Multiword Expressions in Dependency Parsing

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Introduction

- Do we really need to talk about MWEs in dependency parsing?
- Research has been booming in both areas over the last decade!

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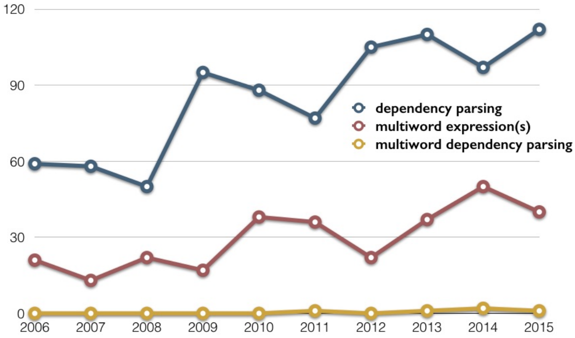
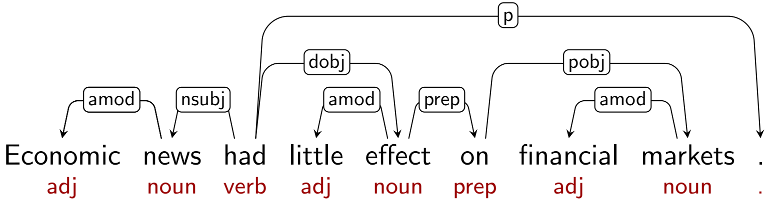


Plan for the Talk

1. Basic concepts of dependency parsing
2. Integrating multiword expressions
   2.1 Linguistic representations
   2.2 Parsing techniques
   2.3 Empirical studies
3. Transition-based joint lexical and syntactic analysis

Dependency Trees

- For a sentence $x = w_1, \ldots, w_n$ and label set L, a dependency tree is a directed tree with labeled arcs over the tokens
- Formally, we model a tree $T = (V, A)$ as follows:
  1. $V = \{1, \ldots, n\}$ is a set of nodes, one for each input token
  2. A is a set of arcs (i, l, j), with $i, j \in V$ and $l \in L$
  3. A is a spanning tree in the graph $G_x = \{(i, l, j) | i, j \in V, l \in L\}$



Dependency Parsing

- The task:
  - Input: sentence $x = w_1, \ldots, w_n$
  - Output: dependency tree $T = (V, A)$ for x
- Graph-based parsing [McDonald et al. 2005]:
  - Learns a (factored) model for scoring spanning trees in G_x
  - Needs efficient spanning tree algorithms for parsing
- Transition-based parsing [Nivre 2003]:
  - Learns a (local) model for scoring parsing actions (transitions)
  - Relies on heuristic search for the optimal sequence of actions

Integrating Multiword Expressions

1. Linguistic representations
   - How do we put MWEs into dependency trees?
2. Parsing techniques
   - How do we process MWEs using dependency parsers?
3. Empirical studies
   - What works and what doesn't?

Linguistic Representations

- How do we represent MWEs in dependency trees?
- Do we need to modify the definition of a dependency tree?
- What about different classes of MWEs?
  - Fixed: by and large, in spite of
  - Semi-fixed: part(s) of speech, kick(s/ed) the bucket
  - Flexible: put off, look for, take a photo
- What about discontiguous MWEs?

The Spanning Tree Assumption

- Basic assumption in (current) dependency parsing:
  - Dependency structure for x is a spanning tree in G_x
  - Every token is a node in the dependency tree (spanning)
  - Every node (except the root) has one incoming arc (tree)
- Possible variations:
  - Give up the tree assumption – allow general graphs
  - Give up the spanning assumption – tokens $\neq$ nodes

Tokens and Nodes

Token	Node	Example
1	1	Ordinary word tokens

Tokens and Nodes

Token	Node	Example
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1	>1	Clitics, contractions

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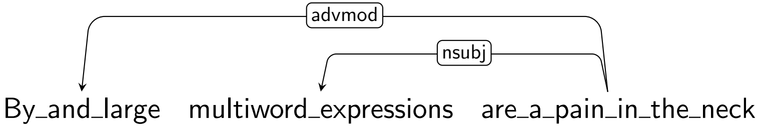
0	1	Ellipsis?

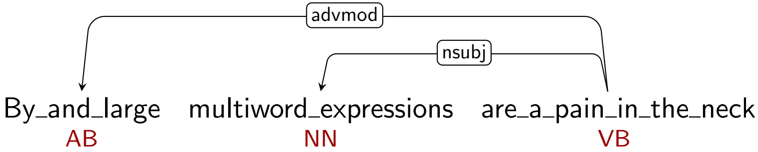
This requires a new type of dependency parser!

MWEs as Special Tokens



- Simplifies parsing **if** MWEs can be identified prior to parsing
- Works for contiguous MWEs, awkward for flexible MWEs
- Common in treebanks (about half of the CoNLL-X data sets)
- What about part-of-speech tags?

MWEs as Special Tokens



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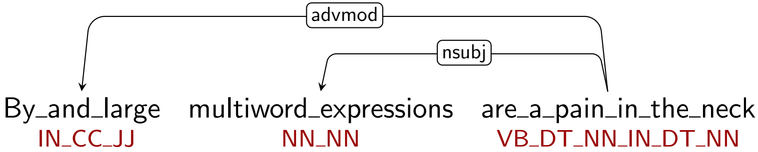

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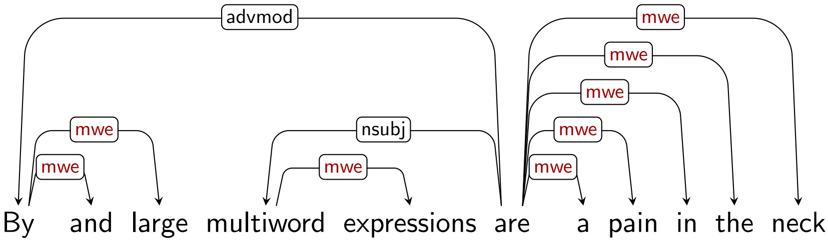
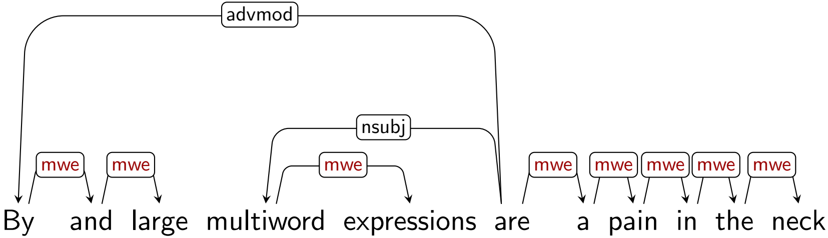
MWEs as Dummy Dependency Structures



- Canonical structure without syntactic significance
- Special labels distinguish from real dependencies
- The problem with part-of-speech tags remain

MWEs as Dummy Dependency Structures



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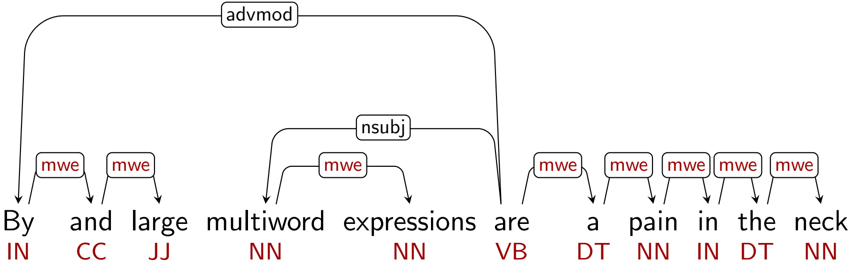

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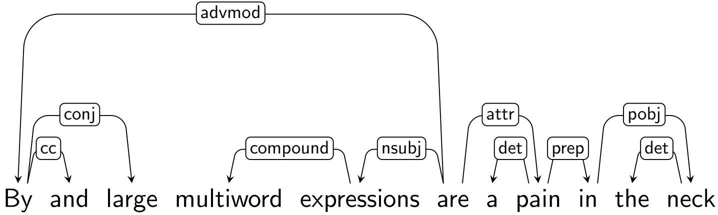
MWEs as Real Dependency Structures



- Dependency structure reflects real internal structure
- Special labels may be used for subtypes (for example, LVCs)
- Part-of-speech tags do not reflect MWE status

So what representations should we use?

- Different types of MWEs require different representations
- At one end of the spectrum: by and large
  - No point in representing internal syntactic structure
  - Equivalent to a single node in dependency structure
  - Special tokens or dummy dependencies?
- At the other end: take a photo
  - Needs internal structure to allow modification and inflection
  - Real dependencies, special labels?
- What about everything in between?

Parsing Techniques

- Three main approaches:
  - Pre-processing – analyze MWEs before parsing
  - Post-processing – analyze MWEs after parsing
  - Joint processing – analyze MWEs during parsing
- Key question:
  - Does MWE identification help parsing or vice versa or both?
  - The answer may be different for different types of MWEs!

Techniques and Representations

	Pre	Joint	Post
Special tokens	yes	no	yes

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	Pre	Joint	Post
Special tokens	yes	no	yes
Dummy dependencies	?	yes	?

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Techniques and Representations

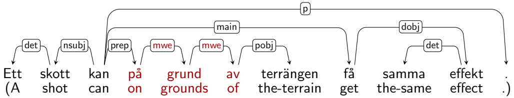
	Pre	Joint	Post
Special tokens	yes	no	yes
Dummy dependencies	?	yes	?
Real dependencies	no	yes	yes

If different types of MWEs require different representations, they may require different processing techniques as well!

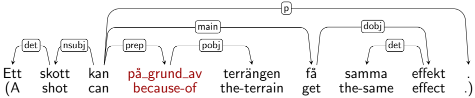
An Early Study [Nivre and Nilsson 2004]

- Swedish treebank with (limited) MWE annotation:
  - Function words like in spite of, at large
  - Names like Carl XVI Gustaf, Swedish Academy
  - Numerical expressions like $2 + 2 = 4$

1. Joint processing with dummy dependencies:



2. Preprocessing with special tokens (gold input):



Results

	MWE	Other
Joint	71.1	80.7
Preprocessing	–	81.6

- Perfect MWE recognition improves parsing accuracy (slightly)
- Typical effects of failing to recognize MWEs:
  - Unusual part-of-speech patterns leads to distorted structure (vad beträffar = as regards)
  - Different attachment preferences for MWEs and compositional phrases (i regel = as a rule)

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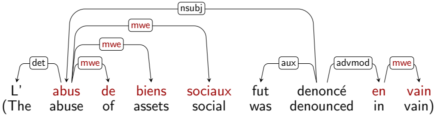
Similar results observed later for Turkish [Eryiğit et al. 2011]

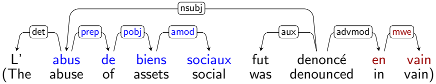
Regular and Irregular MWEs

[Candito and Constant 2014]

- French dependency treebank with dummy MWE dependencies:



- Alternative representations for regular MWEs:



- PoS patterns used to distinguish regular and irregular MWEs

Processing Models

	Irregular	Regular
Joint	Parser	Parser
Joint-Reg	Pre	Parser
Joint-Irreg	Parser	Post
Pipeline	Pre	Post

- Pre = MWEs pre-recognized and merged to single tokens
- Post = MWEs recognized after parsing

Results

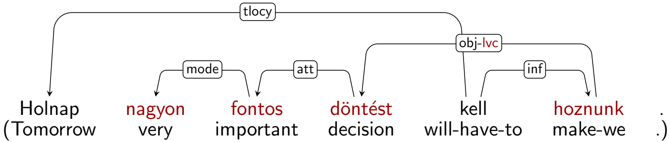
	Dummy		Real	
	MWE[1]	Overall	MWE[2]	Overall
Joint	73.5	84.5	81.4	86.9
Joint-Reg	73.3	84.2	80.4	86.6
Joint-Irreg	75.4	84.4	82.1	87.0
Pipeline	74.4	83.9	80.4	86.5

[1]) All MWEs. [2]) Irregular MWEs only.

- Syntactic accuracy higher with real dependencies
- Irregular MWEs benefit from joint processing
- Regular MWEs better identified after parsing?

Light Verb Constructions [Vincze et al. 2013]

- Hungarian dependency treebank with LVC annotation:



- Can a parser learn to identify light verb constructions?
- How is overall parsing accuracy affected?

Results

	LVC	Overall
Parser plain	–	90.6
Parser LVC	75.6	90.4
Post dictionary	21.3	–
Post C4.5	74.5	–

- Parser improves LVC identification with a marginal drop in overall labeled attachment score
- Parser significantly better than post-classifier on discontiguous LVCs ($64.0 > 60.0$)

Interim Conclusion

- We have only scratched the surface ...
- Complex interaction between several factors:
  - MWE types
  - Linguistic representations
  - Processing techniques
- Tentative conclusions:
  - MWE identification can benefit from syntactic context
  - Regular MWEs should be assigned regular syntactic structure

Joint Lexical and Syntactic Analysis

- Joint work with **Mathieu Constant** [Constant and Nivre 2016]
- Factored representation for lexical and syntactic analysis
  - Lexical trees represent lexical structure (including MWEs)
  - Dependency trees represent syntactic structure
  - Two orthogonal dimensions synchronized at the token level
- Transition-based system that processes both dimensions jointly

Lexical and Syntactic Structure

- Sentence = sequence of tokens $w_1, \ldots, w_n$
- Lexical tree = tree over tokens (possibly discontiguous)

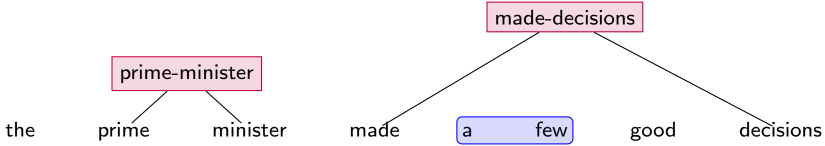
Lexical unit	Tokens	Syntactic unit
Word	1	yes
Fixed MWE	>1	yes
Non-fixed MWE	>1	no

- Syntax tree = tree over syntactic units (words, F-MWEs)

Lexical and Syntactic Structure

the prime minister made a few good decisions

Lexical and Syntactic Structure



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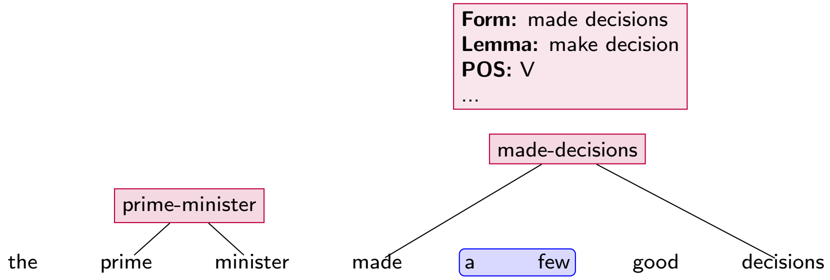

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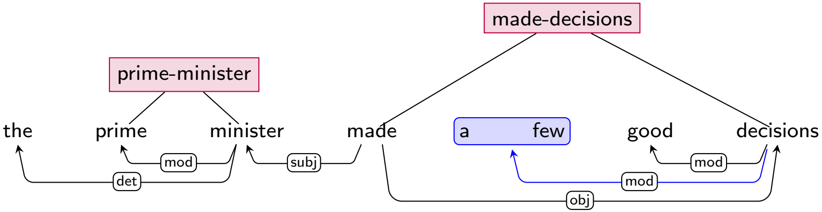
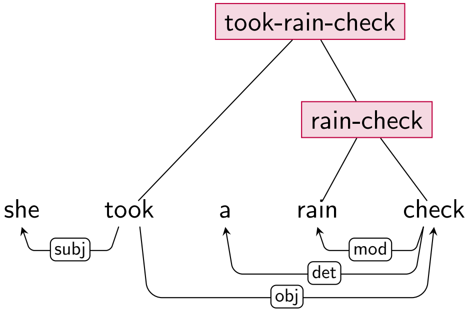


MWE Embedding



A Transition-Based System

- Handling two linguistic dimensions:
  - Two stacks: one syntactic stack and one lexical stack
  - One buffer to synchronize the two dimensions
  - Output: one set of dependency arcs and one set of lexical trees
- Handling MWEs:
  - Mild extension of arc-standard transition system
  - Specific transitions to deal with MWE identification

Transition system

- Configuration:

  (Buffer, SynStack, SynArcs, LexStack, LexTrees)

- Initialization:

  $([w_1, \ldots, w_n], [\,], \{\,\}, [\,], \{\,\})$

  Input: $w_1, \ldots, w_n$

- Termination:

  $([\,], [x]$, SynArcs, $[\,]$, LexTrees)

  Output: SynArcs, LexTrees

Transition system

- **Shift**
  - Moves next token from buffer to both stacks
- **Right-Arc(l), Left-Arc(l)**
  - Adds syntactic arc between top items on syntactic stack
- **Merge$_F$(t)**
  - Creates lexical tree from top items on both stacks – F-MWE
- **Merge$_N$(t)**
  - Creates lexical tree from top items on lexical stack – NF-MWE
- **Complete**
  - Adds lexical tree from lexical stack

Example Parse

Transition

–

Buffer

[he made a few decisions]

SynStack

[ ]

SynArcs

–

LexStack

[ ]

LexTrees

–

Example Parse

Transition
Shift

Buffer
[made a few decisions]

SynStack
[he]

SynArcs
–

LexStack
[he]

LexTrees
–

Example Parse

Transition
Complete

Buffer
[made a few decisions]

SynStack
[he]

SynArcs
–

LexStack
[ ]

LexTrees
he

Example Parse

Transition
Shift

Buffer
[a few decisions]

SynStack
[he made]

SynArcs
–

LexStack
[made]

LexTrees
he

Example Parse

Transition
Left-Arc(subj)

Buffer
[a few decisions]

SynStack
[made]

SynArcs
subj(made, he)

LexStack
[made]

LexTrees
he

Example Parse

Transition
Shift

Buffer
[few decisions]

SynStack
[made a]

SynArcs
subj(made, he)

LexStack
[made a]

LexTrees
he

Example Parse

Transition
Shift

Buffer
[decisions]

SynStack
[made a few]

SynArcs
subj(made, he)

LexStack
[made a few]

LexTrees
he

Example Parse

Transition

Merge_F(A)

Buffer

[decisions]

SynStack

[made A(a, few)]

SynArcs

subj(made, he)

LexStack

[made A(a, few)]

LexTrees

he

Example Parse

Transition
Complete

Buffer
[decisions]

SynStack
[made A(a, few)]

SynArcs
subj(made, he)

LexStack
[made]

LexTrees
he, A(a, few)

Example Parse

Transition
Shift

Buffer
[ ]

SynStack
[made A(a, few) decisions]

SynArcs
subj(made, he)

LexStack
[made decisions]

LexTrees
he, A(a, few)

Example Parse

Transition
Left-Arc(mod)

Buffer
[ ]

SynStack
[made decisions]

SynArcs
subj(made, he)
mod(decisions, A(a, few))

LexStack
[made decisions]

LexTrees
he, A(a, few)

Example Parse

Transition
$\text{Merge}_N(\text{V})$

Buffer
[ ]

SynStack
[made decisions]

SynArcs
subj(made, he)
mod(decisions, A(a, few))

LexStack
[V(made, decisions)]

LexTrees
he, A(a, few)

Example Parse

Transition
Complete

Buffer
[ ]

SynStack
[made decisions]

SynArcs
subj(made, he)
mod(decisions, A(a, few))

LexStack
[ ]

LexTrees
he, A(a, few), V(made, decisions)

Example Parse

Transition
Right-Arc(obj)

Buffer
[ ]

SynStack
[made]

SynArcs
subj(made, he)
mod(decisions, A(a, few))
obj(made, decisions)

LexStack
[ ]

LexTrees
he, A(a, few), V(made, decisions)

Implementation and Evaluation

- Implementation:
  - Greedy parser trained with averaged perceptron
  - Variation: Implicit Completes, triggered by arc transitions
- Evaluation:
  - English Web Treebank and French Treebank
  - Comparisons with
    1. standard parser with special MWE labels
    2. partial systems: only lexical or only syntactic
    3. pipeline systems: fixed MWE identification + parsing

Main Findings

- Compared to standard parser with extended labels:
  - Joint system significantly better for MWE analysis (+2–3%)
  - Implicit Completes help syntactic analysis (+0.1–1%)
- Compared to partial systems:
  - Lexical structure helps syntactic parsing (+0.5–1%)
  - Syntactic structure does not really help lexical analysis
- Comparison with pipeline system
  - Preprocessing F-MWEs improves MWE analysis (+2–3%)
  - But it leads to a slight drop in syntactic analysis (−0.5–1%)

Conclusion

- What we have learned so far (I think):
  - Using dummy trees or special labels to squeeze MWEs into parsing is suboptimal for both lexical and syntactic analysis
  - Non-fixed MWEs should be parsed as syntactically regular – lexical analysis can be done jointly or in post-processing
  - Fixed MWEs should be parsed as atomic syntactic units – lexical analysis can be done jointly or in pre-processing
- Where do we go from here?
  - Explore novel (multi-dimensional) representations
  - Annotate treebanks using these representations
  - Develop more flexible parsing systems

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