RELATIONAL-REALIZATIONAL SYNTAX
An Architecture for Learning and Specifying
Morphosyntactic Descriptions

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Statistical Parsing

Statistical Parsing

"John likes Mary"

Statistical Parsing

"John likes Mary"
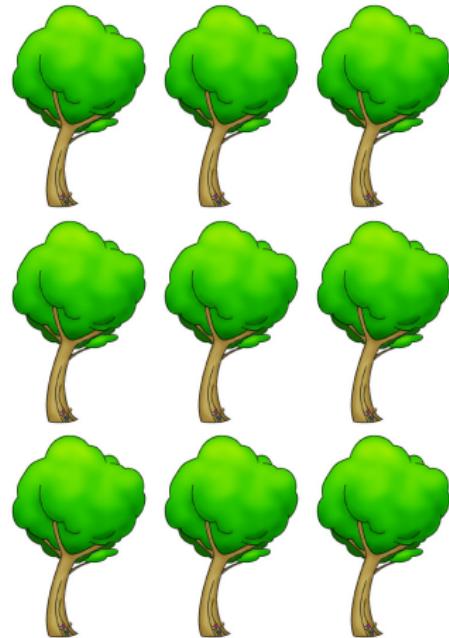
Statistical Parsing
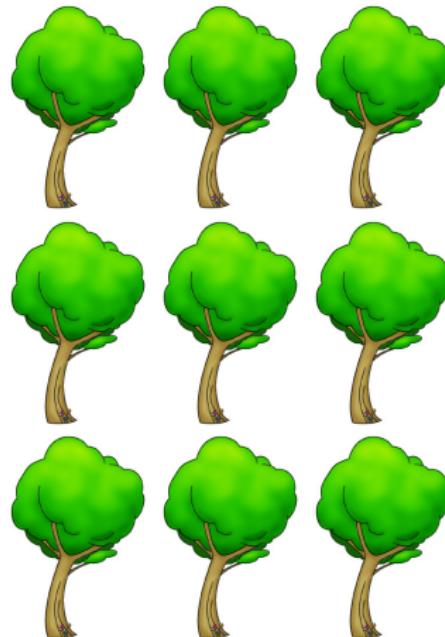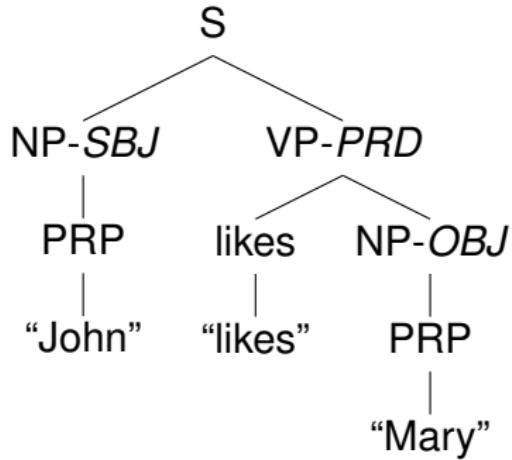
Analysis By Generation
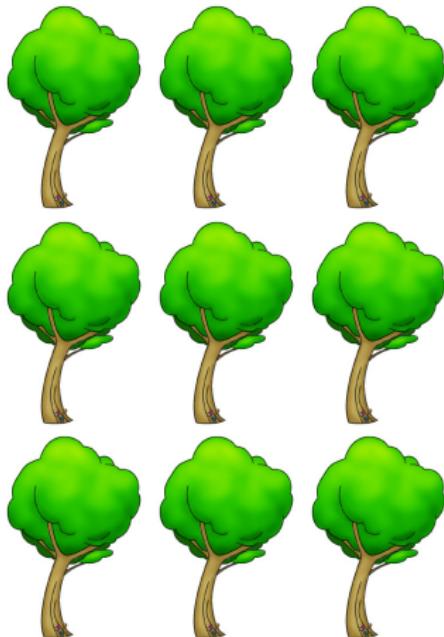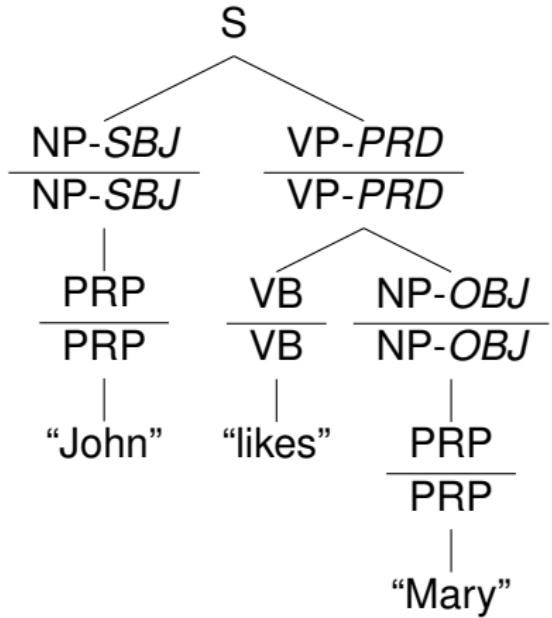
Constituency-Based Statistical Parsing for English

S
- NP-*SBJ*
  - PRP
    - "This"
- VP-*PRD*
  - VB
    - "is"
  - ADJP
    - ADJ
      - "easy"
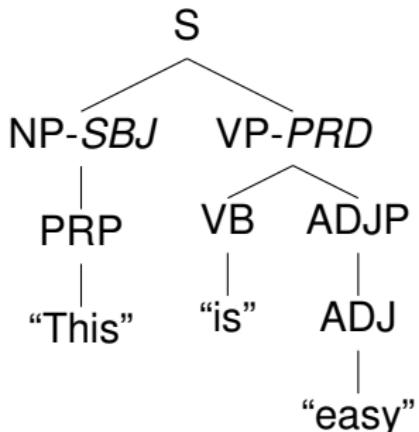
Model	Study	F-Score
Treebank Grammar	Charniak 1996	75
Head-Driven	Collins 1997	88.6
Discriminative Reranking	Collins 2000	89.7
Discriminative-Reranking	Johnson & Charniak 2005	91.0
Self-Training	McClosky 2006	92.1
CRF-CFG	Finkel et al 2008	90.7
State-Splits	Petrov et al 2007	90.1
Forest Reranking	Liang Huang 2008	91.7

Statistical Parsing from a Typological Perspective

And what about this?

إغلي الماء قبل استعماله

And this?

יש להרתיח את המים
לפני השימוש.

And? ...

Language	Parser	F-Score
German	Rafferty & Manning 2008	79.2
Czech	Collins et al. 1999	79.3
Arabic	Maamouri, Bies & Kulick 2008	78.1
Hebrew	Tsarfaty & Sima'an 2007	74.4

The Data

Typological Dimensions of Variation

Morphological Synthesis/Fusion
(Sapir 1921, Greenberg 1954)

Basic Word-Order Typology
(Greenberg 1966, Mithun 1992)

Nonconfigurationality
(Hale 1983, Austin and Bresnan 1996)

Modern Hebrew

A Semitic Language

 SVO

 Highly Synthetic

 'Less-Configurational'

Modern Hebrew

Word-Order

(1)   a.   dani natan et hamatana   ledina
            Dani gave   ACC the-present to-Dina
            "Dani gave the present to Dina" (SVO)

       b.   et hamatana   natan dani ledina
            ACC the-present gave Dani to-Dina
            "Dani gave the present to Dina" (OVS)

       c.   natan dani et hamatana   ledina
            gave Dani ACC the-present to-Dina
            "Dani gave the present to Dina" (VSO)

       d.   ledina   natan dani et hamatana
            to-dina gave Dani ACC the-present
            "Dani gave the present to Dina" (VSO)

Argument Marking in Modern Hebrew

Case-Assigning Prepositions

(2) **a.** dani natan et   hamatana   ledina
     Dani gave   ACC DEF-present DAT-Dina

b. et   hamatana   natan dani ledina
     ACC DEF-present gave   Dani DAT-Dina

c. natan dani et   hamatana   ledina
     gave   Dani ACC DEF-present DAT-Dina

d. ledina   natan dani et   hamatana
     DAT-dina gave   Dani ACC DEF-present

Argument Marking in Modern Hebrew

Differential Object-Marking

(3)   **a.**   dani natan et   hamatana   ledina
       Dani gave   ACC DEF-present to-Dina

     b.   et   hamatana   natan dani ledina
       ACC DEF-present gave   Dani to-Dina

     c.   natan dani et   hamatana   ledina
       gave   Dani ACC DEF-present to-Dina

     d.   ledina   natan dani et   hamatana
       to-dina gave   Dani ACC DEF-present

Argument Marking in Modern Hebrew

Feature Spreading (Danon, 2007)

(4) a. dani natan [et   matnat yom hahuledet] ledina
        Dani gave   [ACC present day   DEF-birth] to-Dina

     b. [et   matnat yom hahuledet] natan dani ledina
         [ACC present day   DEF-birth] gave   Dani to-Dina

     c. natan dani [et   matnat yom hahuledet] ledina
         gave   Dani [ACC present day   DEF-birth] to-Dina

     d. ledina   natan dani [et   matnat yom hahuledet]
         to-dina gave   Dani [ACC present day   DEF-birth]

Argument Marking in Modern Hebrew

Agreement

(5)   a. dani   natan   et   hamatana   ledina
          Dani.MS gave.3MS ACC DEF-present DAT-Dina

      b. et   hamatana   natan   dani   ledina
          ACC DEF-present gave.3MS Dani.MS DAT-Dina

      c. natan   dani   et   hamatana   ledina
          gave.MS Dani.3MS ACC DEF-present DAT-Dina

      d. ledina   natan   dani   et   hamatana
          DAT-dina gave.3MS Dani.MS ACC DEF-present

Argument Marking Modern Hebrew

Pro-Drop and Clitics

(6) a. ani natati et hamatanot ledina
I.1S gave.1S ACC DEF-presents.3FP DAT-Dina
"I gave the presents to Dina"

b. natati et hamatana ledina
gave.1S ACC DEF-presents.3FP DAT-Dina
"I gave the presents to Dina"

c. natatihen ledina
gave.1S.ACC.3FP DAT-Dina
"I gave them to Dina"

The Data

Recap:

CONFIGURATIONAL ——————— NONCONFIGURATIONAL
1:1 —————————————————————— many : many
Vietnamese > English > Hebrew > Warlpiri
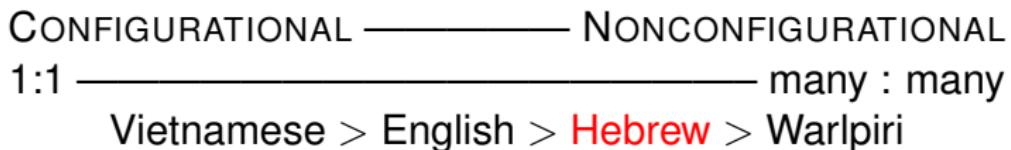
Require:

An architecture to model many-to-many correspondence

The Hypothesis

The Hypothesis

Morphological Exponence

- ► Simple (1:1)
- ► Cumulative (many:1)
- ► Distributed/Extended (1:many)

The Hypothesis

Morphological Exponence : Properties ⤳ Words

- ▶ Simple (1:1)
- ▶ Cumulative (many:1)
- ▶ Distributed/Extended (1:many)

Morphosyntactic Exponence : Relations ⤳ Configurations

- ▶ Simple (e.g., SBJ ⤳ nominative)
- ▶ Cumulative (e.g., SBJ,PRD,OBJ ⤳ clitics)
- ▶ Distributed/Extended (e.g., OBJ ⤳ feature-spreading)

Reminder: Modeling Principles for Morphology

LEXICAL vs. INFERENTIAL Approaches

- LEXICAL:
  morphemes are primary, properties stored in the lexicon
- INFERENTIAL:
  properties are primary, forms are computed

INCREMENTAL vs. REALIZATIONAL Approaches

- INCREMENTAL:
  morphemes/properties are accumulated incrementally
  ("monotonic" rules)
- REALIZATIONAL:
  property-bundles are pre-condition for rule application
  ("spell-out" rules)

Inferential-Realizational Morphology

Paradigmatic Organization

/EAT/	1Sing	2Sing	3Sing	1Pl	2Pl	3Pl
Past	1SingPast	2SingPast	3SingPast	1PlPast	2PlPast	3PlPast
Present	1SingPres	2SingPres	3SingPres	1PlPres	2PlPres	3PlPres
Perfect	1SingPerf	2SingPerf	3SingPerf	1PlPerf	2PlPerf	3PlPerf

Realization Rules

/EAT/   ,   /EAT/   ,   /EAT/   ,   /EAT/
+1SingPast   +3SingPast   +1SingPres   +3SingPres
  | | | |
 'ate'   'ate'   'eats'   'eat'

The Proposal: Relational-Realizational Syntax

Paradigmatic Organization

$S\langle\text{PRED}\rangle$ FEATS	Affirmative	Interrogative	Imperative
ARG-ST			
intransitive	$S_{affirm}+\{SBJ,PRD\}$	$S_{inter}+\{SBJ,PRD\}$	$S_{imper}+\{SBJ,PRD\}$
transitive	$S_{affirm}+\{SBJ,PRD,OBJ\}$	$S_{inter}+\{SBJ,PRD,OBJ\}$	$S_{imper}+\{SBJ,PRD,OBJ\}$
ditransitive	$\boxed{S_{affirm}+\{SBJ,PRD,OBJ,COM\}}$	$S_{inter}+\{SBJ,PRD,OBJ,COM\}$	$S_{imper}+\{SBJ,PRD,OBJ,COM\}$

Realization Rules
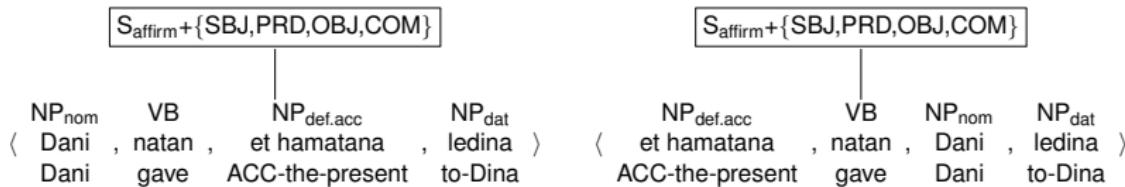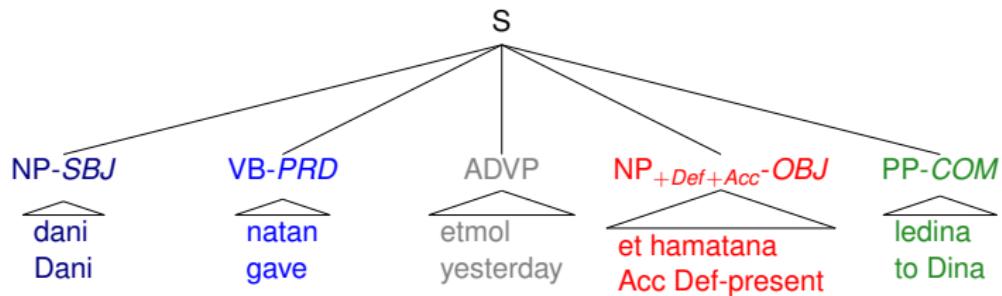
$\boxed{S_{affirm}+\{SBJ,PRD,OBJ,COM\}}$

$$\langle \underset{\substack{\text{Dani} \\ \text{Dani}}}{NP_{nom}}, \underset{\substack{\text{natan} \\ \text{gave}}}{VB}, \underset{\substack{\text{et hamatana} \\ \text{ACC-the-present}}}{NP_{def.acc}}, \underset{\substack{\text{ledina} \\ \text{to-Dina}}}{NP_{dat}} \rangle$$

$\boxed{S_{affirm}+\{SBJ,PRD,OBJ,COM\}}$

$$\langle \underset{\substack{\text{et hamatana} \\ \text{ACC-the-present}}}{NP_{def.acc}}, \underset{\substack{\text{natan} \\ \text{gave}}}{VB}, \underset{\substack{\text{Dani} \\ \text{Dani}}}{NP_{nom}}, \underset{\substack{\text{ledina} \\ \text{to-Dina}}}{NP_{dat}} \rangle$$

The Realization Rules

Relational-Realizational (RR) Parsing

The Realization Rules

## Relational-Realizational (RR) Parsing
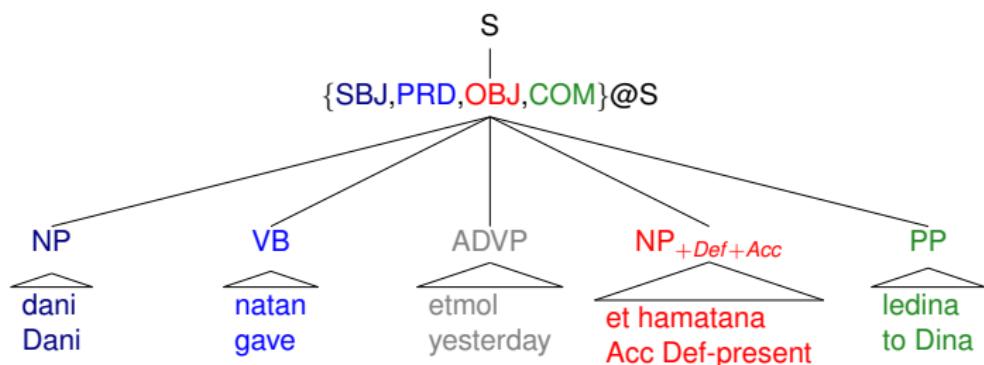
The Realization Rules

Relational-Realizational (RR) Parsing
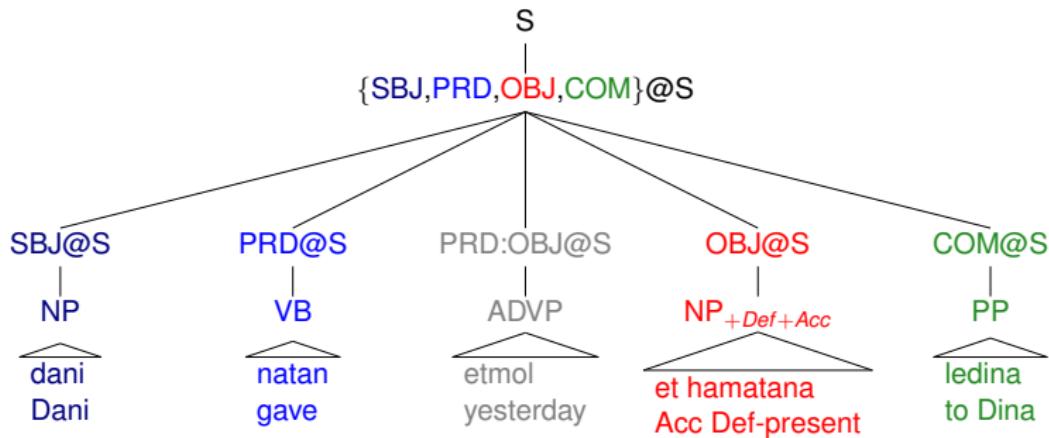
The Realization Rules

Relational-Realizational (RR) Parsing
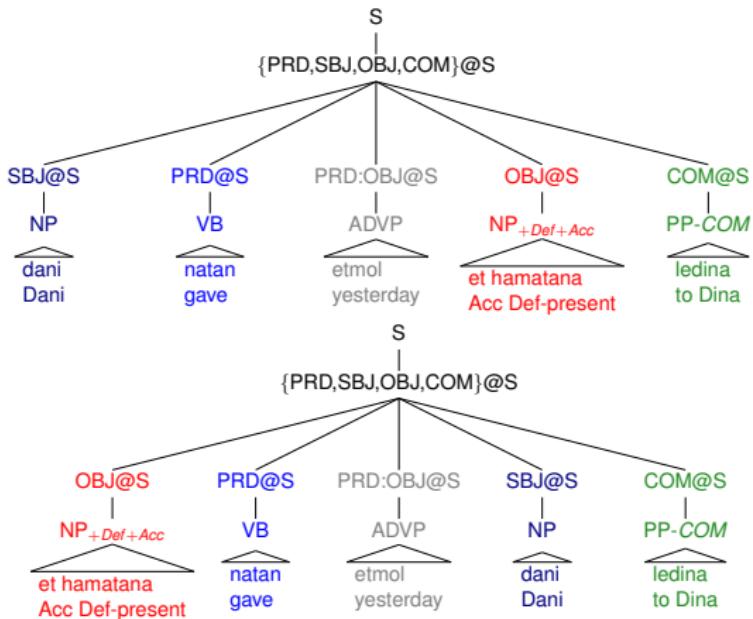
The Model Parameters

Projection:

$$
\begin{array}{c}
P \\
| \\
\{gr_i\}_{i=1}^n @P
\end{array}
$$

Configuration:

$$\{gr_i\}_{i=1}^n @P$$

$$gr_1@P \quad gr_1 : gr_2@P \quad ... \quad gr_n@P$$

Realization:

$$gr_1@P \quad gr_1 : gr_2@P \quad ... \quad gr_n@P$$
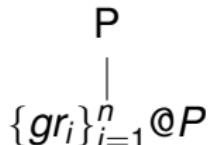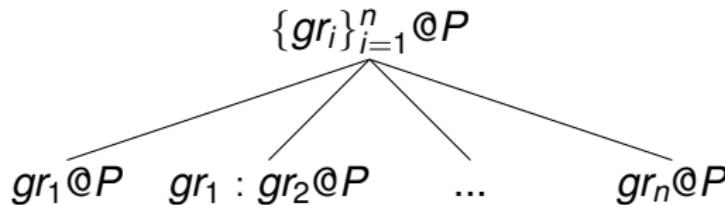
$$C_1 \quad ..C_{1:2_i}.. \quad C_n$$
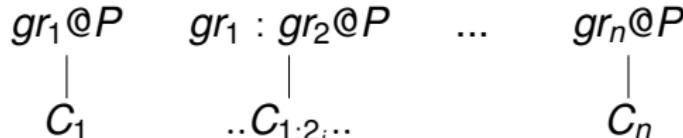
The Probabilistic Model

The RR Probabilities:

$$\mathbf{P_{RR}}(r) =$$

Projection $\quad \mathbf{P_p}(\{gr_i\}_{i=1}^n | P) \times$

Configuration $\quad \mathbf{P_c}(\langle gr_0 : gr_1, g_1, \ldots \rangle | \{gr_i\}_{i=1}^n, P) \times$

Realization $\quad \prod_{i=1}^n \mathbf{P_{r_1}}(C_i | gr_i, P) \times$

$\quad\quad\quad\quad \mathbf{P_{r_2}}(\langle C_{0_1}, ..., C_{0_{m_0}} \rangle | gr_0 : gr_1, P) \times$

$\quad\quad\quad\quad \prod_{i=1}^n \mathbf{P_{r_2}}(\langle C_{i_1}, ..., C_{i_{m_i}} \rangle | gr_i : gr_{i+1}, P)$

The RR Parser:

$$\pi^* = argmax_\pi P(\pi) = argmax_\pi \prod_{r \in \pi} \mathbf{P_{RR}}(r)$$

Experiments

Experiments

	CONFIGURATIONAL	RELATIONAL
INCREMENTAL	Head-Driven Parsing	Dependency Parsing
REALIZATIONAL	Tree Adjoining Grammars	Relational-Realizational

Table: A Taxonomy of Generative Statistical Parsing Frameworks

Application I: Parsing Modern Hebrew

Data
The Modern Hebrew Treebank v2, head annotated.
6500 sentences, 500/5500/500 dev/train/test split

Models

- Grammatical Functions: PRD, SBJ, OBJ, COM, CNJ
- Morphological Splits: **PoS/Def/Acc**
- Conditioning Context: Horizontal/Vertical

Estimation
Relative Frequency + Simple Unknown Words Smoothing

Parsing
Exhaustive Viterbi Parsing (using BitPar, Schmid 2004)

Evaluation
PARSEVAL (i) Overall, and (ii) Per Category Evaluation

Overall Results

Precision/Recall (#parameters)	74.66/74.35 (7385)	73.52/74.84 (21399)	**76.32/76.51 (13618)**

Overall Results

Precision/Recall (#parameters)	74.66/74.35 (7385)	73.52/74.84 (21399)	**76.32/76.51 (13618)**

Results Per Category

NP	77.39 / 74.32	77.94 / 73.75	**78.96 / 76.11**
PP	71.78 / 71.14	71.83 / 69.24	**74.4 / 72.02**
SBAR	55.73 / 59.71	53.79 / 57.49	**57.97 / 61.67**
ADVP	71.37 / 77.01	72.52 / 73.56	**73.57 / 77.59**
ADJP	**79.37 / 78.96**	78.47 / 77.14	78.69 / 78.18
S	**73.25 / 79.07**	71.07 / 76.49	72.37 / 78.33
SQ	36.00 / **32.14**	30.77 / 14.29	**55.56** / 17.86
PREDP	36.31 / 39.63	**44.74** / 39.63	44.51 / **46.95**

Towards Probabilistic Universal Grammar

Basic Word-Order Parameter:
P($<$ *configuration* $>$|{SBJ,PRD,OBJ}@S)

Probability	Configuration	tri-	bi-
0.2%	OBJ □ SUBJ PRD	OSV	OV
0.2%	PRD OBJ SBJ □	VOS	VO
0.2%	□ PRD OBJ □ SBJ □	VOS	VO
0.2 %	PRD SBJ □ OBJ □	VSO	VO
0.4 %	□ PRD □ SBJ □ OBJ □	VSO	VO
0.6 %	OBJ □ PRD SBJ □	OVS	OV
0.8 %	OBJ PRD □ SBJ □	OVS	OV
1 %	□ PRD □ SBJ OBJ □	VSO	VO
1.3%	SBJ □ PRD OBJ □	SVO	VO
1.7%	□ PRD OBJ SBJ □	VOS	VO
1.7%	□ SBJ PRD □ OBJ □	SVO	VO
3%	OBJ PRD SBJ □	OVS	OV
3.7%	□ PRD SBJ □ OBJ □	VSO	VO
4.1%	SBJ □ PRD □ OBJ □	SVO	VO
6.5%	□ SBJ PRD OBJ □	SVO	VO
10.3%	SBJ □ PDR OBJ □	SVO	VO
12.3%	□ PRD SBJ OBJ □	VSO	VO
15.6%	SBJ PRD □ OBJ □	SVO	VO
35.3%	SBJ PRD OBJ □	SVO	VO

Towards Probabilistic Universal Grammar

Differential Object-Marking Parameter:
P($<$ *morphosyntactic representation* $>$| OBJ@S)

Probability	Realization
5.8%	NP.DEF.ACC$\langle$*PRP*$\rangle$@*S*
6.5%	NP.DEF.ACC$\langle$*NNT*$\rangle$@*S*
6.7%	NP.DEF.ACC$\langle$*NN.DEF*$\rangle$@*S*
7.4%	NP.DEF.ACC$\langle$*NNP*$\rangle$@*S*
8.8%	NP$\langle$*NNT*$\rangle$@*S*
14.7%	NP.DEF.ACC$\langle$*NN*$\rangle$@*S*
43.5%	NP.$\langle$*NN*$\rangle$@*S*

Application II: Towards Computational Typology?

Can we Use the RR parameters to...

- ► Quantify Intra-Language Variation?
- ► Quantify Cross-Linguistic Variation?
- ► Learn Parameters Settings from Data?
- ► Quantify Nonconfigurationality?

The Relational-Realizational Framework

Specifying and Learning Linguistic Descriptions

- ▶ Simple
- ▶ Formal
- ▶ Robust
- ▶ Implementable
- ▶ Interpretable
- ▶ Explanatory

⤳ Syntactic paradigms augmented with realization rules provide a powerful strategy

PRRR

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For more Information
Relational-Realizational Parsing
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Thank You!

Questions?

LFG vs. RR

LFG

- ▶ Parallel ($\rightsquigarrow$ Model-Theoretic)
- ▶ Form-to-Function
- ▶ Hierarchical Feature-Checking
- ▶ 'Lexical' treatment of morphosyntax

    LEXICON (LI) ; c-str $\rightarrow$ f-str $\rightarrow$ s-str $\rightarrow$ ...

RR

- ▶ Integrated ($\rightsquigarrow$ Generative-Enumerative)
- ▶ Function-to-Form
- ▶ Local feature-checking
- ▶ 'Realizational' treatment of morphosyntax

    ... s-str $\rightarrow$ f-str $\rightarrow$ c-str $\rightarrow$ r-str ; LEXICON (IR)