The XDG Development Kit

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Overview

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Declarative Grammar Formalisms

- specify linguistic knowledge independently from processing
- parsers/generators: can be generically created for all grammars

Examples

- LFG (Bresnan 2001)
- HPSG (Pollard/Sag 1994)
- TAG (Joshi 1987)
- CCG (Steedman 2000)

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Grammar Development Systems

- tools for grammar creation
- parsers
- generators

Examples

- XLE (Kaplan/Maxwell 1996) for LFG
- LKB (Copestake 2002) for HSPG
- XTAG (XTAG Group 2001) for TAG
- OpenCCG (White 2004) for CCG

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Existing Formalisms and Word Order

- languages with freer word order than English (e.g. German, Czech, Hindi etc.) pose problems
- Smolka (Smolka/Uszkoreit 1996): Could more advanced constraint programming techniques improve linguistic processing?

Axiomatization of Dependency Trees

- (Duchier 1999, 2003): axiomatization of valid dependency trees using finite set constraints
- parsing: reduced to constraint programming
- grammar formalism: Topological Dependency Grammar (TDG) (Duchier/Debusmann 2001)
- elegant new treatment of free word order

Extensible Dependency Grammar (XDG)

- generalization of TDG (Debusmann et al. 2004)
- graph description language for modeling arbitrary many levels of linguistic structure
- same parsing methods by constraint programming (Duchier 1999, 2003)
- goes beyond syntax:
  - semantics (Debusmann/Duchier/Koller/Kuhlmann/Smolka/Thater 2004)
  - information structure (Debusmann/Postolache/Traat 2005), out of an IGK-project also with Ciprian Gerstenberger and Stefan Thater

XDG Grammar Development Kit (XDK)

- first grammar development system for XDG
- implemented in Mozart/Oz, published in the Mozart Global User Library (MOGUL)

Facilities

- new abstract lexicon language
- grammar file compiler
- graphical interfaces
- solver for parsing and generation

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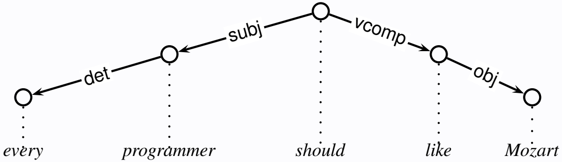
- XDG describes labeled graphs
- uses the linguistic notion of dependency grammar

Example



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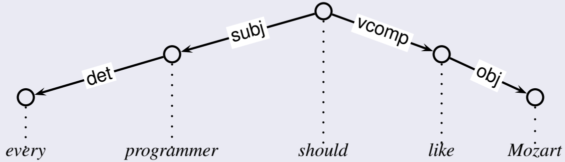
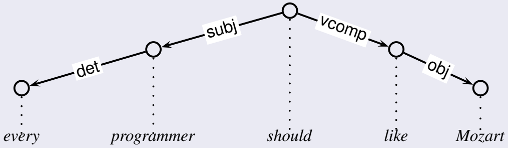


Multiple Graphs

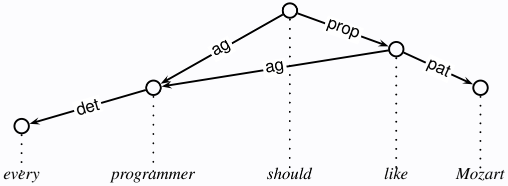
- XDG typically describes an arbitrary number of graphs called dimensions
- same set of nodes, different edges

Example

Syntax tree

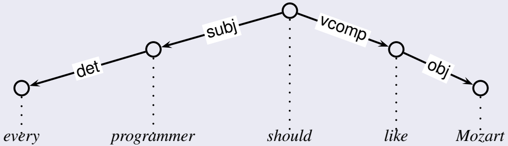


Semantic dag

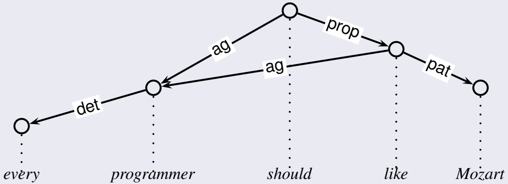


Example

Syntax tree



Semantic dag



Well-Formedness Conditions

- interaction of principles and the lexicon
- principles: restrictions on one or more dimensions
- subset of an extensible principle library
- lexicon: feature structures controlling the principles

Example Principles

- tree: dimension i must be a tree
- dag: dimension i must be a dag
- valency: for each node on dimension i, the incoming edges must be licensed by the in specification, and the outgoing edges by the out specification
- order: constrains the order of words on dimension i, e.g. subjects precede objects
- linking: constrains how arguments on dimension i (semantics) must be realized on dimension j (syntax), e.g. agents are realized as subjects

Example Lexical Entry

- lexical entry for *like*, controls valency and linking principles:

$$
\textit{like} = \begin{bmatrix} \textit{syn} & : & \begin{bmatrix} \text{in} & : & \{\text{vcomp?}\} \\ \text{out} & : & \{\text{obj!}\} \end{bmatrix} \\ \textit{sem} & : & \begin{bmatrix} \text{in} & : & \{\text{prop?}\} \\ \text{out} & : & \{\text{ag!}, \text{pat!}\} \\ \text{link} & : & \{\text{ag} : \{\text{subj}\} \\ & & \text{pat} : \{\text{obj}\}\} \end{bmatrix} \end{bmatrix}
$$

Overview

XDK Features

- new abstract lexicon language
- grammar file compiler
- graphical interfaces
- solver for parsing and generation

Lexicon Language

- XDG: linguistic information mostly specified in the lexicon
- but: lexicon grows huge even for medium-sized grammars
- need facilities for adequate modularization and factorization
- types: specify feature structures, define combination operation
- metagrammar (Crabbe/Duchier 2004): abstract description language for lexicon construction

Types

- each type: set L and partial function $\sqcap : L \times L \to L$ (combination operation of L)
- $\sqcap$: typically greatest lower bound

Supported types

domains, records, valencies, sets, tuples, strings

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Domain Types

- e.g. set of edge labels:

$$\textit{syn.label} \quad = \quad \{\mathsf{det}, \mathsf{subj}, \mathsf{obj}, \mathsf{vcomp}\}$$

- combination operation: $a \sqcap a = a$, $a \sqcap b$ undefined for $a \neq b$

Record Types

- given set of features $(f_i)_{i=1\ldots n}$ and types $T_i = (L_i, \sqcap_i)$:

$$\{f_1 : v_1, \ldots, f_n : v_n\}$$

  where $v_i \in L_i$.
- combination operation defined feature-wise:

$$\{f_1 : v_1, \ldots, f_n : v_n\} \sqcap \{f_1 : v'_1, \ldots, f_n : v'_n\} = \{f_1 : v_1 \sqcap_1 v'_1, \ldots, f_n : v_n \sqcap_n v'_n\}$$

Valency Types

- e.g. in and out specifications:

$$\mathit{syn.valency} \quad = \quad \mathsf{valency}(\mathit{syn.label})$$

- defines *syn.valency* to be the record type:

$$\{\mathit{det} : \mathit{mode},\ \mathit{subj} : \mathit{mode},\ \mathit{obj} : \mathit{mode},\ \mathit{vcomp} : \mathit{mode}\}$$

- $\mathit{mode} = \{0, ?, !, *\}$
- mode combination operation (specialization):

$$0 \sqcap x = x \qquad * \sqcap ! = ! \qquad * \sqcap ? = ? \qquad ? \sqcap ! = !$$

- convenient notation:

$$\{\mathit{det} : 0, \mathit{subj} : !, \mathit{obj} : ?, \mathit{vcomp} : 0\} \quad = \quad \{\mathsf{subj}!, \mathsf{obj}?\}$$

Metagrammar

- abstract description language for lexicon construction
- lexical classes:

$$\mathit{Class} \quad ::= \quad \mathit{ClassName} \rightarrow \mathit{ClassBody}$$

- class body:

$$\begin{array}{lll} \mathit{ClassBody} & ::= & \mathit{ClassBody}_1 \,\&\, \mathit{ClassBody}_2 \\ & | & \mathit{ClassBody}_1 \mid \mathit{ClassBody}_2 \\ & | & \mathit{ClassName} \\ & | & \mathit{partialLexicalEntry} \end{array}$$

- &: combination operation
- |: non-deterministic choice
- *ClassName*: class reference

Example (1)

- finite verbs can be roots or the head of a relative clause:

$$\begin{array}{rcl} \mathsf{root} & \rightarrow & \left[\ \mathit{syn}\ :\ \left[\ \mathsf{in}\ :\ \{\}\ \right]\ \right] \\ \mathsf{rel} & \rightarrow & \left[\ \mathit{syn}\ :\ \left[\ \mathsf{in}\ :\ \{\mathsf{relcl?}\}\ \right]\ \right] \\ \mathsf{finite} & \rightarrow & \mathsf{root} \mid \mathsf{rel} \end{array}$$

Example (2)

- finite verbs may be either intransitive, transitive or ditransitive:

$$
\begin{array}{rcl}
\text{intr} & \rightarrow & \left[\ \textit{syn} : \left[\ \text{out} : \{\text{subj!}\}\ \right]\ \right] \\
\text{tr} & \rightarrow & \text{intr}\ \&\left[\ \textit{syn} : \left[\ \text{out} : \{\text{obj!}\}\ \right]\ \right] \\
\text{ditr} & \rightarrow & \text{tr}\ \&\left[\ \textit{syn} : \left[\ \text{out} : \{\text{iobj!}\}\ \right]\ \right] \\
\text{verb} & \rightarrow & \text{intr} \mid \text{tr} \mid \text{ditr}
\end{array}
$$

Example (3)

- finite verb:

$$\begin{array}{rcl} \mathsf{finiteVerb} & \rightarrow & \mathsf{finite}\ \&\ \mathsf{verb} \\ & = & (\mathsf{root} \mid \mathsf{rel})\ \&\ (\mathsf{intr} \mid \mathsf{tr} \mid \mathsf{ditr}) \end{array}$$

- all possibilities of

$$\begin{array}{lll} (\mathsf{root}\ \&\ \mathsf{intr}) & (\mathsf{root}\ \&\ \mathsf{tr}) & (\mathsf{root}\ \&\ \mathsf{ditr}) \\ (\mathsf{rel}\ \&\ \mathsf{intr}) & (\mathsf{rel}\ \&\ \mathsf{tr}) & (\mathsf{rel}\ \&\ \mathsf{ditr}) \end{array}$$

- e.g.:

$$\mathsf{rel}\ \&\ \mathsf{ditr} \rightarrow \left[\ \mathit{syn} : \left[\begin{array}{rcl} \mathsf{in} & : & \{\mathsf{relcl?}\} \\ \mathsf{out} & : & \{\mathsf{subj!}, \mathsf{obj!}, \mathsf{iobj!}\} \end{array}\right]\ \right]$$

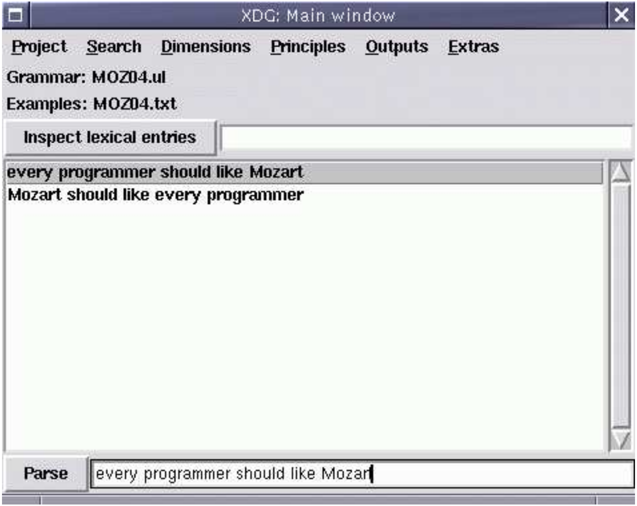
Grammar File Compiler

- fast static grammar checker
- fast grammar file compilation
- prepared for very large grammars (GNU GDBM support)
- three concrete syntaxes for different purposes:
  - XML language: automated grammar development
  - User Language (UL): handcrafted grammars
  - Intermediate Language (IL): record-based language, tailored for Mozart/Oz and further processing within the XDK

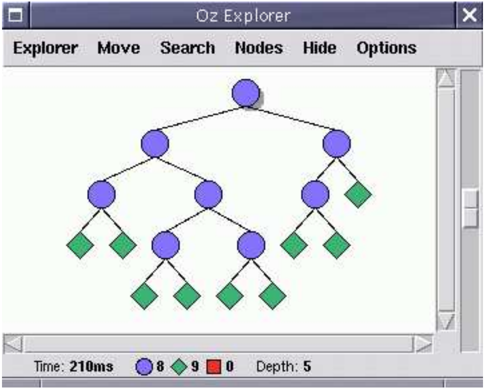
Graphical Interfaces

- comprehensive graphical user interface (GUI)
- solver search tree visualization: Oz Explorer (Schulte 1997), IOzSeF (Tack 2003)
- visualization of partial/full analyses: output library:
  - Tcl/Tk dag display
  - LaTeX dag output (using Denys Duchier's dtree.sty)
  - internal solver language output using the Oz Inspector (Brunklaus 2000)

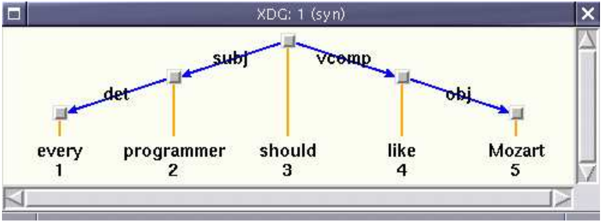
GUI

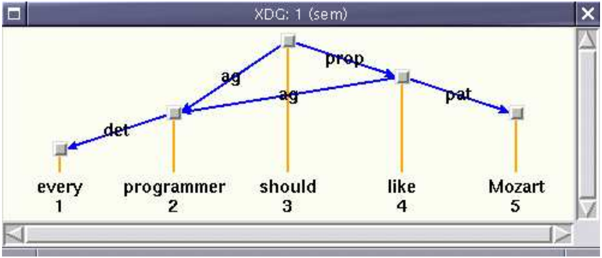

XDG: Main window
Project
Search
Dimensions
Principles
Outputs
Extras
Grammar: MOZ04.ul
Examples: MOZ04.txt
Inspect lexical entries
every programmer should like Mozart
Mozart should like every programmer
Parse
every programmer should like Mozart

Oz Explorer


Oz Explorer
Explorer
Move
Search
Nodes
Hide
Options
Time: 210ms
8
9
0
Depth: 5

Dag display


XDG: 1 (syn)
subj
vcomp
det
obj
every
1
programmer
2
should
3
like
4
Mozart
5


XDG: 1 (sem)
prop
ag
ag
pat
det
every
1
programmer
2
should
3
like
4
Mozart
5

Solver

- based on axiomatization of dependency parsing in (Duchier 1999, 2003)
- factorized into modular, extensible principle library
- principles: sets of constraint functors
- e.g. valency principle: in constraint and out constraint
- starting sequence regulated by global constraint priorities to increase efficiency

Preferences and Search

- idea: guide the search for solutions by external knowledge sources: oracles
- idea by Thorsten Brants and Denys Duchier, extended in (Dienes et al. 2003)
- oracles interact with solver using sockets
- XDK: supports new standard oracle architecture created by Marco Kuhlmann

Overview

Summary

- introduced XDG Development Kit (XDK)
- new lexicon specification language
- grammar file compiler
- graphical interfaces
- solver for parsing and generation
- extensive documentation (200+ pages), PDF, PS, HTML, GNU info

Future Work

- solver: fairly efficient for handcrafted grammars, but not for automatically generated ones
- why? grammar encoding or solver or both?
- theoretical investigation of fragments of XDG
- integration of the new faster GECODE constraint library (Christian Schulte, Guido Tack, Gabor Szokoli)
- super-tagging (lexicon disambiguation before parsing/generation)

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Thank you!