Model Theory of HPSG grammars

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- but what is it that they represent?
- in how far are we talking about language when building HPSG grammars?
- what are the conclusions to draw from possible answers?
Outline

- comparison of the formal foundations of HPSG 87 and 94
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- quick glimpse at the ideas behind formalizing HPSG 87
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  - King 1999: Exhaustive models
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- hints on how the different views can be dealt with
HPSG as in P & S 1987

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- but: **ontological status** of the structures is subject to dispute
P & S 1994: Feature structures as object types

- Knowledge of language is knowledge of its object types
- Object types are real objects present in the minds of speakers
- A theory of a grammar should include mathematical entities that model object types
- There is a conventional correspondence between token and modeled object type
- Linguists have to agree on a correspondence
- If they don't, no falsification is possible
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King 1999: Exhaustive models

- Exhaustive models: object types are not a useful concept because there is no evidence for them.
- The grammar should talk directly about observable data, which are the language tokens.
- There are no intervening mathematical structures between grammar and observable data.
- It must introduce possible tokens that are part of a grammar, but never occur.
- This allows for ways to avoid falsification of a theory by observable data.
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- insists on an intervening mathematical domain
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- BUT: real understanding of what is going on requires an intuitionistic logic
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SRL - Speciate Re-Entrant Logic

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SRL signature

Σ is an **SRL signature** iff

- Σ is a triple \(< S, A, F >\) where
- \(S\) is a set, the set of **species**, and
- \(A\) is a set, the set of **attributes**, and
- \(F : S \times A \rightarrow P(S)\) is the **appropriateness function**
Interpretation of an SRL signature

I is a $\Sigma$ interpretation iff

- I is a triple $\langle U, S, A \rangle$ where
- $U$ is a set, the set of entities in the universe,
- $S : U \rightarrow S$ is the species assignment function,
- $A$ is the attribute interpretation function.
How To Flatten Sort Hierarchies

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- this is no loss in expressiveness because

- sort hierarchies of HPSG 94 are finite partial orders
- if \( \sigma_1 \) is a subsort of \( \sigma_2 \) then \( \sigma_1 \subseteq \sigma_2 \)
- each entity belongs to exactly one maximally specific sort
- non-maximal sorts are unions of maximal sorts
- attribute inheritance enforced by attribute interpretation
- we can give functions to map any sort hierarchy to an SRL signature without loss of information
- formal languages of SRL can express all aspects of sort hierarchies: to state something about non-maximal sorts, we build a disjunction of all their subspecies
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Γ is an **SRL grammar** iff

- Γ is a pair \(<\Sigma, \theta>\),
- \(\Sigma\) is an SRL signature, and
- \(\theta\) is a subset of the set of descriptions over \(\Sigma\)
SRL theory denotation function

For each \( \Sigma \) interpretation \( I = \langle U, S, A \rangle \),

- \( \Theta_I \) is the total function mapping sets of descriptions to entities, such that for each set of descriptions \( \theta \),
- \( \Theta_I(\theta) = \{ u \in U | u \text{ is in the interpretation of each description in } \theta \} \)
Models in SRL

For each $\Sigma$ interpretaiton $I = \langle U, S, A \rangle$,

- $I$ is a $\Gamma$ model iff $\Theta_I(\theta) = U$. 
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- directly characterizing language without intervention of a mathematical structure
- natural languages themselves as intended models of grammars
Why models are not sufficient

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- the model theory should give us models that tell us whether a grammar overlicenses or underlicenses
Motivation

Outline

Two kinds of HPSG
Three model theories for HPSG 94

HPSG 87
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HPSG 94
SRL: An Overview
Model Theory A: King 1999
Model Theory B: Pollard & Sag 1994
Model Theory C: Pollard 1999

Conclusion

References

Intuition behind exhaustive models

- we can never be sure
  - if a model contains all the intended structures, there might be a bigger model of the grammar that contains structures not intended: the grammar might overlicense
  - if a model does not contain all the intended structures, there might be a bigger model that contains all these structures: we cannot tell whether the grammar underlicenses
- the model theory should give us models that tell us whether a grammar overlicenses or underlicenses
- those models are to be the exhaustive models of a grammar
Step I: Components of Entities

An entity $u_1$ is a component of another entity $u_2$ iff
- there is a term which in the given interpretation describes $u_2$
  and
- there is a description path leading from this term to $u_1$
Step II: Interpretation under Entities

An interpretation is the interpretation under an entity $u$ iff

- its universe comprises only all the components of $u$
- its species assignment function assigns species only to the components of $u$
- its attribute interpretation function only describes attributes of the components of $u$
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- its attribute interpretation function only describes attributes of the components of \( u \)
- this can be seen as the subalgebra generated by \( u \) in its interpretation
Step III: Subconfigurations of Entities

\[
\langle u, l_u \rangle \text{ is a configuration of entities under an entity } u
\]

\[\text{iff}\]

\[l_u \text{ is the interpretation under } u \text{ in } l\]
Step III: Subconfigurations of Entities

\(< u, I_u >\) is a configuration of entities under an entity \( u \) iff

\( I_u \) is the interpretation under \( u \) in \( I \)
Step IV: SRL Congruence between Configurations

Two configurations are **SRL congruent iff**

- there is a bijection between the components of both configurations that
  - assigns to each component a component of equal species
  - lets each component have the same attributes as its counterpart
  - maps the values of those attributes to their counterparts
Step V: Conditions for a Grammar

An SRL grammar is true of a natural language only if

1. the natural language can be seen as an interpretation of the grammar’s signature

2. this interpretation is a model of the grammar

3. any entity of another interpretation for which no entity in the model has a isomorphic configuration does not fulfill one of the descriptions in the grammar
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▶ condition 1 ties intended interpretations to the signature
▶ condition 2 ties intended interpretations to the theory
▶ condition 3 says the model contains all possible tokens of the language and is thus an exhaustive model
Step VI: Simulation of Interpretations

- why do we have a class of exhaustive models?
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- to define this class, we need a notion of simulation:

An interpretation simulates another interpretation iff

- for each entity in one interpretation, the configuration under this entity has a SRL congruent counterpart in the other interpretation
Step VII: Exhaustive Models

An interpretation is an **exhaustive model** iff

- it is a model of the grammar and
- it simulates every other model of the grammar

- for every configuration under an entity in any other model of the grammar, we find an SRL congruent counterpart in I.
Step VIII: Existence of Exhaustive Models

Theorem

For each SRL signature $\Sigma$, for each $\Sigma$ theory $\theta$, there exists a $\Sigma$ interpretation $I$ such that $I$ is an exhaustive $<\Sigma, \theta>$ model.

- this theorem allows us to explain the meaning of an arbitrary SRL grammar in terms of its exhaustive models
an HPSG 94 grammar is about the object types of a language, not about possible tokens
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How to link this to SRL

- losing the distinction between indiscernible possible tokens and grouping them together to classes represented by object types makes the intuitive difference between P & S and King
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- abstract feature structures correspond to the object types of natural language
- system of possible tokens then corresponds to a collection of concrete feature structures
- this means: object types can be seen as equivalence classes of tokens
Relation of 94 concrete feature structures to SRL entities

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- SRL congruence can be seen as CFS equivalence with different node names
From 94 CFS to object types

- isomorphic concrete feature structures have different nodes and cannot be collapsed
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- The set of abstract feature structures admitted by a grammar is basically equivalent to one of its exhaustive models.
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- the set of abstract feature structures admitted by a grammar is basically equivalent to one of its exhaustive models
- each object type is an equivalence class of indiscernible possible tokens
Pollard 1999: SGC in HPSG

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- no claims about status of object types, redefines them as isomorphism classes of structures that include idealized tokens
- modeling structures are no longer classical feature structures
- Pollard’s goal: a precise explanation in which sense an HPSG grammar is a generative grammar
- that means: formal definition of the **Strong Generative Capacity** of a grammar.
Model Theory of HPSG grammars

Johannes Dellert

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Intuitions about the SGC

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Step I: Pollard Feature Structures

A Pollard feature structure determined by $u$ in $I$ is

- the interpretation containing all entities that are “accessible” from $u$
Step II: Pollard Abstract Feature Structures

An **Pollard abstract feature structure** is

- a set of isomorphic Pollard feature structure fed into a node abstraction that constructs equivalence classes of entities
Step III: Strong Generative Capacity

For each SRL signature $\Sigma$, the SGC is

- the total function from grammars to classes of Pollard abstract feature structures over $\Sigma$ such that
- for each theory consisting of SRL descriptions over $\Sigma$,
- the abstract feature structures in the respective SGC comprise only those that are abstractions of entities in some interpretation of the grammar and that are discernable from each other because not isomorphically structured
Parallels to the other theories

- SGC can be defined starting from abstract feature structures (as we did), from exhaustive models or from a notion of generation that again relies on the abstract feature structures modeled by the grammar
- the SGC must also be an exhaustive model of the grammar
- the abstraction step makes it similar to a collection of object types
Conclusion: Linking the approaches

- there are different views on the meaning of HPSG grammars that differ in philosophically significant ways
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- however, it is still useful to know something about the background
- understanding at least one of the theories helps answer the most urgent questions about the meaning of the feature structures we are dealing with each day
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Thank you.