Constructive Description Logics: what, why and how?

Valeria de Paiva

Intelligent System Lab
Palo Alto Research Center

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Outline

- Motivation
- Textual Inference Logic
- Constructive description logic I
- Constructive description logic II
- Related work
- Discussion

An applied logician's job is never done…

- When modeling an implemented system as a logic you can start from the system

- Or you can start from logics that could fit it
- Hopefully the two meet up…

Motivation: Logic for Text Understanding

- A logic for reasoning about questions and answers using formulae automatically created from texts in English

- Logic used both to create logical representation of information and to answer/solve/infer questions

- How?

- Build upon decades of work on NLP at PARC

Architecture: The Bridge System
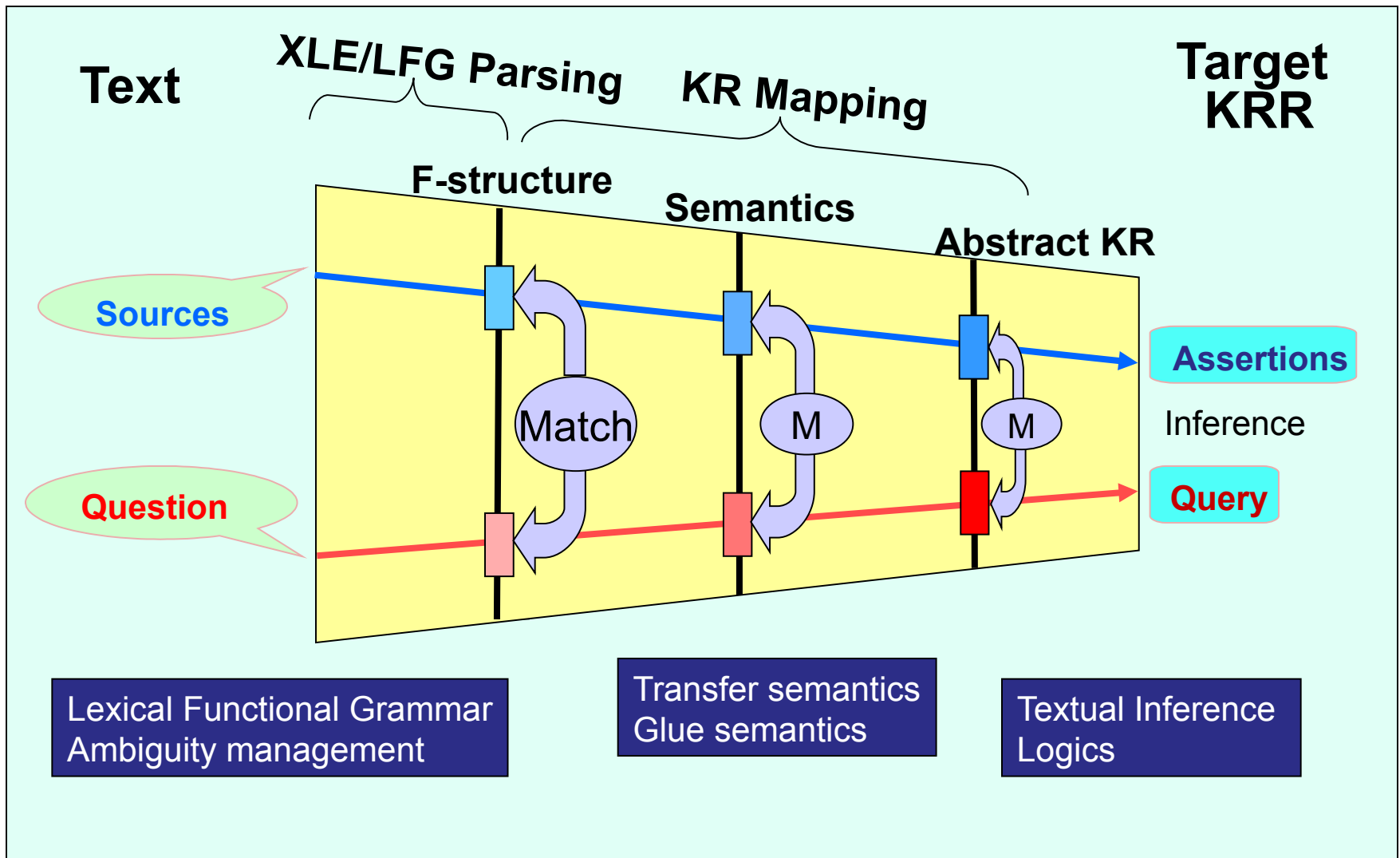
Key Process: Canonicalization of representations

- Sentences are parsed into f(unctional)-structures using XLE

- F-structures are (somewhat) semantic representations

- Transform f-structures into (flat and contexted) transfer semantic structures,

  (inspired by Glue, needed to 'pack' semantics)

- Transform transfer sem-structures into abstract (contexted) knowledge representation AKR structures

- Today: Discuss logics for AKR structures

Abstract KR: "Ed fired the boy."

$$\begin{bmatrix} \text{PRED} & \text{fire<Ed, boy>} \\ \text{TENSE} & \text{past} \\ \text{SUBJ} & [\text{ PRED Ed }] \\ \text{OBJ} & \begin{bmatrix} \text{PRED} & \text{boy} \\ \text{DEF} & + \end{bmatrix} \end{bmatrix}$$

```
(subconcept Ed3 Person)
(subconcept boy2 MaleChild)
(subconcept fire_ev1 DischargeWithPrejudice)
(role fire_ev1 performedBy Ed3)
(role fire_ev1 objectActedOn boy2)
```
Conceptual

```
(context t)
(instantiable Ed3 t)
(instantiable boy2 t)
(instantiable fire_ev1 t)
```
Contextual

```
(temporalRel startsAfterEndingOf Now
   fire_ev1)
```
Temporal

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Canonicalization helps matching

- Argument structure:
  - Mary bought an apple/An apple was bought by Mary.
- Synonyms and hypernyms:
  - Mary bought/purchased/acquired an apple.
- Factivity and contexts:
  - Mary bought an apple/Mary did not buy an apple.
  - Mary managed/failed to buy an apple.
  - Ed prevented Mary from buying an apple.
  - We know/said/believe that Mary bought an apple.
  - Mary didn't wait to buy an apple.
- A Basic Logic for Textual Inference (Bobrow et al, July 05)

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Textual Inference Logic (TIL)

- A **contexted** version of a **description** logic with concepts and roles
- Cyc concepts: `Person`, `MaleChild`,, `DischargeWithPrejudice`, etc..
- Cyc Roles: `objectActedOn`, `performedBy`, `infoTransferred`, etc
- Dynamic concepts like `Ed3` and `fire_ev1`
- WordNet/VerbNet as fallback mechanisms
- Limitations → move to new ontology WordNet/VerbNet

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Ed fired the boy.

```
context(t),
instantiable('Ed##0',t),
instantiable('boy##3',t),
instantiable('fire##1',t),
role('Agent','fire##1','Ed##0'),
role('Theme','fire##1','boy##3'),
subconcept('Ed##0',[[7626,4576]]),
subconcept('boy##3',[[10131706],[9725282],[10464570],[9500236])
(A1, subconcept('fire##1',[[1124984],[1123061],[1123474]])),
(A2, subconcept('fire##1',[[2379472]])),
temporalRel(startsAfterEndingOf,'Now','fire##1')
```

So far starting from the system…

For off-the-shelf logical systems:

- – Modal logic
- – Hybrid logic
- – Description logic
- – MCS/LMS
- – FOL/ HOL
- – Intensional Logic
- – Etc…

TIL as logic of contexts?

- Context as Constructive Modality (Context2003/CRR2005)
- But TIL constructive and **contexted** description logic
- Must provide constructive description logic and then contexted description logic!
- Today's talk: constructive description logic
- What are the options?

What Are Description Logics?

- A family of logic based Knowledge Representation formalisms
  - Descendants of semantic networks and KL-ONE
  - Describe domain in terms of concepts (classes), roles (properties, relationships) and individuals
- Distinguished by:
  - Formal semantics (typically model theoretic)
    - » Decidable fragments of FOL (often contained in C_2)
    - » **Closely related to Propositional Modal, Hybrid & Dynamic Logics**
    - » Closely related to Guarded Fragment
  - Provision of inference services
    - » Decision procedures for key problems (satisfiability, subsumption, etc)
    - » Implemented systems (highly optimised)

Thanks Ian Horrocks!

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DL Basics

- Concepts (**formulae**)
  - E.g., Person, Doctor, HappyParent, (Doctor **t** Lawyer)
- Roles (**modalities**)
  - E.g., hasChild, loves
- Individuals (**nominals**)
  - E.g., John, Mary, Italy
- Operators (for forming concepts and roles) restricted so that:
  - Satisfiability/subsumption is decidable and, *if possible*, of low complexity
  - No need for explicit use of variables
    - » Restricted form of **9** and **8** (**direct correspondence with hii and [i]**)
  - Features such as counting (**graded modalities**) succinctly expressed

Description Logics: Translation as Definition

- DL can be defined via translation t1 into FOL

- DL can be defined via t2 translation into multimodal K (Schilds91)

DL Basics

- Concepts (**unary predicates**)
  - E.g., Person(x), Doctor(x), HappyParent(x), …
- Roles (**binary relations**)
  - E.g., hasChild(x,y), loves(x,y)
- Individuals (**constants**)
  - E.g., John, Mary, Italy
- Operators (for forming concepts and roles) restricted so that:
  - Satisfiability/subsumption is decidable and, *if possible*, of low complexity, restricted fragment of FOL

DL Basics

- **Concepts** (propositional **formulae**)
  - E.g., Person, Doctor, HappyParent, (Doctor **t** Lawyer)
- **Roles** (**modalities**)
  - E.g., hasChild, loves
- **Individuals** (**nominals**)
  - E.g., John, Mary, Italy
- **Operators** (for forming concepts and roles) restricted so that:
  - Satisfiability/subsumption is decidable and, *if possible*, of low complexity
  - No need for explicit use of variables
    - » Restricted form of **9** and **8** (**direct correspondence with hii and [i]**)

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Constructive Description Logic via Translation

- DL can be defined via t1 translation into FOL

- To constructivize it transform FOL into IFOL
   Call system IALC

- DL can be defined via t2 translation into multimodal K (Schilds91)

- Need to choose a constructive K

- Using IK (Simpson's thesis) call system iALC, using CK (Mendler & de Paiva) call system cALC

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Constructive Description Logic I: IALC

- Basic idea: translate description syntax using t1 into IFOL, instead of FOL

- No excluded middle, no duality between existential and universal quantifiers, no duality between conjunction and disjunction

- Pros: IFOL fairly standard
  - Can provide IALC models easily

- Cons: semantics of IFOL more complicated…

- Result: Given IALC model M, given formula Φ,   M satisfies Φ iff M satisfies t1(Φ), that is

  t1 is truth-preserving translation

Constructive Description Logic II: iALC and cALC

- Basic idea: translate description syntax using t2 into constructive modal logic, instead of modal Kn.

- Which constructive K?

- If Simpson's IK$\rightarrow$ iALC, if Mendler/de Paiva CK$\rightarrow$ cALC

- Difference: distribution of possibility over disjunction and nullary one

  §(A ⎽ B) ！ (§A ⎽ §B) and §? ！ ?

Constructive Description Logic II: iALC

- Note that translation t2 into constructive modal logic is the same for both iALC and cALC, just the target language change.

- For iALC, can use our work on intuitionistic hybrid logic

- Models easily described

- Framework: several modal logics + geometric theories

- Referee's remark: complexity?

Constructive Description Logic II: cALC

- For cALC, can use our work on an extended Curry-Howard isomorphism for constructive modal logic

- No Framework: can only do S4 and K

- Can do Kripke models and categorical models

- Haven't investigated interpolation, decidability or complexity

Related Work

- Odintsov and Wansing's "Inconsistent-tolerant description logic I and II"
  - Motivation is paraconsistency, not constructivity
- Hofmann's "Proof theoretical Approach to DL"
  - Motivation is fixpoints in description logics and their complexity
- Straccia's and Patel-Schneider's papers on 4-valued description logic
  - Motivations are fuzziness and uncertainty

Discussion

- This is very preliminary
- While it is true that constructive reasoning multiply concepts, there should be criteria to identify best system(s?)
- Part of bigger programme of constructivizing logics for computer science
- Want to keep criteria both from theory and applications
- Next steps: criteria from modal/hybrid logic, bisimulations, complexity bounds, temporal logics, etc…

References

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Thanks!