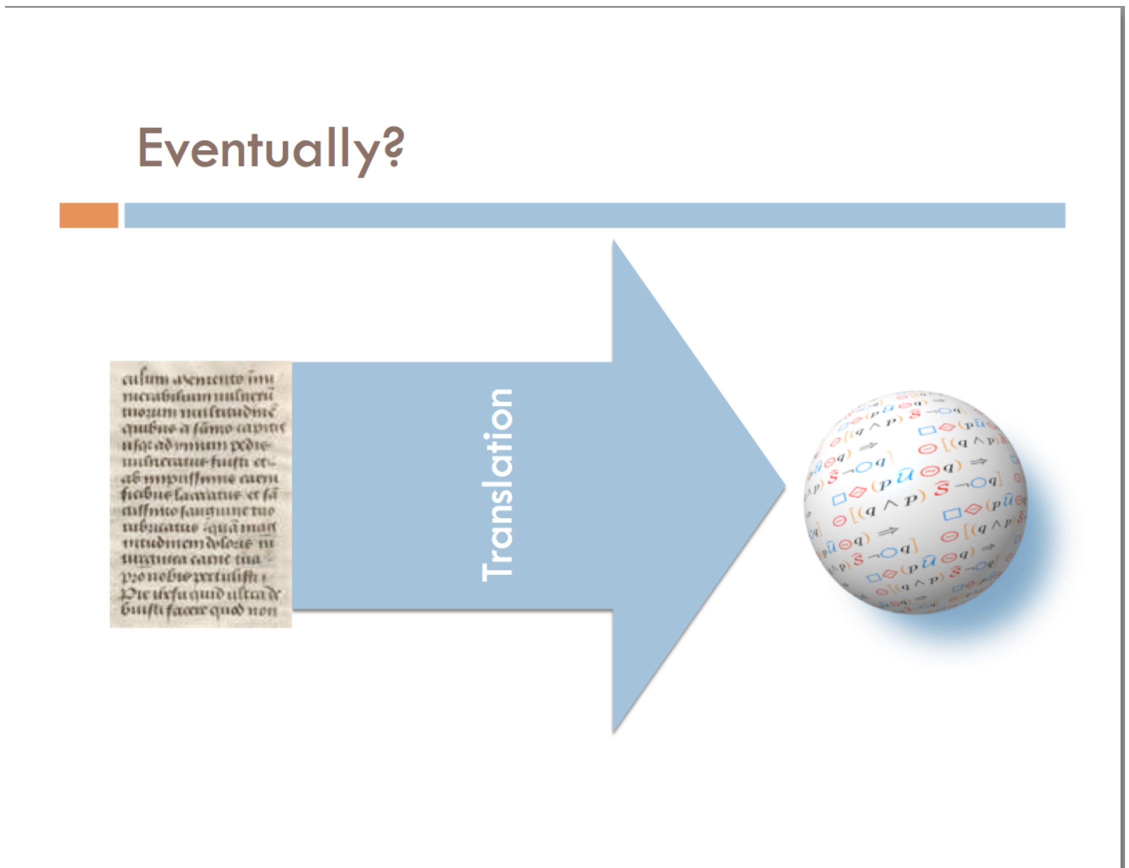
https://www.parc.com/event/934/adventures-in-searchland.html

Nowadays: redoing PARC work in Portuguese…

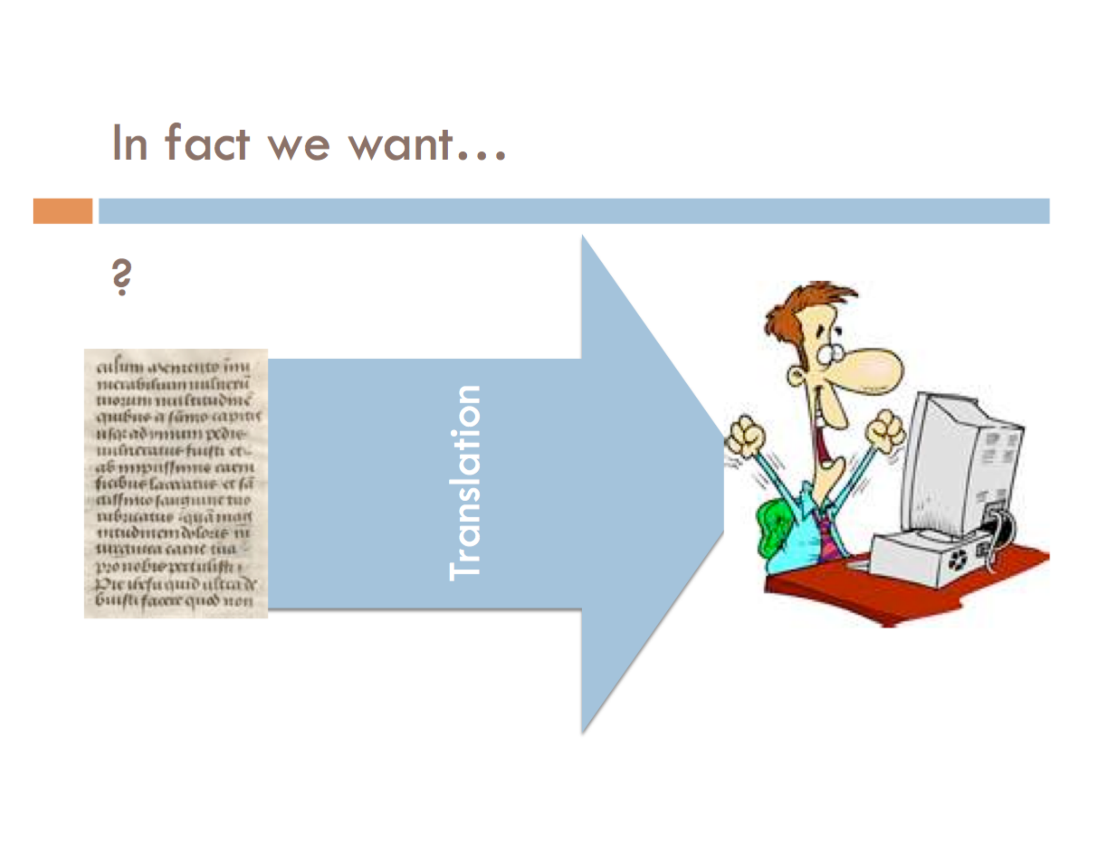
Goals in 2010



Goals in 2010



Goals in 2010…



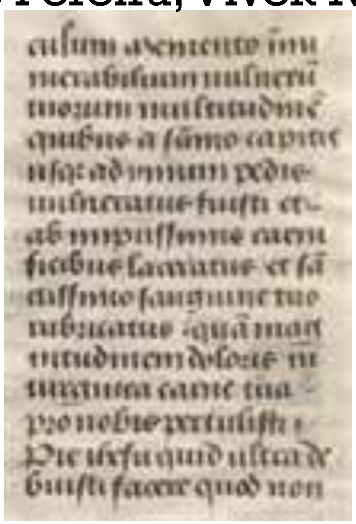
- ☐ Content analysis /large-scale intelligent information extraction, access and retrieval
- ☐ Text understanding
- ☐ Text generation
- ☐ Text simplification
- ☐ Automatic summarization
- ☐ Dialogue systems
- ☐ Question answering
- ☐ Machine Translation
- ☐ Named Entity Recognition,
- ☐ Anaphora/co-reference 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:

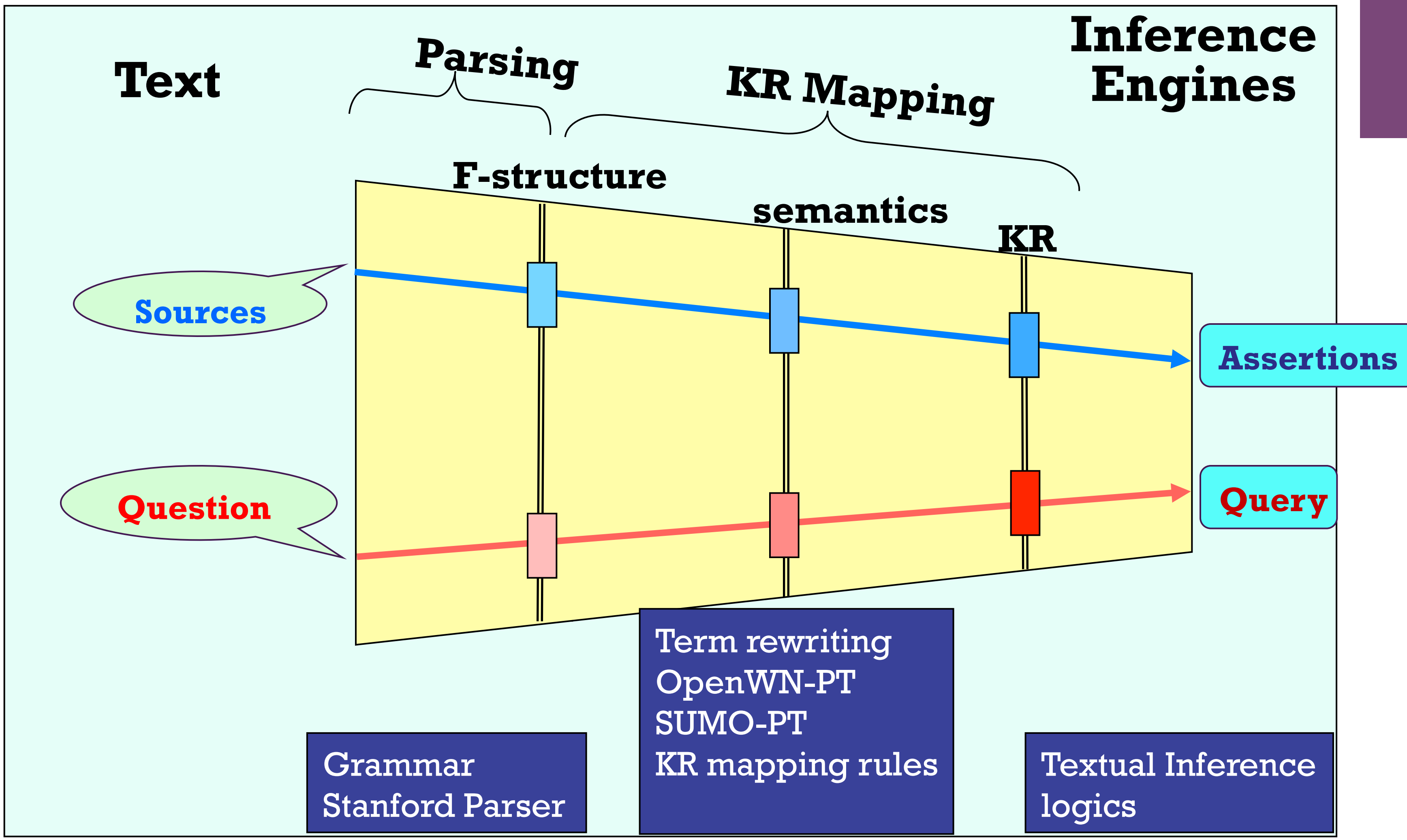
What can we do?
Logic and Lexical Ontologies

Group: Alexandre Rademaker, Bruno Lopes, Claudia Freitas, Dario Oliveira,Gerard de Melo, Livy Real, Suemi Higuchi, Hermann Hauesler, Luiz Carlos Pereira, Vivek Nigam and Valeria de Paiva



Improving Lexical Resources and Inferential Systems to work with Logic coming from free form text.

+ PARC's Bridge System (1999-2008)

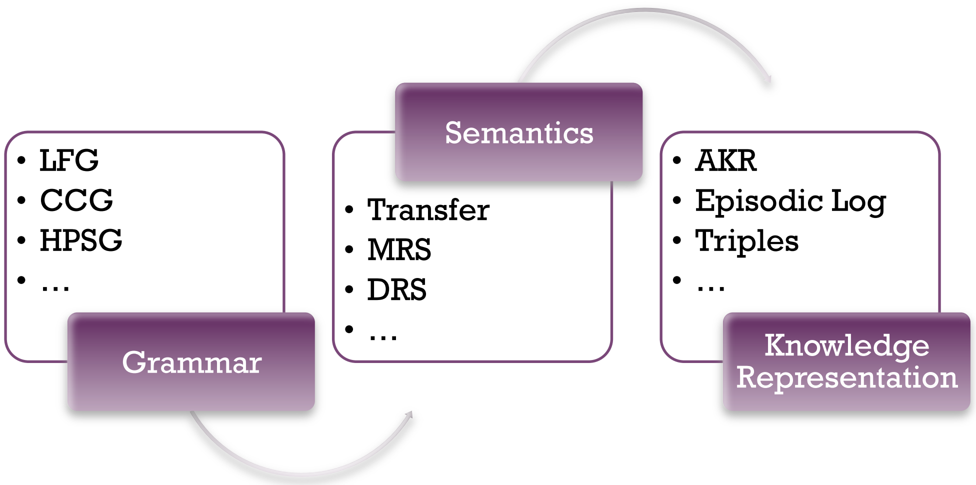


Idea: Simplify and reproduce components in PORTUGUESE

Pipeline Envisaged in 2010

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



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

Today: Inference, any one?...

- **Textual entailment** methods recognize, generate, and extract pairs ⟨T,H⟩ 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…

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RTE Competitions

- 15 meetings so far in http://aclweb.org/aclwiki/index.php?title=Textual_Entailment_References
- A BIG area, lots of research: tutorials, books, courses…
- 8th Recognizing Textual Entailment Challenge at SemEval 2013
- […] NIST and PASCAL
- ACL 2005 Workshop on Empirical Modeling of Semantic Equivalence and Entailment, 2005
  First PASCAL Recognising Textual Entailment Challenge (RTE-1), 2005

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 ∃Crow∃Sleep.Sleep(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: subconcept(crow-1, [crow#n#1,crow#n#2,brag#n#1])
- Same for sleep-2 and have roles relating concepts role(sb,sleep-4,crow-1)
meaning that the sb=subject of the sleeping event is a crow concept

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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

$$\frac{}{s \to s} \qquad \frac{s \to t \qquad s \to r}{r \to t}$$

Inference Rules

Inheritance rules

$$\frac{\text{Nina has a canary, canary} \sqsubseteq \text{bird}}{\text{Nina has a bird}} \qquad \frac{\text{Ed kissed Nina, kiss} \sqsubseteq \text{touch}}{\text{Ed touched Nina}}$$

$$\frac{\text{Every carp is a fish, carp} \sqsupseteq \text{koi}}{\text{Every koi is a fish}}$$

$$\frac{\text{She didn't give him a bird, bird} \sqsupseteq \text{canary}}{\text{She didn't give him a canary}}$$

Modifiers Inference Rules

$$\frac{\text{Ed arrived in the city by bus}}{\text{Ed arrived in the city}} \qquad \frac{\text{Ed did not arrive in the city}}{\text{Ed did not arrive in the city by bus}}$$

$$\frac{\text{Ed arrived in the city, Ed} \sqsubseteq \text{person}}{\text{A person arrived in the city}} \qquad \frac{\text{Ed arrived in Rome, Rome} \sqsubseteq \text{city}}{\text{Ed arrived in a city}}$$

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)

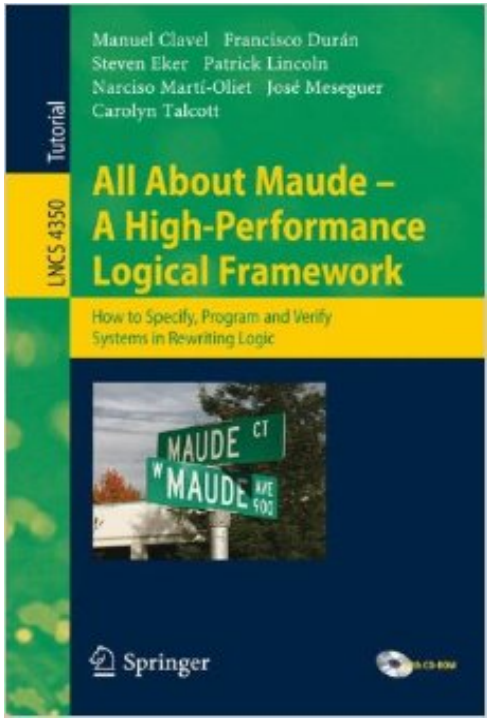
Towards a Rewriting Framework

- 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 (Σ,E,R), with (Σ,E) an equational theory with Σ 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 $\sqsubseteq$ 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 for unifying skolem constants.

Experimental Results: a few theorems

- 1. a crow was thirsty.$\vdash$ a thirsty crow
- 2. a thirsty crow$\vdash$ a crow
- 3. ed arrived and the crow flew away. $\vdash$ the crow flew away
- 4. ed knew that the crow slept $\vdash$ the crow slept
- 5. ed did not forget to force the crow to fly $\vdash$ the crow flew
- 6 the crow came out in search of water $\vdash$ the crow came out
- 7. a crow was thirsty $\vdash$ 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!

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How do we got 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

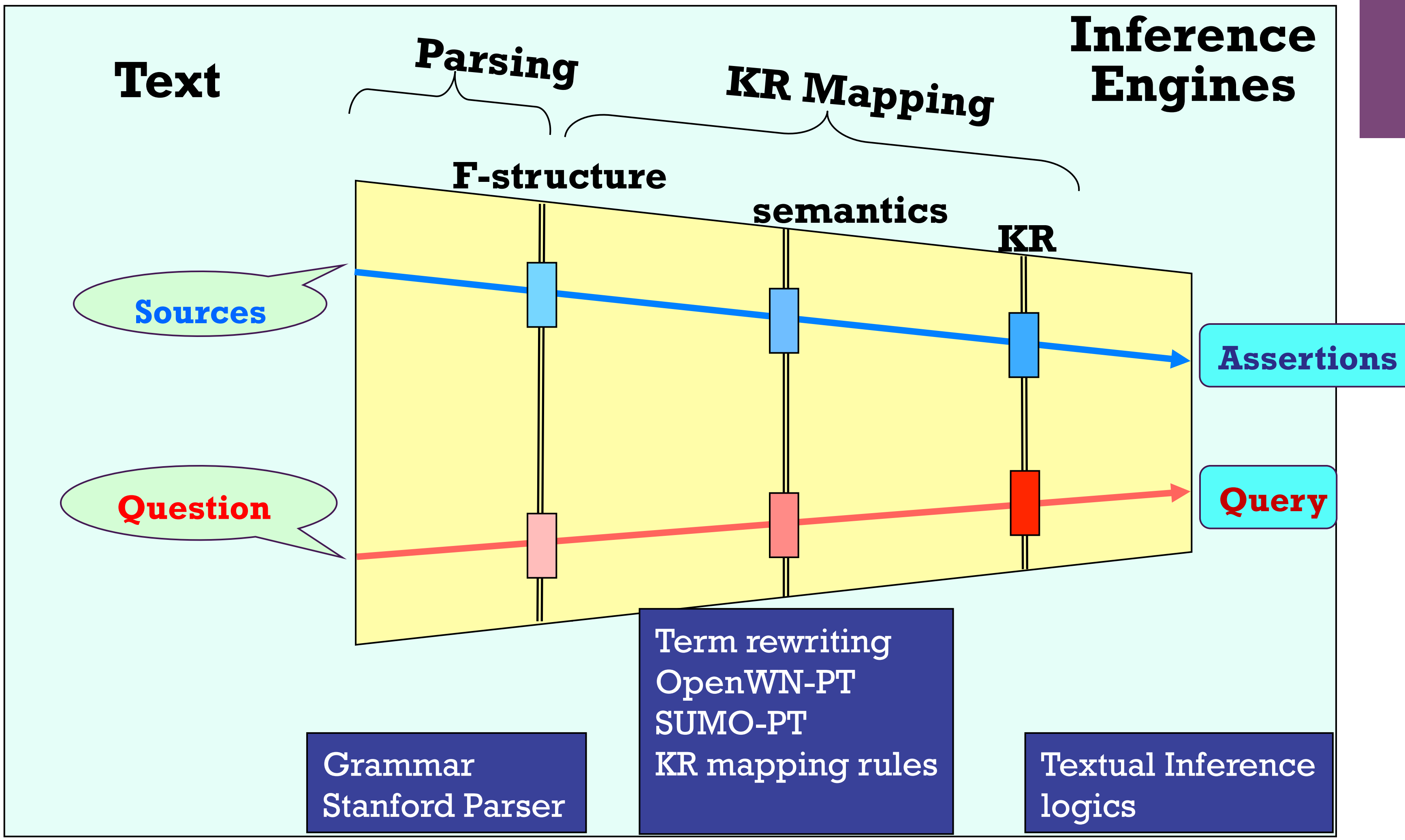
Wish List:

- 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