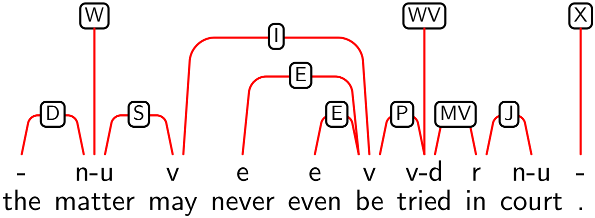
Deriving Multi-Headed Planar Dependency Parses from Link Grammar Parses

Juneki Hong and Jason Eisner

Introduction

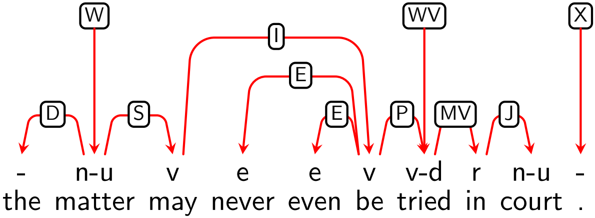
- This talk is about converting from one annotation style to another.
- The conversion could be hard, where information is fragmented, missing, or ambiguous.
- We use a general technique, Integer Linear Programming to help us do this conversion.

In Our Case: What We Started With



Link Grammar: Parse with undirected edges

What We Wanted:



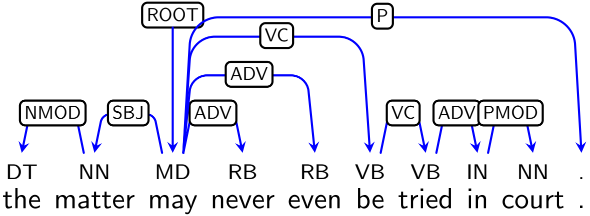
Multiheaded parse with directionalized edges

Why We Wanted That

- We want to develop parsing algorithms for parses that look like this
- We couldn't figure out where to get the data to test them.

Single-headedness

- Dependency parse treebanks today are either single-headed or not planar.
- Stanford Dependencies are multiheaded but not planar



Some example dependency parse.

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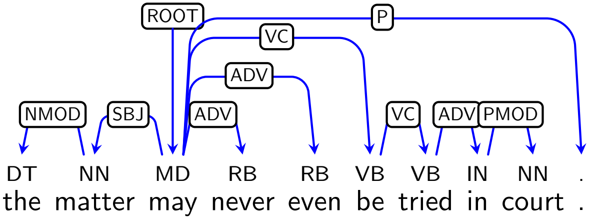


Some example dependency parse.

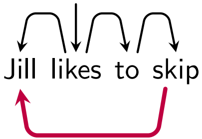
Link Grammar is almost a multiheaded planar corpora! We just need to directionalize the links.

Why Multi-headedness?

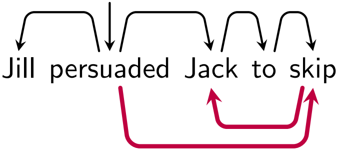
Multi-headedness Can Capture Additional Linguistic Phenomenon

- Control
- Relativization
- Conjunction

Control

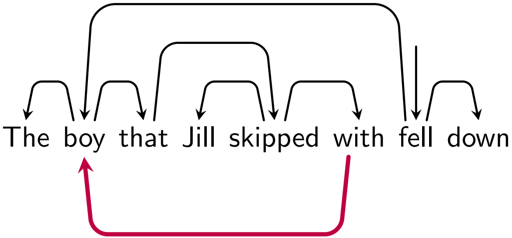


Jill is the subject of two verbs



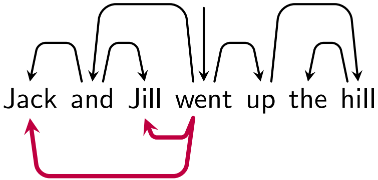
Jack is the object of one verb and the subject of another

Relativization



The boy is the object of *with* as well as the subject of *fell*.

Conjunction



Jack and Jill serve as the two arguments to *and*, but are also subjects of *went*.

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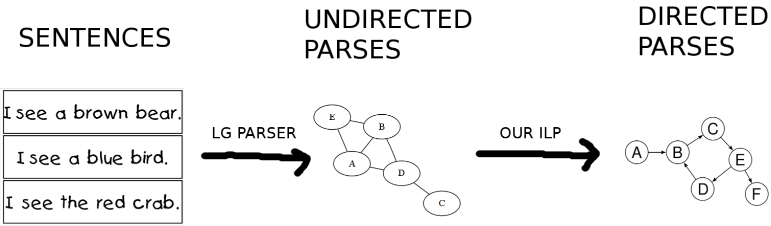
- Such a corpus could be automatically annotated using Integer Linear Programming
- We explored whether the Link Grammar could be adapted for this purpose.
- The results of this are mixed, but provides a good case study.

Corpus Building Strategy

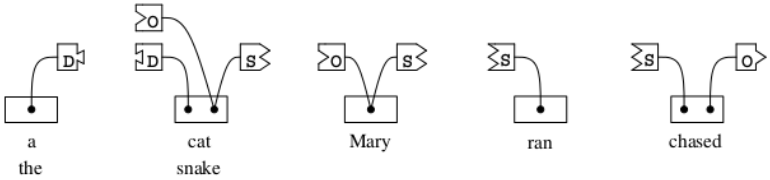
- We start with some sentences and parse them with LG Parser
- We take the undirected parses and try to directionalize them.
- We use an ILP to assign consistent directions for each link type.



Link Grammars

- Grammar-based formalism for projective dependency parsing with undirected links
- Original formalism and English Link Grammar created by Davy Temperley, Daniel Sleator, and John Lafferty (1991)

Link Grammars: How They Work



[1]

[1]These figures were clipped from the original Link Grammar paper: "Parsing English with a Link Grammar" by Sleator and Temperley

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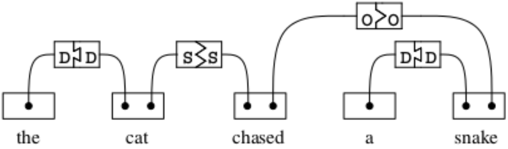

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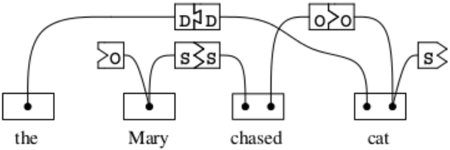
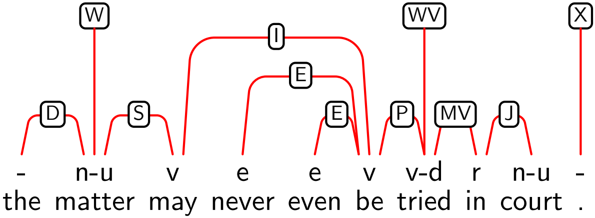


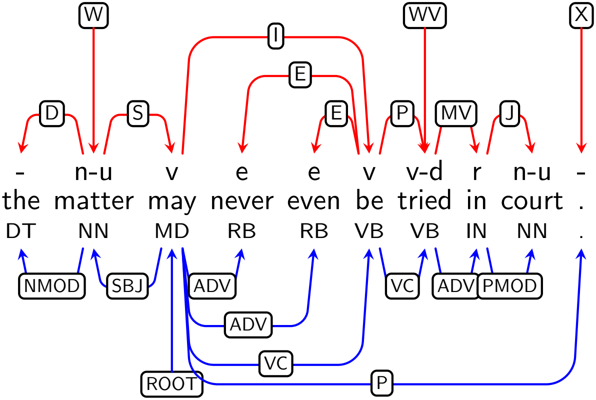
Link Grammars: Same Example Parse From Before Again



Link Parse of a sentence from Penn Tree Bank

Link Grammars

Compare resulting dependency parse with CoNLL 2007 shared task.



Bottom half is CoNLL. Top half is the directionalized link parse.

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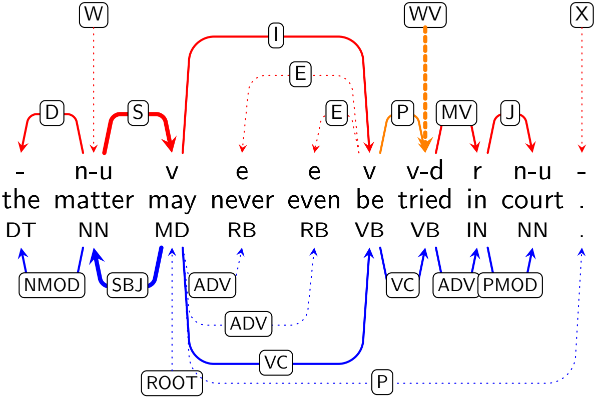

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What is Integer Linear Programming?

- An optimization problem where some or all of the variables are integers.
- The objective function and constraints are linear.
- In general, it's NP-Hard! But good solvers exist that work well most of the time.
- Our ILP is encoded as a ZIMPL program and solved using the SCIP Optimization Suite[2]

[2] http://scip.zib.de/

Integer Linear Programming Model

Encoded Constraints:

- Acyclicity
- Connectedness
- Consistency of Directionalized Links

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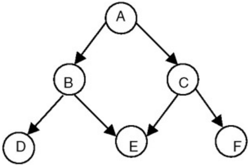

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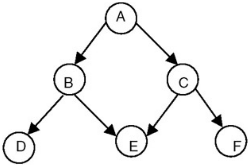
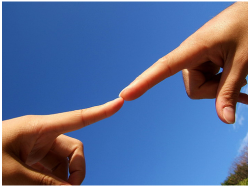
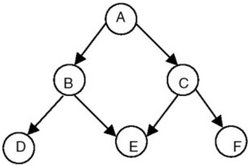


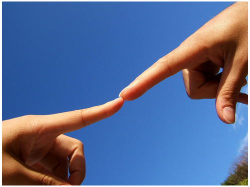


Integer Linear Programming Model

Encoded Constraints:

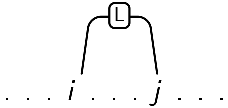
- Acyclicity: (**No cycles!**)
- Connectedness: (**Every word is reachable from a root**)
- Consistency of Directionalized Links:
  (**Similar links oriented the same way**)





Integer Linear Programming Model

For each sentence, for each edge i, j, where $i < j$



Variables:

$x_{ij}, x_{ji} \in \mathbb{Z} \geq 0$: orientation of each link

$x_{ij} + x_{ji} = 1$

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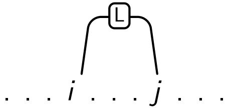

Variables:

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An individual link token can either be oriented left or oriented right

Acyclicity, Connectedness

Acyclicity

Given that node u is the parent of v

n_v: length of the sentence containing node v

$d_v \in [0, n_v]$: depth of the node from the root of the sentence

$$(\forall_u)\ d_v + (1 + n_v) \cdot (1 - x_{uv}) \geq 1 + d_u \tag{1}$$

Connectedness

$$\sum_u x_{uv} \geq 1 \tag{2}$$

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Connectedness

$$\sum_u x_{uv} \geq 1 \qquad (2)$$

A word has at least 1 parent

Consistency of Directionalized Links

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$r_L, \ell_L \in \{0, 1\}$: whether all links with label L allowed left/right

$$x_{ij} \leq r_L \qquad\qquad x_{ji} \leq \ell_L \tag{3}$$

Objective Function:

$$\min \left(\sum_L r_L + \ell_L \right) \tag{4}$$

Consistency of Directionalized Links with Slack

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Objective Function:

$$\min \left(\sum_L r_L + \ell_L \right) \cdot \frac{N_L}{4} + \sum_{ij} s_{ij} \tag{4}$$

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N_L: Number of link tokens with label L

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N_L: Number of link tokens with label L

Slack allows a few links with label L in disallowed directions

Data Sets

Data Sets taken from:

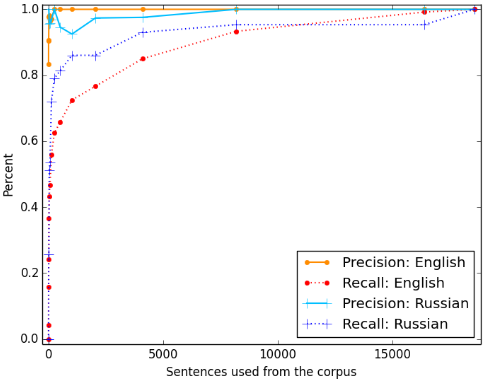
CoNLL 2007 Shared Task (English)

ACL 2013 Shared Task of Machine Translation (Russian)

	Input Sentences	Output Connected Parses
English	18,577	10,960
Russian	18,577	4,913

Stability of Results

- We were worried that the recovered direction mapping might be unstable and sensitive to the input corpus.
- We compared the results of increasing runs of sentences.



On the English Data Set:

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CoNLL Matches

52% of links match CoNLL arcs

57% of CoNLL arcs match links

On the English Data Set:

- Multiheadedness
  - Link Data has 8% additional edges over the CoNLL. (average about 2 multiheaded words per sentence)
- CoNLL Matches
  - 52% of links match CoNLL arcs
  - 57% of CoNLL arcs match links
- Directionality
  - 6.19% of link types allowed both directions
  - 2.07% of link tokens required disallowed direction via slack

ILP Results: Top 25 Most Occurring Labels

Label	Rightward	Multiheaded	CoNLL Match	CoNLL Dir Match
A	0% (0/8501)	0% (0/8501)	84% (7148/8501)	98% (7002/7148)
AN	0% (0/9401)	0% (0/9401)	83% (7825/9401)	98% (7639/7825)
B	100% (1514/1515)	61% (919/1515)	53% (806/1515)	84% (678/806)
C	100% (3272/3272)	0% (0/3272)	3% (85/3272)	53% (45/85)
CO	0% (0/2478)	1% (32/2478)	5% (114/2478)	68% (78/114)
CV	100% (3237/3237)	100% (3237/3237)	56% (1827/3237)	28% (512/1827)
D	0% (56/19535)	0% (71/19535)	85% (16656/19535)	100% (16608/16656)
E	0% (0/1897)	0% (2/1897)	67% (1279/1897)	99% (1263/1279)
G	0% (0/6061)	0% (0/6061)	70% (4258/6061)	96% (4070/4258)
I	100% (5405/5424)	60% (3247/5424)	95% (5168/5424)	47% (2408/5168)
IV	100% (1626/1627)	100% (1626/1627)	85% (1389/1627)	97% (1353/1389)
J	98% (16400/16673)	2% (280/16673)	87% (14522/16673)	97% (14069/14522)
M	100% (9594/9596)	0% (16/9596)	74% (7124/9596)	92% (6583/7124)
MV	100% (13375/13376)	0% (61/13376)	51% (6797/13376)	98% (6681/6797)
MX	100% (1999/1999)	4% (83/1999)	42% (836/1999)	91% (763/836)
O	100% (11027/11028)	0% (0/11028)	81% (8932/11028)	96% (8535/8932)
P	100% (3755/3756)	31% (1167/3756)	94% (3528/3756)	100% (3523/3528)
S	97% (13138/13520)	57% (7662/13520)	92% (12476/13520)	5% (586/12476)
SJ	50% (2736/5468)	0% (0/5468)	69% (3778/5468)	93% (3502/3778)
TO	100% (1733/1734)	0% (1/1734)	0% (5/1734)	100% (5/5)
VJ	51% (765/1500)	1% (8/1500)	71% (1059/1500)	89% (939/1059)
W	100% (10528/10528)	0% (5/10528)	5% (504/10528)	46% (232/504)
WV	100% (7563/7563)	100% (7557/7563)	57% (4345/7563)	97% (4214/4345)
X	80% (13132/16406)	5% (806/16406)	8% (1364/16406)	95% (1300/1364)
YS	0% (0/1645)	0% (0/1645)	98% (1619/1645)	0% (0/1619)

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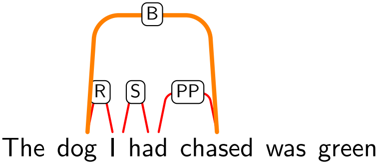
“B” link relative clauses



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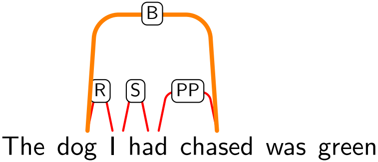

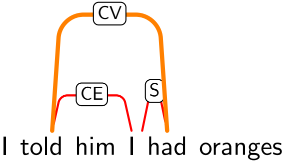

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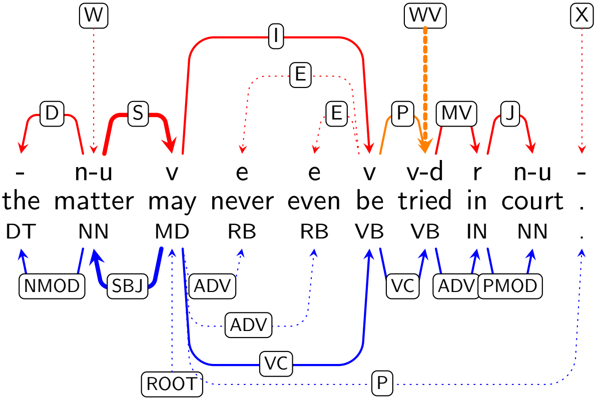
"CV" link conjunctions to main verbs of clauses.

Link Results: Subject-Verb Links are Backwards



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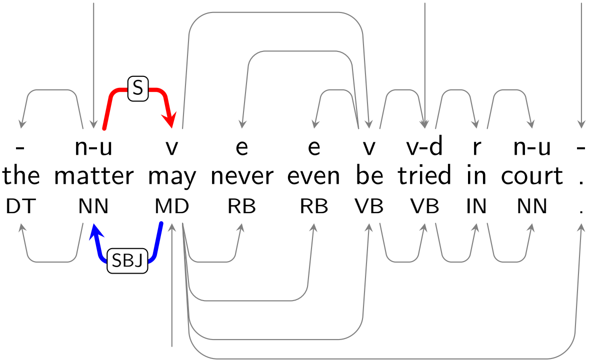
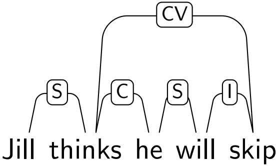
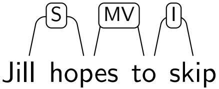


Link Results: Subject-Verb Links are Backwards

- This is due to a possible inconsistency of the Link Grammar, discovered by our method.





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To fix this, we could edit the link grammar, link parses, or the ILP.

Conclusions

- Link Grammar parses can be oriented into connected DAGs
- A new corpus available for building multi-headed dependency parsers
- ILP can be used to help annotate incomplete or missing data in corpora.

Questions?