Arc-Standard Spinal Parsing with Stack-LSTMs

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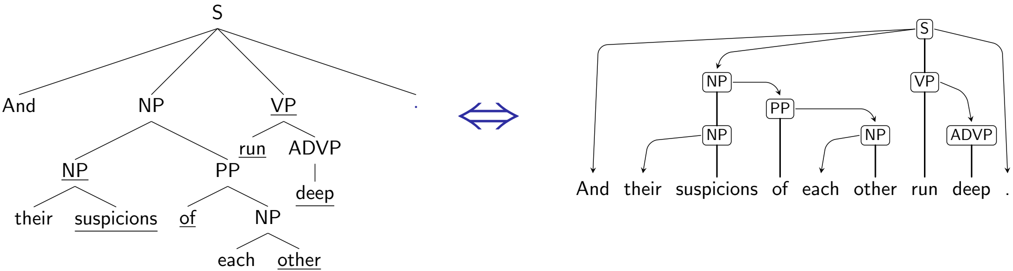
Spinal Trees = Constituency Trees + Dependency Heads

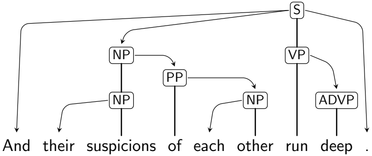


See: Carreras, Collins, and Koo (2008)

See also: Collins (1997); Ballesteros and Carreras (2015); Hayashi, Suzuki, and Nagata (2016)

In this paper . . .

- Arc-standard system for Spinal Parsing
- Stack-LSTMs Dyer et al. (2015)



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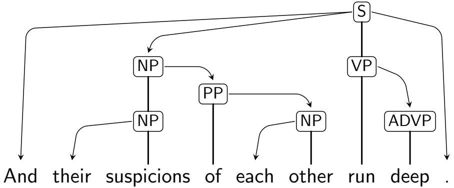
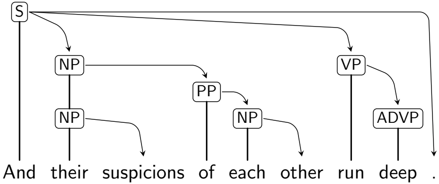
Spinal Trees



(stanford dependencies)



(leftmost heads)

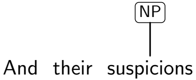
- Spine: a vertical sequence of non-terminals
- Spinal Trees: spines connected by dependencies
- Spinal tree ⇔ Constituent tree + Dependency tree

Arc-Standard Spinal Parsing

Extending Nivre (2004) . . .

Actions $\begin{cases} \texttt{shift token} \\ \texttt{add spinal node} \text{ (new for spinal parsing)} \\ \texttt{left-arc} \text{ and } \texttt{right-arc} \end{cases}$

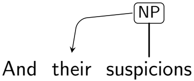
Transition	Buffer β	Stack σ	New Arc in δ
	[And, their, . . .]	[]	
shift	[their, suspicions, . . .]	[And]	
shift	[suspicions, of, . . .]	[And, their]	
shift	[of, each, . . .]	[. . . , their, susp.]	
node(NP)	[of, each, . . .]	[. . . , their, susp.+NP_3^1]	



Arc-Standard Spinal Parsing

Extending Nivre (2004) ...

Actions
- `shift token`
- `add spinal node` (new for spinal parsing)
- `left-arc` and `right-arc`



Transition	Buffer β	Stack σ	New Arc in δ
	[And, their, ...]	[]	
`shift`	[their, suspicions, ...]	[And]	
`shift`	[suspicions, of, ...]	[And, their]	
`shift`	[of, each, ...]	[..., their, susp.]	
`node(NP)`	[of, each, ...]	[..., their, susp.+NP^1_3]	
`left-arc`	[of, each, ...]	[And, susp.+NP^1_3]	(NP^1_3,their)

Arc-Standard Spinal Parsing

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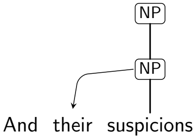

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`node(NP)`	[of, each, . . .]	[. . . , their, susp.+NP$^1_3$]	
`left-arc`	[of, each, . . .]	[And, susp.+NP$^1_3$]	(NP$^1_3$,their)
`node(NP)`	[of, each, . . .]	[And, susp.+NP$^1_3$+NP$^2_3$]	

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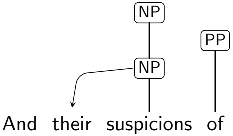

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`node(NP)`	[of, each, ...]	[..., their, susp.+NP^1_3]	
`left-arc`	[of, each, ...]	[And, susp.+NP^1_3]	(NP^1_3,their)
`node(NP)`	[of, each, ...]	[And, susp.+NP^1_3+NP^2_3]	
`shift`	[each, other, ...]	[..., susp.+NP^1_3+NP^2_3, of]	
`node(PP)`	[each, other, ...]	[..., susp.+NP^1_3+NP^2_3, of+PP^1_4]	

Arc-Standard Spinal Parsing

Extending Nivre (2004) . . .

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- `shift token`
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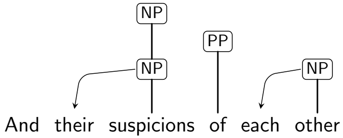

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`shift`	[of, each, . . .]	[. . . , their, susp.]	
`node(NP)`	[of, each, . . .]	[. . . , their, susp.+NP$_3^1$]	
`left-arc`	[of, each, . . .]	[And, susp.+NP$_3^1$]	(NP$_3^1$,their)
`node(NP)`	[of, each, . . .]	[And, susp.+NP$_3^1$+NP$_3^2$]	
`shift`	[each, other, . . .]	[. . . , susp.+NP$_3^1$+NP$_3^2$, of]	
`node(PP)`	[each, other, . . .]	[. . . , susp.+NP$_3^1$+NP$_3^2$, of+PP$_4^1$]	
`shift`	[other, run, . . .]	[. . . , of+PP$_4^1$, each]	
`shift`	[run, deep, . . .]	[. . . , each, other]	
`node(NP)`	[run, deep, . . .]	[. . . , each, other+NP$_6^1$]	
`left-arc`	[run, deep, . . .]	[. . . , of+PP$_4^1$, other+NP$_6^1$]	(NP$_6^1$, each)

Arc-Standard Spinal Parsing

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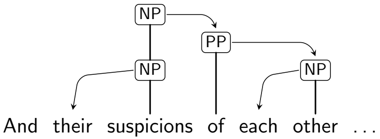

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`left-arc`	[of, each, . . .]	[And, susp.+NP$^{1}_{3}$]	(NP$^{1}_{3}$,their)
`node(NP)`	[of, each, . . .]	[And, susp.+NP$^{1}_{3}$+NP$^{2}_{3}$]	
`shift`	[each, other, . . .]	[. . . , susp.+NP$^{1}_{3}$+NP$^{2}_{3}$, of]	
`node(PP)`	[each, other, . . .]	[. . . , susp.+NP$^{1}_{3}$+NP$^{2}_{3}$, of+PP$^{1}_{4}$]	
`shift`	[other, run, . . .]	[. . . , of+PP$^{1}_{4}$, each]	
`shift`	[run, deep, . . .]	[. . . , each, other]	
`node(NP)`	[run, deep, . . .]	[. . . , each, other+NP$^{1}_{6}$]	
`left-arc`	[run, deep, . . .]	[. . . , of+PP$^{1}_{4}$, other+NP$^{1}_{6}$]	(NP$^{1}_{6}$, each)
`right-arc`	[run, deep, . . .]	[. . . , susp.+NP$^{1}_{3}$+NP$^{2}_{3}$, of+PP$^{1}_{4}$]	(PP$^{1}_{4}$, NP$^{1}_{6}$)
`right-arc`	[run, deep, . . .]	[And, susp.+NP$^{1}_{3}$+NP$^{2}_{3}$]	(NP$^{2}_{3}$, PP$^{1}_{4}$)
. . .			

Arc-Standard Spinal Parsing: Properties

- Like arc-standard dependency parsing Nivre (2008), it builds partial trees bottom-up
    - Thus, it is straightforward to add spinal nodes
- Same transition system proposed by Cross and Huang (2016)
    - They turn shift-reduce constituent parsing to be head-driven (i.e. spinal)
- Previous work on transition-based spinal parsing predicted full spines all at once
    - Long-tail distribution
    - See Ballesteros and Carreras (2015); Hayashi et al. (2016)

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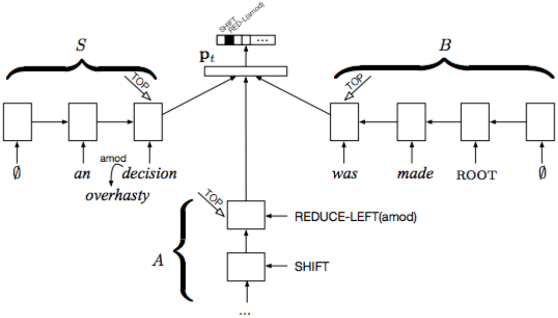
Stack LSTMs

by Dyer, Ballesteros, Ling, Matthews, and Smith (2015)



(figure from Dyer et al. (2015))

Stack LSTMs compute the parser's state combining LSTMs on three stacks: parser stack (S), buffer (B), and action list (A).

Stack LSTMs for Spinal Parsing

Stack LSTMs maintain a state vector $\mathbf{c} \in \mathbb{R}^k$ (i.e. embedding) for each element in the stack. We extend it to spinal parsing.

shift(t)

$$\mathbf{c} = \mathbf{w}_t$$

where:

- t is a token
- $\mathbf{w}_t$ is an embedding (combines word and pos-tag)

left/right arc(h, d)

$$\mathbf{c} = \tanh(\mathbf{U}[\mathbf{h}; \mathbf{d}] + \mathbf{e})$$

where:

- $\mathbf{h}$ is the embedding of the head tree
- $\mathbf{d}$ is the embedding of the dependent tree
- $\mathbf{U}$ and $\mathbf{e}$ are parameter weights and bias terms

node(s, n)

$$\mathbf{c} = \tanh(\mathbf{W}[\mathbf{s}; \mathbf{n}] + \mathbf{b})$$

where:

- $\mathbf{s}$ is the embedding of the current spine
- $\mathbf{n}$ is the embedding of the new node
- $\mathbf{U}$ and $\mathbf{b}$ are parameter weights and bias terms

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Questions:

1. In constituency parsing, what head-rules are more helpful?
2. In dependency parsing, is constituent structure helpful?

Setting:

- Penn Treebank parsing, standard splits
- Word embeddings from (Dyer et al., 2015)
- Head rules:
  - Stanford Dependencies by De Marneffe, MacCartney, Manning, et al. (2006)
  - Yamada and Matsumoto (2003)
  - Leftmost heads, Rightmost heads

Experiments on Development Data

	LR	LP	F1	UAS
Leftmost heads	91.18	90.93	91.05	-
Rightmost heads	91.03	91.20	91.11	-
SD heads	90.75	91.11	90.93	93.49
YM heads	90.82	90.84	90.83	-

- Rightmost and Leftmost heads improve over linguistically-motivated head rules

Experiments on Development Data

	LR	LP	F1	UAS
Leftmost heads	91.18	90.93	91.05	-
↪ no node comp.	90.20	90.76	90.48	-
Rightmost heads	91.03	91.20	91.11	-
↪ no node comp.	90.64	91.24	90.04	-
SD heads	90.75	91.11	90.93	93.49
↪ no node comp.	90.38	90.58	90.48	93.16
YM heads	90.82	90.84	90.83	-

- Rightmost and Leftmost heads improve over linguistically-motivated head rules
- Node composition in the Stack LSTMs is helpful

Experiments on Development Data

	LR	LP	F1	UAS
Leftmost heads	91.18	90.93	91.05	-
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SD heads	90.75	91.11	90.93	93.49
↪ no node comp.	90.38	90.58	90.48	93.16
↪ dummy spines	-	-	-	93.30
YM heads	90.82	90.84	90.83	-

- Rightmost and Leftmost heads improve over linguistically-motivated head rules
- Node composition in the Stack LSTMs is helpful
- Consituent structure is helpful

Experiments: Constituency Results on PTB Test

	LR	LP	F1
Spinal (leftmost)	90.30	90.54	90.42
Spinal (rightmost)	90.23	90.77	90.50
Ballesteros and Carreras (2015)	88.7	89.2	89.0
Carreras et al. (2008)	90.7	91.4	91.1
Vinyals et al. (2014) (PTB-Only)			88.3
Cross and Huang (2016)			89.9
Choe and Charniak (2016) (PTB-Only)			91.2
Choe and Charniak (2016) (Semi-sup)			93.8
Dyer et al. (2016) (Discr.)			91.2
Dyer et al. (2016) (Gen.)			93.3
Kuncoro et al. (2017) (Gen.)			93.5
Liu and Zhang (2017a)	91.3	92.1	91.7
Liu and Zhang (2017b)			90.5
Liu and Zhang (2017b) (semi-rerank)			93.4

Experiments: Dependency Results on PTB Test

	UAS test
Spinal, PTB spines + SD (TB-greedy)	93.15
Spinal, dummy spines + SD (TB-greedy)	93.10
Dyer et al. (2015) (TB-greedy)	93.1
Cross and Huang (2016)	93.4
Ballesteros et al. (2016) (TB-dynamic)	93.6
Kiperwasser and Goldberg (2016) (TB-dynamic)	93.9
Andor et al. (2016) (TB-Beam)	94.6
Kuncoro et al. (2016) (Graph-Ensemble)	94.5
Choe and Charniak (2016)* (Semi-sup)	95.9
Kuncoro et al. (2017)* (Generative)	95.8
Dozat and Manning (2016)*	95.7

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Conclusions

- Contribution: Spinal Stack LSTMs for Dependency+Constituent Parsing
  - Simple extension to the arc-standard system (i.e add node)
  - In general, it is handy to model both constituents and dependencies
  - In practice, Stack-LSTMs do not seem to benefit from linguistic head rules
- Simple extensions:
  - UD
  - Adding dependency labels
  - Other languages
- More interestingly:
  - What kind of hidden structure do LSTMs capture?
  - Is it similar, better, or complementary to that given by head rules?

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