Resource Grammars and Language Learning and Evolution

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Outline

Resources for building (formal) languages (with Aarne Ranta)

Language learning and evolution (with Staffan Larsson)
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Language learning and evolution (with Staffan Larsson)
Natural and formal languages in 20th century linguistics

- languages as sets of strings and early transformational grammar
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- languages as sets of strings and early transformational grammar
- interpreted languages as sets of string-meaning pairs

Montague in 'Universal Grammar':
There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians; indeed I consider it possible to comprehend the syntax and semantics of both kinds of languages within a single natural and mathematically precise theory.
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Natural languages as formal languages – the advantages
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- productive theoretical abstraction allowing application of logical techniques to natural language
Natural languages as formal languages – the advantages

- productive theoretical abstraction allowing application of logical techniques to natural language
- a basis for much computational processing of language
Problems with scaling up beyond fixed fragments
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grammaticality
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- degrees of grammaticality
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- context-dependent grammaticality
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meaning
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- speakers negotiate meaning in dialogue
  - same proper name for different individuals
  - abstract or theoretical concepts like democracy or meaning
Natural languages as collections of resources

▶ a collection of resources (a “toolbox”) which can be used to construct (formal) languages
▶ maintain the insights and precision gained from the formal language view
▶ speakers of natural languages are constantly in the process of creating new language to meet the needs of novel situations in which they find themselves
▶ A corpus of natural language data (even a single dialogue) is not required to be consistent either in terms of grammaticality or in terms of meaning since it represents output based on a collection of related grammars rather than a single grammar.
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Scaling up to multilingual grammar the GF way

Concrete Syntax
- English
- French

Concrete Syntax
- compositional mapping

Abstract Syntax
Scaling up/down to local domain grammars the GF way

API = Application Programming Interface
Importation of definitions
Reusing the resource grammar in GF

Resource Grammar
English

Concrete Syntax
Domain 1
Concrete Syntax
Domain 2

Abstract Syntax
Domain 1
Abstract Syntax
Domain 2
Coordination

Agent A

Resource Grammar

Concrete Syntax Domain

Abstract Syntax Domain

Agent B

Resource Grammar

Concrete Syntax Domain

Abstract Syntax Domain

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Semantic coordination

- agents negotiate domain-specific microlanguages
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Requirements for a theory of semantic coordination

▶ semantics: an account of how meanings (and concepts) can be updated
  ▶ dynamic representations of concepts which can be modified in various ways (Type theory with records, TTR)
Requirements for a theory of semantic coordination

- **semantics**: an account of how meanings (and concepts) can be updated
  - dynamic representations of concepts which can be modified in various ways (Type theory with records, TTR)
- **pragmatics**: an account of how meanings (and concepts) are coordinated in dialogue and how dialogue moves governing coordination are related to semantic updates
  - a description of dialogue strategies involved in semantic coordination (Information State Update, ISU)
Corrective feedback

A frequent pattern in corrective feedback is the following:

original utterance  A says something

innovative utterance  B says something parallel to A’s utterance, containing a use which is innovative for A

learning step  A learns from the innovative use
Abe: I’m trying to tip this over, can you tip it over? Can you tip it over?
Mother: Okay I’ll turn it over for you.

- **offer-form:in-repair**("turn", "_ it over")
- **offer-form**("turn", "tip")
Clarification request

Adam: Mommy, where my plate?
Mother: You mean your saucer?

- \texttt{offer-form:cr(“saucer”, “[poss] _ ”)}
- \texttt{offer-form(“saucer”, “plate”)}
Explicit replace

Naomi: Birdie birdie.
Mother: Not a birdie, a seal.

- offer-form:explicit-replace("seal", "birdie")
- offer-form("seal", "birdie")
Bare correction

Naomi: mittens.
Father: gloves.

- offer-form:bare("gloves")
- offer-form("gloves", "mittens")
Talking about mittens

Resource Grammar/Lexicon
phon: mittens
...

Local Grammar/Lexicon
phon: mittens
ref:
...

Mittens!
Talking about gloves (when you only know about mittens)
Compositional and ontological semantics

Resource Grammar/Lexicon

\[ \lambda x \text{ mitten}'(x) \]

Local Grammar/Lexicon

\[ \lambda x \text{ mitten}'(x) \]

Mittens!
Enriching the local lexicon

Resource Grammar/Lexicon

\[ \lambda x \text{ mitten'(x)} \]

Local Grammar/Lexicon

\[ \lambda x \text{ glove'(x)} \]

Gloves!
Updates

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- semantic coordination updates involve linguistic resources (grammar, lexicon, semantic interpretation rules, ...), i.e. not the standard conversational scoreboard
- agents construct local resources for sublanguages used in specific situations
an agent $A$ may associate a linguistic expression $c$ with a particular concept (or collection of concepts if $c$ is ambiguous) $[c]^A$ in its generic resource
Generic and domain resources

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- concepts in $[c]_{\alpha}$ may be a refinement of one in $[c]_A$, that is, the domain related concepts have an extension which is a proper subset of the extension of the corresponding generic concept
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- concepts in $[c]_\alpha^A$ may be a refinement of one in $[c]^A$, that is, the domain related concepts have an extension which is a proper subset of the extension of the corresponding generic concept
- this will not be the case in general, e.g. black hole in physics not a black hole in the general sense, variables in logic and experimental psychology
Using resources in communicative situations

- motor for generating new local resources – coordinating resources with another agent in a particular communicative situation s
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- $s$ might be a turn in a dialogue, a reading event, …
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- $[c]^A_s$ may be anchored to the specific objects under discussion in $s$
A hierarchy of interpretations for expressions $c$
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- $[c]_s^A$ for communicative situations $s$
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- $[c]_\alpha^A$ for domains $\alpha$
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- Domains are collected into a complex hierarchy or more and less general domains
A hierarchy of interpretations for expressions $c$

- $[c]^A_s$ for communicative situations $s$
- $[c]^A_\alpha$ for domains $\alpha$
- Domains are collected into a complex hierarchy or more and less general domains
- $[c]^A$ - a domain independent linguistic resource
Acquisition of expression-interpretation pairs

- A pairing of an expression $c$ with an interpretation $c'$ progresses through the hierarchy
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- \( c' \) is \([c]_s^A\) for some particular communicative situation \( s\)
Acquisition of expression-interpretation pairs

- A pairing of an expression $c$ with an interpretation $c'$ progresses through the hierarchy.
- $c'$ is $[c]_s^A$ for some particular communicative situation $s$.
- $c' \in [c]_{\alpha}^A$ for a series of increasingly general domains $\alpha$. 
Acquisition of expression-interpretation pairs

▶ a pairing of an expression $c$ with an interpretation $c'$ progresses through the hierarchy
▶ $c'$ is $[c]_s^A$ for some particular communicative situation $s$
▶ $c' \in [c]_{\alpha}^A$ for a series of increasingly general domains $\alpha$
▶ $c' \in [c]^A$, i.e. part of a domain independent generic resource
Factors affecting progression through the hierarchy
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- the utility of the interpretation in different communicative situation
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- the utility of the interpretation in different communicative situation
- positive or negative feedback obtained when using the pairing in a communicative situation
Representing concepts using TTR

Type Theory with Records
Why TTR?

integrates logical techniques such as binding and the lambda-calculus into feature-structure like objects called record types

more structure than in a traditional formal semantics and more logic than is available in traditional unification-based systems

feature structure like properties are important for developing similarity metrics on meanings and for the straightforward definition of meanings modifications involving refinement and generalization

logical aspects are important for relating our semantics to the model and proof theoretic tradition associated with compositional semantics
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Records and record types

Record type

\[
\begin{array}{ll}
\text{ref} & : \text{Ind} \\
\text{size} & : \text{size}(\text{ref}, \text{MuchBiggerThanMe}) \\
\text{shape} & : \text{shape}(\text{ref}, \text{BearShape})
\end{array}
\]
Records and record types

**Record type**

\[
\begin{align*}
\text{ref} & : \text{Ind} \\
\text{size} & : \text{size}(\text{ref}, \text{MuchBiggerThanMe}) \\
\text{shape} & : \text{shape}(\text{ref}, \text{BearShape})
\end{align*}
\]

**Record**

\[
\begin{align*}
\text{ref} & = \text{obj123} \\
\text{size} & = \text{sizesensorreading85} \\
\text{shape} & = \text{shapesensorreading62} \\
\text{colour} & = \text{coloursensorreadning78}
\end{align*}
\]
Types containing manifest fields

\[
\begin{aligned}
\text{ref} = \text{obj123} & : \text{Ind} \\
\text{size} & : \text{size(ref, MuchBiggerThanMe)} \\
\text{shape} & : \text{shape(ref, BearShape)}
\end{aligned}
\]
Type hierarchies

\[
\begin{array}{l}
\text{ref} : \text{Ind} \\
\text{size} : \text{size(ref, MuchBiggerThanMe)}
\end{array}
\]

is a subtype of

\[
\begin{array}{l}
\text{ref} : \text{Ind}
\end{array}
\]
Type hierarchies

\[
\begin{array}{c}
\text{ref} : \text{Ind} \\
\text{size} : \text{size(ref, MuchBiggerThanMe)}
\end{array}
\]
is a subtype of
\[
\begin{array}{c}
\text{ref} : \text{Ind}
\end{array}
\]
as is also
\[
\begin{array}{c}
\text{ref=obj123} : \text{Ind}
\end{array}
\]
The panda

A: That’s a nice bear
B: Yes, it’s a nice panda

offer-form:in-repair("panda", "is a nice _ ")
offer-form("panda", "bear")
A’s concept “bear” in the “zoo” domain

We assume that, before B’s utterance, A has a single concept of “bear” in a domain called “zoo”, that is, a unique member of the collection \([\text{bear}]_\text{zoo}^A\).

\[
\begin{pmatrix}
\text{ref} & : & \text{Ind} \\
\text{phys} & : & \text{phys-obj}(\text{ref}) \\
\text{anim} & : & \text{animate}(\text{ref}) \\
\text{size} & : & \text{size}(\text{ref}, \text{MuchBiggerThanMe}) \\
\text{shape} & : & \text{shape}(\text{ref}, \text{BearShape}) \\
\text{bear} & : & \text{bear}(\text{ref})
\end{pmatrix}
\]
A’s take on the communicative situation

A’s dialogue information state at the time of B’s utterance (much simplified)

\[
\begin{align*}
\text{domain} & : \text{zoo} \\
\text{shared} & : \\
\text{foo} = \text{obj123} & : \text{Ind} \\
\text{com} & : \\
\text{c}_1 & : \text{nice(foo)} \\
\text{c}_2 & : \text{bear(foo)} & : \text{RecType}
\end{align*}
\]
A creates a local “panda”-concept

- \([\text{panda}]_s^A\) where \(s\) is the communicative situation resulting from \(B\)’s utterance
A creates a local “panda”-concept

- \([panda]_s^A\) where \(s\) is the communicative situation resulting from \(B\)’s utterance

- since “panda” has been offered as an alternative for “bear”, the new “panda”-concept is based on the “bear”-concept
A creates a local “panda”-concept

- $[\text{panda}]^A_s$ where $s$ is the communicative situation resulting from $B$’s utterance
- since “panda” has been offered as an alternative for “bear”, the new “panda”-concept is based on the “bear”-concept
- should ‘panda(REF)’ replace ‘bear(REF)’ or be added? – is panda a daughter or a sister of bear in the ontology?
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- assuming the principle of contrast (Clark), find a way in which pandas differ from bears
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- since “panda” has been offered as an alternative for “bear”, the new “panda”-concept is based on the “bear”-concept
- should ‘panda(REF)’ replace ‘bear(REF)’ or be added? – is panda a daughter or a sister of bear in the ontology?
- assuming the principle of contrast (Clark), find a way in which pandas differ from bears
- create first a local situated interpretation \([\text{panda}]_s^A\) based on \([\text{bear}]_{\text{zoo}}^A\)
\[
[panda]_s^A
\]

\[
\begin{align*}
\text{ref} &= \text{obj123} : \text{Ind} \\
\text{phys} & : \text{phys-obj}(\text{ref}) \\
\text{anim} & : \text{animate}(\text{ref}) \\
\text{size} & : \text{size}(\text{ref, MuchBiggerThanMe}) \\
\text{shape} & : \text{shape}(\text{ref, BearShape}) \\
\text{colour} & : \text{colour}(\text{ref, BlackAndWhite}) \\
\text{panda} & : \text{panda}(\text{ref})
\end{align*}
\]
A refines the local “bear”-concept corresponding to the newly formed local “panda”-concept

\[
\begin{align*}
\text{ref} & : \text{Ind} \\
\text{phys} & : \text{phys-obj}(\text{ref}) \\
\text{anim} & : \text{animate}(\text{ref}) \\
\text{size} & : \text{size}(\text{ref}, \text{MuchBiggerThanMe}) \\
\text{shape} & : \text{shape}(\text{ref}, \text{BearShape}) \\
\text{colour} & : \text{colour}(\text{ref}, \text{Brown}) \\
\text{bear} & : \text{bear}(\text{ref})
\end{align*}
\]
A’s updated dialogue information state

\[
\begin{pmatrix}
\text{domain} & : & \text{zoo} \\
\text{foo} = \text{obj123} & : & \text{Ind} \\
\text{shared} & : & \begin{pmatrix}
\text{com} & = & \begin{pmatrix}
\text{c1} & : & \text{nice}(\text{foo}) \\
\text{c2} & : & \text{panda}(\text{foo})
\end{pmatrix} & : & \text{RecType}
\end{pmatrix}
\end{pmatrix}
\]
A dereferenced panda-concept

\[
\begin{array}{ll}
\text{ref} & : \text{Ind} \\
\text{phys} & : \text{phys-obj}(\text{ref}) \\
\text{anim} & : \text{animate}(\text{ref}) \\
\text{size} & : \text{size}(\text{ref, MuchBiggerThanMe}) \\
\text{shape} & : \text{shape}(\text{ref, BearShape}) \\
\text{colour} & : \text{colour}(\text{ref, BlackAndWhite}) \\
\text{panda} & : \text{panda}(\text{ref}) \\
\end{array}
\]

Available for use as \([\text{panda}]_{\text{zoo}}^A\), and for progression through the meaning hierarchy.
Further reading

- http://www.ling.gu.se/~cooper/records