Universal Dependency Parsing

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The Grand Vision
The Grand Vision

The problem

• Why 90% parsing accuracy for English but only 80% for Finnish?
• Are some languages intrinsically harder to parse?
• Not just morphological richness – many typological parameters
The Grand Vision

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An ideal solution

- A universal parser for all languages
- Linguistic universals are hard-coded
- Typological parameters are learned from data
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• A universal parser for all languages
• Linguistic universals are hard-coded
• Typological parameters are learned from data

Gee!
What a neat idea!
Pieces of the Puzzle

1. Morphosyntactic disambiguation
2. Universal dependency annotation
3. Parsing with universal dependencies
Part I

Morphosyntactic Disambiguation

Joint work with Bernd Bohnet, Igor Boguslavsky, Richárd Farkas, Filip Ginter and Jan Hajič
Parsing accuracy for morphologically rich languages tends to be lower than for languages like English (Nivre et al., 2007)

Hypothesized explanations (Tsarfaty et al. 2010, 2013):
- Strict separation morphology-syntax
- Data sparsity due to high type-token ratio

Suggested remedies
- Joint morphological and syntactic analysis (Lee et al., 2011)
- Lexical resources (Hajič, 2000; Goldberg and Elhadad, 2013)
This Study

Parsing techniques:

• Transition-based model for joint morphological and syntactic analysis
• Lexical resources integrated as hard or soft constraints

Evaluation on five morphologically rich languages:

• Czech, Finnish, German, Hungarian, Russian
• New state of the art in dependency parsing for all languages

Representations
Representations

For each word of a sentence $w_1, \ldots, w_n$: 

Ein Haus hat er in Ulm gebaut.
Representations

For each word of a sentence $w_1, \ldots, w_n$:

- A part-of-speech tag $p \in P$
For each word of a sentence \( w_1, \ldots, w_n \):

- A part-of-speech tag \( p \in P \)
- A morphological feature bundle \( m \in M \)

Ein Haus hat er in Ulm gebaut.
Representations

For each word of a sentence $w_1, \ldots, w_n$:

- A part-of-speech tag $p \in P$
- A morphological feature bundle $m \in M$
- A lemma $l \in Z^*$

<table>
<thead>
<tr>
<th>Ein</th>
<th>Haus</th>
<th>hat</th>
<th>er</th>
<th>in</th>
<th>Ulm</th>
<th>gebaut</th>
<th>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ART acc</td>
<td>NN accl</td>
<td>VAFIN sgl</td>
<td>PPER nom</td>
<td>APR</td>
<td>NE datl</td>
<td>VVPP</td>
<td>$</td>
</tr>
</tbody>
</table>
For each word of a sentence $w_1, \ldots, w_n$:

- A part-of-speech tag $p \in P$
- A morphological feature bundle $m \in M$
- A lemma $l \in \mathbb{Z}^*$
- A syntactic head $h \in \{0, w_i, \ldots, w_n\}$
For each word of a sentence $w_1, \ldots, w_n$:

- A part-of-speech tag $p \in P$
- A morphological feature bundle $m \in M$
- A lemma $l \in Z^*$
- A syntactic head $h \in \{o, w_i, \ldots, w_n\}$
- A dependency label $d \in D$
Parsing Framework

Transition system (Bohnet and Nivre, 2012):
- Arc-standard system with online reordering (Nivre, 2009)
- Select morphology when shifting words to the stack

Beam search and structured learning (Zhang and Clark, 2008)

Preprocessing (at learning and parsing time)
- Tagger assigns $k$ best tags and feature bundles
- Parser can only select analyses licensed by preprocessor
**Experiment 1**

**Pipeline**
Preprocessor assigns a single tag and feature bundle per word
Beam = 40 distinct trees

**Joint**
Preprocessor assigns up to 2 tags and feature bundles per word
Beam = 40 distinct trees + 8 tag variants + 8 feature variants

<table>
<thead>
<tr>
<th>Treebank</th>
<th>Train</th>
<th>Dev</th>
<th>Test</th>
<th>P</th>
<th>M</th>
<th>D</th>
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<tbody>
<tr>
<td>cs  PDT (Hajič et al., 2001)</td>
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<td>88K</td>
<td>70K</td>
<td>12</td>
<td>1851</td>
<td>49</td>
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<tr>
<td>de  Tiger (Brants et al., 2002)</td>
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<td>32K</td>
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<td>210K</td>
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<td>33</td>
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<td>ru  SynTagRus (Boguslavsky et al., 2000)</td>
<td>575K</td>
<td>73K</td>
<td>72K</td>
<td>14</td>
<td>454</td>
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Morphological Accuracy

<table>
<thead>
<tr>
<th>Language</th>
<th>Pipeline</th>
<th>Joint</th>
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<tbody>
<tr>
<td>cs</td>
<td>93.0</td>
<td>93.7</td>
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<tr>
<td>de</td>
<td>92.6</td>
<td>92.8</td>
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<td>fi</td>
<td>90.0</td>
<td>89.1</td>
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<tr>
<td>hu</td>
<td>96.2</td>
<td>96.1</td>
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<td>92.6</td>
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</table>
Syntactic Accuracy

Pipeline  Joint

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<th>Language</th>
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<tbody>
<tr>
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<td>83.3</td>
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<td>92.0</td>
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<tr>
<td>fi</td>
<td>79.9</td>
<td>80.6</td>
</tr>
<tr>
<td>hu</td>
<td>88.4</td>
<td>88.9</td>
</tr>
<tr>
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Experiment 2

Morphological lexicons

- Lookup of tag, feature bundle and lemma
- Added as **hard** or **soft** constraints to preprocessor and parser
- Lemma selected deterministically from form + tag + feature bundle

<table>
<thead>
<tr>
<th>Language</th>
<th>Lexicon</th>
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<tr>
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<td>PDT (Hajič and Hladká, 1998)</td>
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<tr>
<td>de</td>
<td>SMOR (Schmid et al., 2004)</td>
</tr>
<tr>
<td>fi</td>
<td>OMorFi (Pirinen, 2011)</td>
</tr>
<tr>
<td>hu</td>
<td>morphdb.hu (Trón et al., 2006)</td>
</tr>
<tr>
<td>ru</td>
<td>ETAP-3 (Apresian et al., 2003)</td>
</tr>
</tbody>
</table>
Morphological Accuracy

<table>
<thead>
<tr>
<th>Language</th>
<th>Joint</th>
<th>LexHard</th>
<th>LexSoft</th>
</tr>
</thead>
<tbody>
<tr>
<td>cs</td>
<td>93.7</td>
<td>94.4</td>
<td>94.5</td>
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<tr>
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<td>92.9</td>
<td>91.2</td>
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Morphological Accuracy

- **cs**: Joint 93.7, LexHard 92.9, LexSoft 94.4
- **de**: Joint 90.0, LexHard 91.2, LexSoft 91.2
- **fi**: Joint 89.1, LexHard 91.1, LexSoft 91.6
- **hu**: Joint 96.2, LexHard 97.1, LexSoft 97.4
- **ru**: Joint 92.8, LexHard 94.5, LexSoft 95.1

The chart shows the morphological accuracy for different languages and methods.
Discussion

Joint inference benefits both morphology and syntax
  • Strongest effect on morphology for Czech and German – syncretism?
  • Strongest effect on syntax for Finnish and Hungarian – why?

Lexical resources mitigate data sparseness
  • Strongest effect on morphology – soft constraints always best?
  • Weaker effect on syntax – relevant errors fixed by joint inference?
  • Strong effect on syntax for Finnish – sparse data?
Discussion

Joint inference benefits both morphology and syntax

• Strongest effect on morphology for Czech and German – syncretism?
• Strongest effect on syntax for Finnish and Hungarian – why?

Lexical resources mitigate data sparseness

• Strongest effect on morphology – soft constraints always best?
• Weaker effect on syntax mitigated by joint inference?
• Strong effect on Finnish – sparse data?

Nice!
But why only 82% for Finnish?

Can we even compare the numbers?
Part 2
Universal Dependency Annotation

Joint work with Ryan MacDonald, Slav Petrov, Chris Manning, Marie de Marneffe, Jinho Choi, Filip Ginter, Yoav Goldberg, Jan Hajič and Reut Tsarfaty
Apples and Oranges
Apples and Oranges

Treebank annotation schemes vary across languages

• Hard to compare parsing results across languages (Nivre et al., 2007)
• Hard to evaluate cross-lingual learning (McDonald et al., 2013)
• Hard to make progress towards a universal parser?
Apples and Oranges

Treebank annotation schemes vary across languages

- Hard to compare parsing results across languages (Nivre et al., 2007)
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- Hard to make progress towards a universal parser?

Recent initiatives:

- **HamleDT**: Conversion of 29 existing treebanks to a PDT-like annotation scheme (Zeman et al., 2012)
- **Universal Dependency Treebank Project**: New annotation, conversion and harmonization to Google universal PoS tags and Stanford dependencies (McDonald et al., 2013)
## Case Study

Delexicalized transfer parsing with universal PoS tags

<table>
<thead>
<tr>
<th>Source Training Language</th>
<th>Target Test Language</th>
<th>Unlabeled Attachment Score (UAS)</th>
<th>Labeled Attachment Score (LAS)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Germanic</td>
<td>Romance</td>
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<td></td>
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<td>DE</td>
<td>EN</td>
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<td>DE</td>
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<td>74.86</td>
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Case Study

Delexicalized transfer parsing with universal PoS tags

First evaluation of labeled accuracy

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Case Study

Delexicalized transfer parsing with universal PoS tags

Results make typological sense

First evaluation of labeled accuracy

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Too Many Standards?
Too Many Standards?

English SD
de Marneffe et al. (2006)
Too Many Standards?

- **English SD**
  - de Marneffe et al. (2006)

- **Google SD**
  - McDonald et al. (2013)
Too Many Standards?

- English SD
  - de Marneffe et al. (2006)

- Google SD
  - McDonald et al. (2013)

- Finnish SD
  - Haverinen et al. (2013)

- Hebrew SD
  - Tsarfaty (2013)
Too Many Standards?

- **English SD**
  - de Marneffe et al. (2006)
- **HamleDT**
  - Zeman et al. (2012)
- **Google SD**
  - McDonald et al. (2013)
- **Finnish SD**
  - Haverinen et al. (2013)
- **Hebrew SD**
  - Tsarfaty (2013)

- **CLEAR**
  - Choi (2012)
Too Many Standards?

Universal Dependencies

Universal Dependencies

http://universaldependencies.github.io/docs/

In dem Restaurant isst Maria den Fisch.

ADP DET NOUN VERB PNOUN DET NOUN
CASE=DAT CASE=DAT TENSE=PRES CASE=NOM CASE=ACC CASE=ACC
NUM=SIN NUM=SIN GEN=NEU GEN=NEU NUM=SIN GEN=MAS

1.1 1.2 2 Restaurant 3 isst 4 Maria 5 den 6 Fisch

1

Im Restaurant isst Maria den Fisch.

ADP DET NOUN VERB PNOUN DET NOUN
CASE=DAT CASE=DAT TENSE=PRES CASE=NOM CASE=ACC CASE=ACC
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1
In Restaurant isst Maria den Fisch.

- ADP: Im
- DET: dem
- NOUN: Restaurant
- VERB: isst
- PNNOUN: Maria
- DET: den
- NOUN: Fisch

Case: DAT
Num: SIN
Gen: NEU

Tense: PRES
Case: NOM
In dem Restaurant isst Maria den Fisch.

ADP  DET  NOUN  VERB  PNNOUN  DET  NOUN
CASE=DAT CASE=DAT TENSE=PRES CASE=NOM CASE=ACC CASE=ACC
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GEN=NEU GEN=MAS

Google Universal Part-of-Speech Tags + Morphological Features
Universal Dependencies

In dem Restaurant ist Maria den Fisch.

Explicit Mapping from Tokens to Words

1.1 Im 1.2 2 Restaurant 3 isst 4 Maria 5 den 6 Fisch 7 .
Guiding Principles
Guiding Principles

Maximize parallelism

• Don’t annotate the same thing in different ways
• Don’t make different things look the same
Guiding Principles

Maximize parallelism
  • Don’t annotate the same thing in different ways
  • Don’t make different things look the same

But don’t overdo it
  • Don’t annotate things that are not there
  • Languages select from a universal pool of categories
  • Allow language-specific extensions
• Keeping content words as heads promotes parallelism
• Function words often correlate with morphology
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• Function words often correlate with morphology
Dependency Structure

- Keeping content words as heads promotes parallelism
- Function words often correlate with morphology
Dependency Relations

- Taxonomy of 42 universal grammatical relations, broadly supported across many languages in language typology
- Language specific subtypes can be added

<table>
<thead>
<tr>
<th>Core dependents of clausal predicates</th>
<th>Non-core dependents of clausal predicates</th>
<th>Special clausal dependents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal dep</td>
<td>Predicate dep</td>
<td>Modifiers dep</td>
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<tr>
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<td>csubj</td>
<td>advd</td>
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<td>nsubjpass</td>
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<table>
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<tr>
<th>Noun dependents</th>
<th>Compounding and unanalyzed</th>
<th>Coordination</th>
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</tbody>
</table>
Morphology

• The lexicalist hypothesis
  • Grammatical relations hold between words (including clitics)
  • Morphological categories are properties of words

• Morphological annotation
  • Revised Google Universal Part-of-Speech Tags (Petrov et al., 2012)
  • Universal inventory of morphological features (under construction)
Tokens and Words

Principle of recoverability

• Clitics and contractions are split to allow meaningful annotation
• Mapping from basic tokenization is explicitly represented
• Heuristic mapping of annotation to basic tokens is provided

Encoded in revised CoNLL format (CoNLL-U)
Tokens and Words

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Work in Progress

Current time plan:
  • Stable annotation guidelines by end of September
  • First release of data sets before the end of 2014

Follow our progress and give feedback:
  • Universal Dependencies: http://universaldependencies.github.io/docs/

Check out old releases:
  • Uni-Dep-TB: https://code.google.com/p/uni-dep-tb/

Let’s work together!
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Let’s work together!

Hey, wait a minute!

How is this going to improve parsing?
Part 3

Parsing with Universal Dependencies

Confessions of a converted dependency parser
Taking Stock
Taking Stock

Motivation for universal dependencies

• Improve comparability of parsing results across languages
• Facilitate development of multilingual systems
• Enable typological studies of syntactic structure
Taking Stock

Motivation for universal dependencies

- Improve comparability of parsing results across languages
- Facilitate development of multilingual systems
- Enable typological studies of syntactic structure

What about parsing?

- Not likely to improve parsing accuracy with existing parsers
- Parsers tend to prefer function words as heads (Schwarz et al., 2012)
- We risk bringing English down to 80% instead of Finnish up to 90%
What’s the Problem?
What’s the Problem?

- Dependency parsers know only one syntactic relation.
What’s the Problem?

• Dependency parsers know only one syntactic relation
• They do not interpret dependency labels
What’s the Problem?

- Dependency parsers know only one syntactic relation
- They do not interpret dependency labels
- They represent a construction primarily by its head
A Simple Case

The dog was chased by the black cat.
A Simple Case

The dog was chased by the black cat.

• All criteria point to cat being the head
A Simple Case

The dog was chased by the cat.

- All criteria point to *cat* being the head
- Little (syntactic) information is lost by dropping *black*
A Tricky Case

The dog *was chased* by the black cat.
A Tricky Case

The dog _was_ _chased_ by the black cat.

- Some criteria point to _was_, others to _chased_ as the head
A Tricky Case

The dog **was** chased by the black cat.

- Some criteria point to **was**, others to **chased** as the head
- Neither word can represent the whole
A Tricky Case

The dog was chased by the black cat.

• Some criteria point to was, others to chased as the head
• Neither word can represent the whole
• The same problem arises with by (the black cat)
• Three fundamental syntactic relations (Tesnière, 1959)

• Tesnière-style dependency treebank (Sangati and Mazza, 2009)
Universal Dependencies
Universal Dependencies

- The UD representation is a simple dependency tree

\[
\begin{array}{ccccccccc}
\text{Fido} & \text{was} & \text{chased} & \text{by} & \text{Kitty} & \text{and} & \text{Tiger} & . \\
\text{PNOUN} & \text{AUX} & \text{VERB} & \text{ADP} & \text{PNOUN} & \text{CONJ} & \text{PNOUN} & \\
\text{nsubjpass} & \text{auxpass} & \text{agent} & \text{case} & \text{conj} & \text{cc} & . & . \\
\end{array}
\]
Universal Dependencies

- The UD representation is a simple dependency tree
- But labels are universal and can be interpreted
Universal Dependencies

- The UD representation is a simple dependency tree
- But labels are universal and can be interpreted
- Therefore, we can put more knowledge into the parser
Final Remarks
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Constituency parsing – largely driven by PTB

- Perhaps too much emphasis on English (until recently)
- But deep analysis of categories and representations
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Can UD give us the best of both worlds?
Thanks for Your Attention!
Questions?

http://stp.lingfil.uu.se/~nivre/