Assembling Syntax: Modeling Constituent Questions in a Grammar Engineering Framework

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Seminar on the Interactions between Formal and Computational Linguistics

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Part I: Introduction. Formal or Computational?

Rafael's School of Athens (*circa* 1510)

- Common point of view:
  - CL is a statistical field which could interact with formal linguistic theory more
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- **Ancient debate with no right answer**

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- Today: Computational syntax with HPSG
  - Typologically informed

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    - PTB, PSD, UD (which were created by people) as **target** representations

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- Traditionally separate
  - Can we combine them?

Combining breadth, depth, ideas, and empiricism

- Computational modeling
  - of the theory
  - ...for reproducibility and rigor
  - with emphasis on data patterns
  - for robustness
  - Goal: assemble fragments of in-depth analyses
  - ...into a typologically diverse system
  - ...which is fully implemented

Computational syntax

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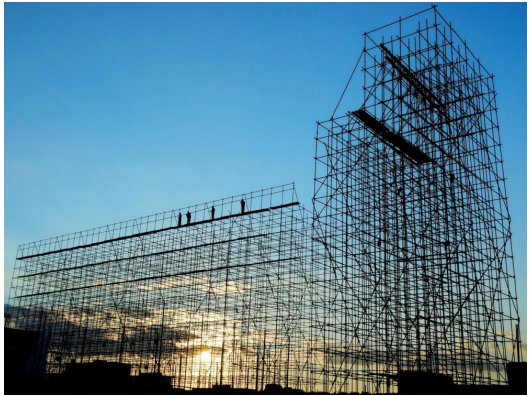
- Grow grammars and accumulate knowledge artifacts
- Growing the area of applicability of a set of hypotheses which grammars represent

Philosophy: Method of fragments and Pragmatism

- Fully explicit **grammar fragments**[2] that can be extended
  - ...constitute research artifacts that can be literally built upon
  - ...together and over time, contribute to our understanding of syntax



https://www.theinformationlab.co.uk/2017/08/09/data-scaffolding-easy-steps-fill-missing-data/

2 Montague 1974

Interim summary for Part I

- Philosophy of science applies to CL like to any field
- Empiricism and Rationalism have been at odds for centuries
- But they continue to walk hand in hand
- Next: Computational syntax
  - Implementing 🖼 formal 🏛 theories

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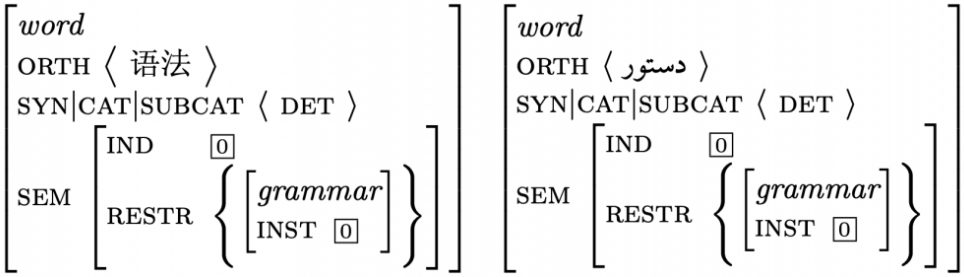
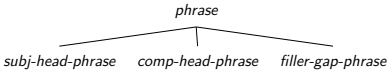
Part II: Formal depth, implemented on computer



https://hpsg.hu-berlin.de/hpsg2020/

Head-Driven Phrase Structure Grammar

- **Fully explicit** formalism[3]
- Lexicalist and surface-oriented
- A grammar is a hierarchy of **types** encoded as **feature structures** where features are constrained to have some values
- A structure licensing a sentence must be **well-formed**



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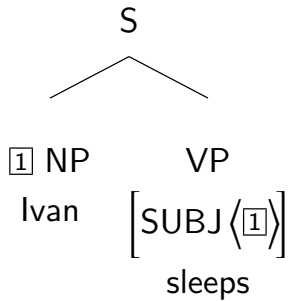
[3] Pollard and I. A. Sag 1994

HPSG Phrase Structure Rule

- Describes a feature structure that is a phrase and can be visualized as a tree
- "Mother" and "daughter" nodes
- Identities (tags)



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HPSG: Theoretical and Computational

- Both types of research exist
- HPSG formalism can be used to posit multiple theories
- DELPH-IN HPSG 🐬
  - International research consortium[4]
  - Restricted version of HPSG formalism

[4] https://github.com/delph-in, http://moin.delph-in.net/wiki/

DELPH-IN main projects

- The English Resource Grammar (ERG) [5]
  - **Broad** coverage; used in NLP[6]
    - Semantic representations (ERS, MRS, DMRS) used widely for **evaluating semantic parsers**[7]

5 Flickinger 2000, 2011

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  - Bootstrap grammar development for more languages[10]

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10 Bender 2010; Crowgey 2019; Inman 2019

Example: First cross-linguistic analysis of constituent (wh) questions in DELPH-IN HPSG[11]

- Classic 🏛 set of questions for syntactic theory:
  - How are question words ("wh-") distributed?
  - How to represent interrogative semantics?
    - Quantification, scope, wh-words as question parameters of different clauses...
  - How to model question word fronting (4)?
  - How to model optional fronting (5)?

(4) Gde kto chto vidit?
where who.NOM what.ACC see.3SG
'Who sees what where?'[rus]

(5) Ty gde rabotaesh?
you where work.3SG
'Where do you work?'[rus]

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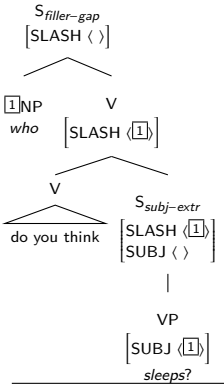
Fronting analysis in HPSG

- "Nonlocal" features are propagated up the tree[12]
- Feature SLASH creates a long-distance dependency at the level of the verb
- The *filler-gap* rule discharges the dependencies



(5) Who do you think sleeps? [eng]

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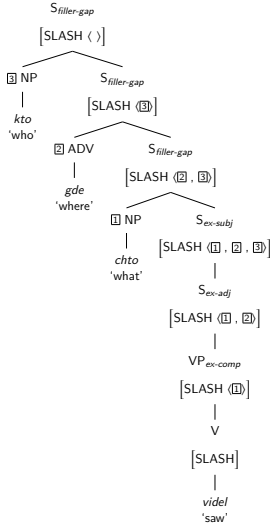
12 Pollard and I. A. Sag 1994; Ginzburg and I. Sag 2000

Extending the fragment: Multiple question fronting

- Recursive application of *filler-gap*[13]
- Theoretical takeaways arising from computational implementation:
  - "Optional" fronting is hard![14]
    - New evidence from HPSG
  - Simpler analysis of multiple fronting → less simple morphological marking[15]
    - Must a system be "elegant"?



(6) kto gde chto vidit?
who.NOM where what.ACC see.3SG
'Who sees what where?'[rus]

13 Zamaraeva and Emerson 2020; Crysmann 2015

14 Zamaraeva 2021

15 Zamaraeva to appear

Interim Summary

- HPSG is a fully-explicit syntactic formalism
- Can implement grammar gragments rigorously
- Most insights come from **assembling** the fragments into a system
  - ...intractable by hand
  - 🤦🏽‍♀️
- Next: The Grammar Matrix: A typologically driven meta-grammar engineering framework

Assembling and evaluating typologically diverse analyses

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Assembling grammars systematically

- **Goal**: Make implemented linguistic grammars bigger and more accessible to broader research community
- **Method**: Meta-grammar engineering with Head-Driven Phrase Structure Grammar
- **Project**: Analysis of constituent questions for a grammar engineering system
- **Result**:
  - New library in the system; more complex hypotheses can be tested
  - Archived test suites and analyses for several languages
  - Some takeaways regarding the interaction of different analyses

Questionnaire – Analysis – Semantics

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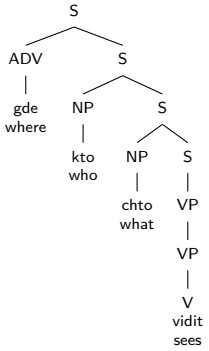

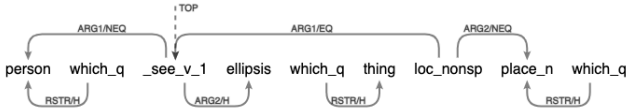

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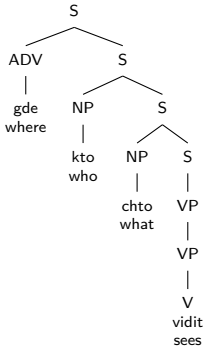
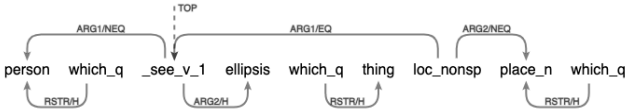


Choices regarding the position of question phrases

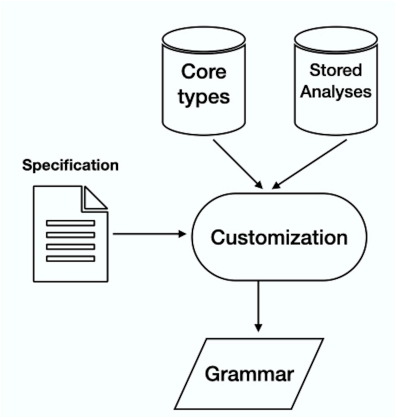
Question phrases can appear at the left edge of the sentence regardless of the position the questioned constituent would appear in (*Who did you see? I know who you saw* etc.):

- ○ Only one question phrase can be fronted
- ◉ All question phrases can be fronted
- ○ Question phrases cannot be fronted (stay *in situ*)



The Grammar Matrix

- Meta-grammar engineering framework[16]
- Input: Typological specification, lexicon, morphological rules
- Output: Implemented HPSG grammar fragment
  - Parse and generate sentences
  - Output syntactic and **semantic** representations
- Many syntactic phenomena are supported[17]

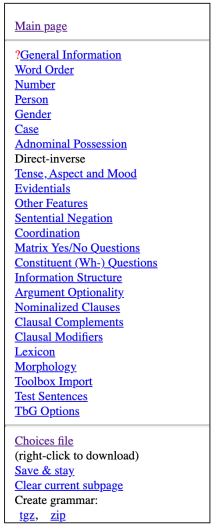


16 https://matrix.ling.washington.edu/customize/matrix.cgi

17 Zamaraeva 2021; Zamaraeva, Howell, and Bender 2019; Howell and Zamaraeva 2018; Saleem 2010; Song 2014; Nielsen 2018; Drellishak and Bender 2005; Crowgey 2013; Bender and Flickinger 2005

Matrix libraries

- Specify several phenomena at the same time
- Click to **get a grammar fragment** covering all of them[18]
- Test hypotheses **in interaction**
- Parse and **generate** data within fragment's area of coverage
  - Large lexicons can be imported



[18] There may be bugs 🐞

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- Libraries are evaluated with **held-out languages**
- Growing **regression testing** base
  - Language specs + test suites paired with "gold" semantic representations
  - Check **automatically** how any small change affects the **all** of the pairings

[19] Bender, Drellishak, et al. 2010; Oepen and Flickinger 1998

Meta-grammar engineering research question

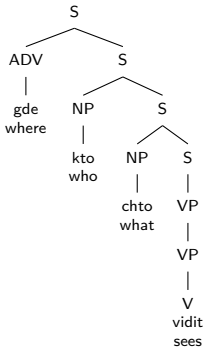
RQ: *What constitutes a model of a range of typologically attested ways of forming constituent questions within the given framework?*

Evaluation: How well does the analysis generalize to a set of randomly picked "held-out" languages?

Constituent questions in the Matrix

(4) Gde kto chto vidit?
where who.NOM what.ACC see.3SG
'Who sees what where?'[rus]

- New library[20]
- Typological scope:[21]
  - Position of question phrase
    - **Fronting**, *in situ*
    - Fronting optionality
  - Morphological marking
  - Question particles
    - position
    - obligatoriness
  - Question words



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19 König and Siemund 2007; Hagège 2008; Miyagawa 1987, *inter alia*

Assembling 🖼 fronting

Specification	Types	Core?	New?	Custom features
single oblig. front.	*wh-ques-phrase*	no	yes	SLASH
	subj-, obj-, adj-ex.	no	no	none
multi oblig. front.	*wh-ques-phrase*	no	yes	HDR|QUE MODIFIED *hasmod*
	subj-, obj-, adj-ex.	no	no	none
single opt. front.	*wh-ques-phrase*	no	yes	SLASH
	in-sutu-phrase	no	yes	none
	subj-, obj-, adj-ex.	no	no	none
multi opt. front.	*wh-ques-phrase*	no	yes	MODIFIED *hasmod*
	in-sutu-phrase	no	yes	HDR|L-QUE –
	subj-, obj-, adj-ex.	no	no	HDR|L-QUE –
in situ (no front.)	*in-sutu-phrase*	no	yes	none

The position of question phrases customization summary[22]

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- **How well can the system handle examples from an "unseen" language, as it is described in the reference grammar?**

Evaluating the constituent questions library[22][23]

Language	ISO-639-3	Family	Gram. items	Coverage%	Question typology
Apinajé	[apn]	Macro-Jê	17	82.3	single front.
Makah	[myh]	Wakashan	14	78.5	morphological,int. verbs
Pacoh	[pac]	Austroasiatic	26	84.6	single opt. front.
Paresi-Haliti	[pab]	Arawakan	64	56.0	single front., int. verbs
Jalkunan	[bxl]	Mande	33	78.8	*in situ*, particle, int. verbs

✓ Single fronting, particles, morphological marking, interrogative verbs

✗ Question words as predicates

Grammars made correct predictions where I didn't expect them to!

Bugs consistent with theoretical predictions

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- **Assembling fragments of our understanding of language**

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- The work presented today was partially funded by the United States National Science Foundation under Grant No. BCS-1561833 (PI Bender).
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