

# Joint Models for NLP

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# Outline

- Motivation
- Statistical Models
- Deep Learning Models



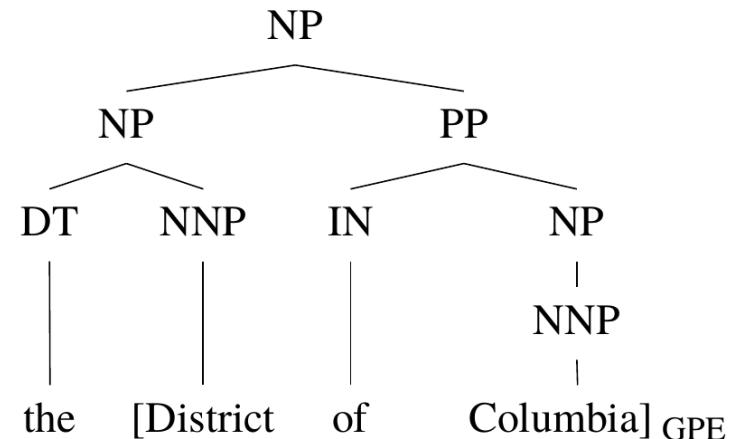
# Outline

- Motivation
- Statistical Models
- Deep Learning Models



# Motivation

- Related tasks in NLP
  - Constituents and named entities





# Motivation

- Related tasks in NLP
  - NER, Chunking and POS Tagging

<b>Sentence:</b>	Joi	runs	the	MIT	Media	Lab	.
<b>POS Tagging:</b>	NNP	VBZ	DT	NNP	NNP	NNP	.
<b>NER:</b>	PER	O	O	B-ORG	I-ORG	I-ORG	O
<b>Chunking:</b>	S	S	S	B	I	E	O



# Motivation

- Pipelines in NLP
  - Segmentation → POS tagging

布朗访问上海



布朗/ 访问/ 上海/

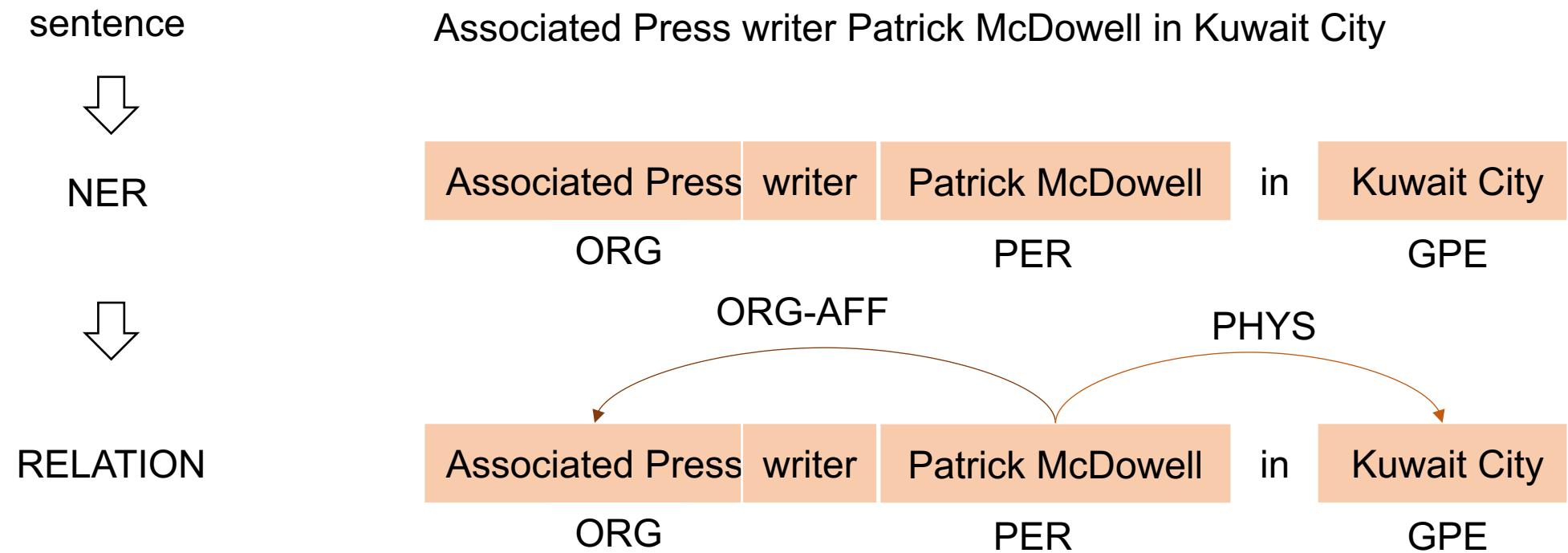


布朗/NR 访问/VV 上海/NR



# Motivation

- Pipelines in NLP
    - Entity and Relation





# Motivation

- Pipelines in NLP
  - Entity and Sentiment

sentence

So excited to meet my baby Farah !!!



NER

So excited to meet my [baby Farah] !!!

PER



Sentiment

So excited to meet my [baby Farah]+ !!!

PER + POSITIVE



# Motivation

- Joint model
  - Reduce error propagation
  - Allow information exchange between tasks
- Challenge
  - Joint learning
  - Search



# Solutions

- Covered by this talk

## Learning

Search

	Joint	Separate
Joint	Statistical Neural	Statistical
Separate	Neural	



# Outline

- Motivation
- Statistical Models
- Deep Learning Models

# Statistical Models

- Graph-Based Methods
- Transition-Based Methods



# Statistical Models

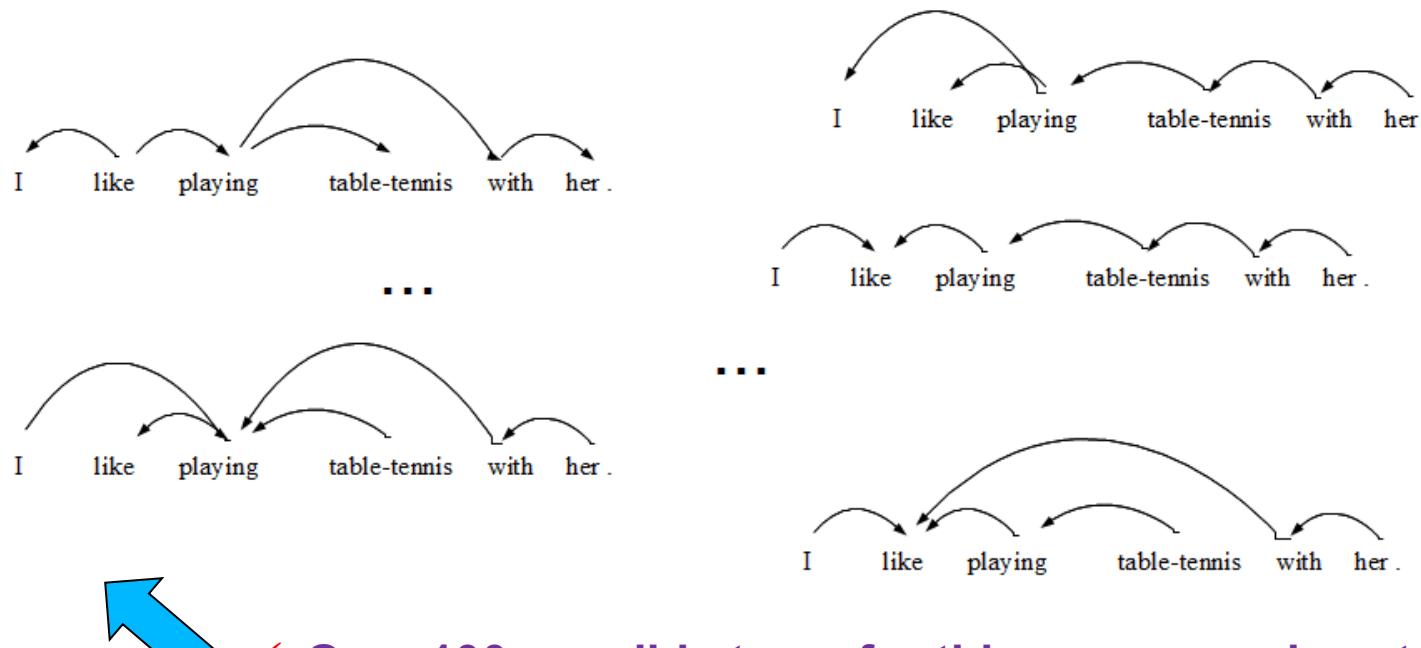
- Graph-Based Methods
- Transition-Based Methods





# Graph-Based Methods

- Traditional solution
  - Score each candidate, select the highest-scored output
  - Search-space typically exponential



- ✓ Over 100 possible trees for this seven-word sentence.
- ✓ Over one million trees for a 20-word sentence.



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Single task)



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Single task)



# Graph-Based Methods

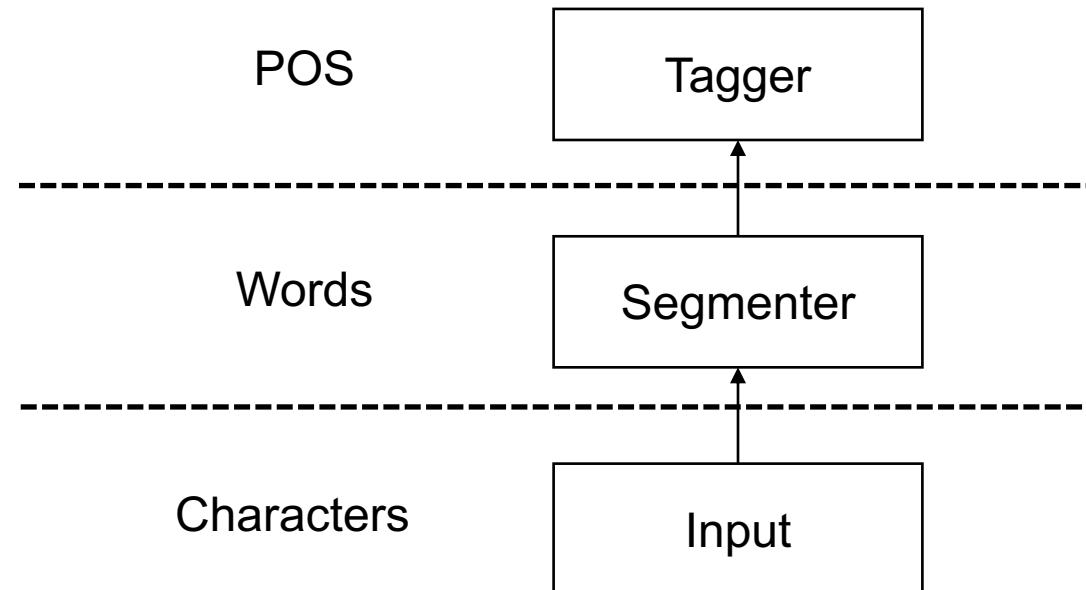
- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (S)

Joint Learning , Joint Search



# Joint Segmentation and POS tagging

- Tasks





# Joint Segmentation and POS tagging

- Traditional pipeline

Segmentation		
	布朗	访问 上海
	NN	VV NN
POS Tagging		



# Joint Segmentation and POS tagging

- One-at-a-Time, Word-Based POS Tagger : Feature

- (a)  $W_n (n = -2, -1, 0, 1, 2)$
- (b)  $W_n W_{n+1} (n = -2, -1, 0, 1)$
- (c)  $W_{-1} W_1$
- (d)  $Pu(W_0)$
- (e)  $T(W_{-2})T(W_{-1})T(W_0)T(W_1)T(W_2)$
- (f)  $POS(W_{-1})$
- (g)  $POS(W_{-2})POS(W_{-1})$



# Joint Segmentation and POS tagging

- Collapsing labels

BE BE BE

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NN VV NN

B-NN E-NN B-VV E-VV B-NN E-NN



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# Joint Segmentation and POS tagging

- One-at-a-Time, Character-Based POS Tagger : Feature
  - (a)  $C_n$  ( $n = -2, -1, 0, 1, 2$ )
  - (b)  $C_n C_{n+1}$  ( $n = -2, -1, 0, 1$ )
  - (c)  $C_{-1} C_1$
  - (d)  $W_0 C_0$
  - (e)  $Pu(C_0)$
  - (f)  $T(C_{-2})T(C_{-1})T(C_0)T(C_1)T(C_2)$
  - (g)  $POS(C_{-1W_0})$
  - (h)  $POS(C_{-2W_0})POS(C_{-1W_0})$



# Joint Segmentation and POS tagging

- All-at-Once, Character-Based POS Tagger and Segmenter : Feature

- (a)  $C_n$  ( $n = -2, -1, 0, 1, 2$ )
- (b)  $C_n C_{n+1}$  ( $n = -2, -1, 0, 1$ )
- (c)  $C_{-1} C_1$
- (d)  $W_0 C_0$
- (e)  $Pu(C_0)$
- (f)  $T(C_{-2}) T(C_{-1}) T(C_0) T(C_1) T(C_2)$
- (g)  $B(C_{-IW_0}) POS(C_{-IW_0})$
- (h)  $B(C_{-2W_0}) POS(C_{-2W_0}) B(C_{-IW_0}) POS(C_{-IW_0})$



# Joint Segmentation and POS tagging

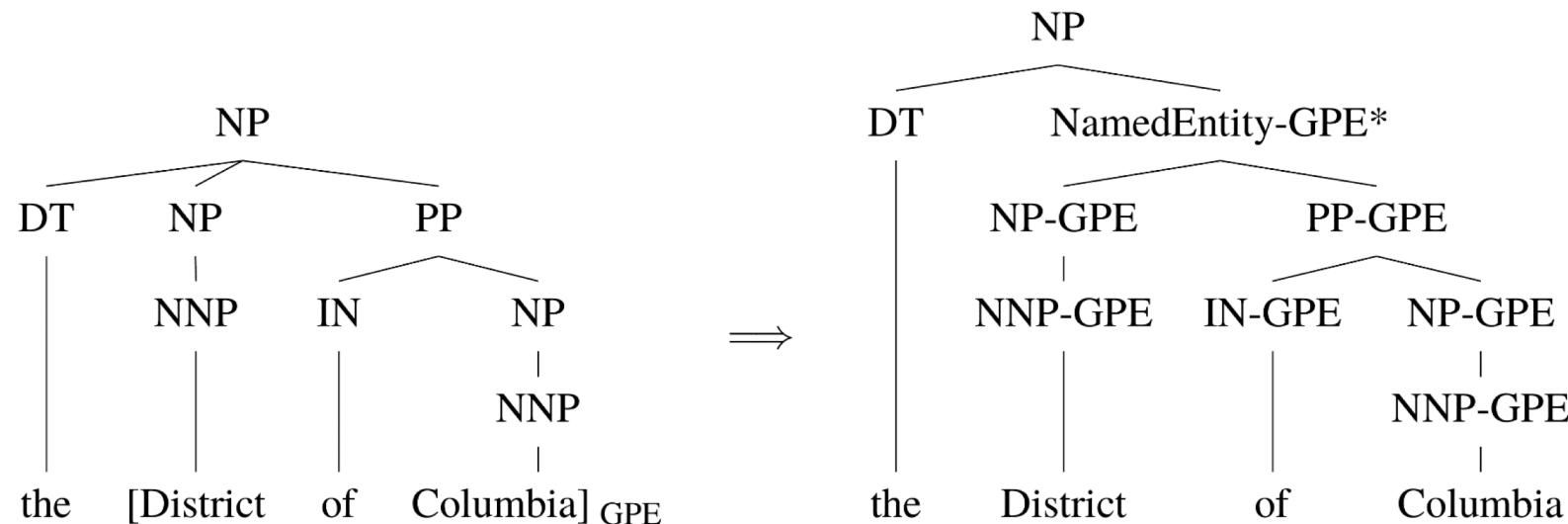
- Results on CTB

Method	Word Seg F-measure (%)	POS Accuracy (%)	Total Testing Time
One-at-a-Time Word-Based	95.1	84.1	1 min 20 secs
One-at-a-Time Char-Based	95.1	91.7	1 min 50 secs
All-At-Once Char-Based	95.2	91.9	20 mins



# Joint Parsing and NER

- A joint model of both parsing and named entity recognition.

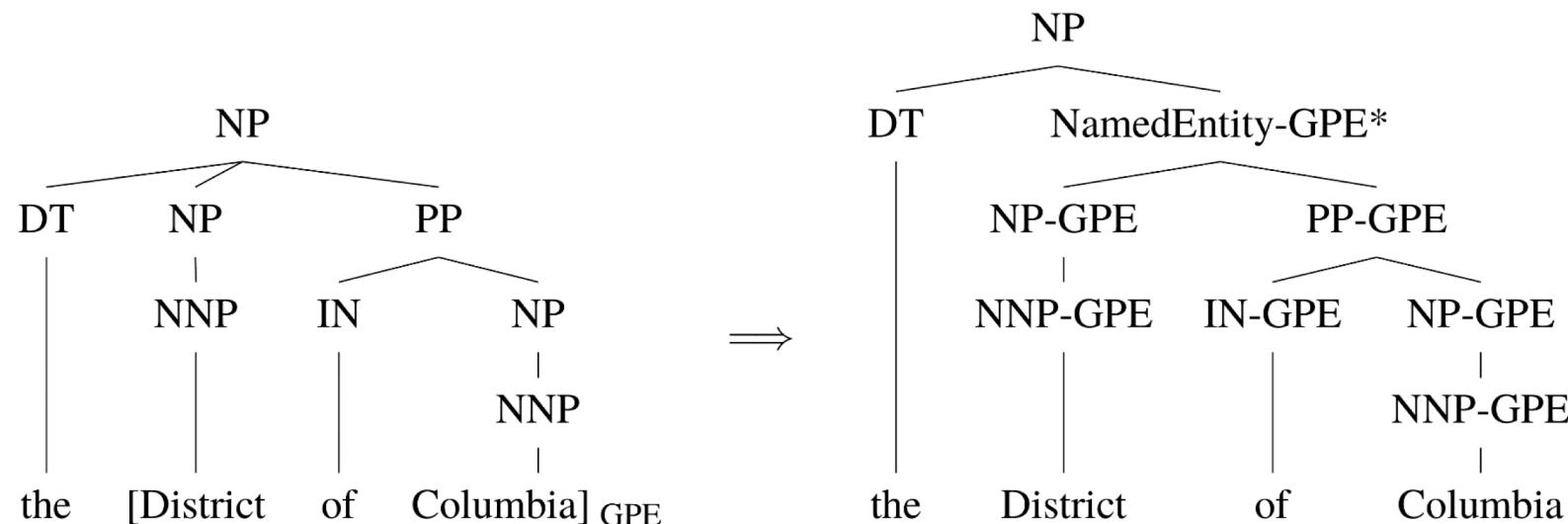


Finkel, Jenny Rose, and Christopher D. Manning. "Joint parsing and named entity recognition." *Proceedings of Human Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics*. Association for Computational Linguistics, 2009.



# Joint Parsing and NER

- A feature-based CRF-CFG parser operating over tree structures augmented with NER information.



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Finkel, Jenny Rose, and Christopher D. Manning. "Joint parsing and named entity recognition." *Proceedings of Human Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics*. Association for Computational Linguistics, 2009.



# Joint Parsing and NER

- Results on OntoNotes

		Parse Labeled Bracketed						Training Time
		Precision	Recall	F				
ABC	Just Parse	70.18%	70.12%	<b>70.15%</b>		–		25m
	Just NER		–		76.84%	72.32%	74.51%	
	Joint Model	69.76%	70.23%	69.99%	77.70%	72.32%	<b>74.91%</b>	45m
CNN	Just Parse	76.92%	77.14%	77.03%		–		16.5h
	Just NER		–		75.56%	76.00%	75.78%	
	Joint Model	77.43%	77.99%	<b>77.71%</b>	78.73%	78.67%	<b>78.70%</b>	31.7h
MNB	Just Parse	63.97%	67.07%	65.49%		–		12m
	Just NER		–		72.30%	54.59%	62.21%	
	Joint Model	63.82%	67.46%	<b>65.59%</b>	71.35%	62.24%	<b>66.49%</b>	19m
NBC	Just Parse	59.72%	63.67%	61.63%		–		10m
	Just NER		–		67.53%	60.65%	63.90%	
	Joint Model	60.69%	65.34%	<b>62.93%</b>	71.43%	64.81%	<b>67.96%</b>	17m
PRI	Just Parse	76.22%	76.49%	76.35%		–		2.4h
	Just NER		–		82.07%	84.86%	83.44%	
	Joint Model	76.88%	77.95%	<b>77.41%</b>	86.13%	86.56%	<b>86.34%</b>	4.2h
VOA	Just Parse	76.56%	75.74%	76.15%		–		2.3h
	Just NER		–		82.79%	75.96%	79.23%	
	Joint Model	77.58%	77.45%	<b>77.51%</b>	88.37%	87.98%	<b>88.18%</b>	4.4h

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Finkel, Jenny Rose, and Christopher D. Manning. "Joint parsing and named entity recognition." *Proceedings of Human Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics*. Association for Computational Linguistics, 2009.



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Single task)



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (S)

Separate Learning , Joint Search



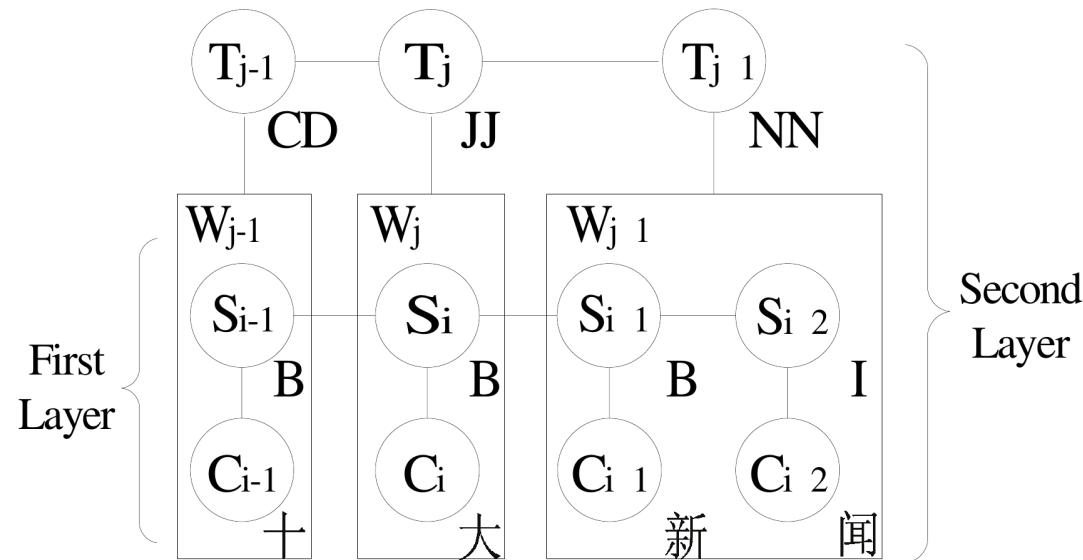
# Joint Segmentation and POS Tagging

- Conditional Random Field(CRF) models for both Segmentation and POS Tagging .
- Separately trained, reranking.
- Use tag sequence score to rank segmentation.



# Joint Segmentation and POS Tagging

- Dual-layer CRFs





# Joint Segmentation and POS Tagging

- Results for Segmentation

	1	2	3	4	5	6
Baseline	97.3%	97.2%	95.4%	96.7%	96.2%	93.1%
Joint decoding	97.4%	97.3%	95.7%	96.9%	96.4%	93.4%

	7	8	9	10	average
Baseline	95.9%	94.8%	95.7%	96.2 %	95.85%
Joint decoding	96.0%	95.2%	95.9%	96.3%	96.05%

	AS			CTB		
	P	R	F1	P	R	F1
Baseline	96.7%	96.8%	96.7%	88.5%	88.3%	88.4%
Joint Decoding	96.9%	96.7%	96.8%	89.4%	88.7%	89.1%

	PK			HK		
	P	R	F1	P	R	F1
Baseline	94.9%	94.9%	94.9%	94.9%	95.5%	95.2%
Joint Decoding	95.3%	95.0%	95.2%	95.0%	95.4%	95.2%



# Joint Segmentation and POS Tagging

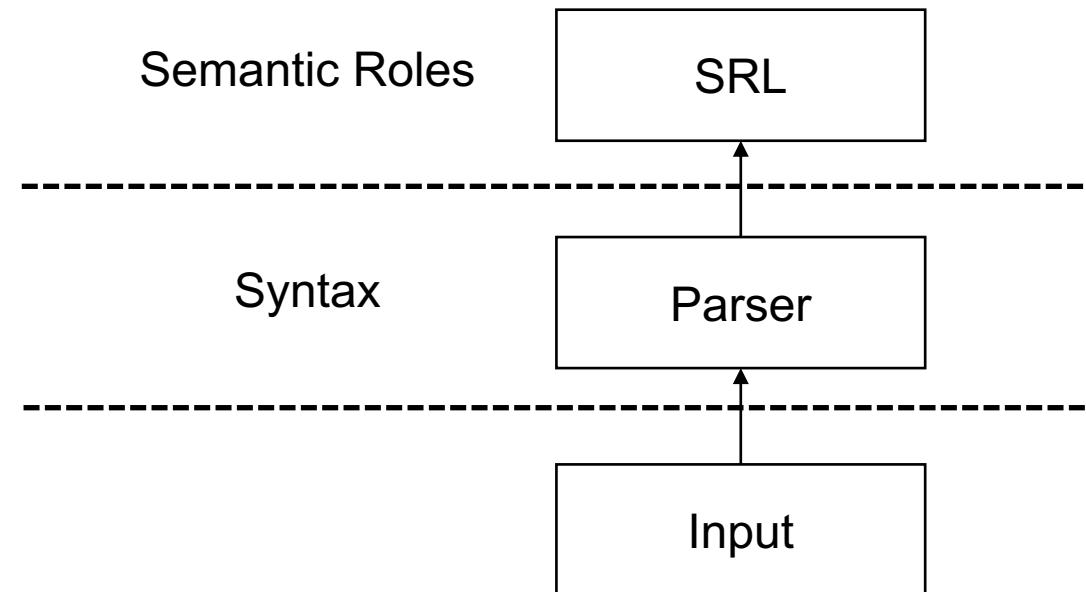
- Results for POS Tagging

	1	2	3	4	5	6
Baseline	93.8%	93.7%	90.2%	92.0%	93.3%	87.2%
Joint Decoding	94.0%	93.9%	90.4%	92.2%	93.4%	87.5%
	7	8	9	10	average	
Baseline	92.2%	90.8%	91.5%	92.0 %	91.67%	
Joint Decoding	92.4%	91.0%	91.7%	92.1%	91.86%	



# Joint Parsing and SRL

- Task





# Joint Parsing and SRL

- The goal: narrow the gap between SRL results from gold parses and from automatic parses.
- aims to achieve this by jointly performing parsing and semantic role labeling in a single probabilistic model.
- This paper rerank the k-best parse trees from a probabilistic parser using an SRL system.



# Joint Parsing and SRL

- Results on CoNLL

	Precision	Recall	$F_{\beta=1}$
Development	64.43%	63.11%	63.76
Test WSJ	68.57%	64.99%	66.73
Test Brown	62.91%	54.85%	58.60
Test WSJ+Brown	67.86%	63.63%	65.68

- Did *not* beat a pipeline baseline

Many subsequent CoNLL shared tasks show difficulties for this joint task



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Single task)



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Semi-supervised)

Separate Learning , Joint Search



# Joint Modeling

- Joint Search, separate training
- Search complex problem
  - ILP
  - BP
  - Dual Decomposition

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Auli, Michael, and Adam Lopez. "A comparison of loopy belief propagation and dual decomposition for integrated CCG supertagging and parsing." *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies-Volume 1*. Association for Computational Linguistics, 2011.



# Joint Entity and Sentiment

- Opinion linking relations
  - The numeric subscripts denote linking relations, one of IS-ABOUT OR IS-FROM
- Opinion entities:
  - Opinion expressions: O
  - Opinion targets: T
  - Opinion holders: H

jointly identifies opinion-related entities, as well as opinion linking relations

[The workers]<sub>[H<sub>1,2</sub>]</sub> were irked<sub>[O<sub>1</sub>]</sub> by [the government report]<sub>[T<sub>1</sub>]</sub>  
and were worried<sub>[O<sub>2</sub>]</sub> as they went about their daily chores.



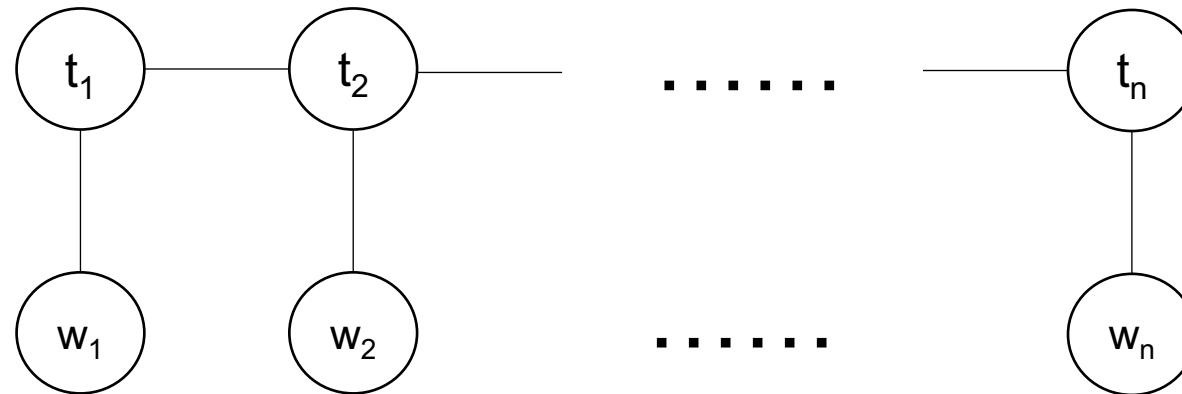
# Joint Entity and Sentiment

- Model
  - **Opinion entity identification:** sequence labeling using conditional random fields (CRFs);
  - **Relation extraction:** binary classification using L1-regularized logistic regression;
  - Optimize the joint objective function which is defined as a linear combination of the potentials from different predictors with a parameter  $\lambda$  to balance the contribution of these two components: opinion entity identification and opinion relation extraction.



# Joint Entity and Sentiment

- CRF for Opinion Entity Identification



D – Opinion expression

T – Opinion target

H – Opinion Holder

N – Opinion None



# Joint Entity and Sentiment

- Relation Extraction
  - A classification model for opinion target relation
  - A classification model for opinion holder relation
  - Syntactic and semantic features are used



# Joint Entity and Sentiment

- Joint scoring function by linearposition

$$\begin{aligned} Score = & \lambda \cdot Score_{(entity)} \\ & + (1 - \lambda) \cdot Score_{(relation)} \end{aligned}$$



# Joint Entity and Sentiment

- ILP for search
  - Constraint 1: Uniqueness
  - Constraint 2: Non-overlapping
  - Constraint 3: Consistency between the opinion-arg and opinion-implicit-arg classifiers
  - Constraint 4: Consistency between opinion-arg classifier and opinion entity extractor
  - Constraint 5: Consistency between the opinion-implicit-arg classifier and opinion entity extractor



# Joint Entity and Sentiment

- Results on MPQA

Method	Opinion Expression			Opinion Target			Opinion Holder		
	P	R	F1	P	R	F1	P	R	F1
CRF	82.21	66.15	73.31	73.22	48.58	58.41	72.32	49.09	58.48
CRF+Adj	82.21	66.15	73.31	80.87	42.31	55.56	75.24	48.48	58.97
CRF+Syn	82.21	66.15	73.31	81.87	30.36	44.29	78.97	40.20	53.28
CRF+RE	83.02	48.99	61.62	85.07	22.01	34.97	78.13	40.40	53.26
Joint-Model	71.16	77.85	<b>74.35*</b>	75.18	57.12	<b>64.92**</b>	67.01	66.46	<b>66.73**</b>
CRF	66.60	52.57	58.76	44.44	29.60	35.54	65.18	44.24	52.71
CRF+Adj	66.60	52.57	58.76	49.10	25.81	33.83	68.03	43.84	53.32
CRF+Syn	66.60	52.57	58.76	50.26	18.41	26.94	74.60	37.98	50.33
CRF+RE	69.27	40.09	50.79	60.45	15.37	24.51	75	38.79	51.13
Joint-Model	57.39	62.40	<b>59.79*</b>	49.15	38.33	<b>43.07**</b>	62.73	62.22	<b>62.47**</b>



# Joint Entity and Sentiment

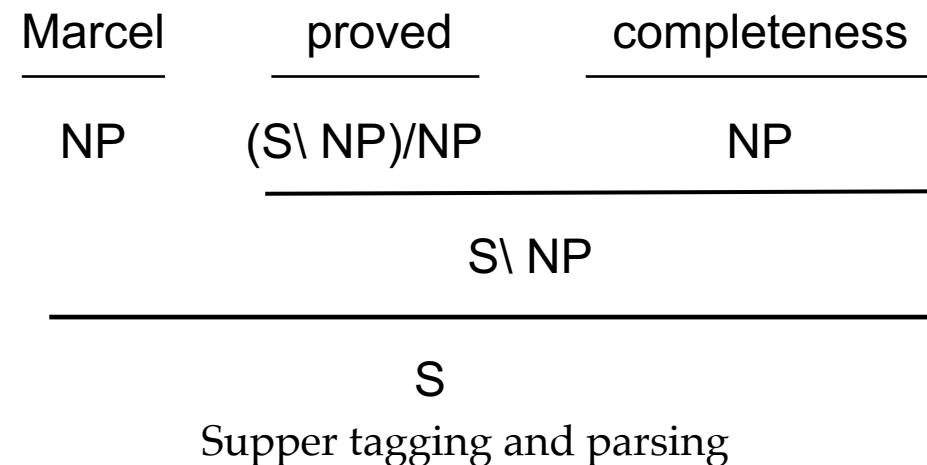
- Results on MPQA

Method	IS-ABOUT			IS-FROM		
	P	R	F1	P	R	F1
CRF+Adj	73.65	37.34	49.55	70.22	41.58	52.23
CRF+Syn	76.21	28.28	41.25	77.48	36.63	49.74
CRF+RE	78.26	20.33	32.28	74.81	37.55	50.00
CRF+Adj-merged-10-best	25.05	61.18	35.55	30.28	62.82	40.87
CRF+Syn-merged-10-best	41.60	45.66	43.53	48.08	54.03	50.88
CRF+RE-merged-10-best	51.60	33.09	40.32	47.73	54.40	50.84
Joint-Model	64.38	51.20	<b>57.04**</b>	64.97	58.61	<b>61.63**</b>



# Joint Supertagging and Parsing

- **CCG parsing** (for English, Chinese and other languages) is to find the syntactic structures of written text based on combinatory categorial grammars.





# Joint Supertagging and Parsing

- CCG traditionally done by supertagging -> parsing

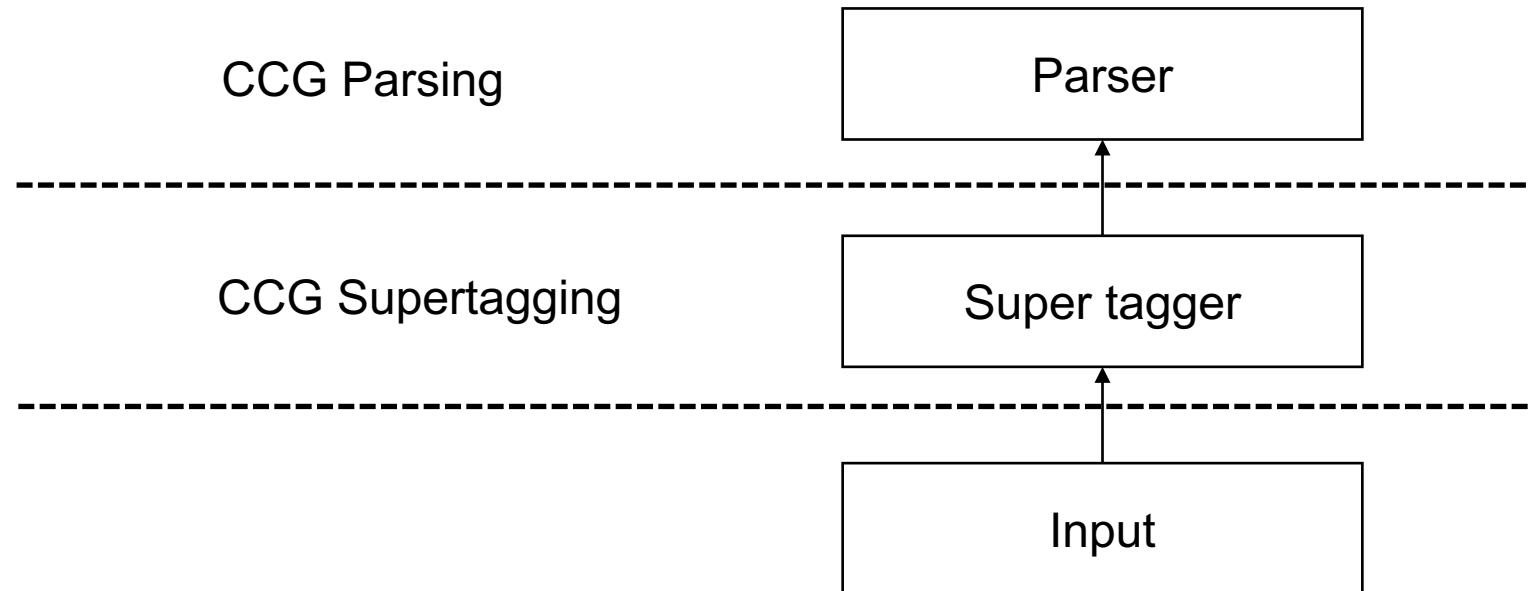
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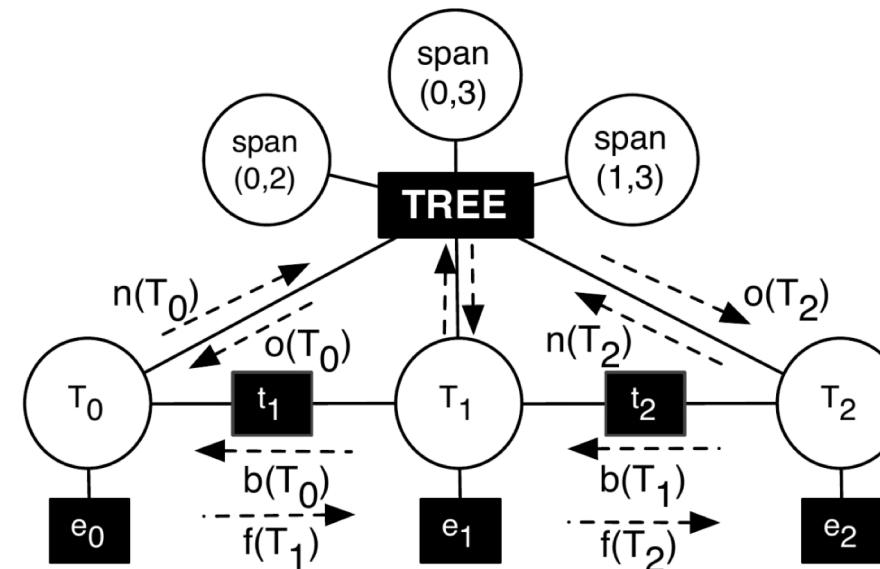
# Joint Supertagging and Parsing

- Tasks



# Joint Supertagging and Parsing

- Loopy belief propagation: factor graph for the combined parsing and supertagging model





# Joint Supertagging and Parsing

- Dual decomposition

$$\arg \max_{y \in Y, z \in Z} f(y) + g(z) \quad (9)$$

such that  $y(i, t) = z(i, t)$  for all  $(i, t) \in I$     (10)

$$L(u) = \max_{y \in Y} (f(y) - \sum_{i,t} u(i, t)y(i, t)) \quad (11)$$

$$+ \max_{z \in Z} (f(z) + \sum_{i,t} u(i, t)z(i, t))$$



# Joint Supertagging and Parsing

- Results on CCGBank

	section 00 (dev)						section 23 (test)					
	AST			Reverse			AST			Reverse		
	LF	UF	ST	LF	UF	ST	LF	UF	ST	LF	UF	ST
Baseline	87.38	93.08	94.21	87.36	93.13	93.99	87.73	93.09	94.33	87.65	93.06	94.01
C&C '07	87.24	93.00	94.16	-	-	-	87.64	93.00	94.32	-	-	-
BP <sub>k=1</sub>	87.70	93.28	94.44	<b>88.35</b>	93.69	<b>94.73</b>	<b>88.20</b>	<b>93.28</b>	<b>94.60</b>	88.78	93.66	94.81
BP <sub>k=25</sub>	87.70	93.31	94.44	88.33	<b>93.72</b>	94.71	88.19	93.27	94.59	88.80	93.68	94.81
DD <sub>k=1</sub>	87.40	93.09	94.23	87.38	93.15	94.03	87.74	93.10	94.33	87.67	93.07	94.02
DD <sub>k=25</sub>	<b>87.71</b>	<b>93.32</b>	<b>94.44</b>	88.29	93.71	94.67	88.14	93.24	94.59	<b>88.80</b>	<b>93.68</b>	<b>94.82</b>



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (Single task)



# Graph-Based Methods

- Joint Label Structure
- Reranking
- Joint Modeling (Multi task)
- Joint Modeling (e.g.,

**Joint Learning , Joint Search**



# Joint Modeling (Single task)

- A Single Model

$$Score = \Phi(\mathbf{y}) \cdot \vec{\omega}$$

where  $\mathbf{y}$  is the model features



# Joint Segmentation and POS Tagging

- Directly model combined output using features.

Input

我喜欢读书

I like reading books

Output

我/PN 喜欢/V 读/V 书/N I/PN like/V reading/V books/N



# Joint Segmentation and POS Tagging

- Feature templates for the baseline segmentor

1	word $w$	9	word $w$ immediately before character $c$
2	word bigram $w_1 w_2$	10	character $c$ immediately before word $w$
3	single-character word $w$	11	the starting characters $c_1$ and $c_2$ of two consecutive words
4	a word of length $l$ with starting character $c$	12	the ending characters $c_1$ and $c_2$ of two consecutive words
5	a word of length $l$ with ending character $c$	13	a word of length $l$ with previous word $w$
6	space-separated characters $c_1$ and $c_2$	14	a word of length $l$ with next word $w$
7	character bigram $c_1 c_2$ in any word		
8	the first / last characters $c_1$ / $c_2$ of any word		



# Joint Segmentation and POS Tagging

- Feature templates for the baseline POS tagger

1	tag $t$ with word $w$	11	tag $t$ on a word containing char $c$ (not the starting or ending character)
2	tag bigram $t_1t_2$	12	tag $t$ on a word starting with char $c_0$ and containing char $c$
3	tag trigram $t_1t_2t_3$	13	tag $t$ on a word ending with char $c_0$ and containing char $c$
4	tag $t$ followed by $w$	14	tag $t$ on a word containing repeated char $c$
5	word $w$ followed by	15	tag $t$ on a word starting with character category $g$
6	word $w$ with tag $t$ at	16	tag $t$ on a word ending with character category $g$
7	word $w$ with tag $t$ at		
8	tag $t$ on single-character trigram $c_1wc_2$		
9	tag $t$ on a word starting with char $c$		
10	tag $t$ on a word ending with char $c$		



# Joint Segmentation and POS Tagging

- Averaged perceptron algorithm for training

**Inputs:** training examples  $(x_i, y_i)$

**Initialization:** set  $\vec{w} = 0$

**Algorithm:**

for  $t = 1..T, i = 1..N$

    calculate  $z_i = \arg \max_{y \in \text{GEN}(x_i)} \Phi(y) \cdot \vec{w}$

    if  $z_i \neq y_i$

$\vec{w} = \vec{w} + \Phi(y_i) - \Phi(z_i)$

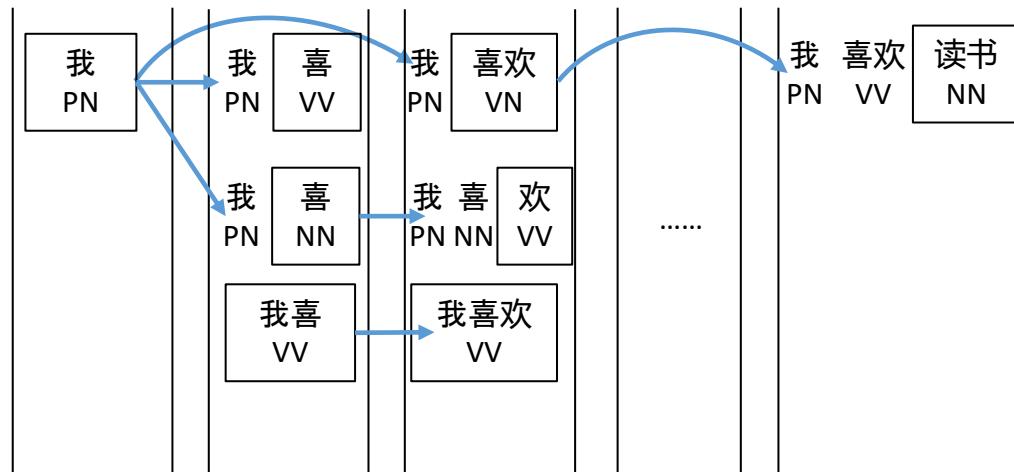
**Outputs:**  $\vec{w}$

The perceptron learning algorithm



# Joint Segmentation and POS Tagging

- Beam search decoding: agendas[i] stores the best sequences that end at i



## Algorithm:

```

for end_index = 1 to sent.length:
    foreach tag:
        for start_index =
            max(1, end_index - maxlen[tag] + 1)
            to end_index:
            word = sent[start_index..end_i]
            if (word, tag) consistent with tag
                for item ∈ agendas[start_index]:
                    item1 = item
                    item1.append((word, tag))
                    agendas[end_index].insert(item1)

```

**Outputs:** agendas[sent.length].best\_item



# Joint Segmentation and POS Tagging

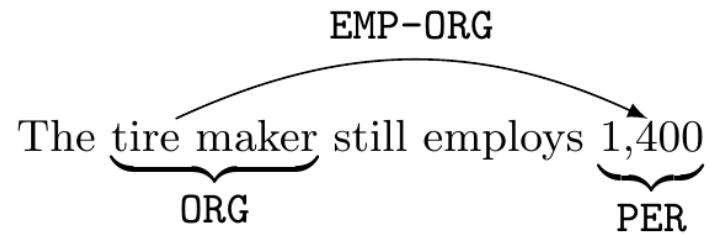
- Results by 10-fold cross validation using CTB

Model	<i>SF</i>	<i>TF</i>	<i>TA</i>
Baseline+ (Ng)	95.1	–	91.7
Joint+ (Ng)	95.2	–	91.9
Baseline+* (Shi)	95.85	91.67	–
Joint+* (Shi)	96.05	91.86	–
Baseline (ours)	95.20	90.33	92.17
Joint (ours)	95.90	91.34	93.02

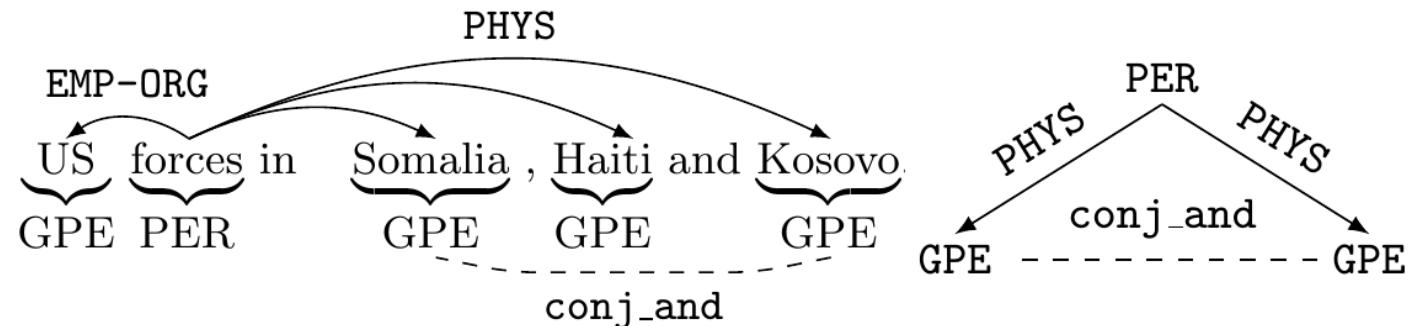


# Joint Entity Relation Extraction

- Task



(a) Interactions between Two Tasks



(b) Example of Global Feature



# Joint Entity Relation Extraction

- A Single Model

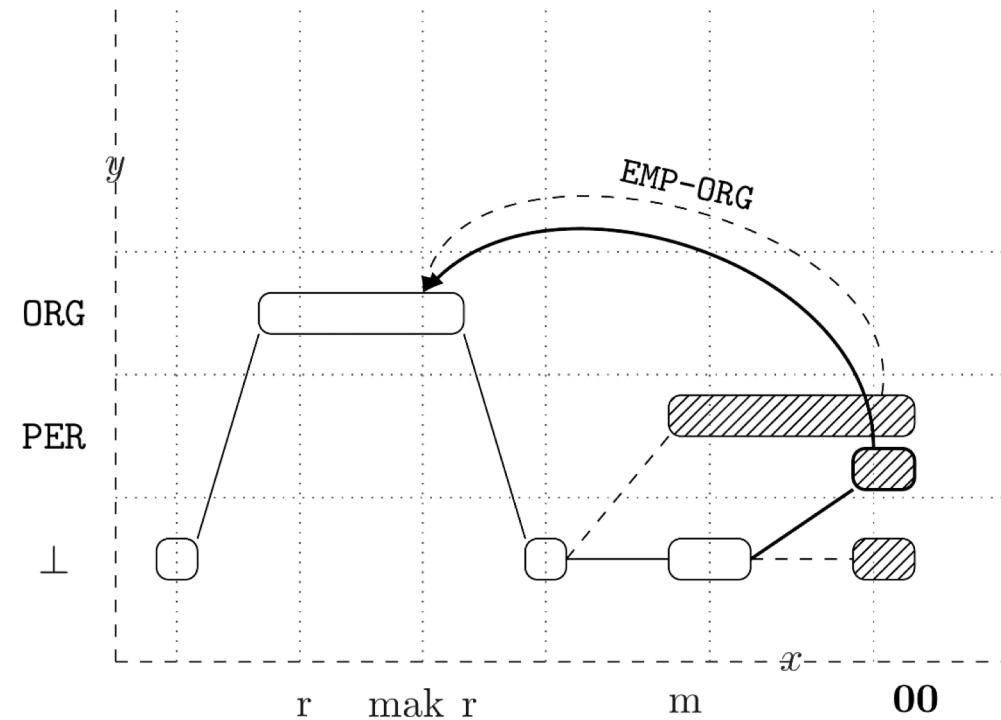
$$\hat{y} = \operatorname{argmax}_{y' \in \mathcal{Y}(x)} \mathbf{f}(x, y') \cdot \mathbf{w}$$

- Beam Search



# Joint Entity Relation Extraction

- Example of decoding steps





# Joint Entity Relation Extraction

- Feature
  - Local features
    - Gazetteer features
    - Case features
    - Contextual features
    - Parsing-based features
  - Global entity mention features
    - Coreference consistency
    - Neighbor coherence
    - Part-of-whole consistency
  - Global relation features
    - Role coherence
    - Triangle constraint
    - Inter-dependent compatibility
    - Neighbor coherence



# Joint Entity Relation Extraction

- Experiments
  - Data:
    - Training data: ACE'05
    - Validation data: ACE'04



# Joint Entity Relation Extraction

- Results on ACE

Model	Entity Mention (%)			Relation (%)			Entity Mention + Relation (%)		
	P	R	F <sub>1</sub>	P	R	F <sub>1</sub>	P	R	F <sub>1</sub>
Score	83.2	73.6	78.1	67.5	39.4	49.8	65.1	38.1	48.0
Pipeline	84.5	76.0	80.0	68.4	40.1	50.6	65.3	38.3	48.3
Joint w/ Local	85.2	76.9	<b>80.8</b>	68.9	41.9	<b>52.1</b>	65.4	39.8	<b>49.5</b>
Annotator 1	91.8	89.9	90.9	71.9	69.0	70.4	69.5	66.7	68.1
Annotator 2	88.7	88.3	88.5	65.2	63.6	64.4	61.8	60.2	61.0
Inter-Agreement	85.8	87.3	86.5	55.4	54.7	55.0	52.3	51.6	51.9

# Statistical Models

- Graph-Based Methods
- Transition-Based Methods





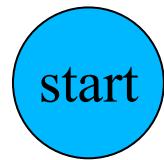
# A Transition System

- Automata
  - State
    - Start state —— an empty structure
    - End state —— the output structure
    - Intermediate states —— partially constructed structures
  - Actions
    - Change one state to another



# A Transition System

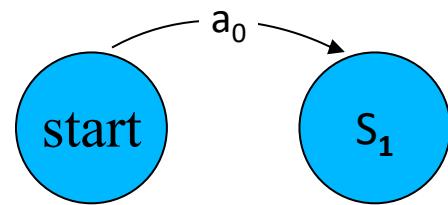
- Automata





# A Transition System

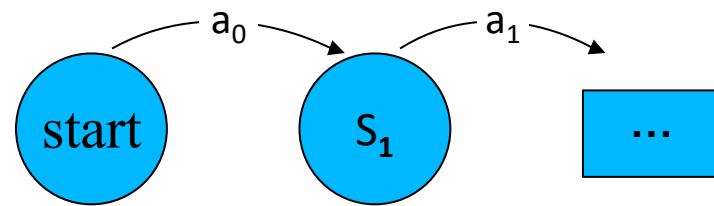
- Automata





# A Transition System

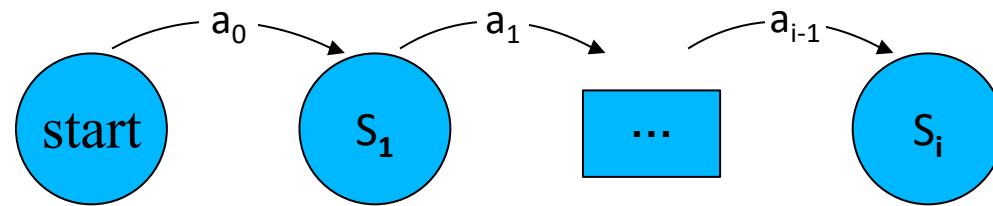
- Automata





# A Transition System

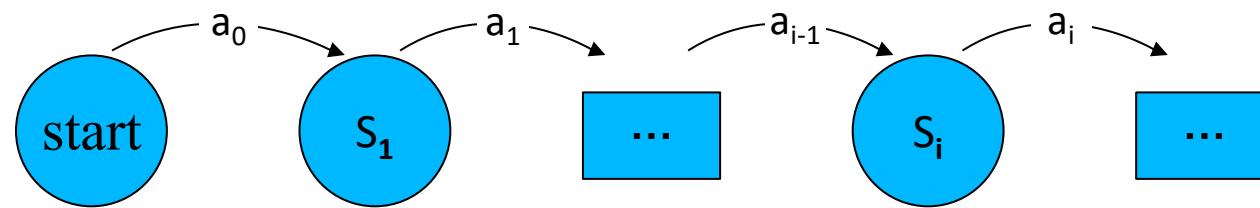
- Automata





# A Transition System

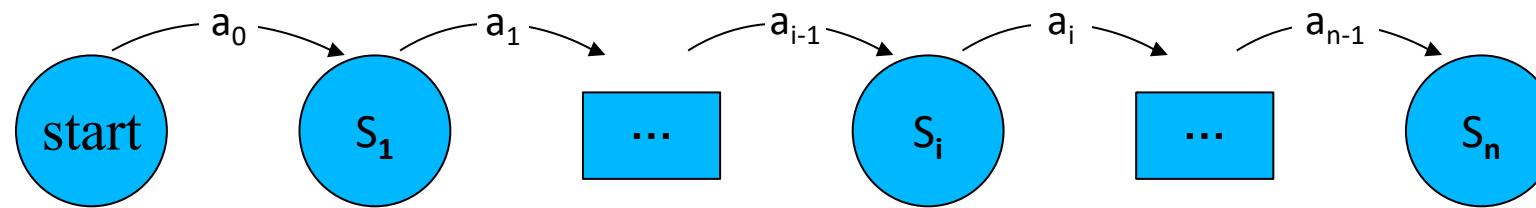
- Automata





# A Transition System

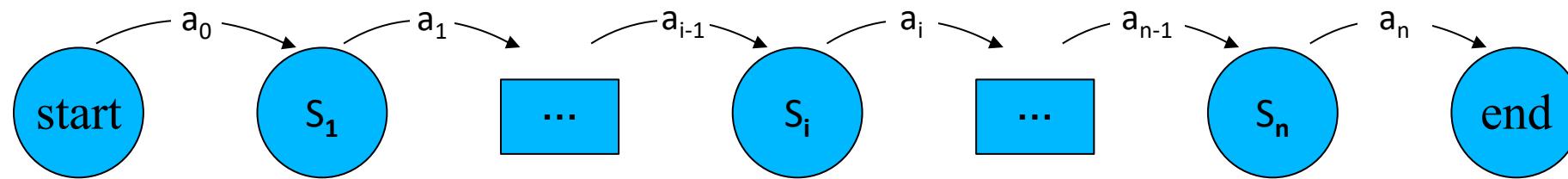
- Automata





# A Transition System

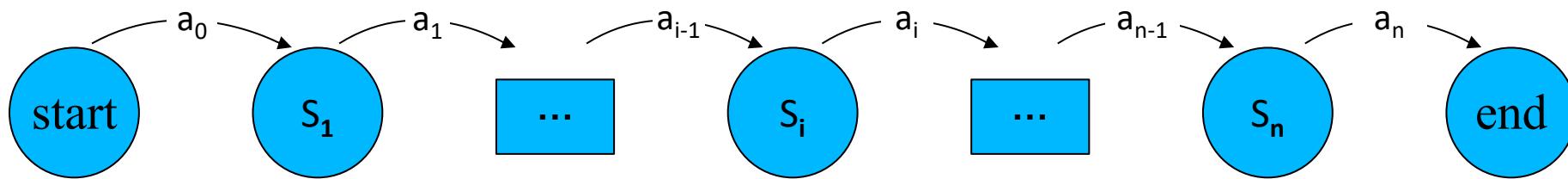
- Automata





# A Transition System

- State
  - Corresponds to partial results during decoding
    - start state, end state,  $S_i$



- Actions
  - The operations that can be applied for state transition
  - Construct output incrementally
    - $a_i$



# Transition-based Dependency Parsing

- An Example
    - S-SHIFT
    - R-REDUCE
    - AL-ARC-LEFT
    - AR-ARC-RIGHT
- He does it here



# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

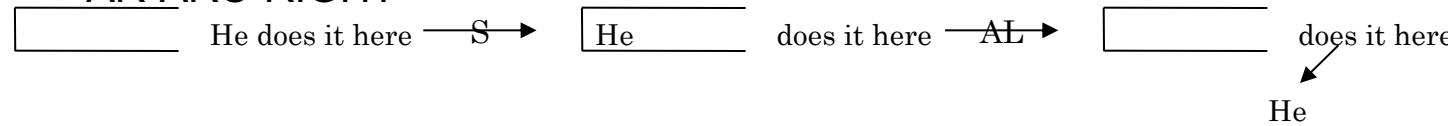
\_\_\_\_\_ He does it here —S→ \_\_\_\_\_ He \_\_\_\_\_ does it here



# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

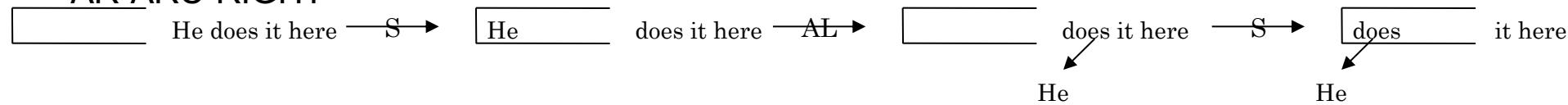




# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

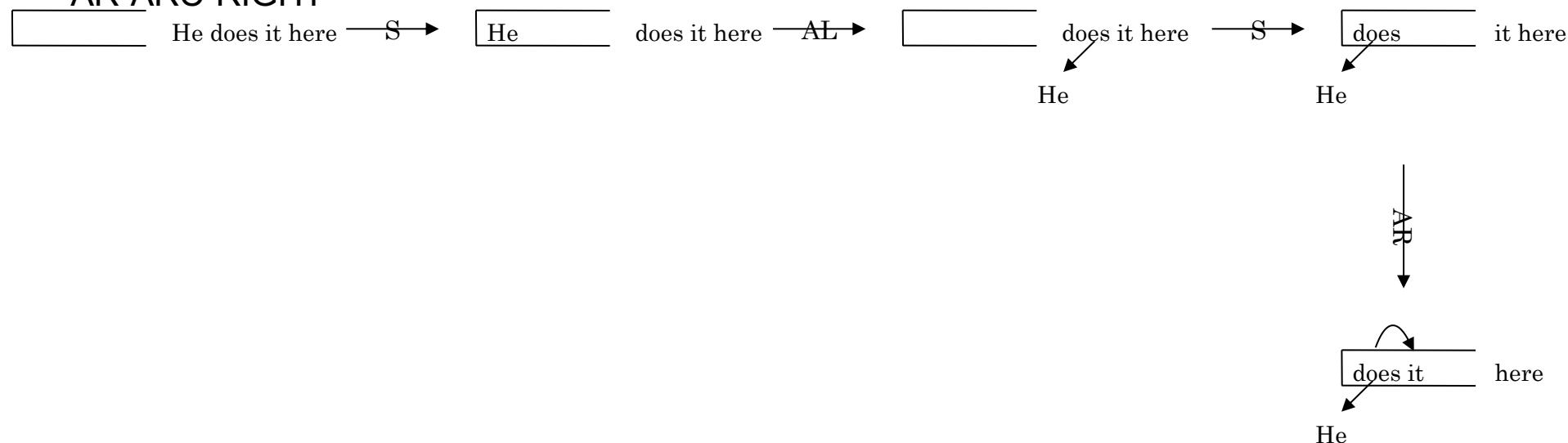




# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

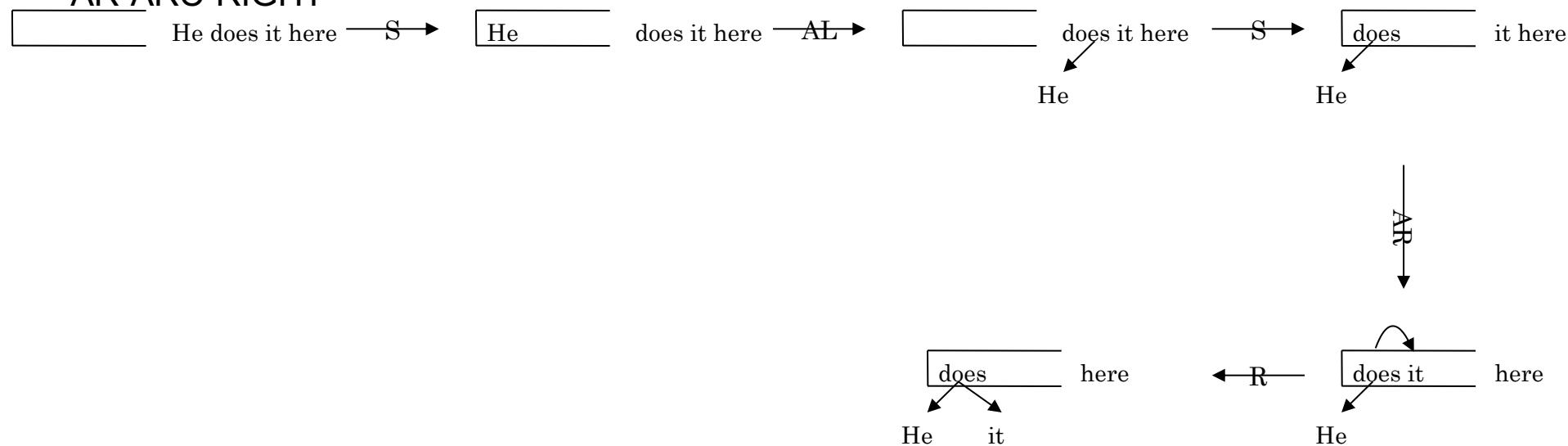




# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

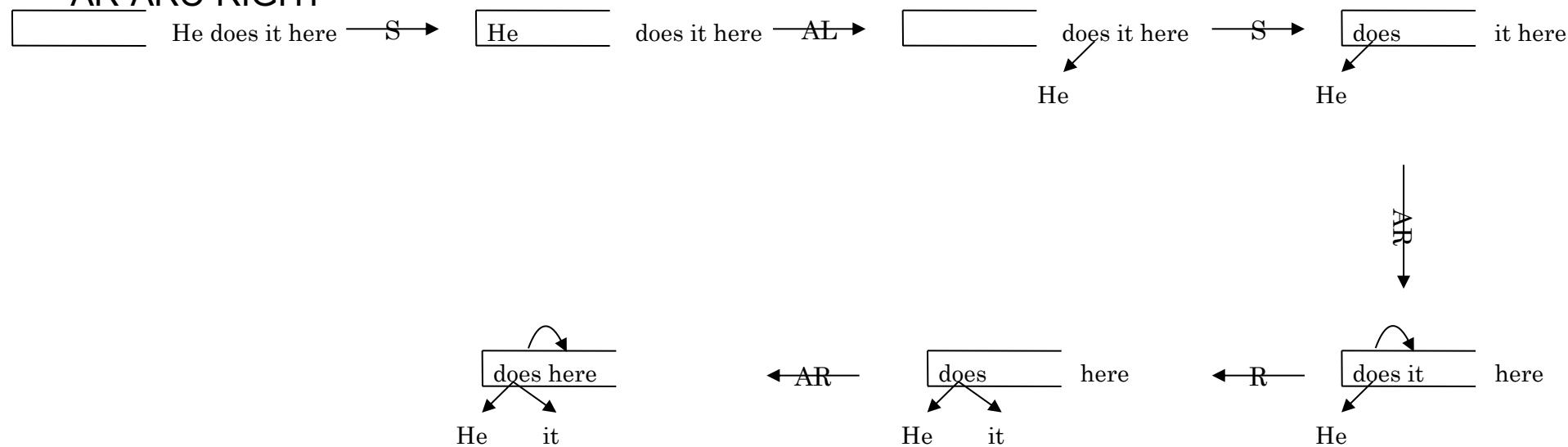




# Transition-based Dependency Parsing

- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT

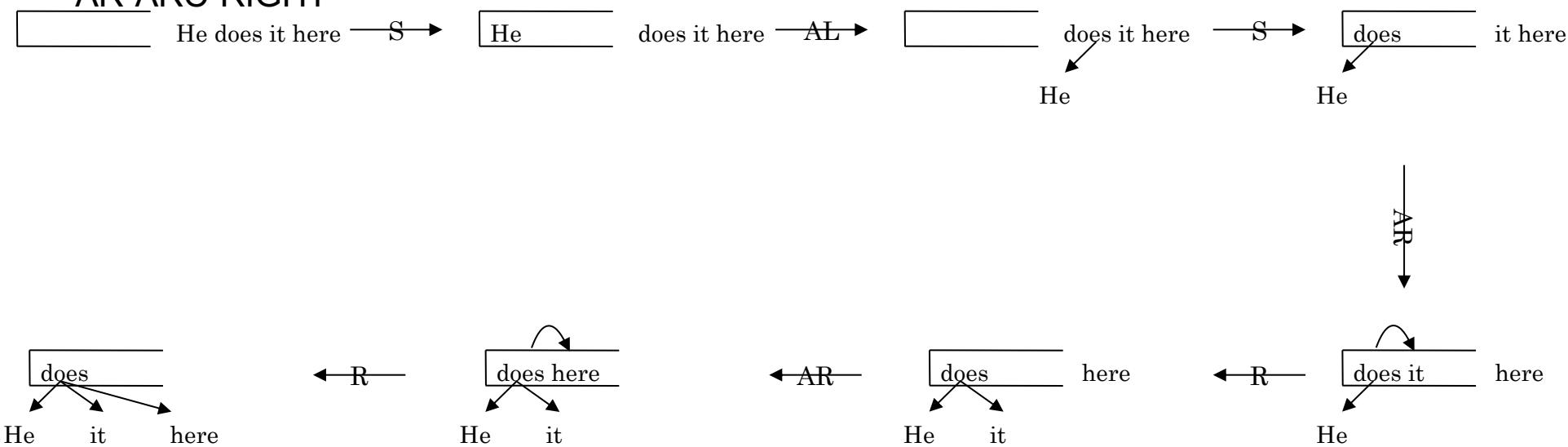




# Transition-based Dependency Parsing

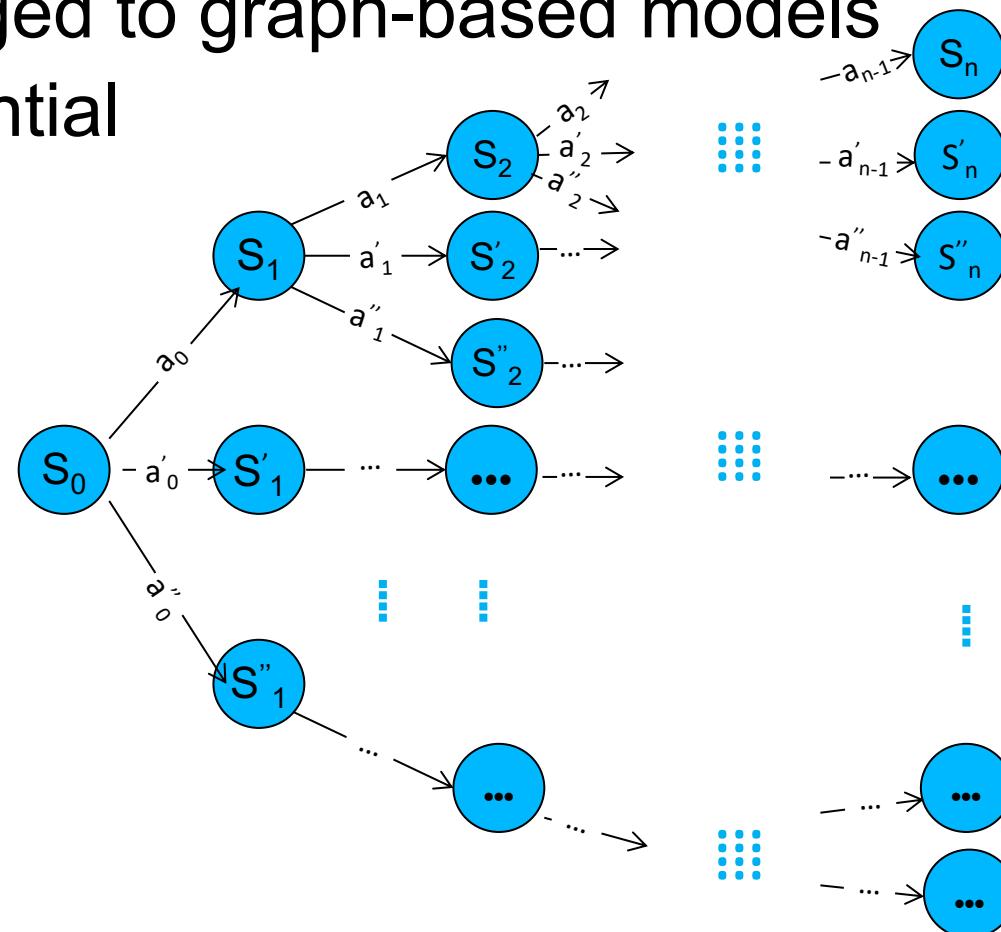
- An Example

- S-SHIFT
- R-REDUCE
- AL-ARC-LEFT
- AR-ARC-RIGHT



# Search Space

- Similar challenged to graph-based models
- Typical exponential



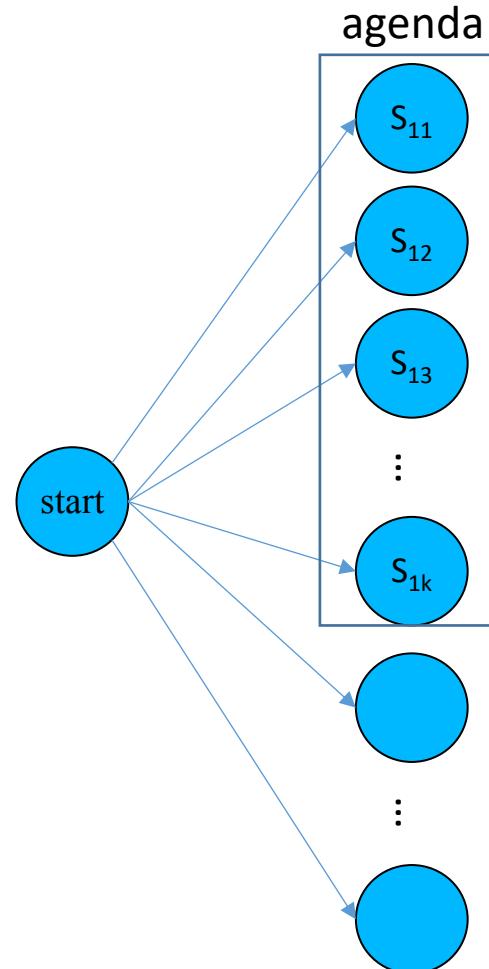
# A Learning+Search Framework



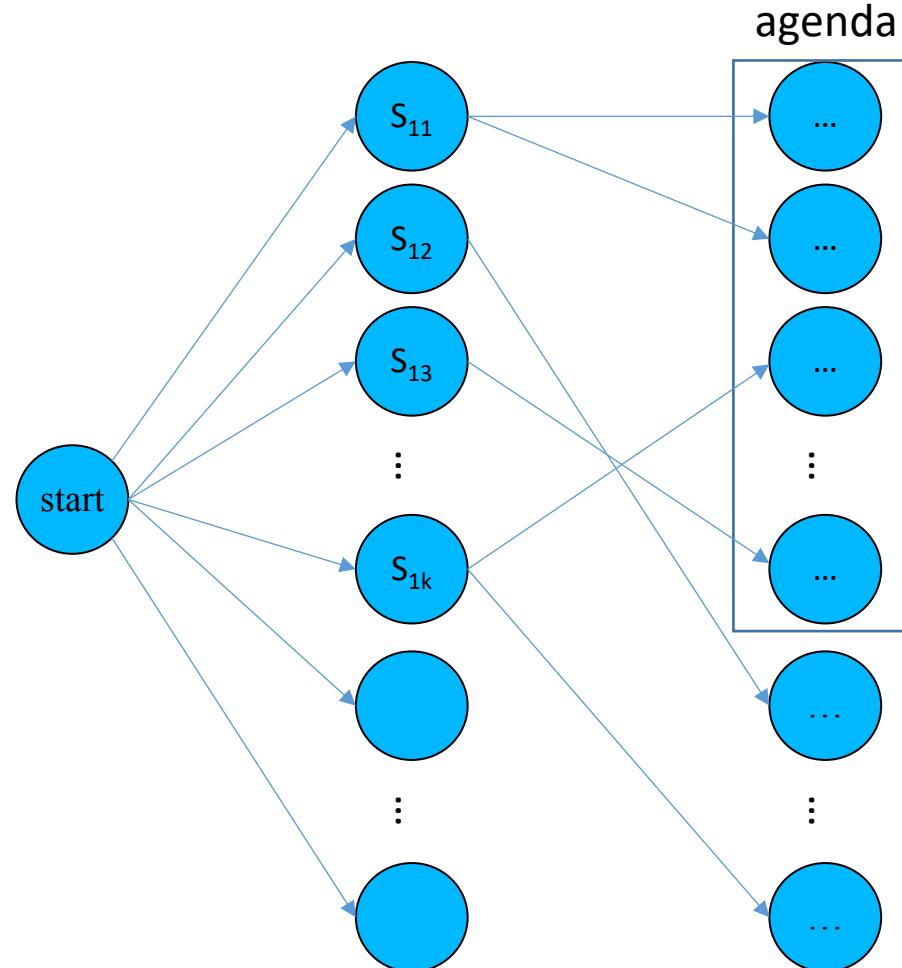
start



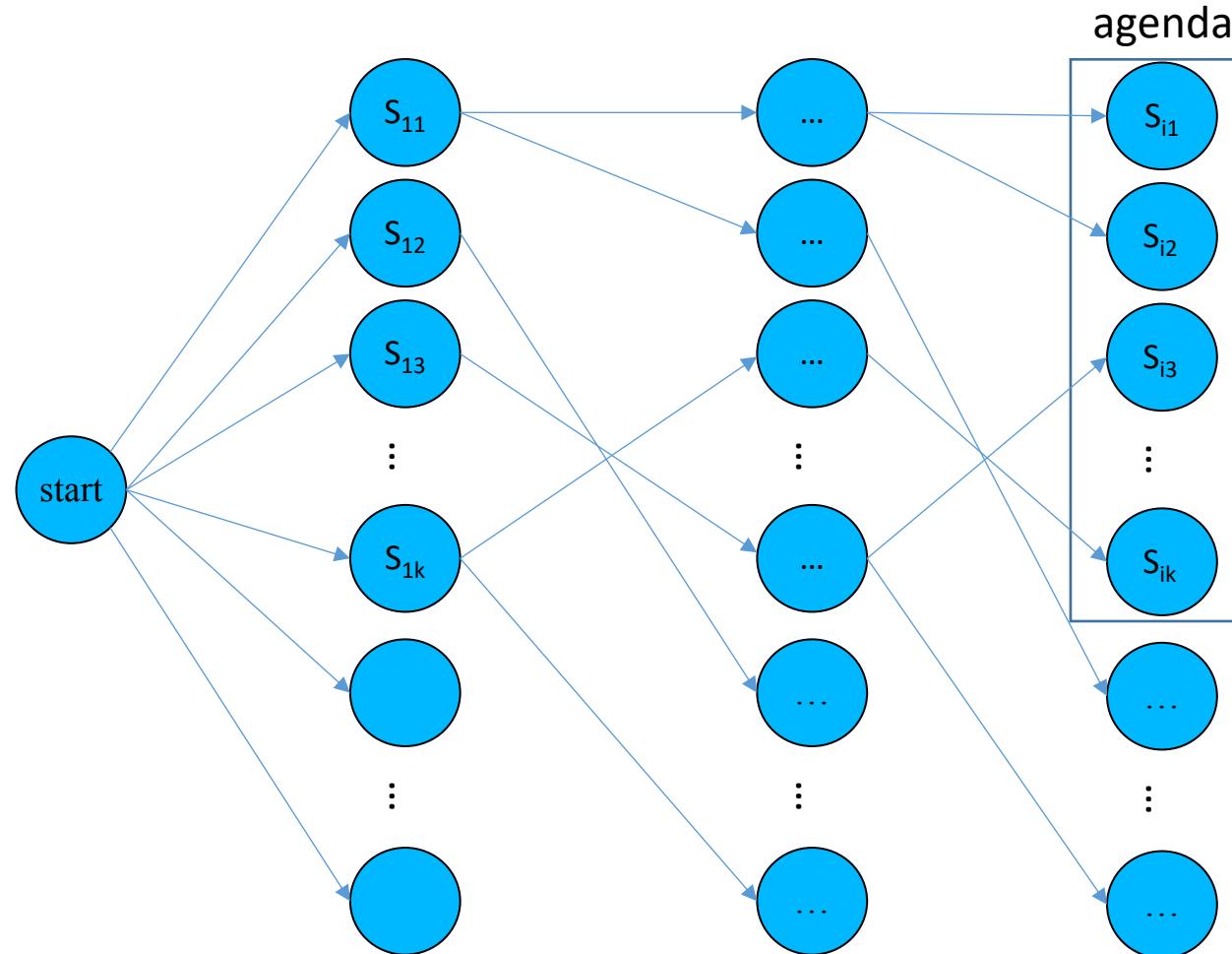
# A Learning+Search Framework



# A Learning+Search Framework

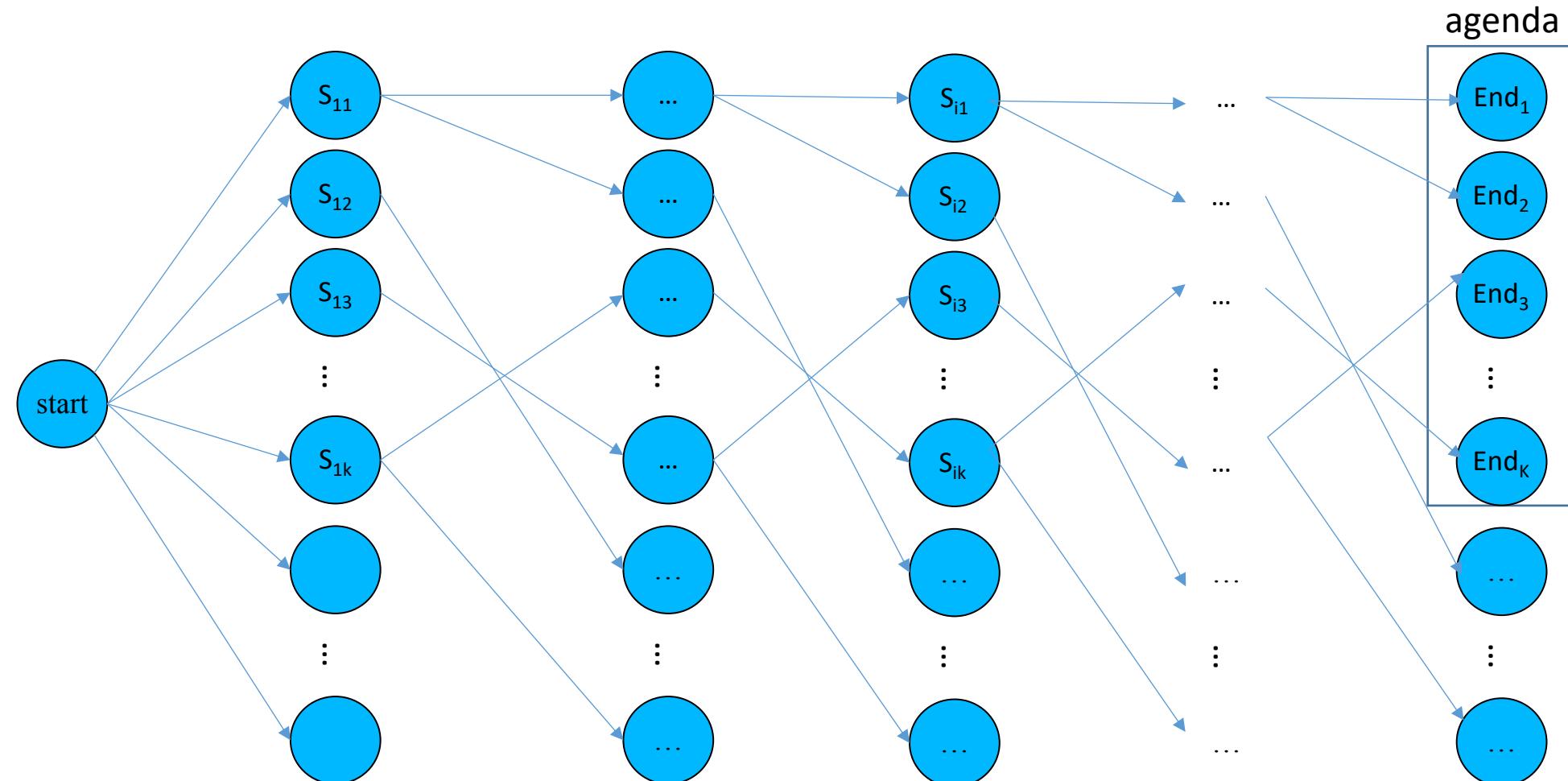


# A Learning+Search Framework





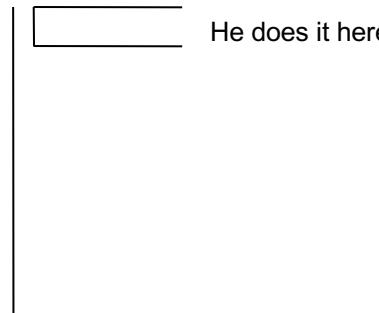
# A Learning+Search Framework





# A Learning+Search Framework

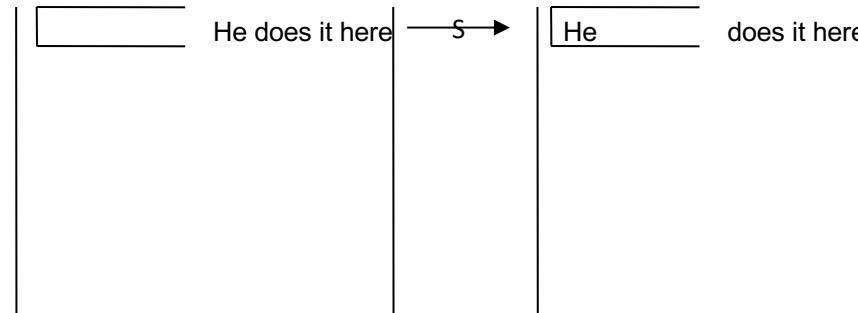
- Dependency Parsing Example
  - Decoding





# A Learning+Search Framework

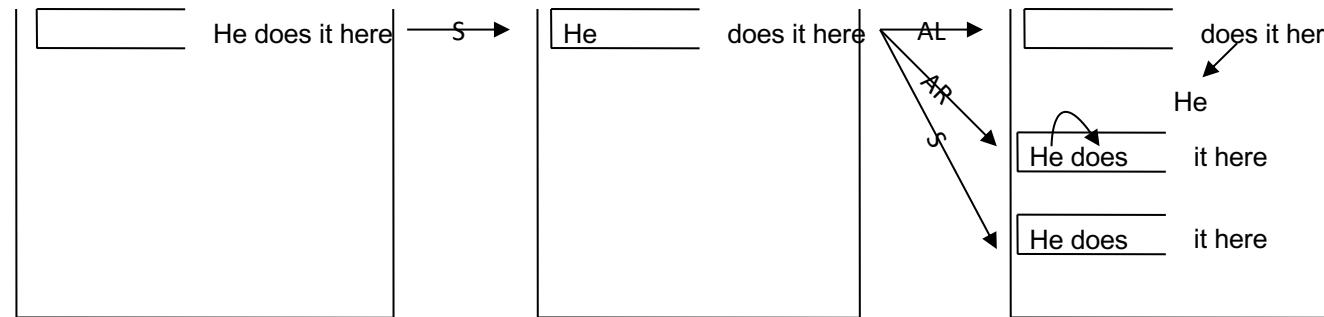
- Dependency Parsing Example
  - Decoding





# A Learning+Search Framework

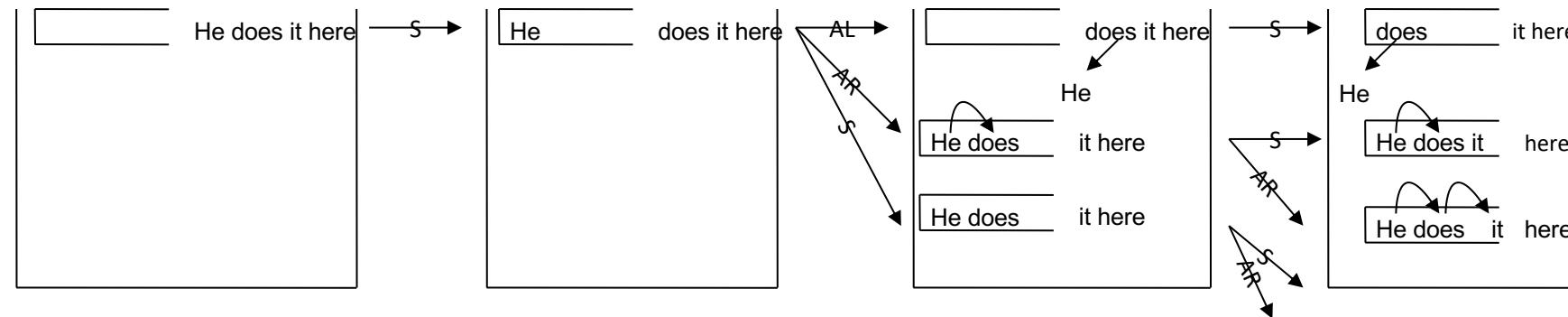
- Dependency Parsing Example
  - Decoding





# A Learning+Search Framework

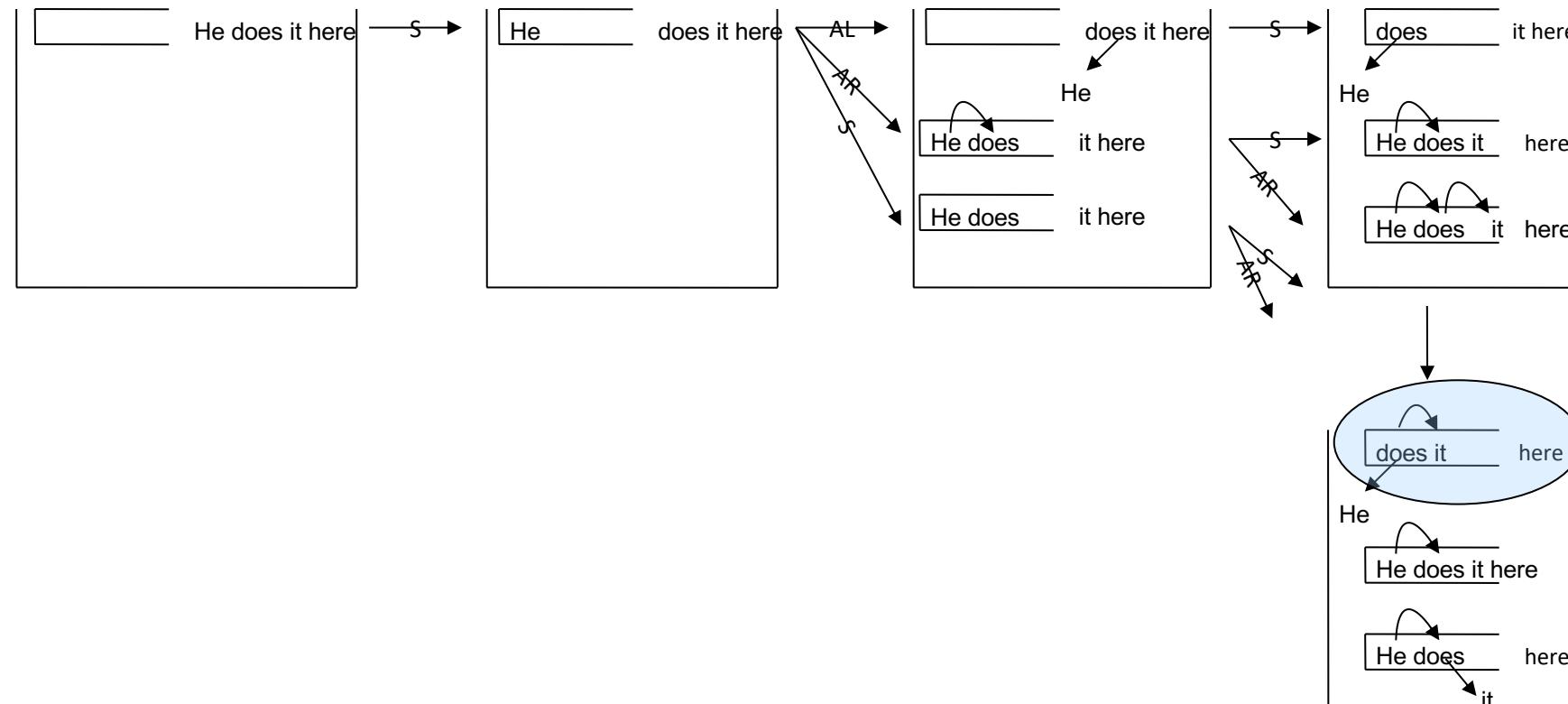
- Dependency Parsing Example
  - Decoding





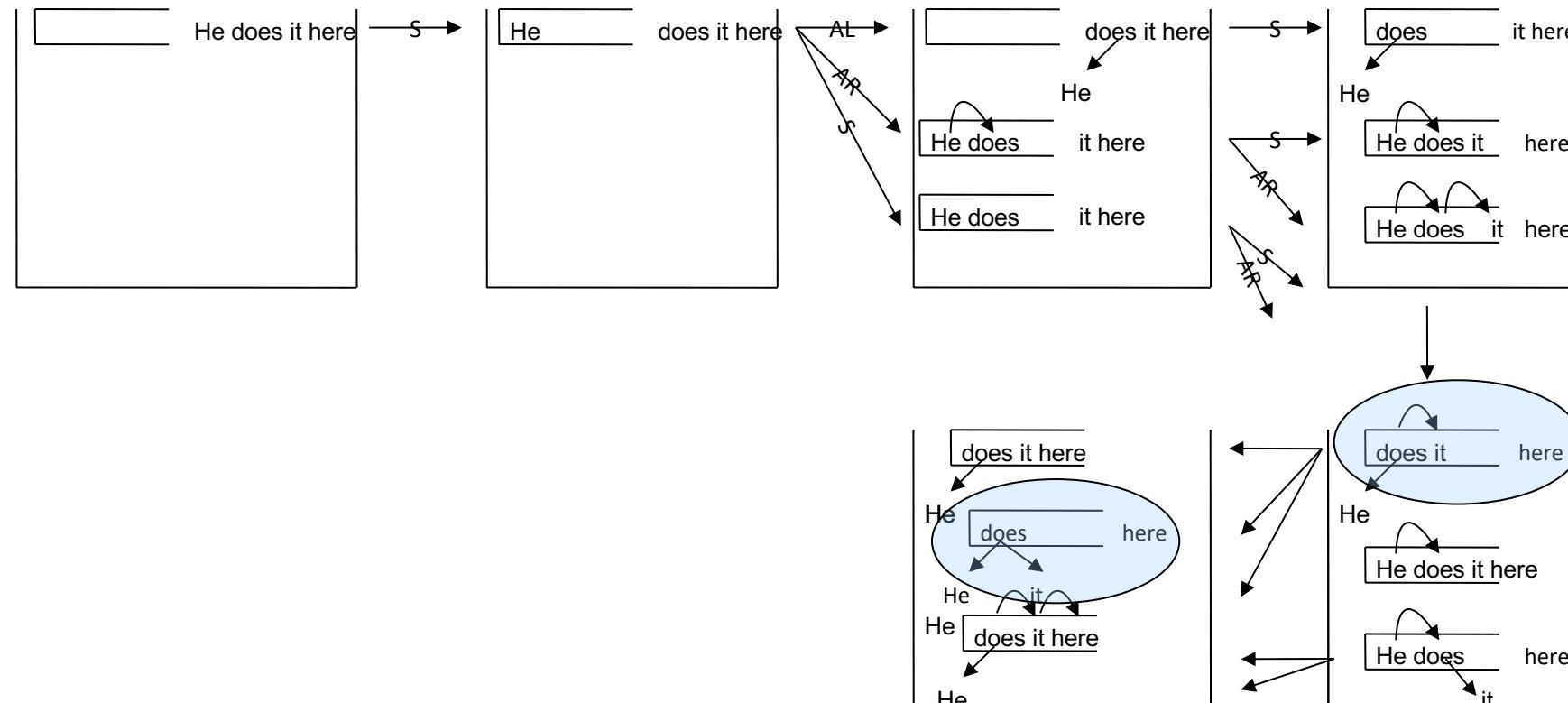
# A Learning+Search Framework

- Dependency Parsing Example
  - Decoding



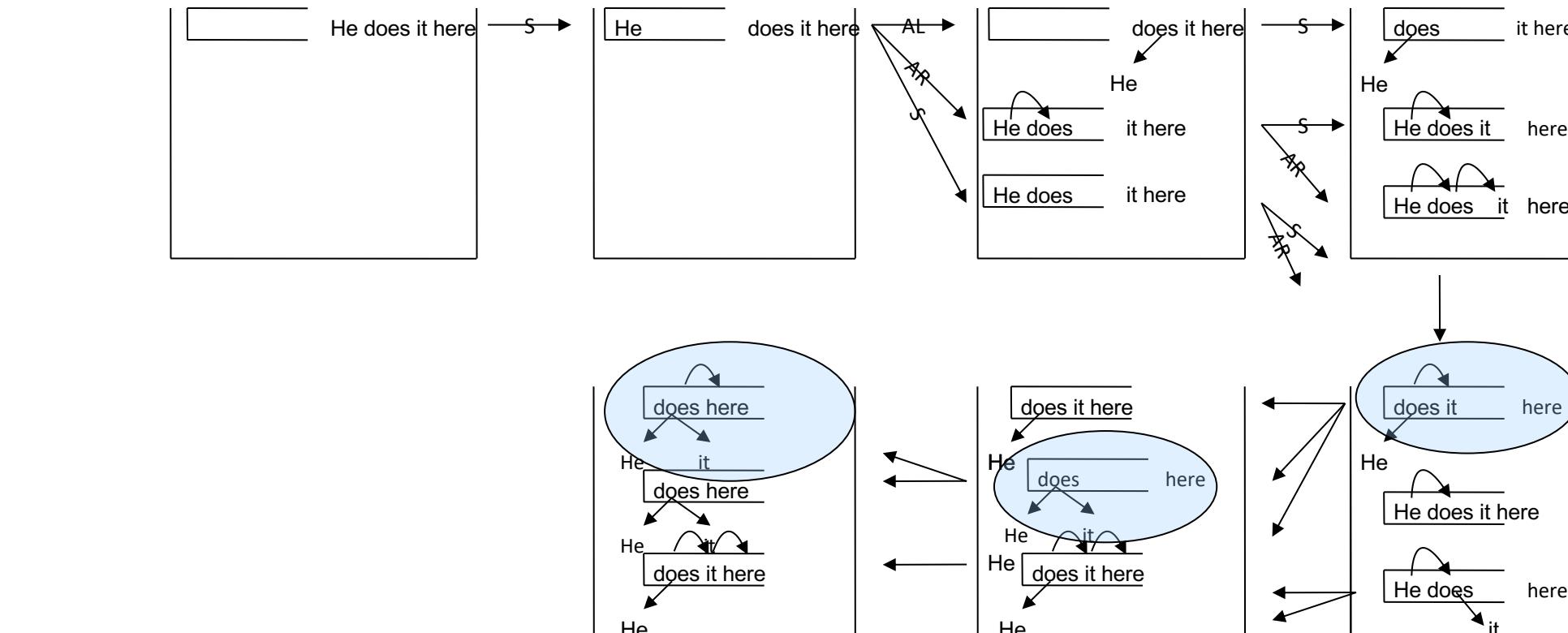
# A Learning+Search Framework

- Dependency Parsing Example
  - Decoding



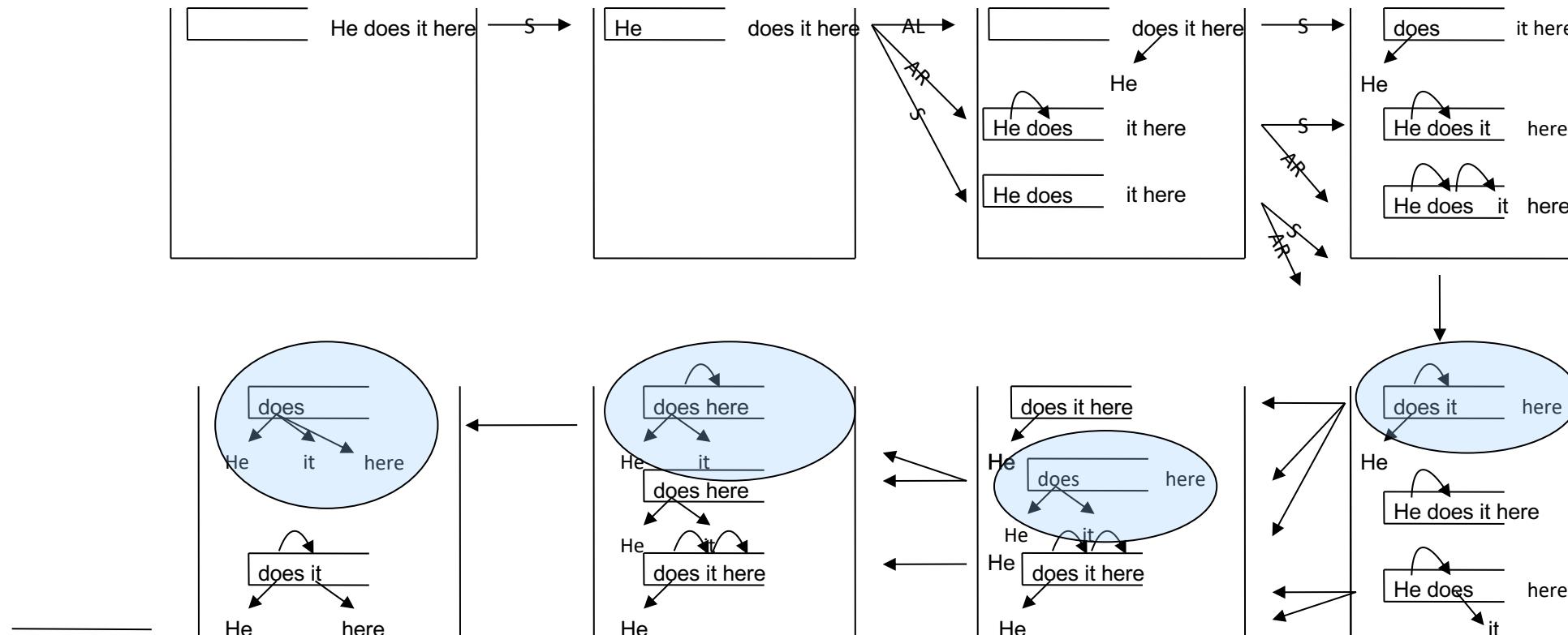
# A Learning+Search Framework

- Dependency Parsing Example
  - Decoding



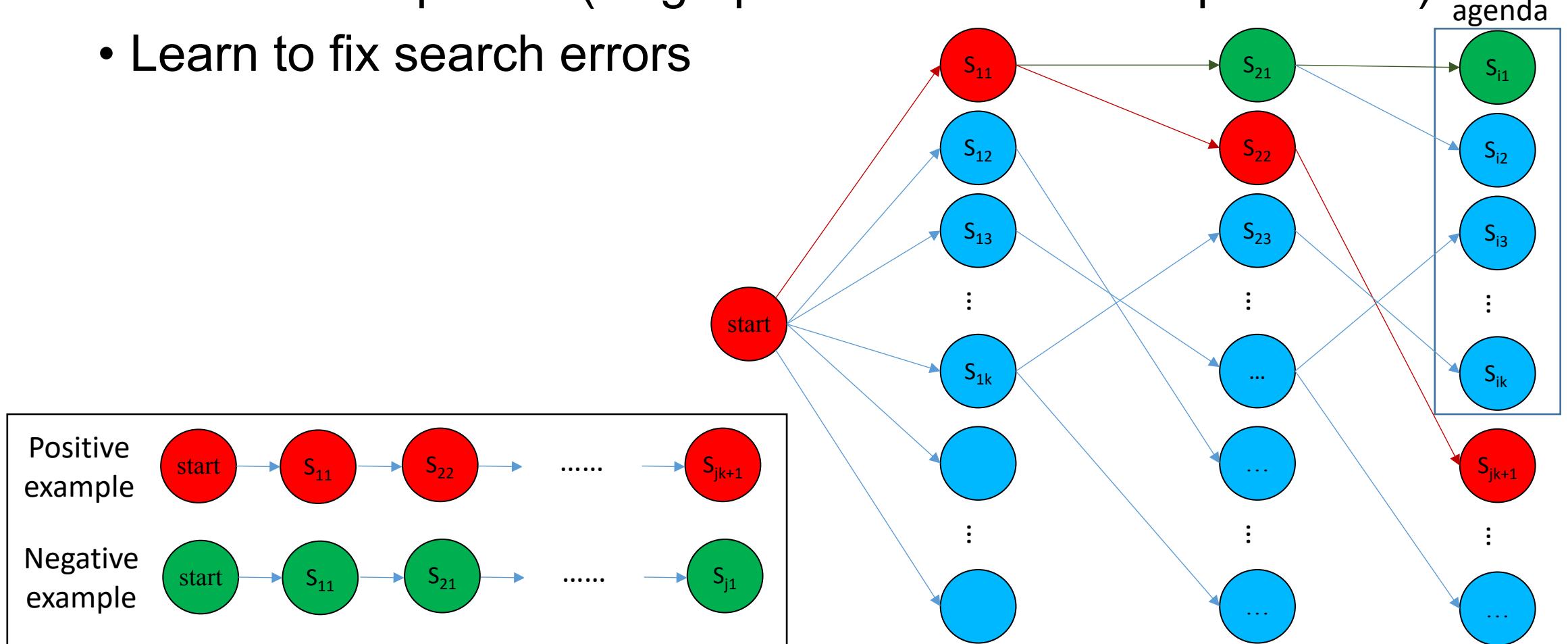
# A Learning+Search Framework

- Dependency Parsing Example
  - Decoding



# A Learning+Search Framework

- Search not optional (vs graph-based structured prediction)
- Learn to fix search errors





# A Learning+Search Framework

- Advantages
  - Low computation complexity
  - Arbitrary non-local features
  - Learning-guided-search



# A Learning+Search Framework

- State-of-the-art **accuracies** and **speeds**
  - Constituent parsing
  - Dependency parsing
  - Word Segmentation
  - CCG parsing
- Enable joint models
  - Address complex search space and use joint features, which have been difficult for traditional models



# A Learning+Search Framework

- State-of-the-art **accuracies** and **speeds**
  - Constituent parsing
  - Dependency parsing
  - Word Segmentation
  - CCG parsing
- Enables joint learning and search
  - **Joint Learning**: learn joint models
  - **Joint Search**: search and use joint features, which have



# A Learning+Search Framework

- Global Normalization for Neural Structured Prediction
  - Zhou et al., (2015)
  - Watanabe et al., (2015)
  - Andor et al., (2016)
  - Rush et al., (2016)

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Hao Zhou, Yue Zhang, Shujian Huang and Jiajun Chen. A Neural Probabilistic Structured-Prediction Model for Transition-based Dependency Parsing. In Proceedings of ACL 2015, Beijing, China, July.

Watanabe, Taro, and Eiichiro Sumita. "Transition-based neural constituent parsing." Proceedings of the 53rd Annual Meeting of the Association for Computational Linguistics and the 7th International Joint Conference on Natural Language Processing (Volume 1: Long Papers). Vol. 1. 2015.

Andor Daniel, Chris Alberti, David Weiss, Aliaksei Severyn, Alessandro Presta, Kuzman Ganchev, Slav Petrov, Michael Collins "Globally normalized transition-based neural networks." arXiv preprint arXiv:1603.06042 (2016).

Wiseman, Sam, and Alexander M. Rush. "Sequence-to-sequence learning as beam-search optimization." arXiv preprint arXiv:1606.02960 (2016).



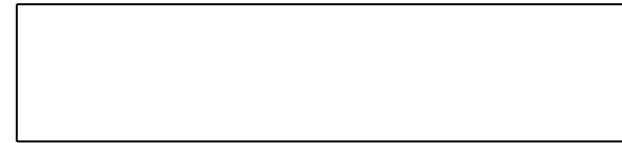
# Joint Segmentation and POS Tagging

- The transition system
  - State
    - Partial segmented results
    - Unprocessed characters
  - Two actions
    - Separate ( $t$ ) :  $t$  is a POS tag
    - Append



# Joint Segmentation and POS Tagging

- The transition system
  - Initial state



我喜欢读书



# Joint Segmentation and POS Tagging

- The transition system
  - Separate(PN)

我/PN

喜欢读书



# Joint Segmentation and POS Tagging

- The transition system
  - Separate (V)

我/PN 喜/V

欢读书



# Joint Segmentation and POS Tagging

- The transition system
  - Append

我/PN 喜欢/V

读书



# Joint Segmentation and POS Tagging

- The transition system
  - Separate (V)

我/PN 喜欢/V 读/V

书



# Joint Segmentation and POS Tagging

- The transition system
  - Separate (N)

我/PN 喜欢/V 读/V 书/N



# Joint Segmentation and POS Tagging

- The transition system
  - End state

我/PN 喜欢/V 读/V 书/N



# Joint Segmentation and POS Tagging

- Segmentation Feature templates

Feature templates for the word segmentor.

	Feature template	When $c_0$ is
1	$w_{-1}$	separated
2	$w_{-1}w_{-2}$	separated
3	$w_{-1}$ , where $\text{len}(w_{-1}) = 1$	separated
4	$\text{start}(w_{-1})\text{len}(w_{-1})$	separated
5	$\text{end}(w_{-1})\text{len}(w_{-1})$	separated
6	$\text{end}(w_{-1})c_0$	separated
7	$c_{-1}c_0$	appended
8	$\text{begin}(w_{-1})\text{end}(w_{-1})$	separated
9	$w_{-1}c_0$	separated
10	$\text{end}(w_{-2})w_{-1}$	separated
11	$\text{start}(w_{-1})c_0$	separated
12	$\text{end}(w_{-2})\text{end}(w_{-1})$	separated
13	$w_{-2}\text{len}(w_{-1})$	separated
14	$\text{len}(w_{-2})w_{-1}$	separated

Non-local

$w$  = word;  $c$  = character. The index of the current character is 0.



# Joint Segmentation and POS Tagging

- POS Feature templates

POS feature templates for the joint segmentor and POS-tagger.

	Feature template	when $c_0$ is
1	$w_{-1}t_{-1}$	separated
2	$t_{-1}t_0$	separated
3	$t_{-2}t_{-1}t_0$	separated
4	$w_{-1}t_0$	separated
5	$t_{-2}w_{-1}$	separated
6	$w_{-1}t_{-1}end(w_{-2})$	separated
7	$w_{-1}t_{-1}c_0$	separated
8	$c_{-2}c_{-1}c_0t_{-1}$ , where $len(w_{-1}) = 1$	separated
9	$c_0t_0$	separated
10	$t_{-1}start(w_{-1})$	separated
11	$t_0c_0$	separated or appended
12	$c_0t_0start(w_0)$	appended
13	$ct_{-1}end(w_{-1})$ , where $c \in w_{-1}$ and $c \neq end(w_{-1})$	separated
14	$c_0t_0cat(start(w_0))$	separated
15	$ct_{-1}cat(end(w_{-1}))$ , where $c \in w_{-1}$ and $c \neq end(w_{-1})$	appended
16	$c_0t_0c_{-1}t_{-1}$	separated
17	$c_0t_0c_{-1}$	appended

Word-level

$w$  = word;  $c$  = character;  $t$  = POS-tag. The index of the current character is 0.



# Joint Segmentation and POS Tagging

- Experiments on CTB 5

	SF	JF
K09 (error-driven)	97.87	93.67
<b>This work</b>	<b>97.78</b>	<b>93.67</b>
Zhang 2008	97.82	93.62
K09 (baseline)	97.79	93.60
J08a	97.85	93.41
J08b	97.74	93.37
N07	97.83	93.32

SF = segmentation F-score; JF = joint segmentation and POS-tagging F-score



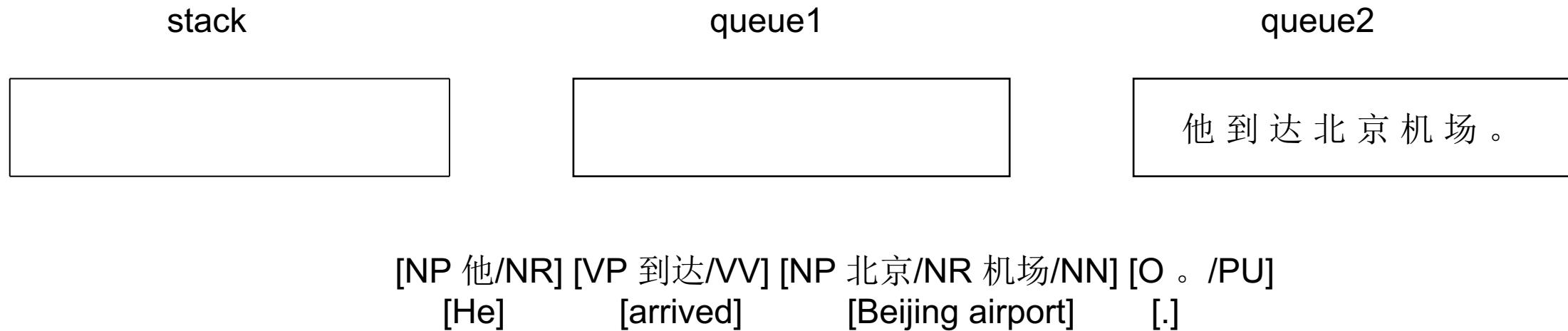
# Joint Segmentation/Tagging/Chunking

- Input 他到达北京机场。  
Output [NP 他/NR] [VP 到达/VV] [NP 北京/NR 机场/NN] [O 。 /PU]  
[He] [arrived] [Beijing airport] [.]
- Chunking knowledge can potentially improve segmentation/tagging.
- To address the sparsity of full chunk features, a semi-supervised method is proposed to derive chunk cluster features from large-scale automatically-chunked data.



# Joint Segmentation/Tagging/Chunking

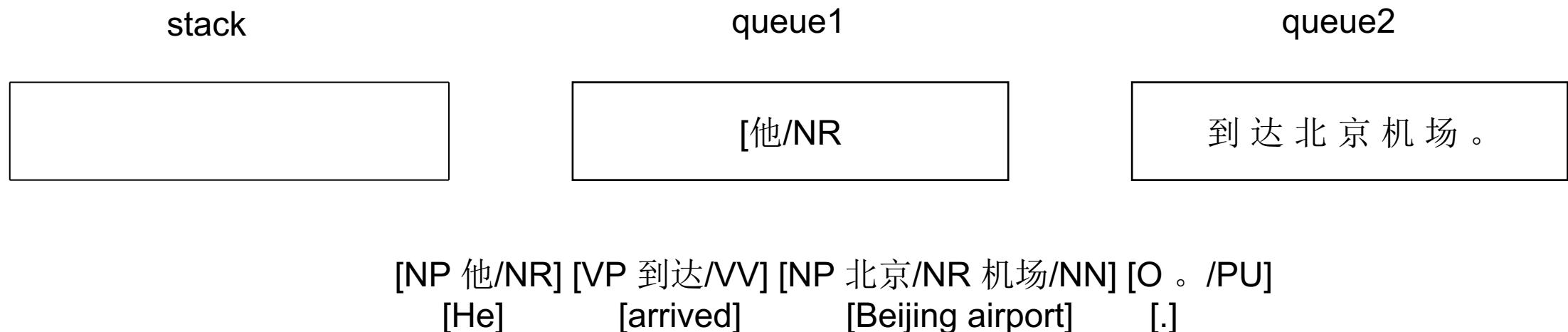
- Character-based chunking
  - Action: initial state





# Joint Segmentation/Tagging/Chunking

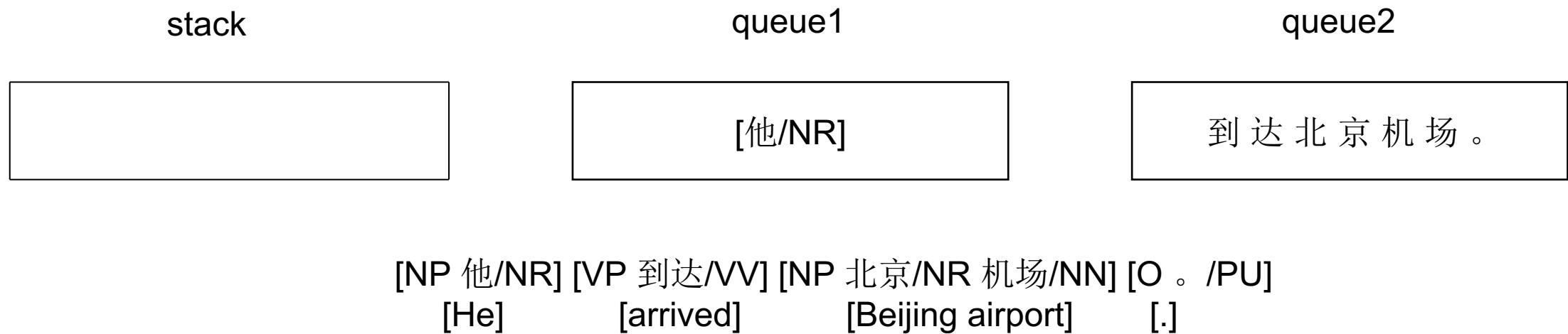
- Character-based chunking
  - Action: SEP(NR)





# Joint Segmentation/Tagging/Chunking

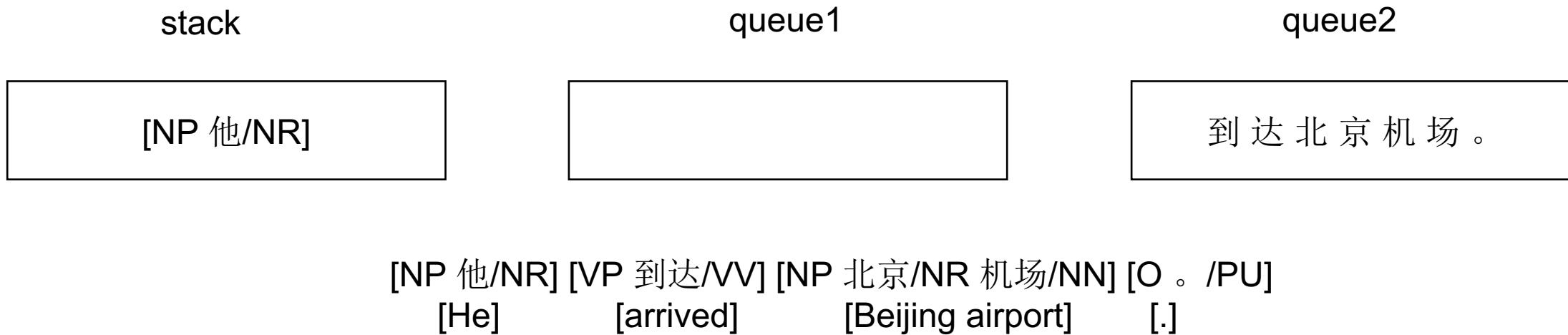
- Character-based chunking
  - Action: FIN W





# Joint Segmentation/Tagging/Chunking

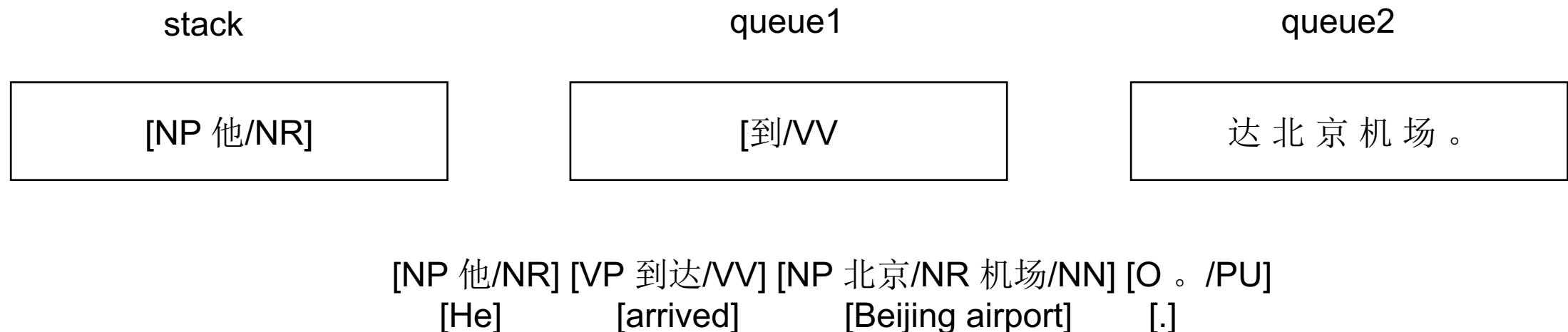
- Character-based chunking
    - Action: SEP(NP)





# Joint Segmentation/Tagging/Chunking

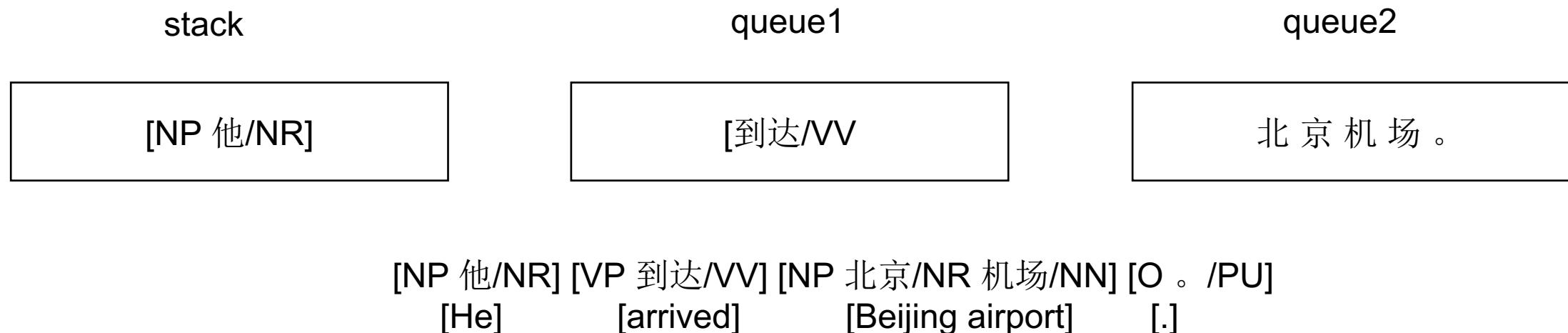
- Character-based chunking
  - Action: SEP(VV)





# Joint Segmentation/Tagging/Chunking

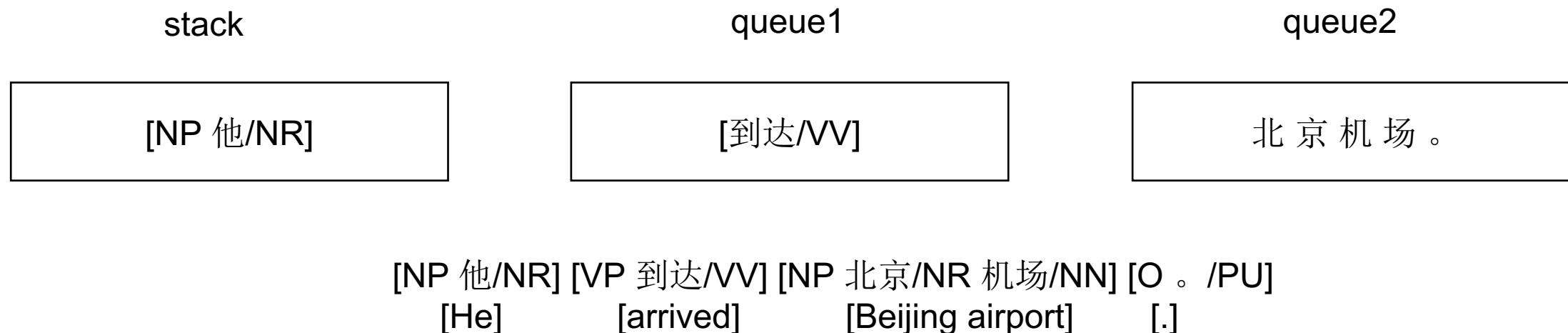
- Character-based chunking
  - Action: APP W





# Joint Segmentation/Tagging/Chunking

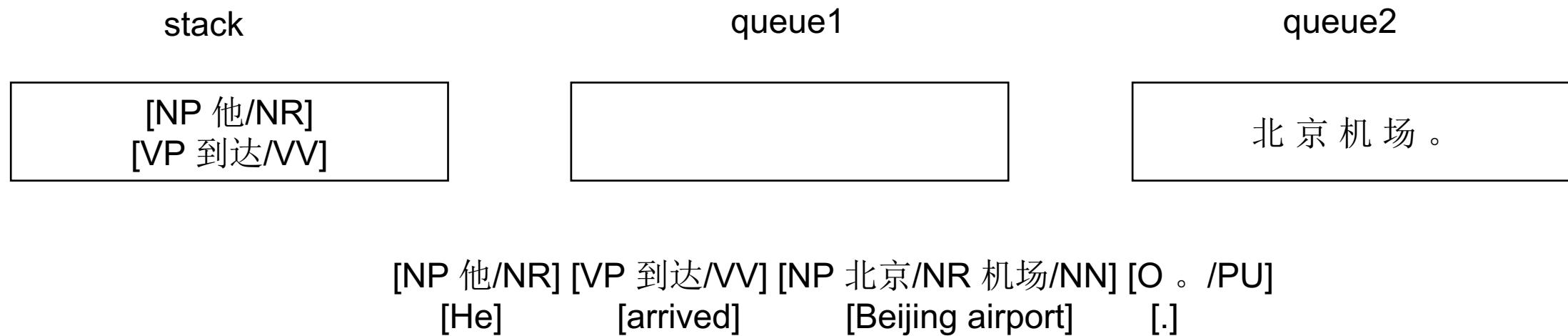
- Character-based chunking
  - Action: FIN W





# Joint Segmentation/Tagging/Chunking

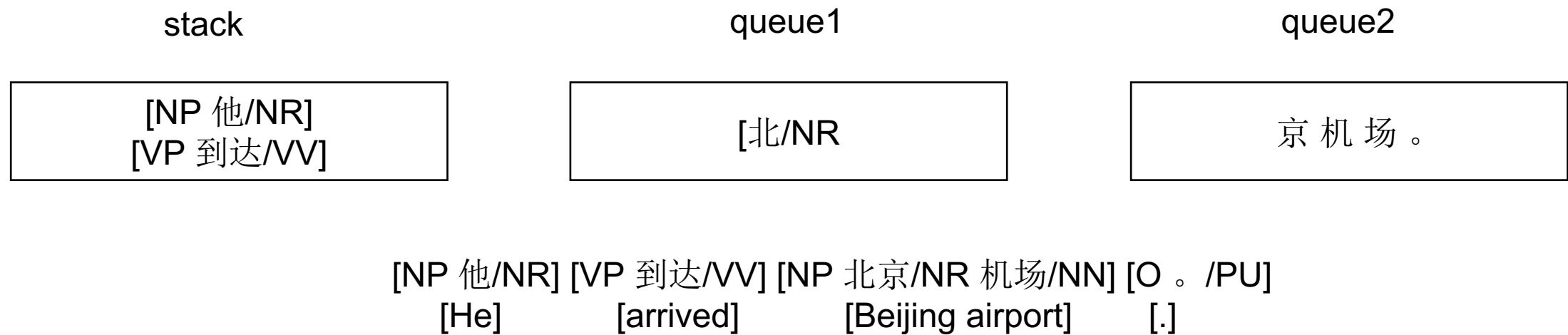
- Character-based chunking
  - Action: SEP(VP)





# Joint Segmentation/Tagging/Chunking

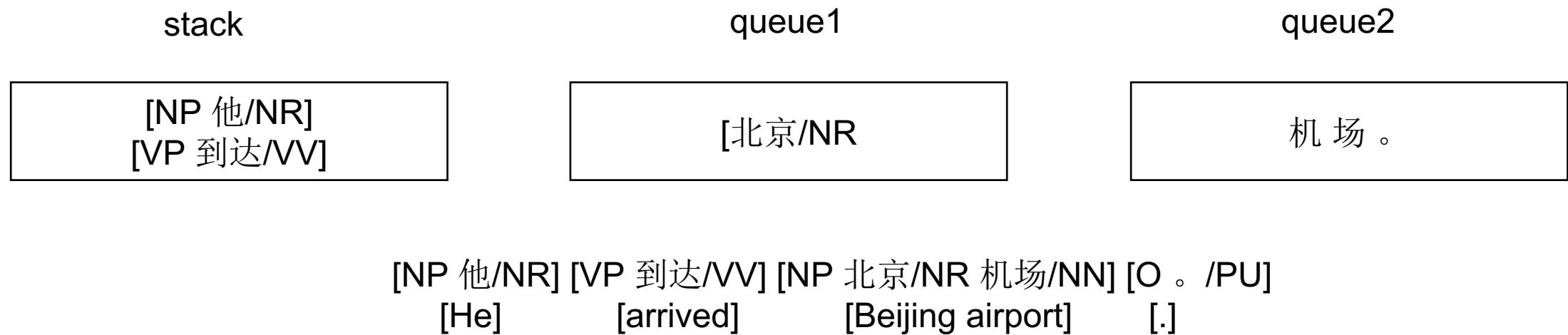
- Character-based chunking
  - Action: SEP(NR)





# Joint Segmentation/Tagging/Chunking

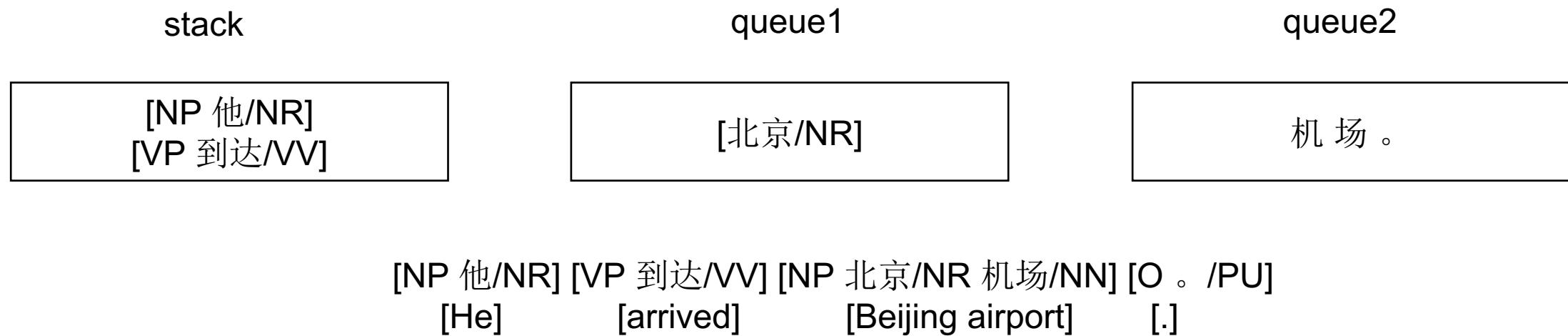
- Character-based chunking
  - Action: APP W





# Joint Segmentation/Tagging/Chunking

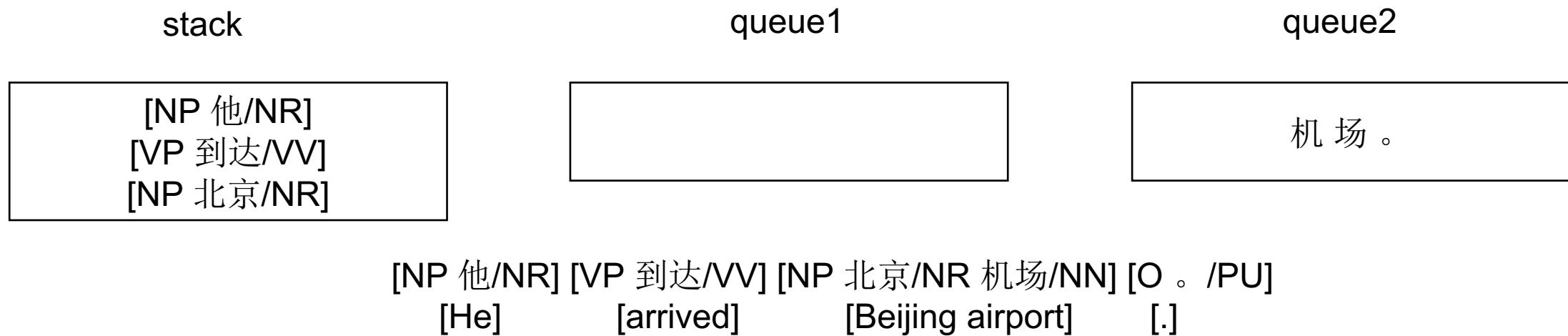
- Character-based chunking
  - Action: FIN W





# Joint Segmentation/Tagging/Chunking

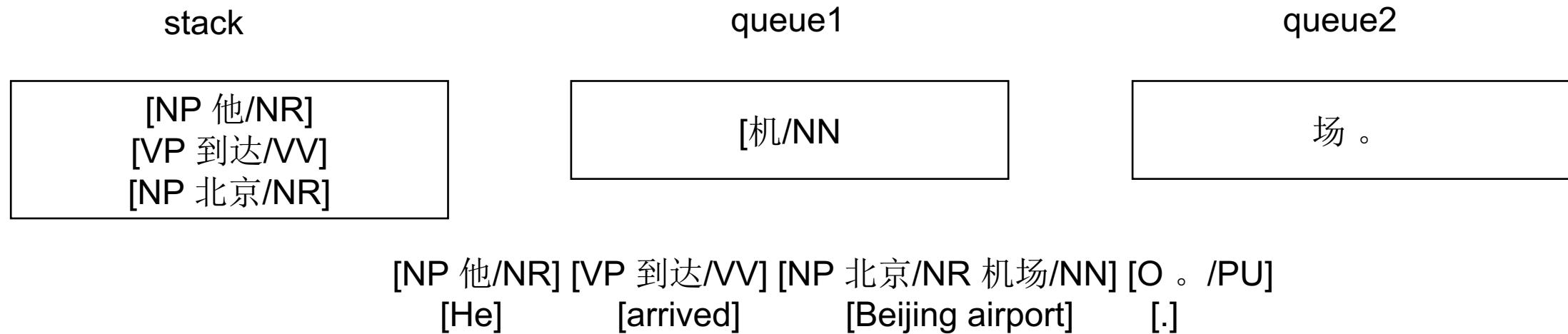
- Character-based chunking
    - Action: SEP(NP)





# Joint Segmentation/Tagging/Chunking

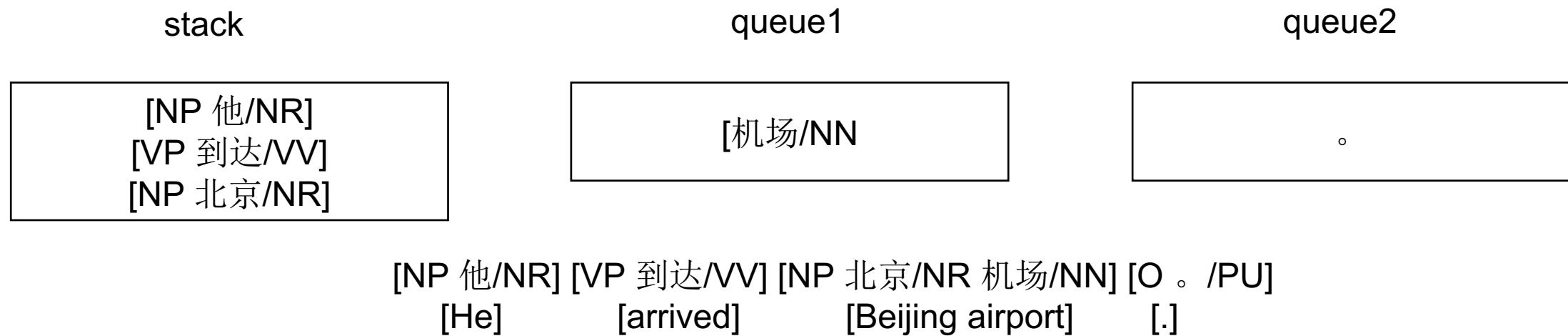
- Character-based chunking
  - Action: SEP(nn)





# Joint Segmentation/Tagging/Chunking

- Character-based chunking
  - Action: APP W





# Joint Segmentation/Tagging/Chunking

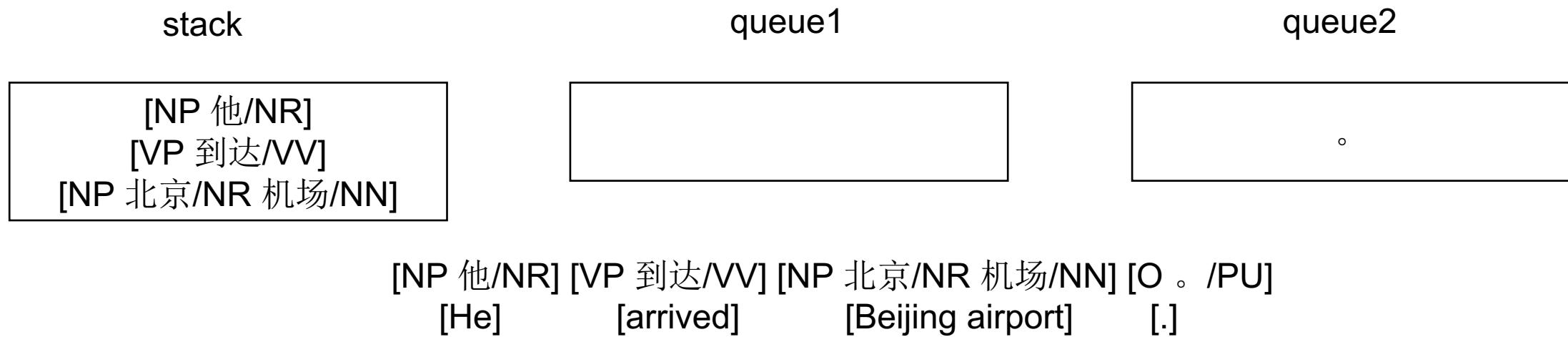
- Character-based chunking
  - Action: FIN W





# Joint Segmentation/Tagging/Chunking

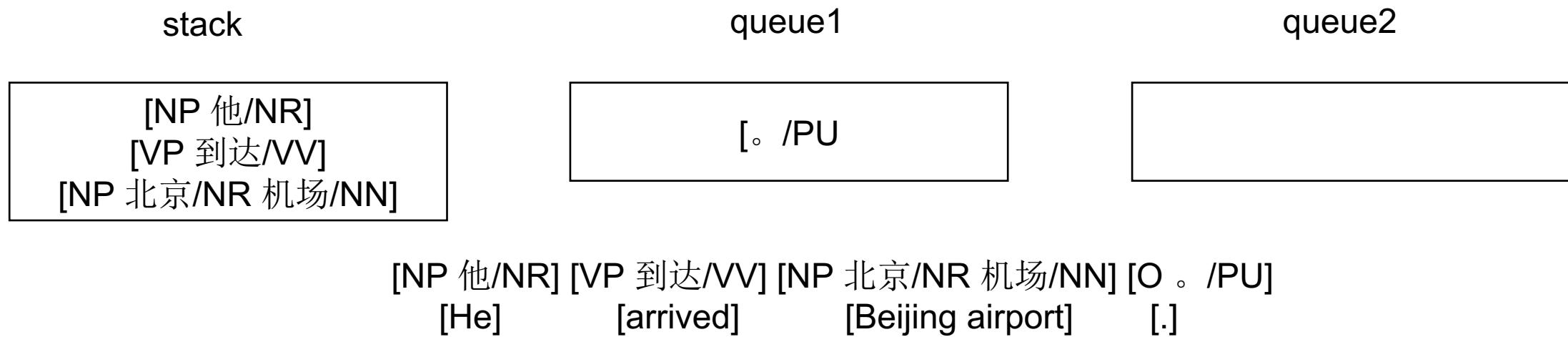
- Character-based chunking
    - Action: APP C





# Joint Segmentation/Tagging/Chunking

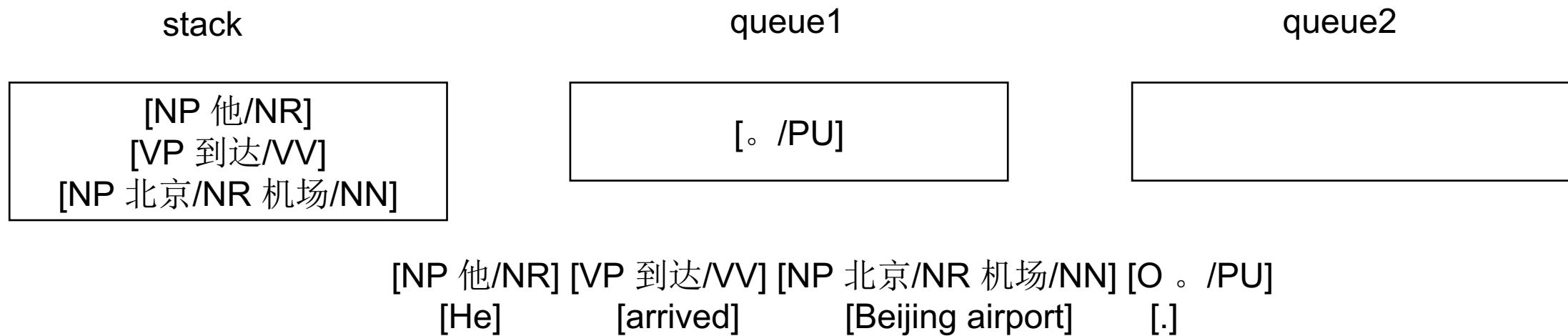
- Character-based chunking
    - Action: SEP(PU)





# Joint Segmentation/Tagging/Chunking

- Character-based chunking
    - Action: FIN W





# Joint Segmentation/Tagging/Chunking

- Character-based chunking
  - Action: SEP(O)





# Joint Segmentation/Tagging/Chunking

- Character-based chunking feature template

ID	Feature Templates
1	$C_0$
2	$C_0 \cdot T_0$
3	$C_0 \cdot POSset(C_0)$
4	$C_0$ , where $\text{len}(C_0) = 1$
5	$C_0 \cdot N_0 w$
6	$C_0 \cdot N_0 w \cdot T_0$
7	$C_{-1} \cdot C_0$
8	$T_{-1} \cdot C_0$
9	$C_{-1} \cdot T_0$
10	$C_0 \cdot \text{end\_word}(C_{-1})$
11	$C_{-1} \cdot \text{len}(C_0)$
12	$C_0 \cdot \text{len}(C_{-1})$
13	$C_0 \cdot \text{end\_word}(C_{-1}) \cdot T_0$
14	$C_{-1} \cdot T_{-1} \cdot C_0 \cdot T_0$
15	$w_{-2} \cdot w_{-1}$



# Joint Segmentation/Tagging/Chunking

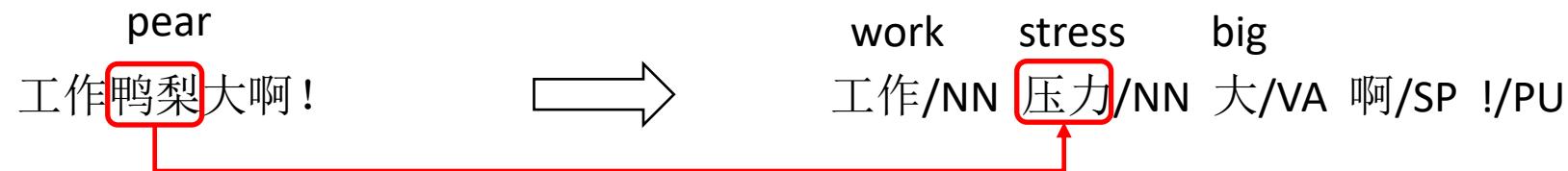
- Results on CTB

	SEG	POS	CHUNK
Pipeline	88.81	80.64	69.02
Pipeline-C	88.81	80.64	68.82
Pipeline-Semi-C	88.81	80.64	69.45
Joint	89.85	81.94	70.96
Joint-C	89.83	81.78	70.63
Joint-Semi-C	<b>90.67</b>	<b>82.45</b>	<b>72.09</b>



# Joint Segmentation, Tagging and Normalization

- Text normalization is introduced as a pre-processing step for microblog processing, which transforms informal words into their standard forms. For example, “tmrw” has been frequently used in tweets for is for “tomorrow”.
- This paper proposed a transition-based model for joint word segmentation, POS tagging and text normalization.





# Joint Segmentation, Tagging and Normalization

- Normalization dictionary

鸭梨- 压力

pear - pressure

孩纸- 孩子

child paper - child

围脖- 微博

neckerchief - microblog

盆友- 朋友

basin friend - friend

.....



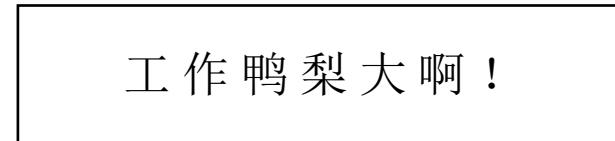
# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: initial state

stack



queue



工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: SEP(工, NN)

stack

queue

工/NN

作 鸭 梨 大 啊 !

工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: APP(作)

stack

queue

工作/NN

鸭梨大啊！

工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: SEP(鴨, NN)

stack

queue

工作/NN 鴨/NN

梨 大 啊 !

工作/NN 壓力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: APP(梨)

stack

queue

工作/NN 鸭梨/NN

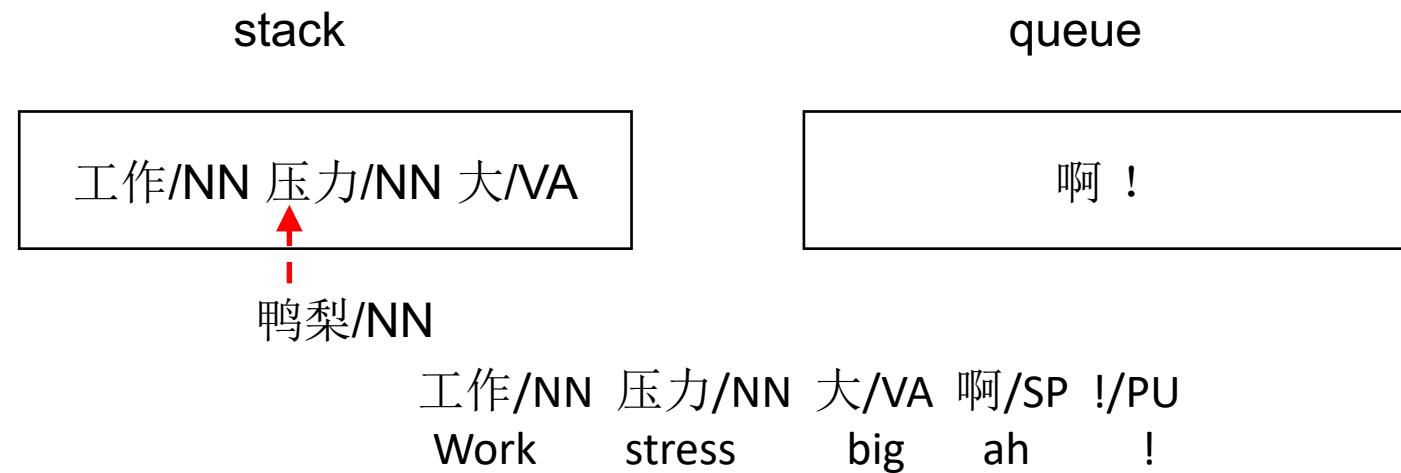
大 啊 !

工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: SEPS(大, VA, 压力)





# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions: SEP(啊, SP)

stack

工作/NN 压力/NN 大/VA 啊/SP

queue

!

工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !



# Joint Segmentation, Tagging and Normalization

- Transition actions for joint segmentation, tagging and normalization
  - Actions:  $\text{SEP}(!, \text{PU})$

stack

工作/NN 压力/NN 大/VA 啊/SP ! /PU

queue

工作/NN 压力/NN 大/VA 啊/SP !/PU  
Work stress big ah !

# Joint Segmentation, Tagging and Normalization



- Features
  - The segmentation feature templates of Zhang and Clark (2011)
  - Extracting language model features by using word-based language model learned from a large quantity of standard texts



# Joint Segmentation, Tagging and Normalization

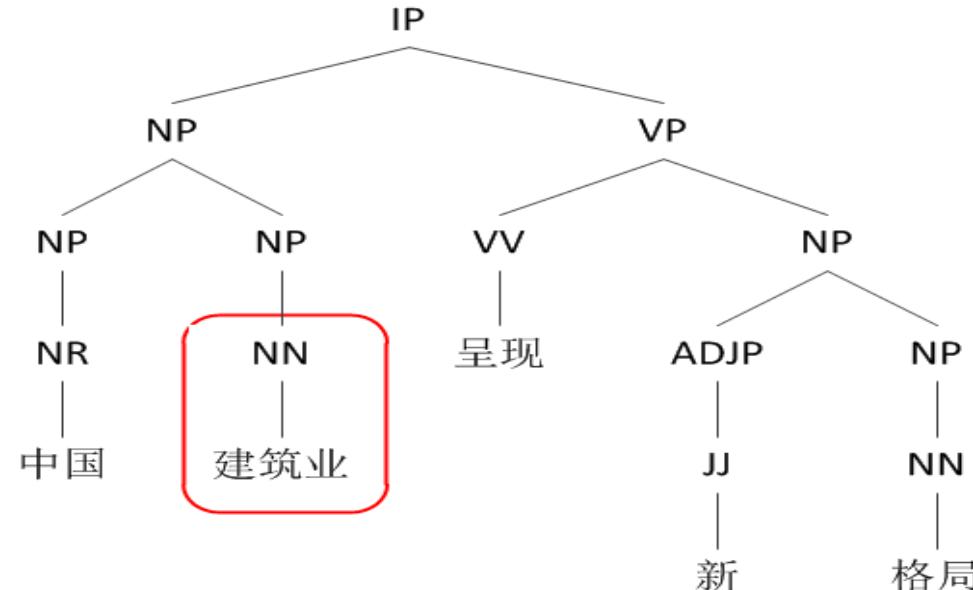
- Results on CTB

	Seg-F	POS-F	Nor-F
Stanford	<b>0.9058</b>	0.8163	
ST	0.8934	0.8263	
S;N;T	0.8885	0.8197	0.4058
SN;T	0.8945	0.8287	0.4207
SNT	0.8995	<b>0.8296</b>	<b>0.4391</b>
ST+lm	0.9162	0.8401	
S;N;T+lm	0.9132	0.8341	0.6276
SN;T+lm	0.9240	0.8439	0.6392
SNT+lm	<b>0.9261</b>	<b>0.8459</b>	<b>0.6413</b>



# Joint Segmentation, POS-tagging and Constituent Parsing

- Traditional: word-based Chinese parsing

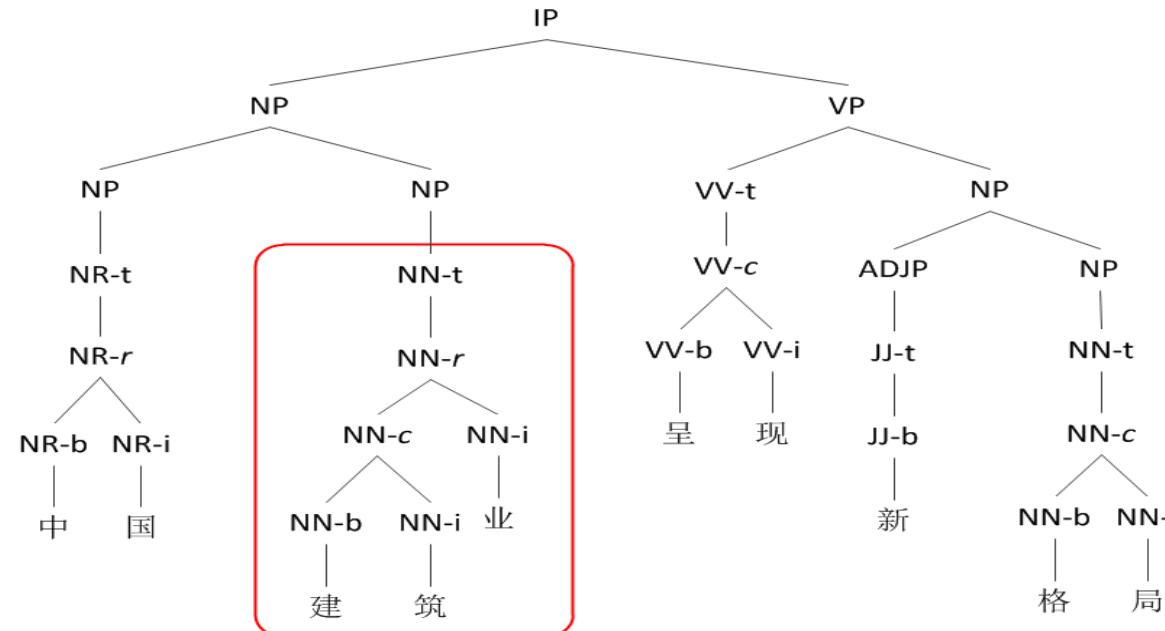


CTB-style word-based syntax tree for “中国 (China) 建筑业 (architecture industry) 呈现 (show) 新 (new) 格局 (pattern)”.



# Joint Segmentation, POS-tagging and Constituent Parsing

- This: character-based Chinese parsing

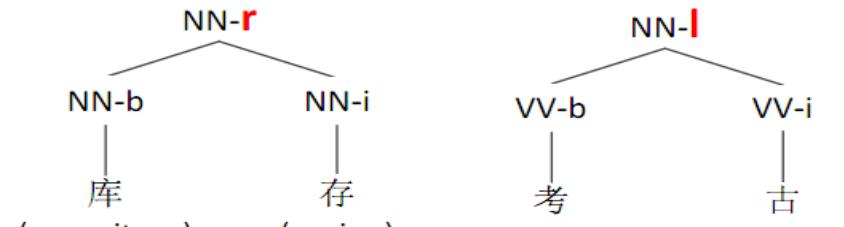


Character-level syntax tree with hierachal word structures for “中 (middle) 国 (nation) 建 (construction) 筑 (building) 业 (industry) 呈 (present) 现 (show) 新 (new) 格 (style) 局 (situation)”.

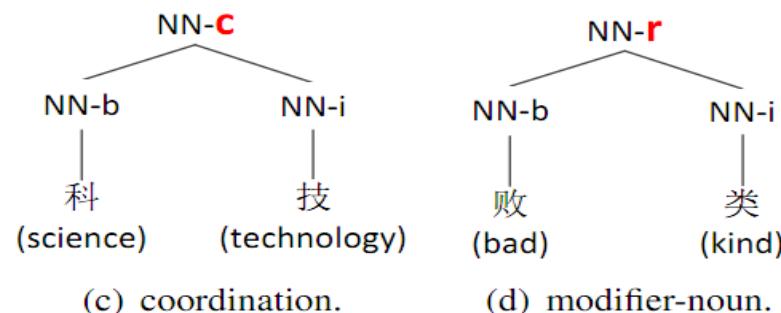


# Joint Segmentation, POS-tagging and Constituent Parsing

- Why character-based?
  - Chinese words have syntactic structures.



(a) subject-predicate. (b) verb-object.

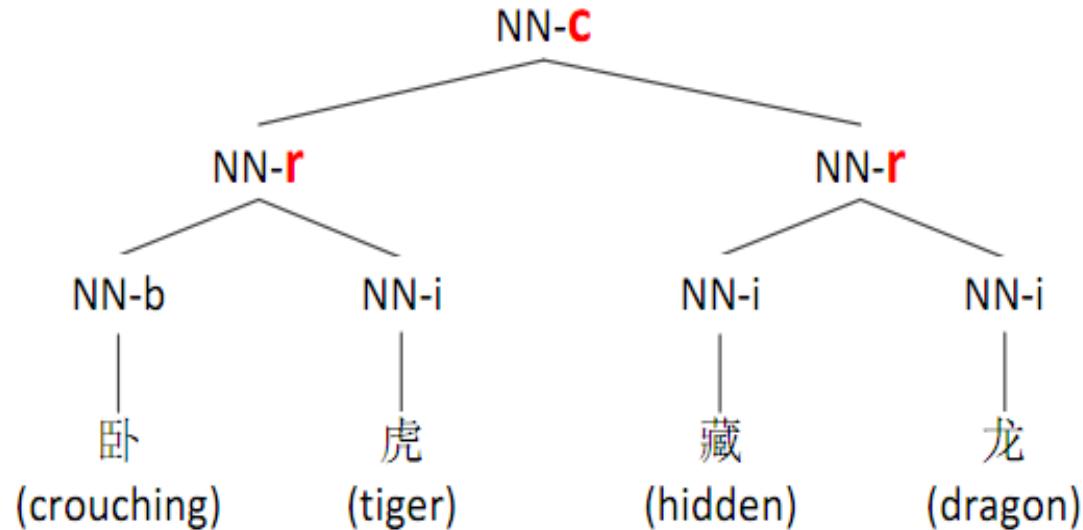


(c) coordination. (d) modifier-noun.



# Joint Segmentation, POS-tagging and Constituent Parsing

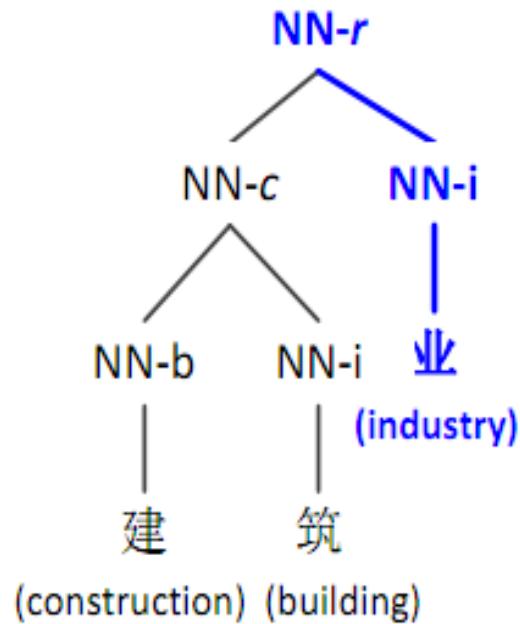
- Why character-based?
  - Chinese words have syntactic structures.





# Joint Segmentation, POS-tagging and Constituent Parsing

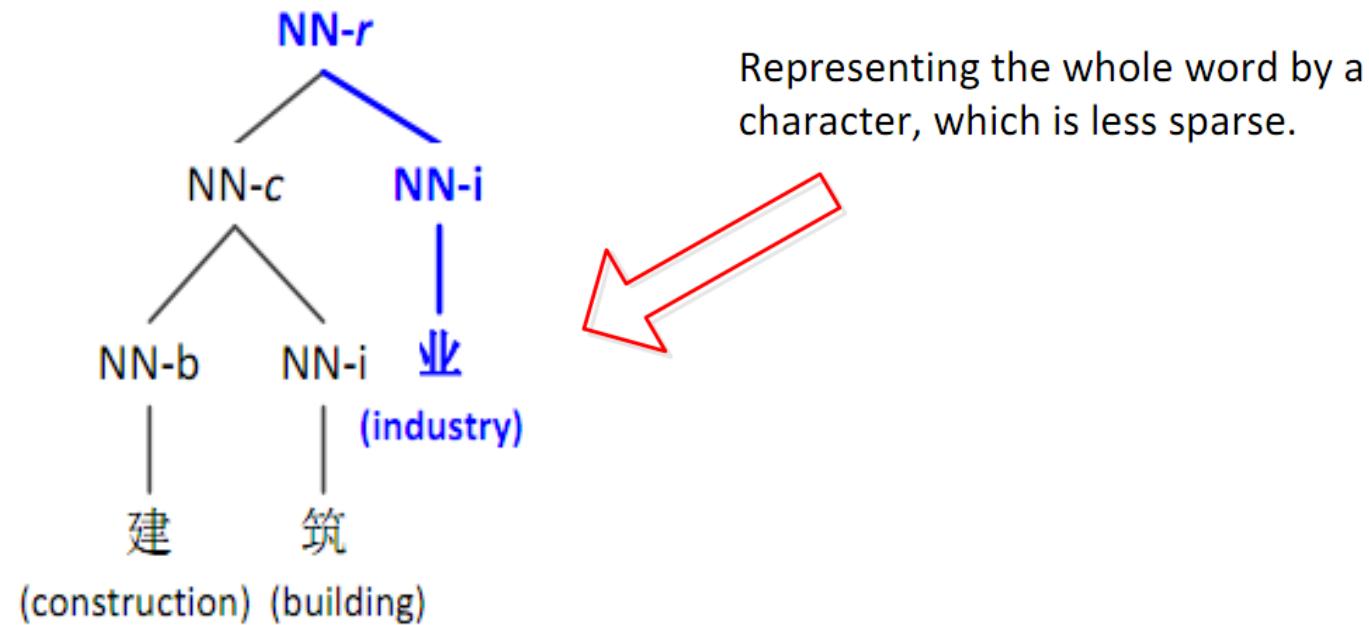
- Why character-based?
  - Deep character information of word structures.





# Joint Segmentation, POS-tagging and Constituent Parsing

- Why character-based?
  - Deep character information of word structures.



# Joint Segmentation, POS-tagging and Constituent Parsing

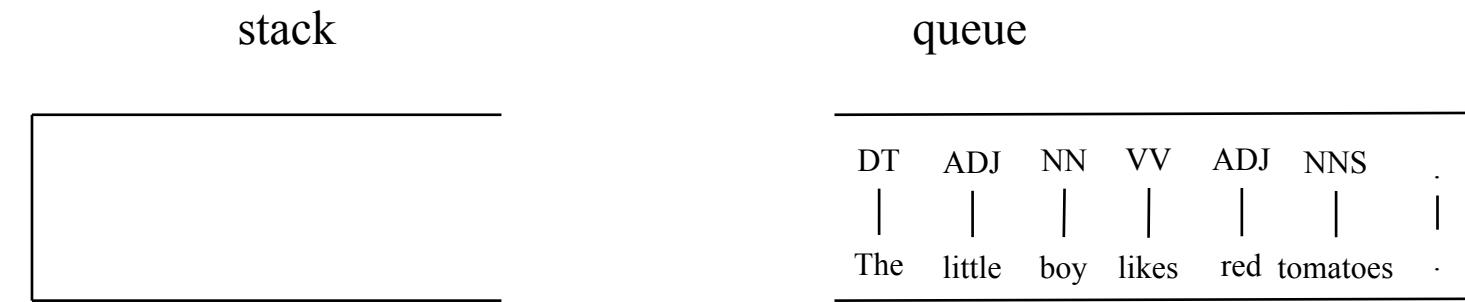


- The character-based parsing model
  - A transition-based parser



# Transition-based Constituent Parsing

- Example
  - SHIFT





# Transition-based Constituent Parsing

- Example
  - SHIFT





# Transition-based Constituent Parsing

- Example
  - SHIFT





# Transition-based Constituent Parsing

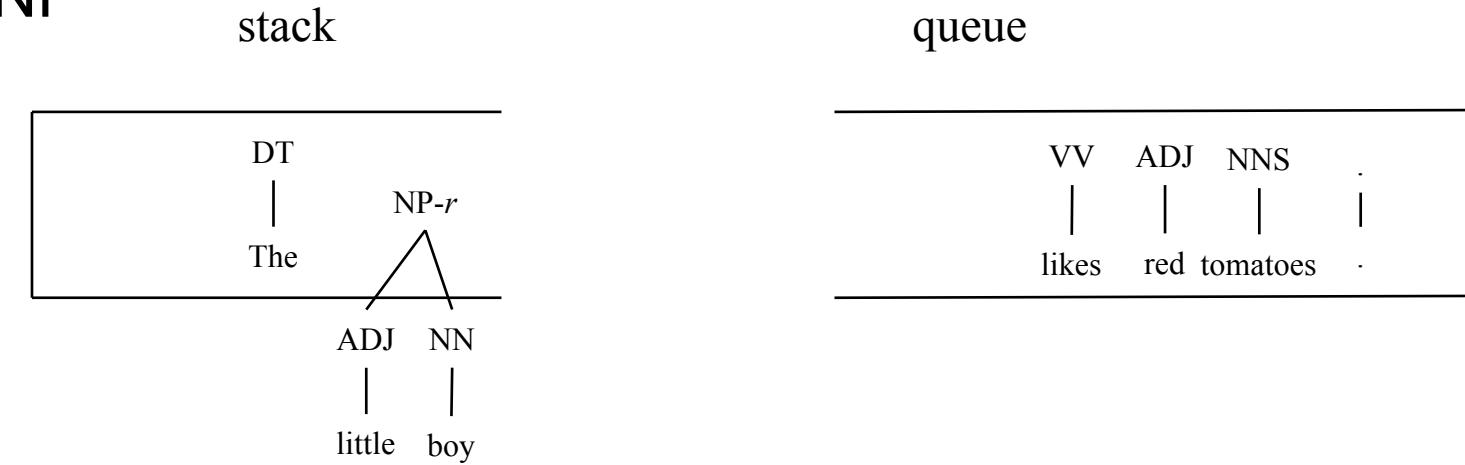
- Example
  - REDUCE-R-NP





# Transition-based Constituent Parsing

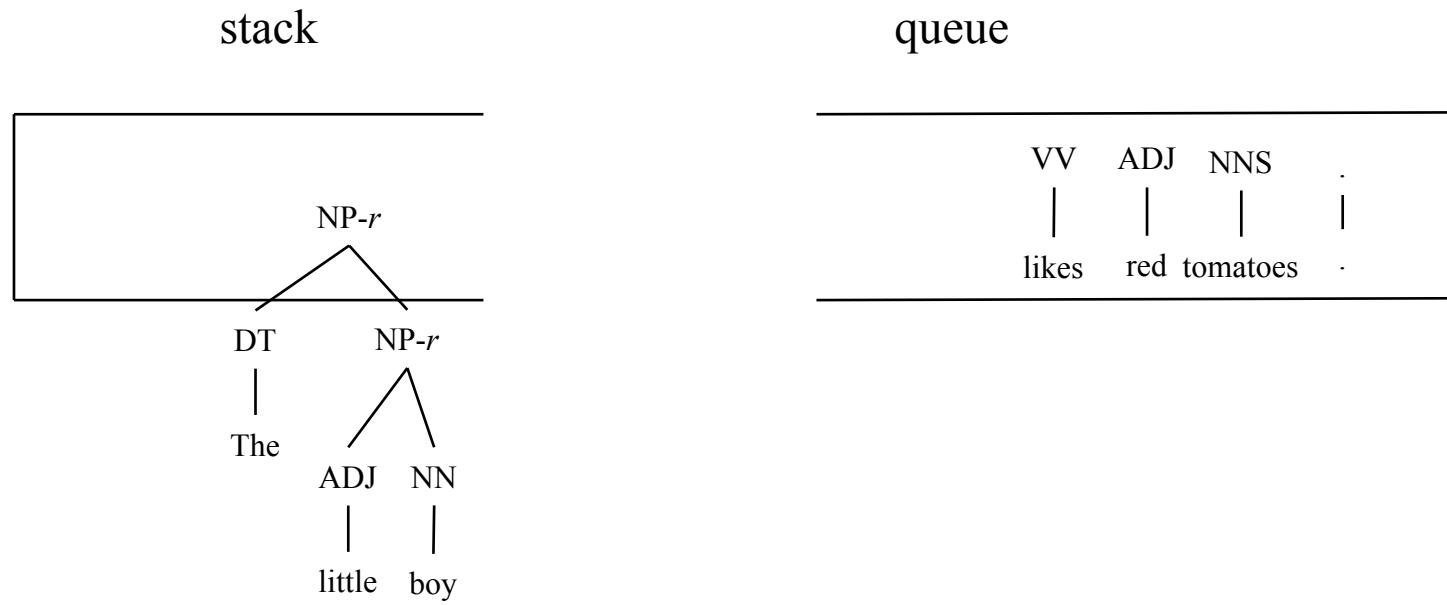
- Example
  - REDUCE-R-NP





# Transition-based Constituent Parsing

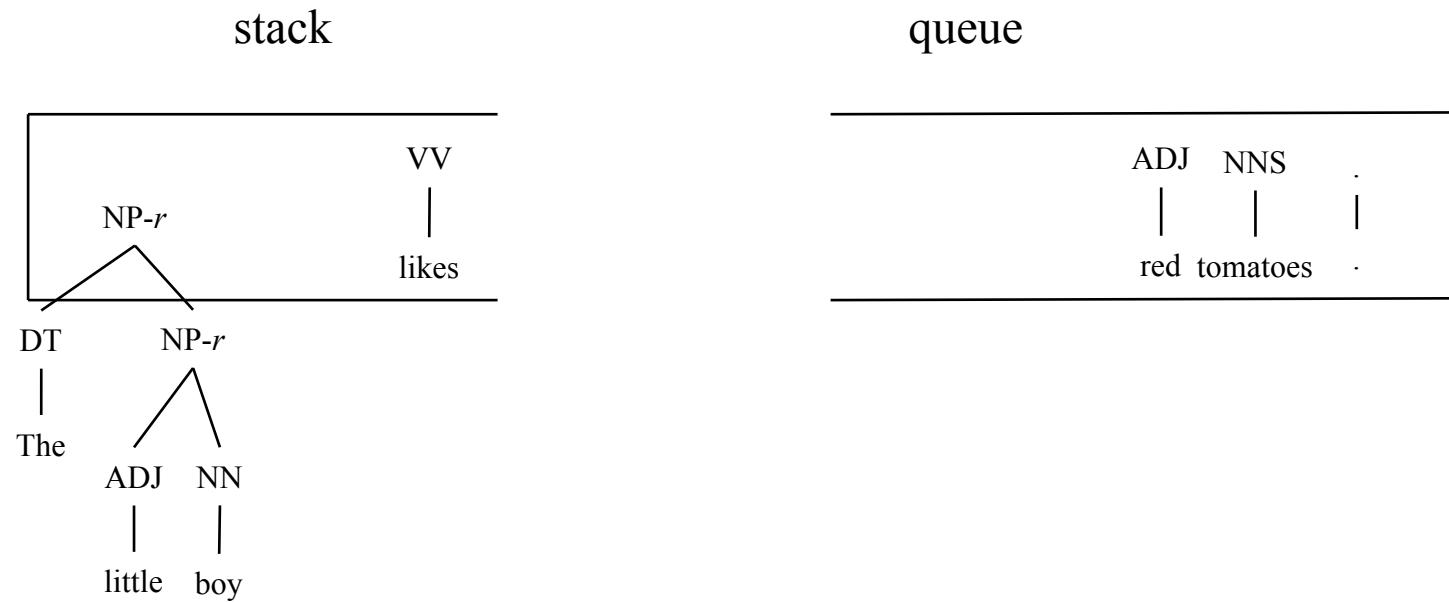
- Example
  - SHIFT





# Transition-based Constituent Parsing

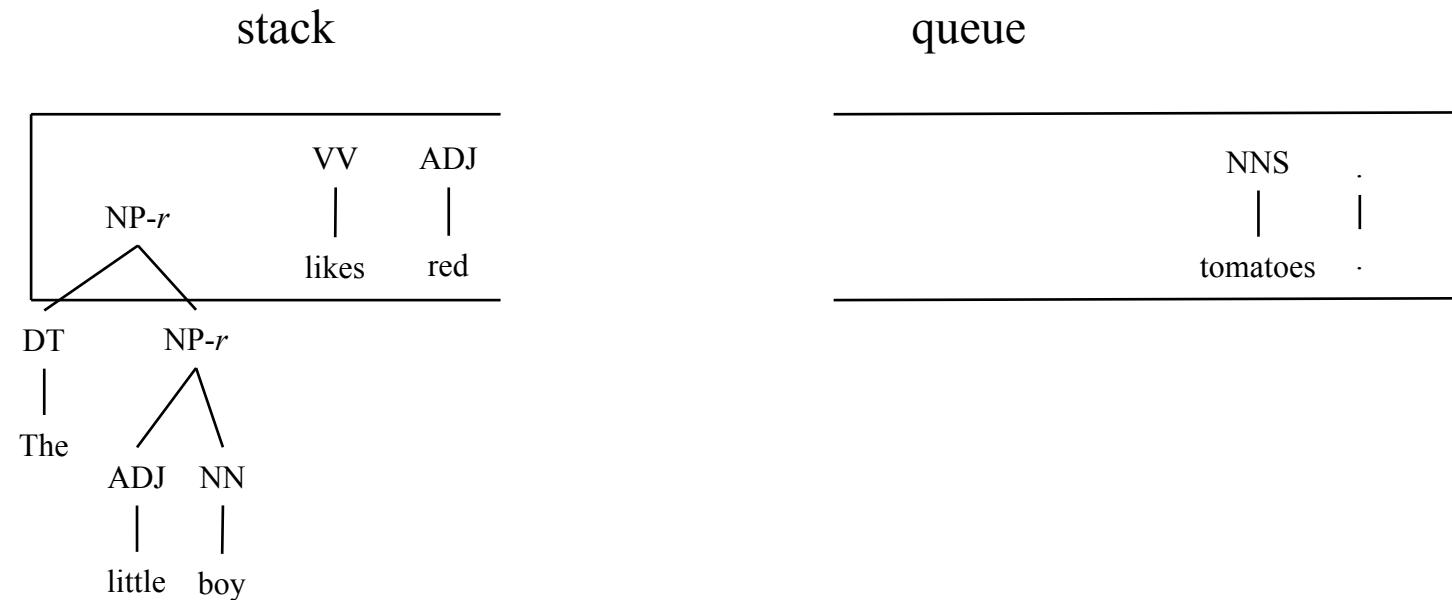
- Example
  - SHIFT





# Transition-based Constituent Parsing

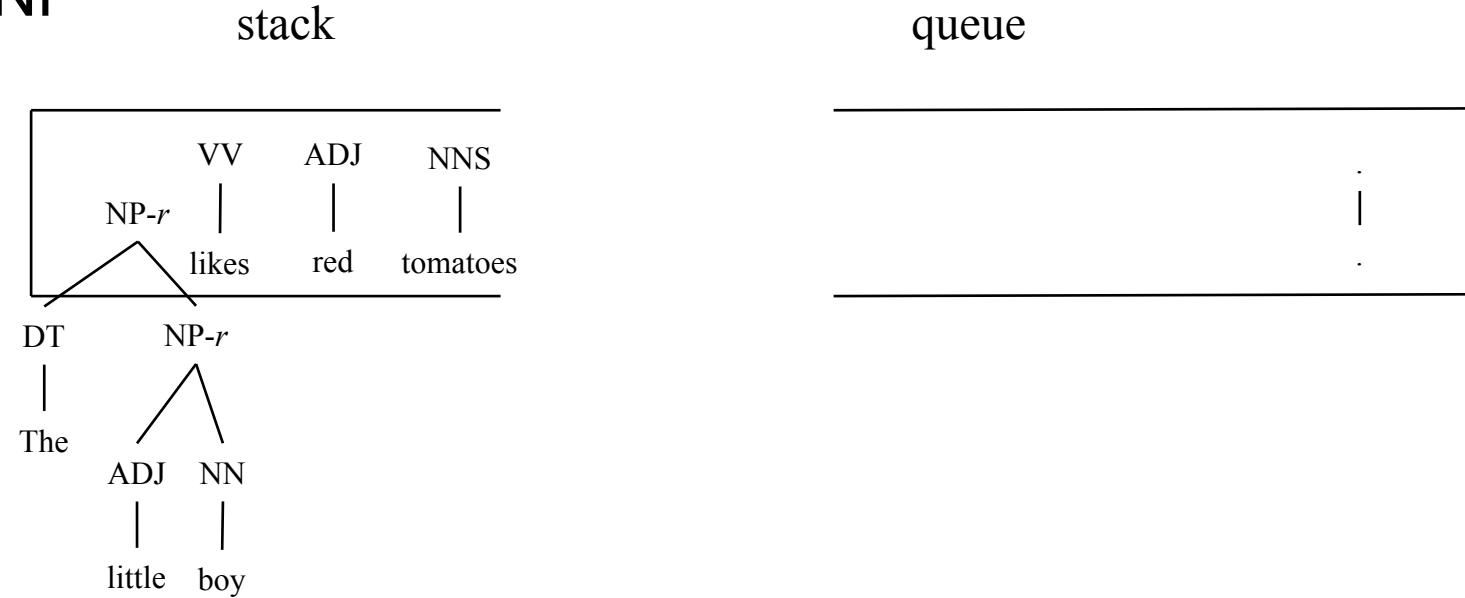
- Example
  - SHIFT





# Transition-based Constituent Parsing

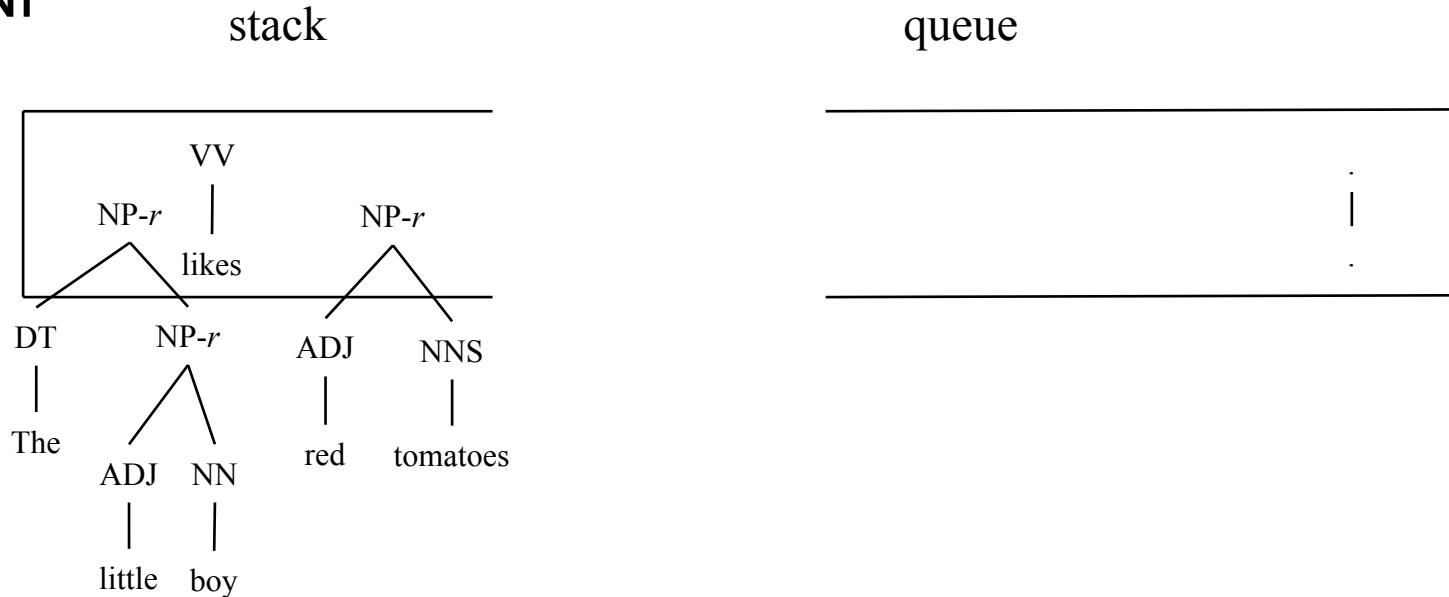
- Example
    - REDUCE-R-NP





# Transition-based Constituent Parsing

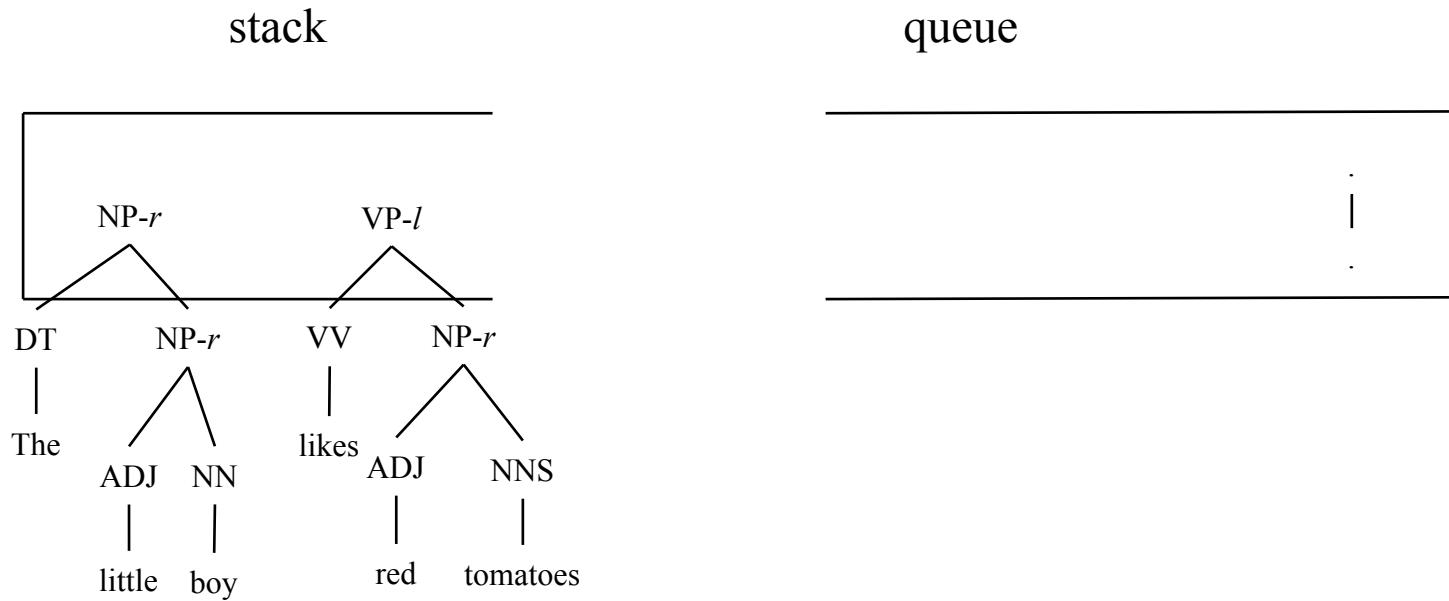
- Example
  - REDUCE-L-NP





# Transition-based Constituent Parsing

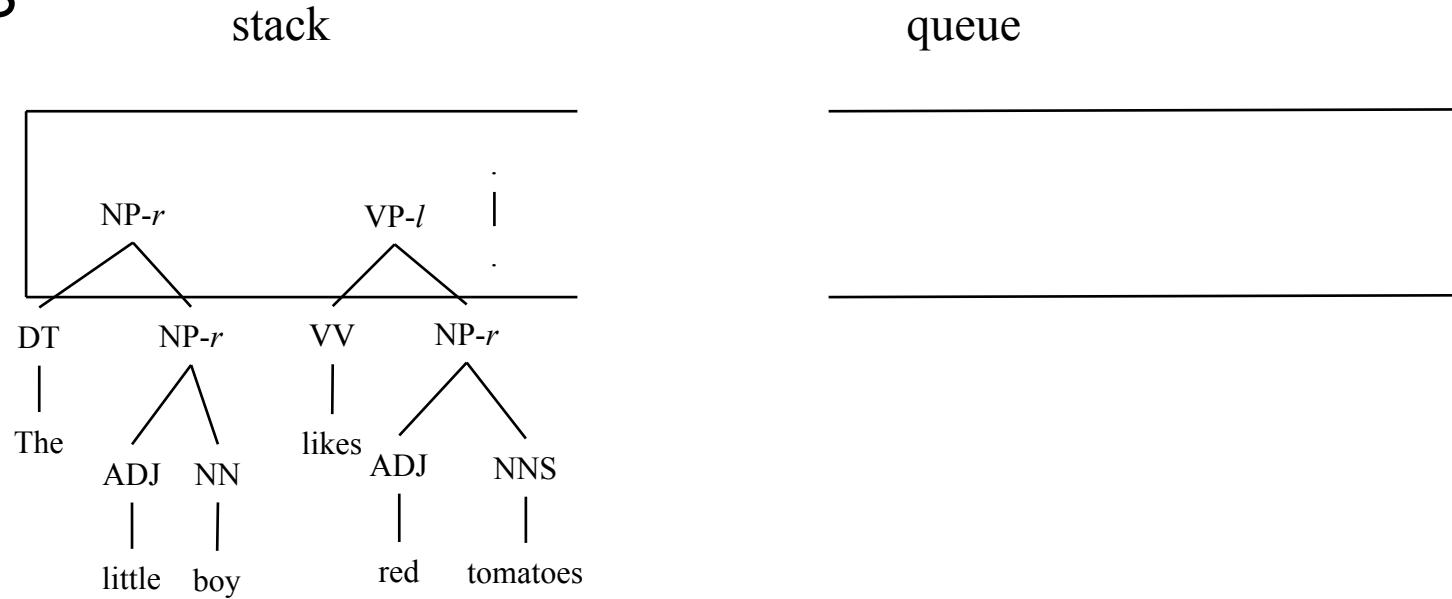
- Example
  - SHIFT





# Transition-based Constituent Parsing

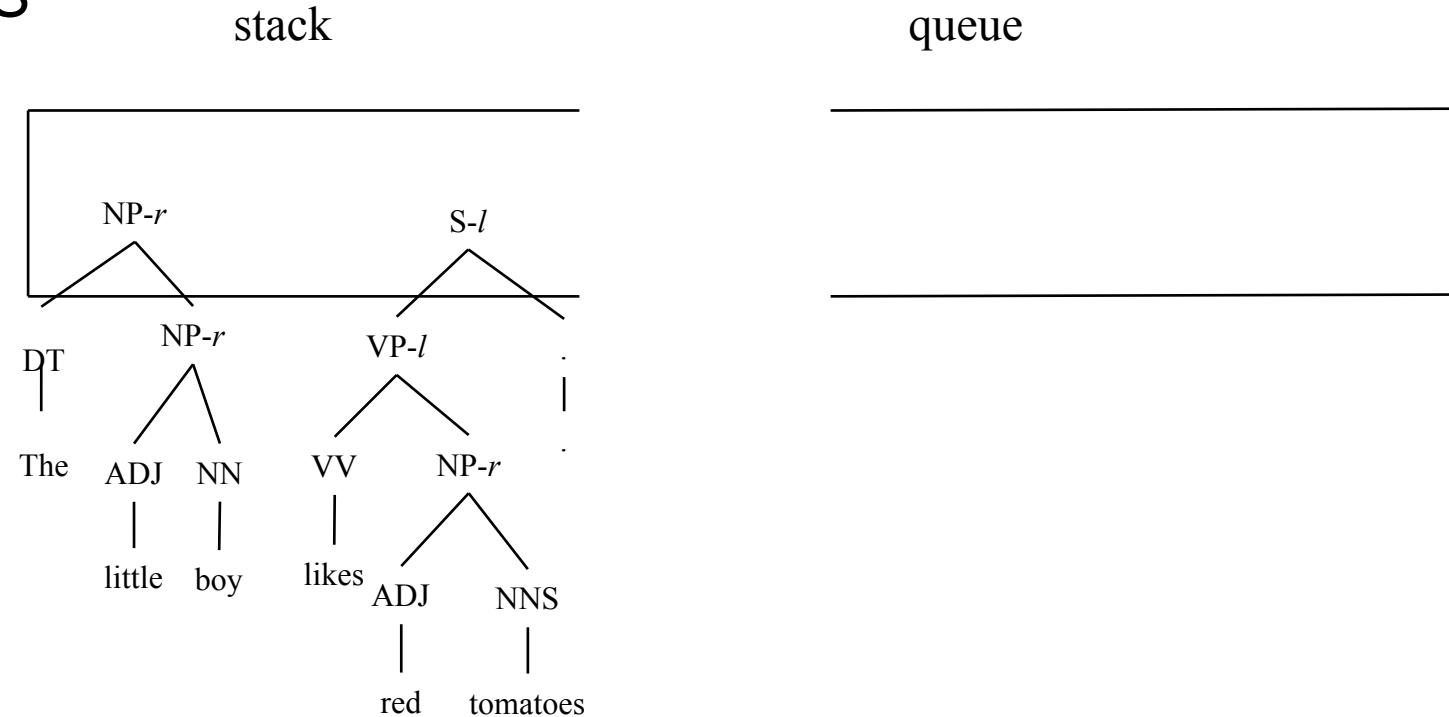
- Example
  - REDUCE-L-S





# Transition-based Constituent Parsing

- Example
    - REDUCE-R-S



Yue Zhang and Stephen Clark. 2011. *Syntactic Processing Using the Generalized Perceptron and Beam Search*. In *Computational Linguistics*, 37(1), March.

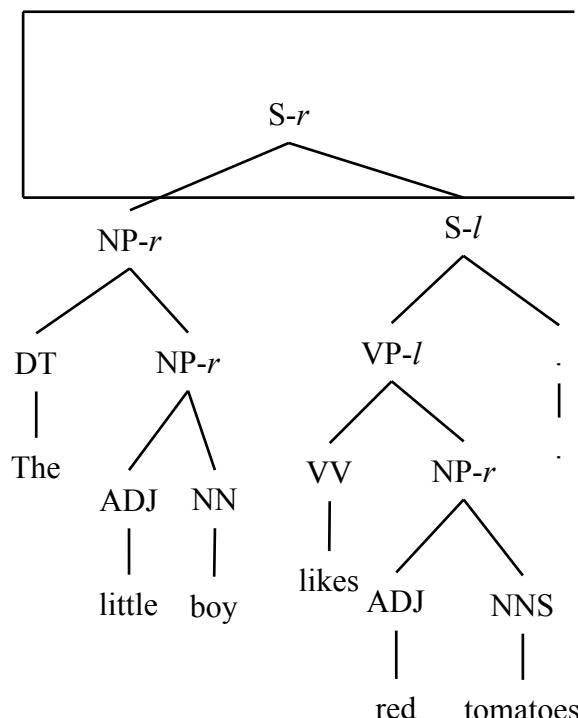


# Transition-based Constituent Parsing

- Example
  - TERMINATE

stack

queue



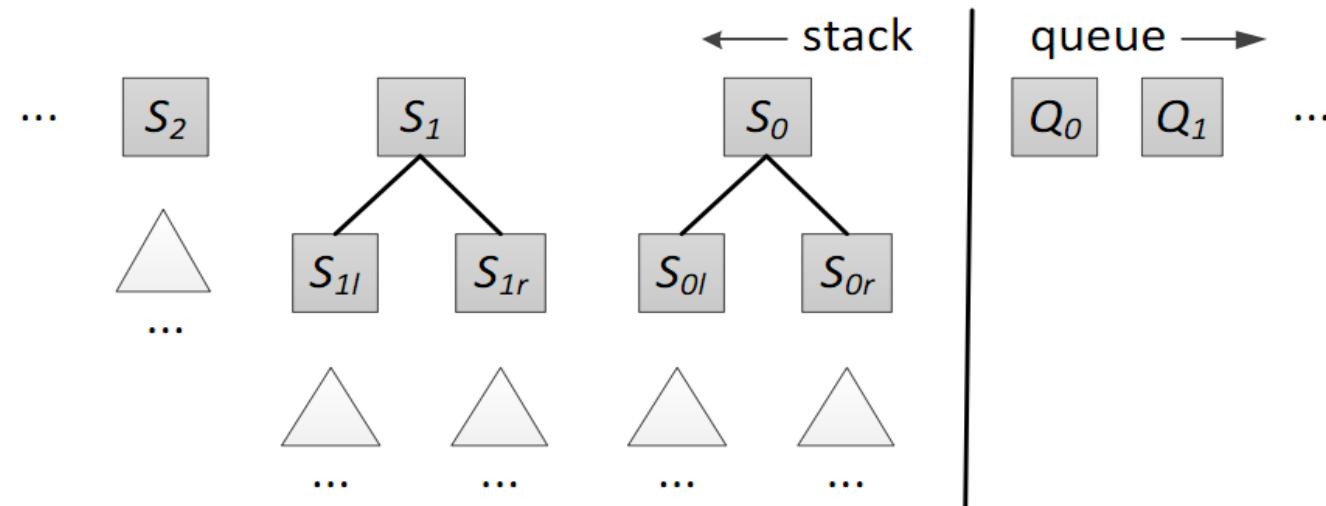
Yue Zhang and Stephen Clark. 2011. *Syntactic Processing Using the Generalized Perceptron and Beam Search*. In *Computational Linguistics*, 37(1), March.



# Joint Segmentation, POS-tagging and Constituent Parsing

- The transition system

- State:



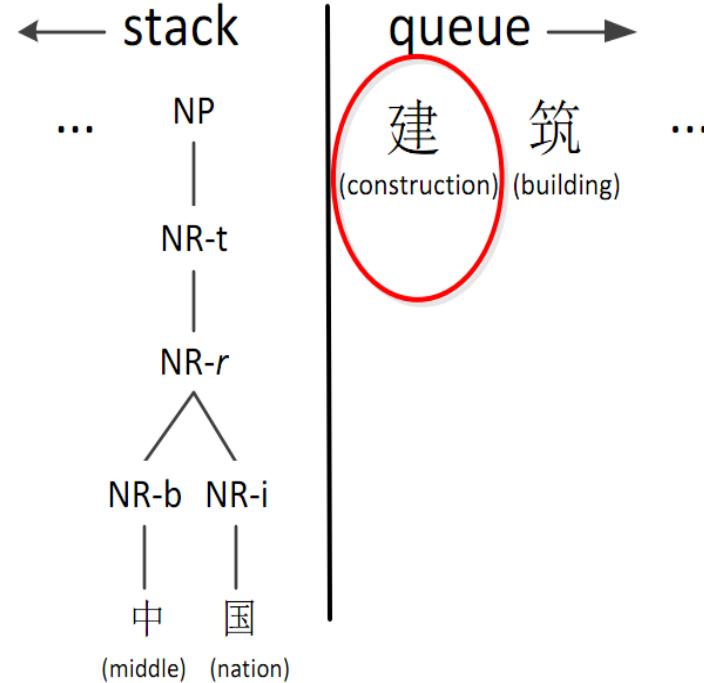
- Actions:

- SHIFT-SEPARATE( $t$ ), SHIFT-APPEND, REDUCE-SUBWORD( $d$ ),  
REDUCE-WORD, REDUCE-BINARY( $d;I$ ), REDUCE-UNARY( $I$ ), TERMINATE

# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

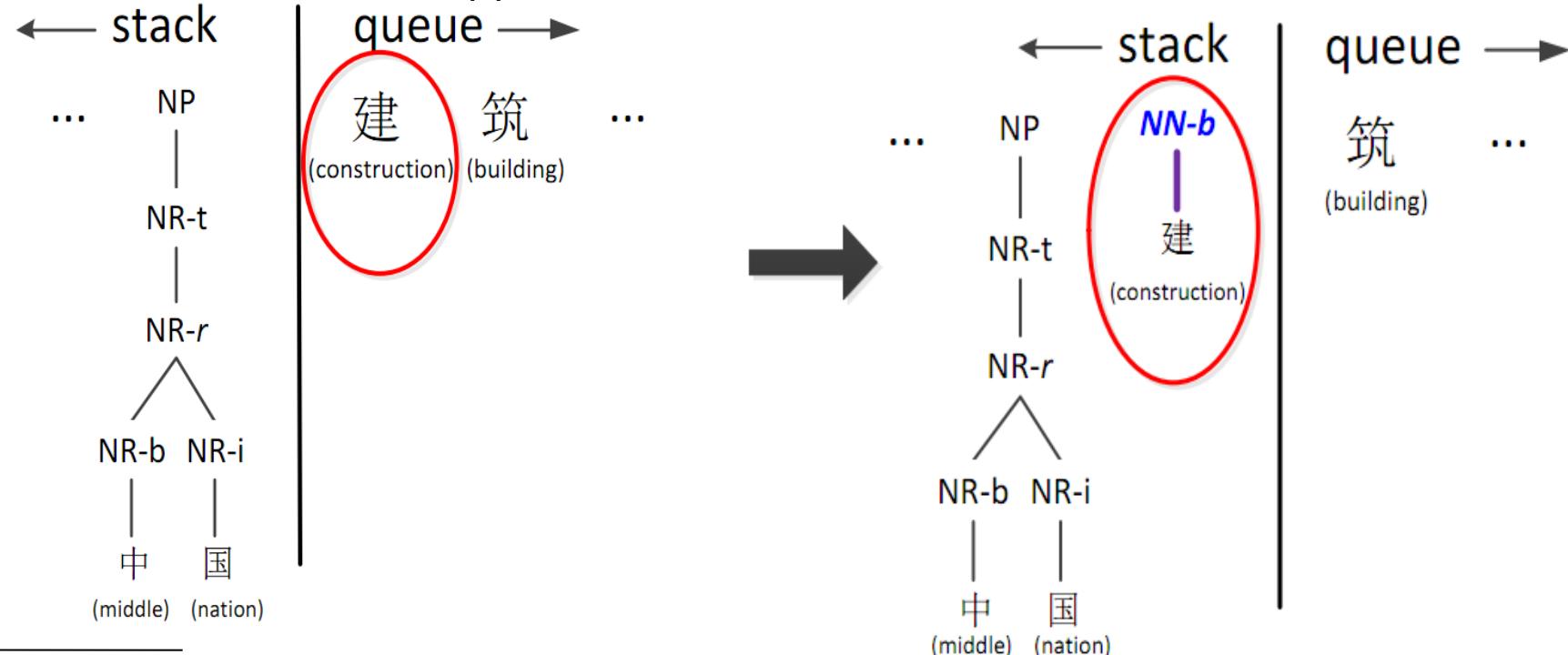
- SHIFT-SEPARATE( $t$ )



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

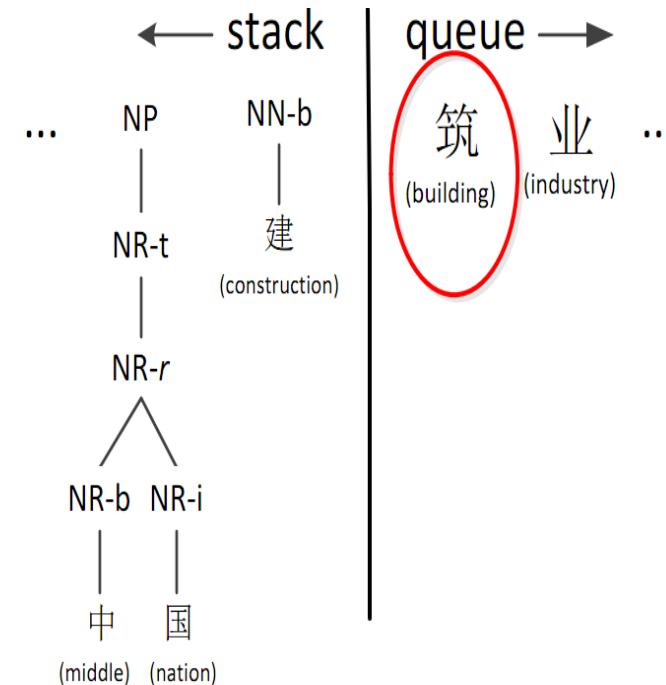
- SHIFT-SEPARATE( $t$ )





# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions
  - SHIFT-APPEND

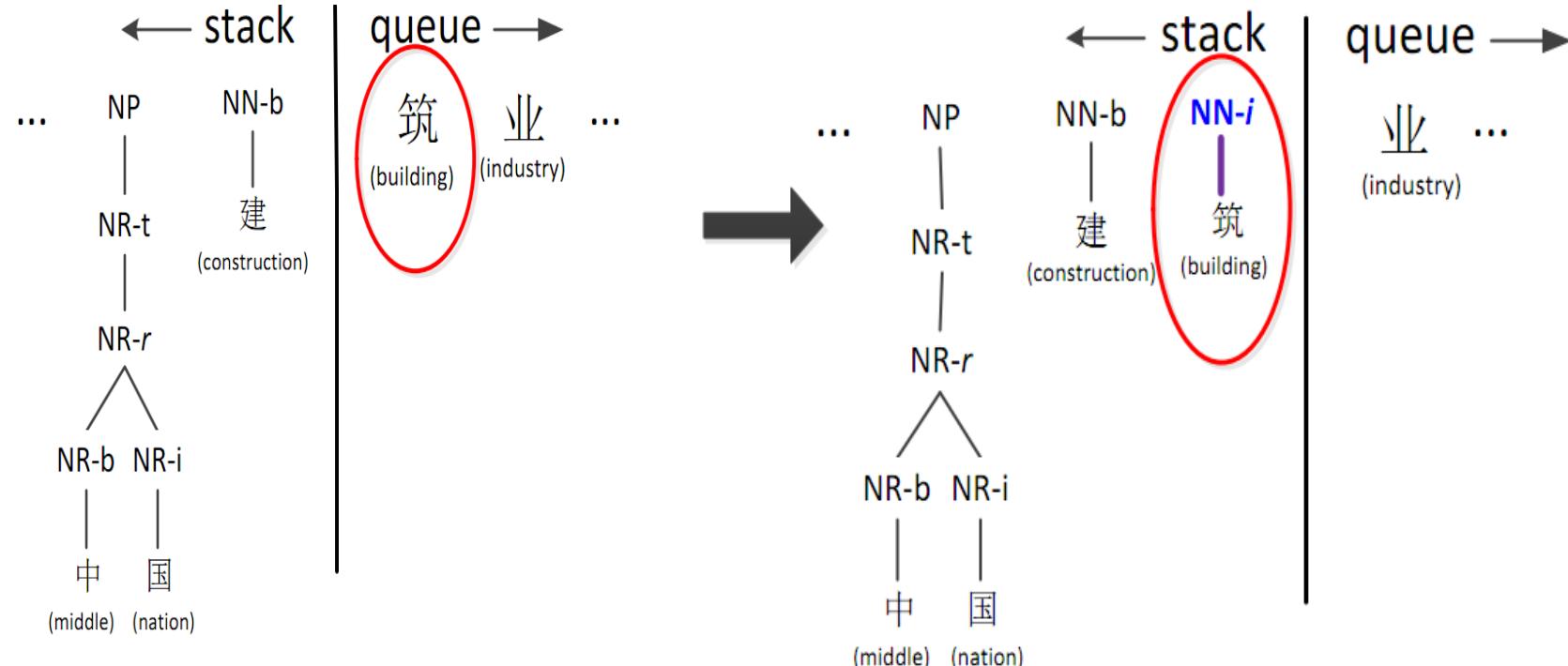


# Joint Segmentation, POS-tagging and Constituent Parsing



- ## • Actions

- SHIFT-APPEND

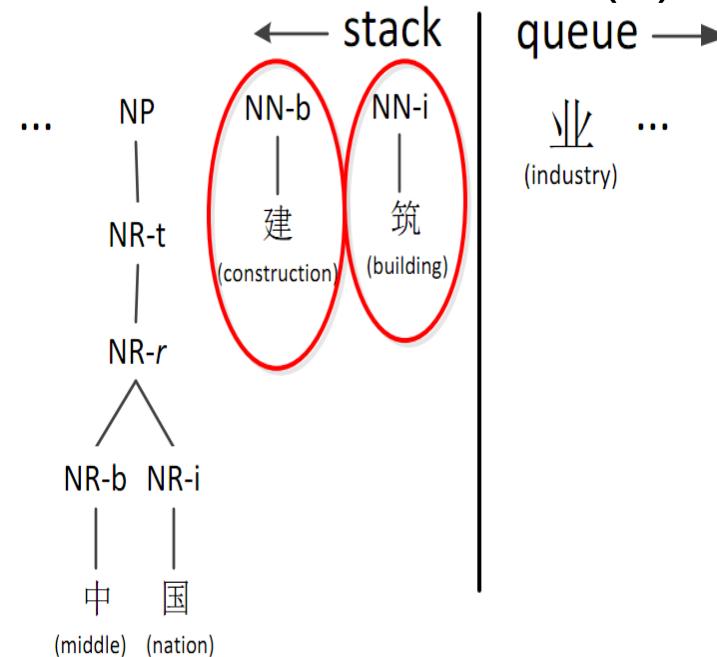




# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

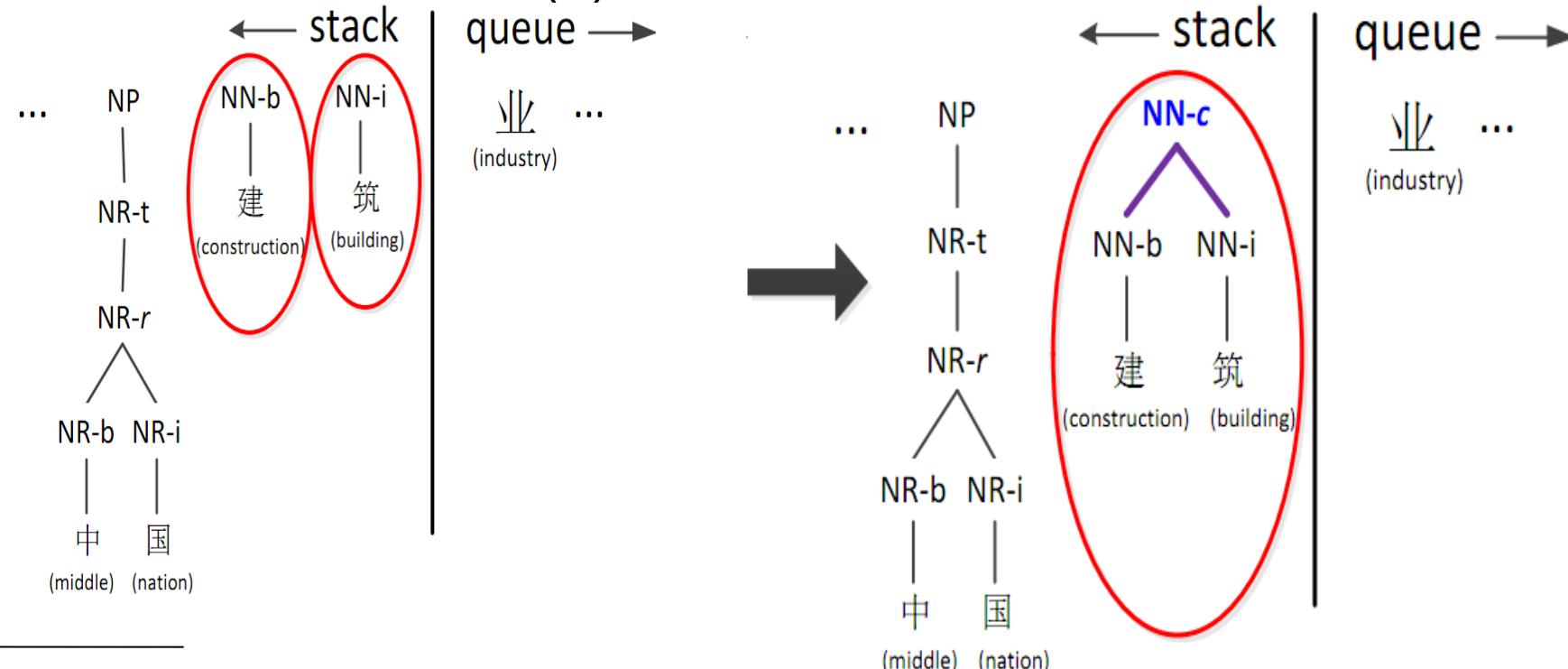
- REDUCE-SUBWORD(d)



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

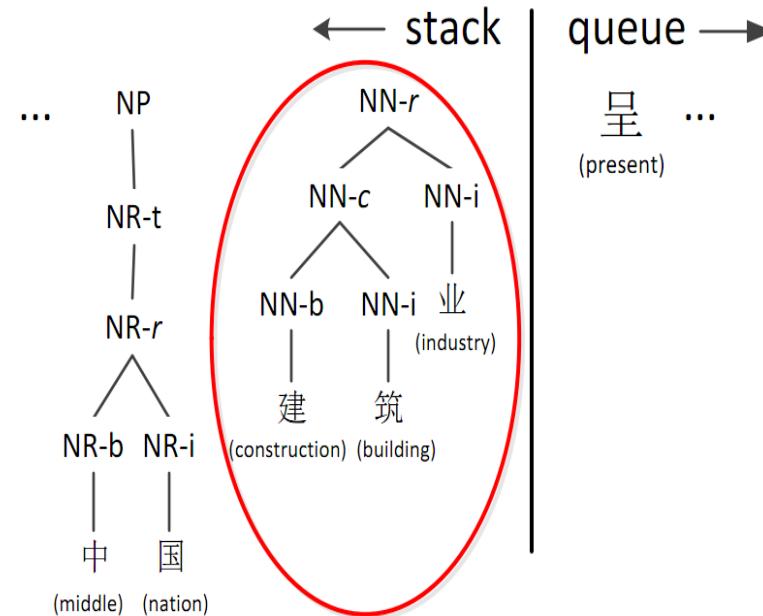
- REDUCE-SUBWORD(d)



# Joint Segmentation, POS-tagging and Constituent Parsing

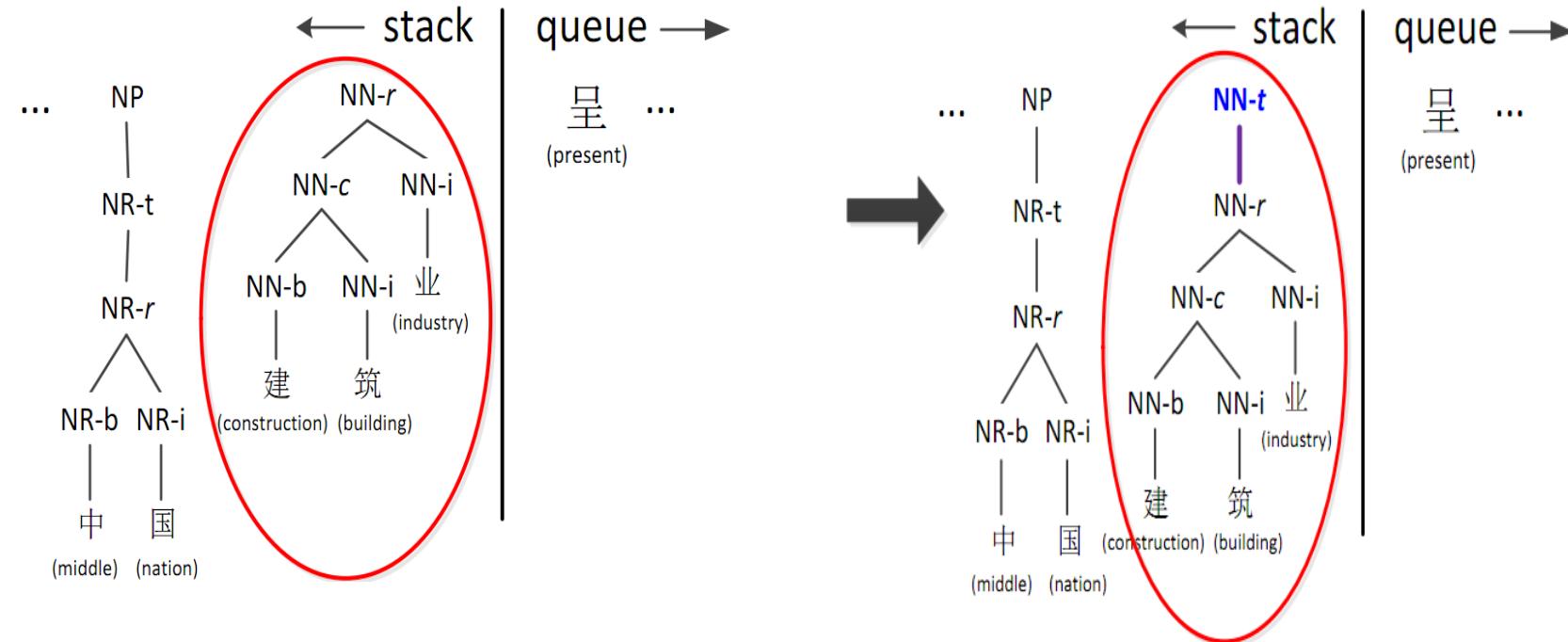


- Actions
    - REDUCE-WORD



# Joint Segmentation, POS-tagging and Constituent Parsing

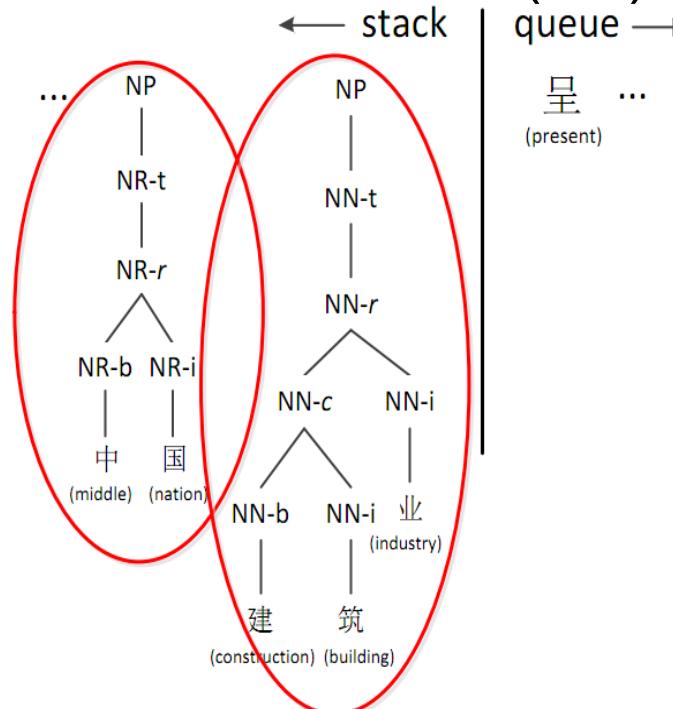
- Actions
  - REDUCE-WORD



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

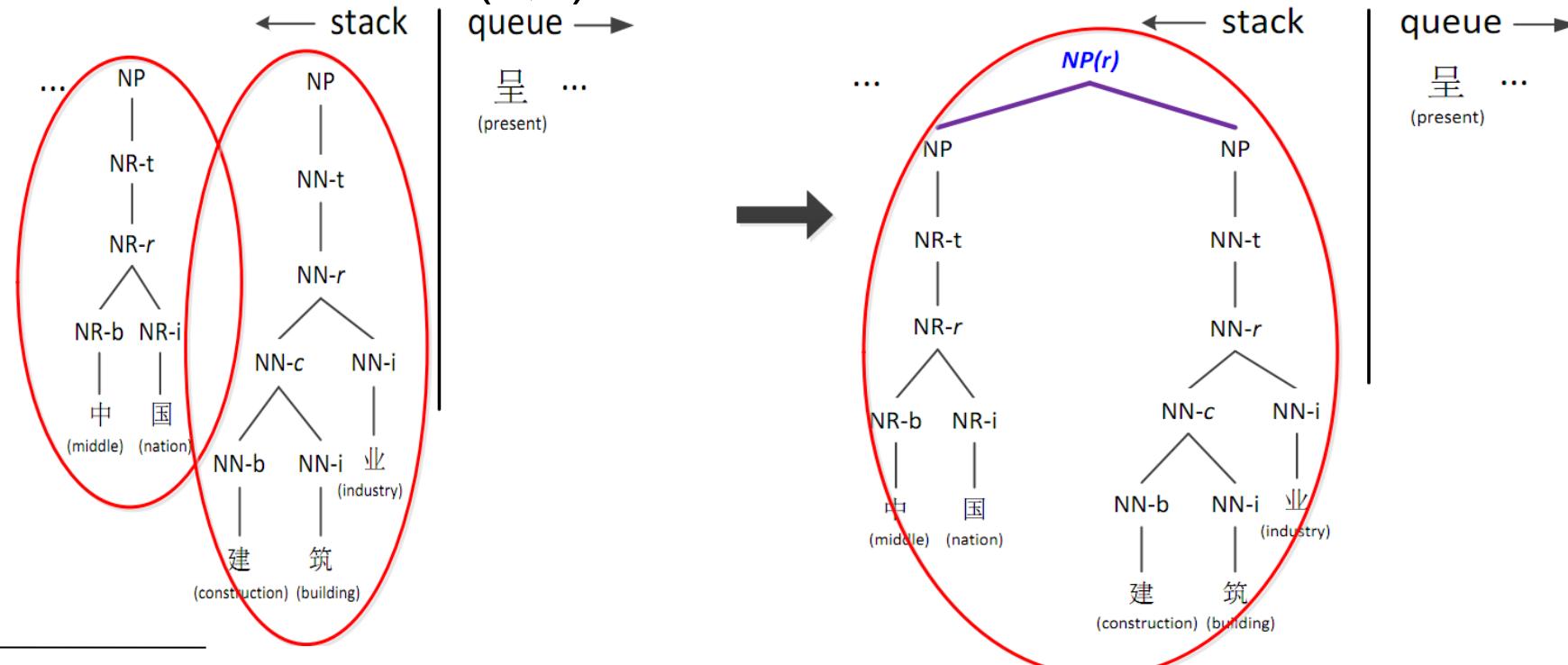
- REDUCE-BINARY( $d; l$ )



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

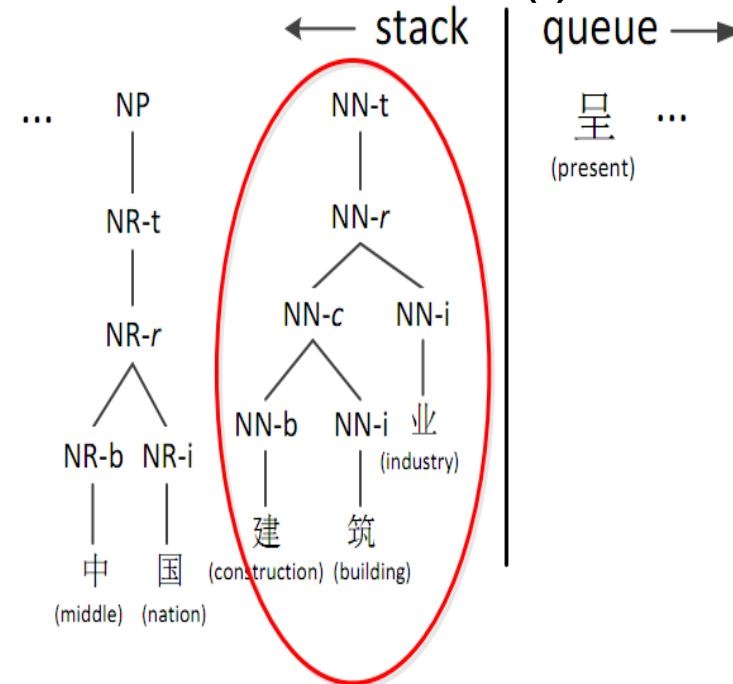
- REDUCE-BINARY( $d; l$ )



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

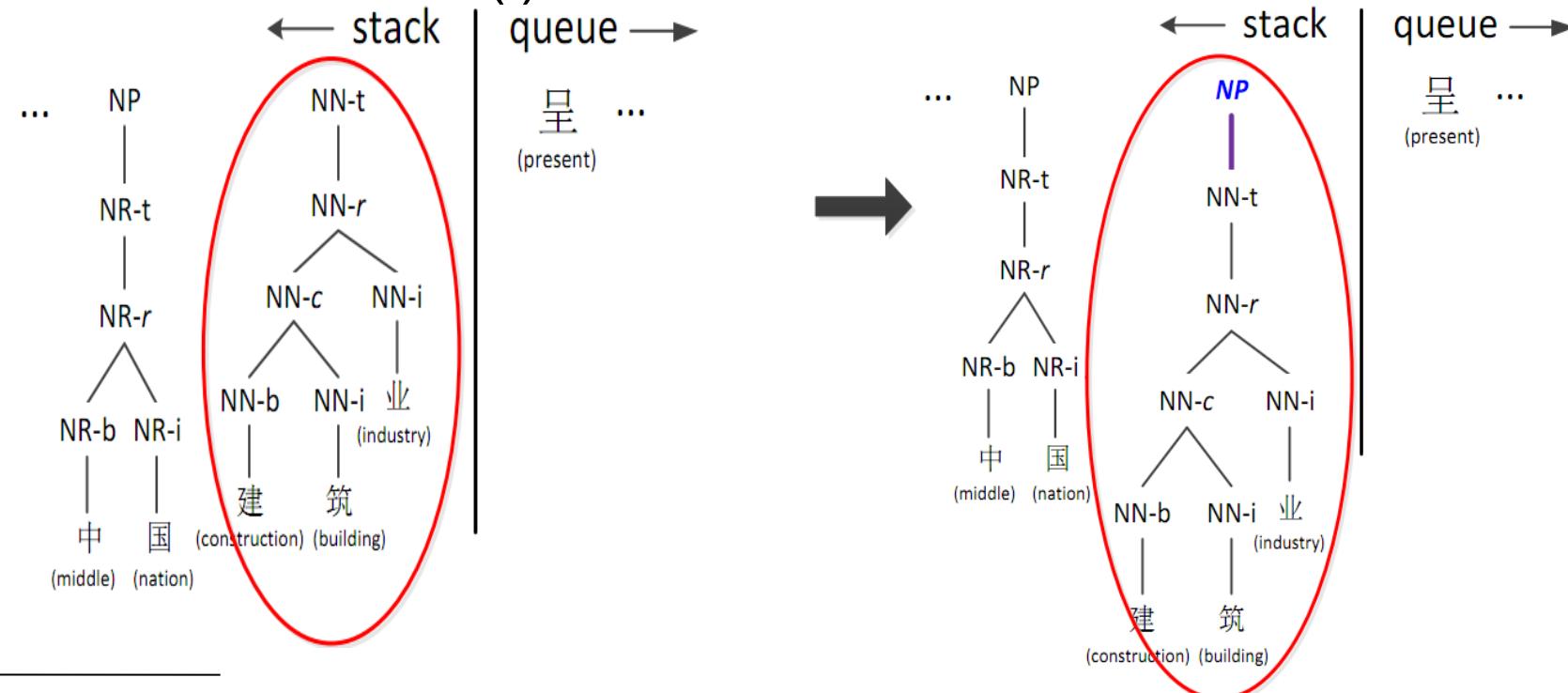
- REDUCE-UNARY(*i*)



# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions

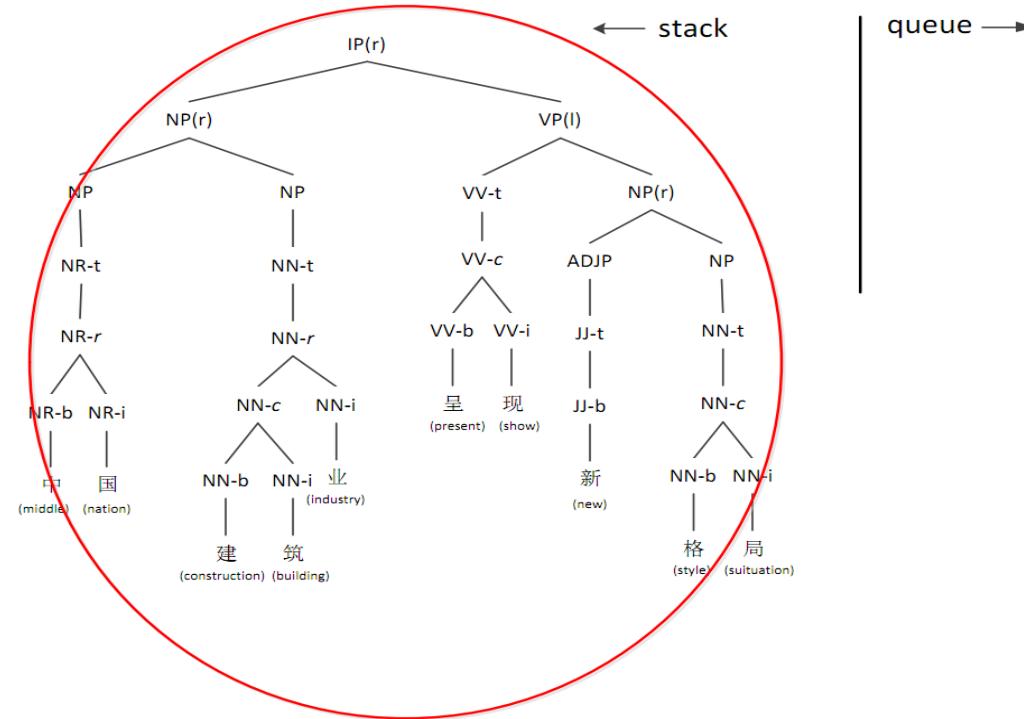
- REDUCE-UNARY(I)





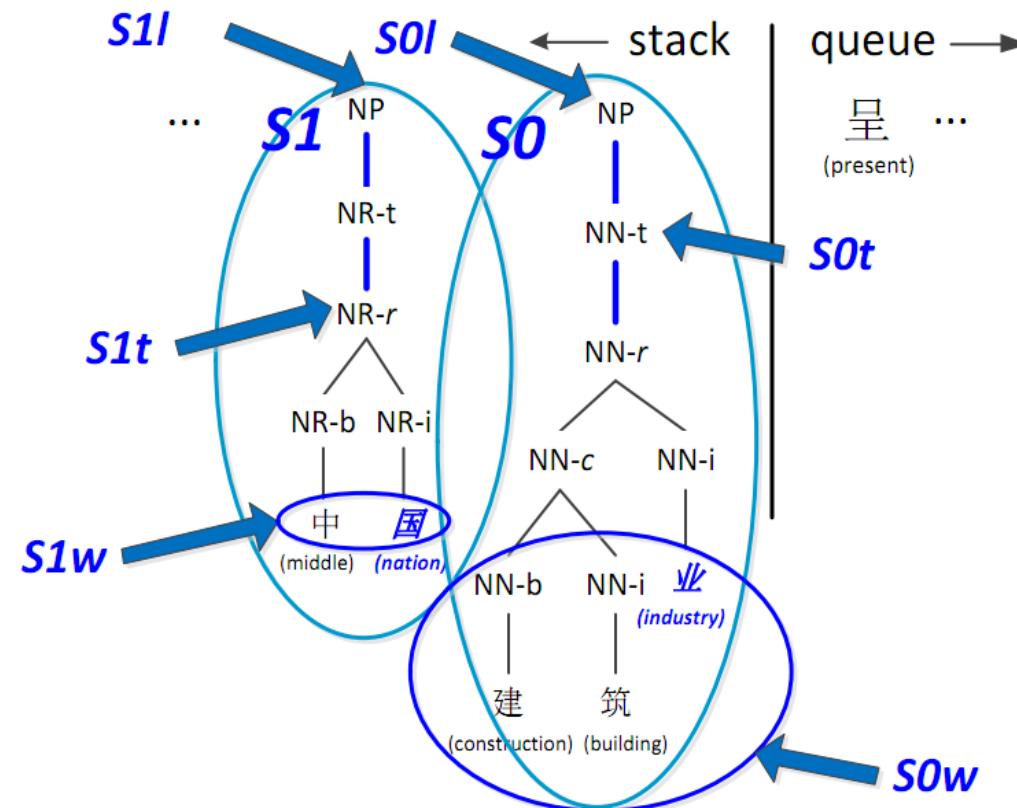
# Joint Segmentation, POS-tagging and Constituent Parsing

- Actions
  - TERMINATE



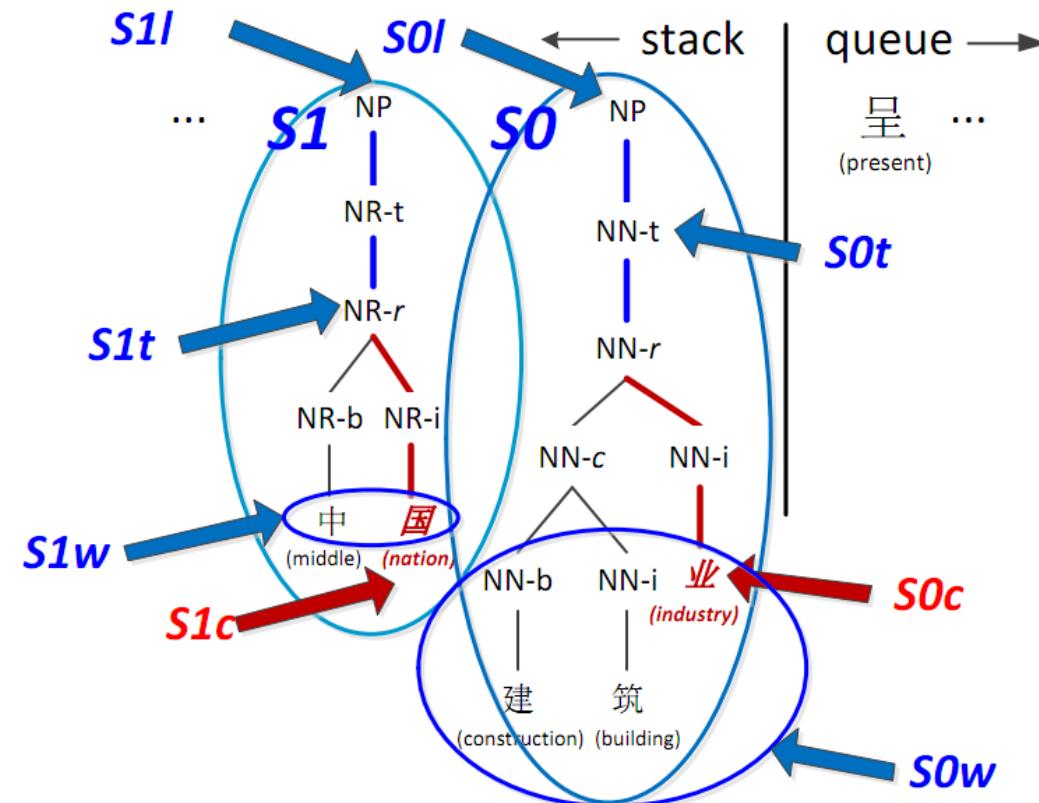
# Joint Segmentation, POS-tagging and Constituent Parsing

- Features



# Joint Segmentation, POS-tagging and Constituent Parsing

- Features





# Joint Segmentation, POS-tagging and Constituent Parsing

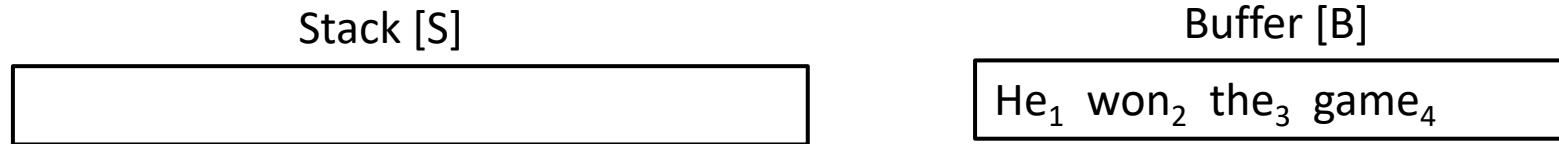
- Results on CTB

Task	Seg	Tag	Parse
Kruengkrai+ '09	97.87	93.67	—
Sun '11	98.17	94.02	—
Wang+ '11	98.11	94.18	—
Li '11	97.3	93.5	79.7
Li+ '12	97.50	93.31	—
Hatori+ '12	98.26	94.64	—
Qian+ '12	97.96	93.81	82.85
Ours pipeline	97.69	93.83	82.26
Ours joint flat	97.73	94.48	83.61
Ours joint annotated	97.84	94.80	84.43



# Joint POS tagging and Dependency Parsing

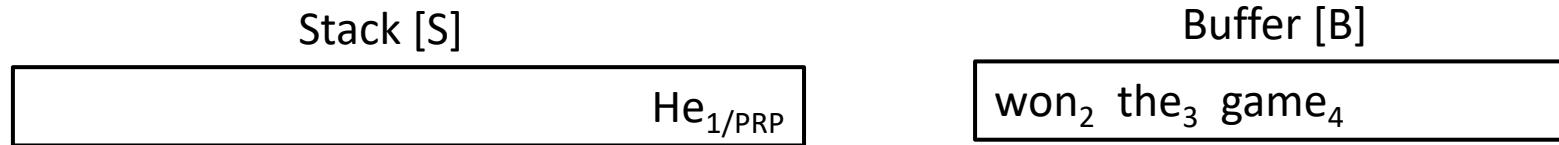
- Actions
  - INITIALIZATION





# Joint POS tagging and Dependency Parsing

- Actions
  - SHIFT(TAG<sub>PRP</sub>)





# Joint POS tagging and Dependency Parsing

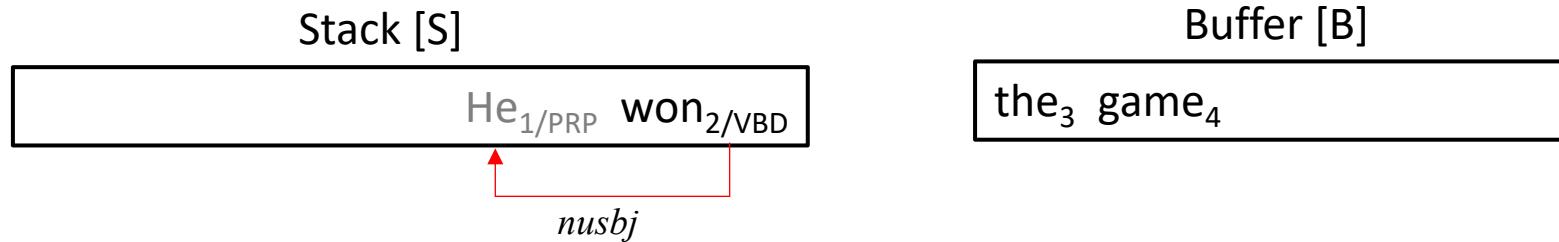
- Actions
  - SHIFT( $\text{TAG}_{\text{VBD}}$ )





# Joint POS tagging and Dependency Parsing

- Actions
  - $\text{LEFT}(\text{LABEL}_{n\text{subj}})$





# Joint POS tagging and Dependency Parsing

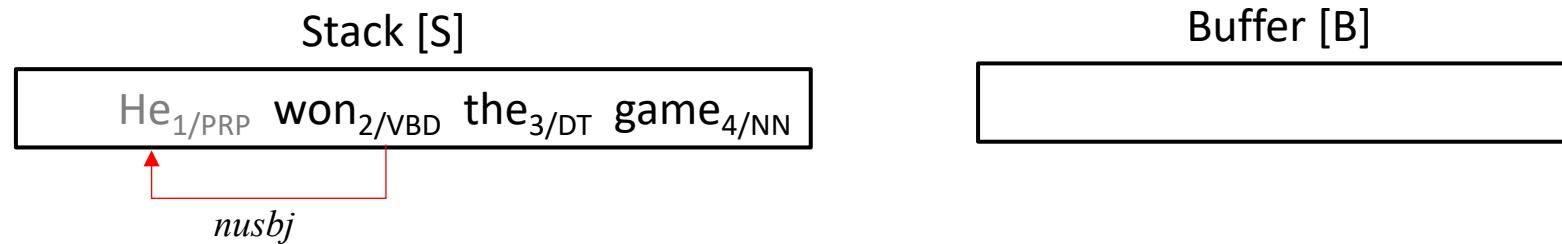
- Actions
  - SHIFT( $\text{TG}_{\text{DT}}$ )





# Joint POS tagging and Dependency Parsing

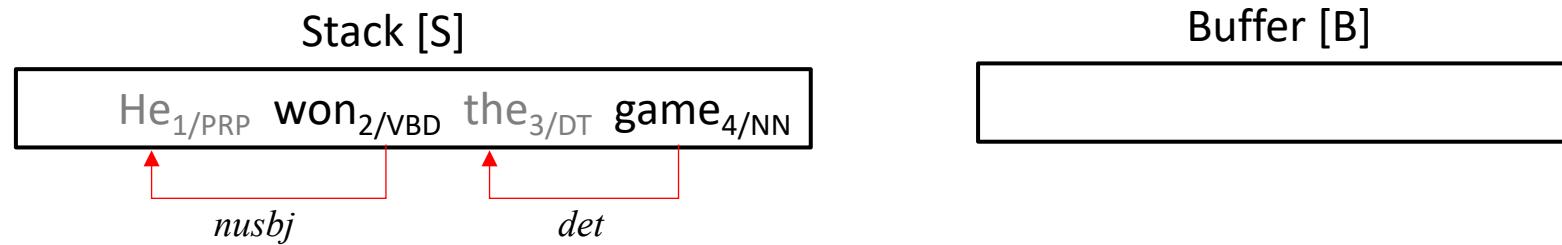
- Actions
  - SHIFT(TAG<sub>NN</sub>)



# Joint POS tagging and Dependency Parsing



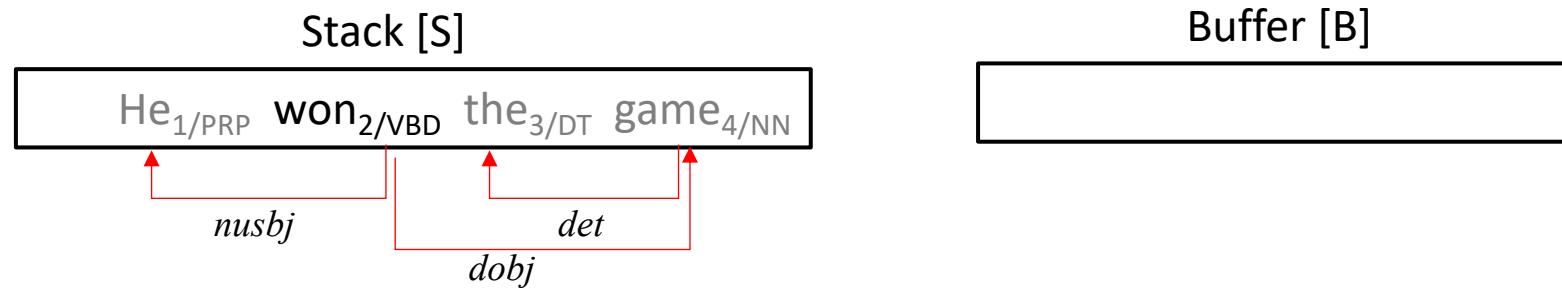
- Actions
  - $\text{LEFT}(\text{LABEL}_{\text{det}})$





# Joint POS tagging and Dependency Parsing

- Actions
  - $\text{RIGHT}(\text{LABEL}_{\text{dobj}})$





# Joint POS tagging and Dependency Parsing

- Results

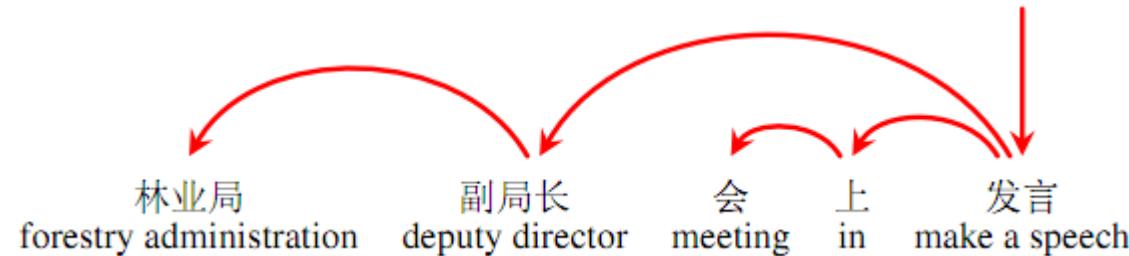
Confusion	Baseline		Joint	
	Freq	F-score	Freq	F-score
VVINF → VVFIN	28	91.1	2	97.7
VVINF → VVPP ADJ* NN	5		9	
VVFIN → VVINF	43	94.2	5	98.5
VVFIN → VVPP	20		2	
VAINF → VAFIN	10	99.1	1	99.9
NE → NN	184		128	
NE → ADJ* ADV FM	24	90.7	18	92.4
NE → XY	12		21	
NN → NE	85	97.5	67	98.1
NN → ADJ* XY ADV VV*	39		29	
PRELS → ART	13	92.9	5	95.4
PRELS → PWS	0		2	

*Selected entries for POS in German (benefit from joint model)*



# Joint Segmentation, POS-tagging and Dependency Parsing

- Traditional word-based dependency parsing
  - Inter-word dependencies

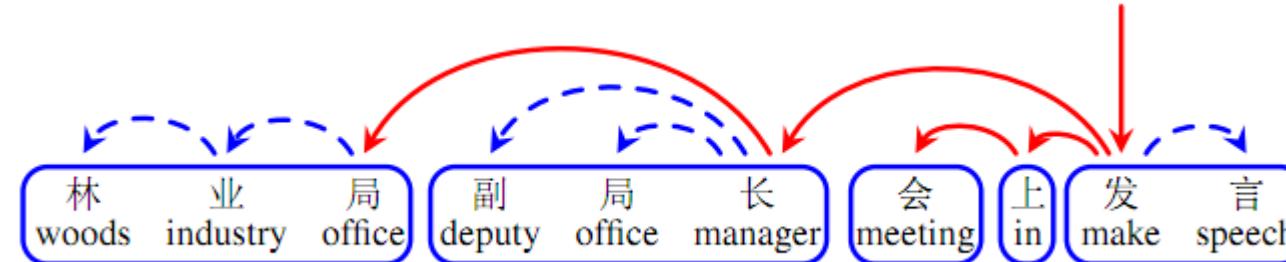


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Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

# Joint Segmentation, POS-tagging and Dependency Parsing

- Character-level dependency parsing
  - Inter- and intra-word dependencies



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Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

# Joint Segmentation, POS-tagging and Dependency Parsing



- Extensions from word-level transition-based dependency parsing models
  - Arc-standard (Nirve 2008; Huang et al., 2009 )
  - Arc-eager (Nirve 2008; Zhang and Clark, 2008)

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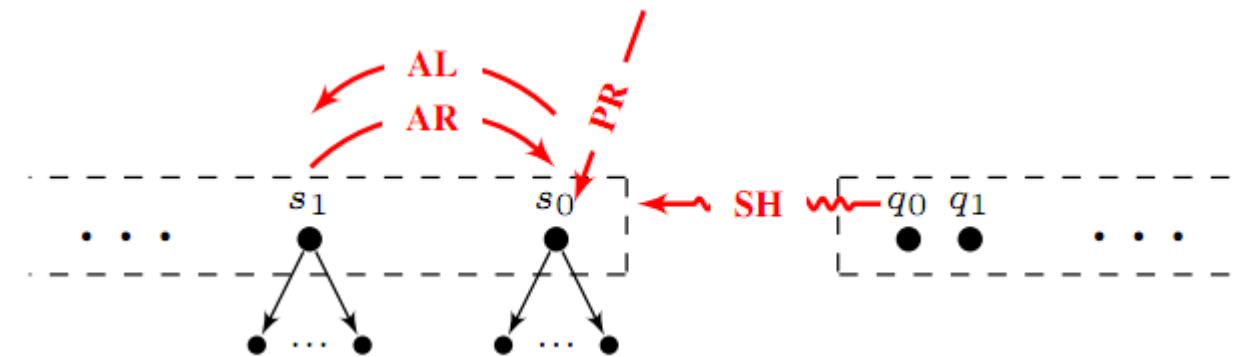
Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.

Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.



# Joint Segmentation, POS-tagging and Dependency Parsing

- Arc-standard



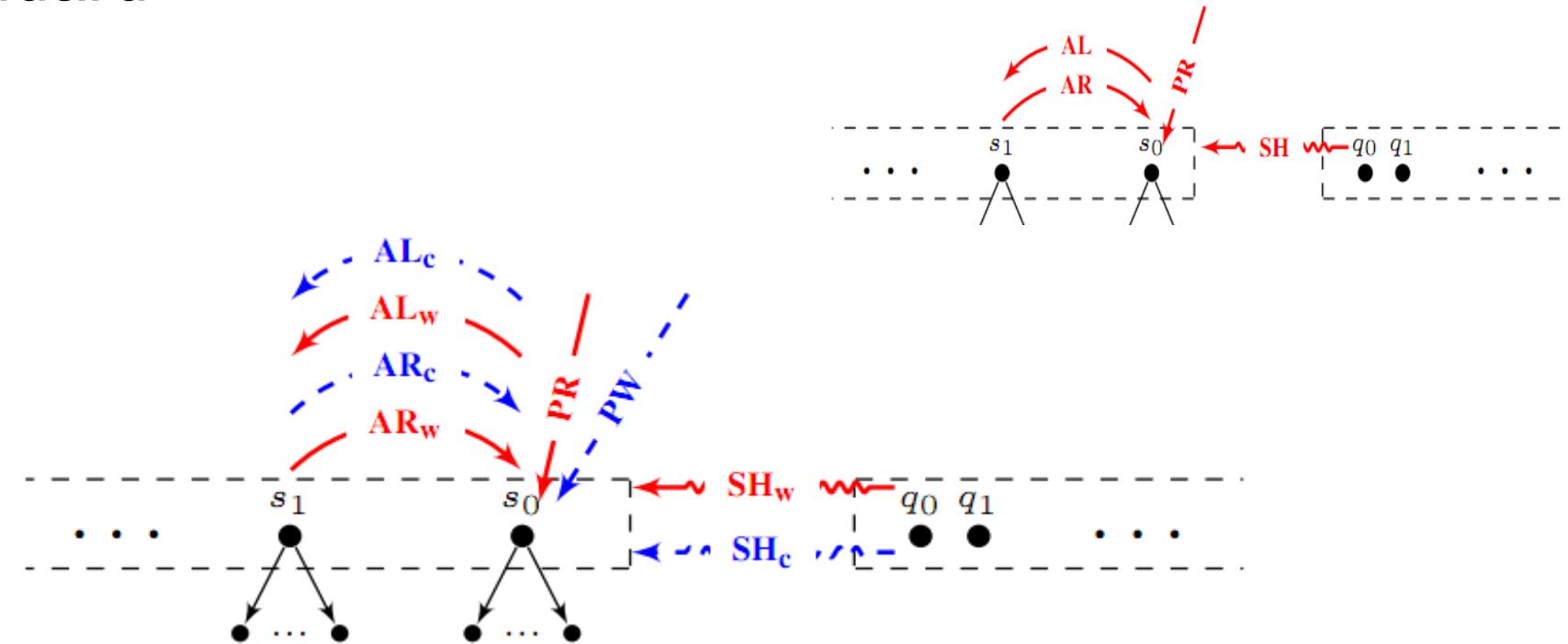
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Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
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# Joint Segmentation, POS-tagging and Dependency Parsing

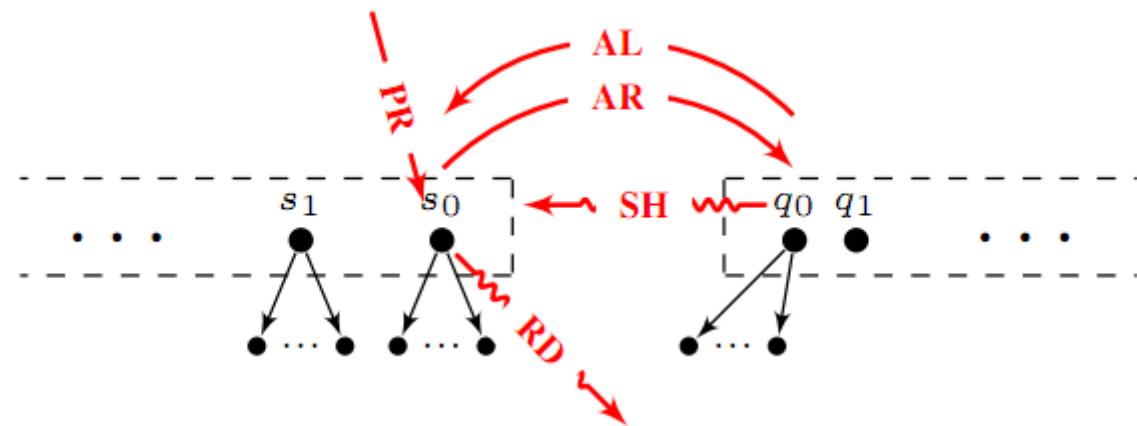
- Arc-standard



Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

# Joint Segmentation, POS-tagging and Dependency Parsing

- Arc-eager

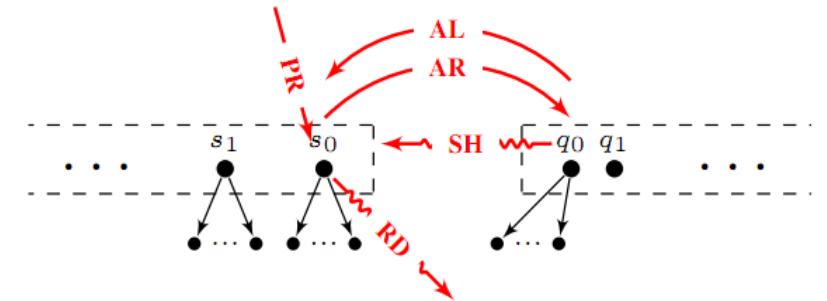
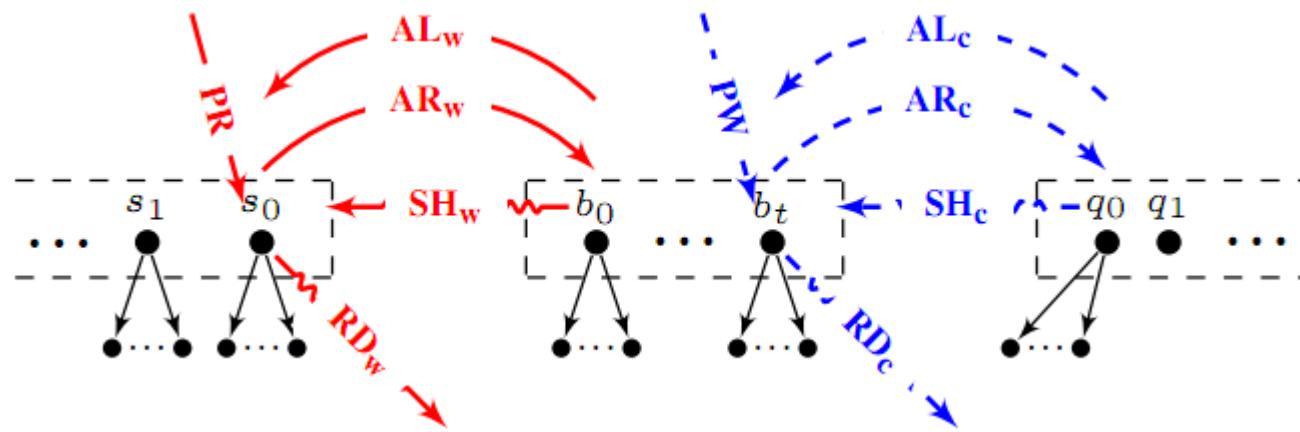



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Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
 Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

# Joint Segmentation, POS-tagging and Dependency Parsing

- Arc-eager




---

Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.  
 Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

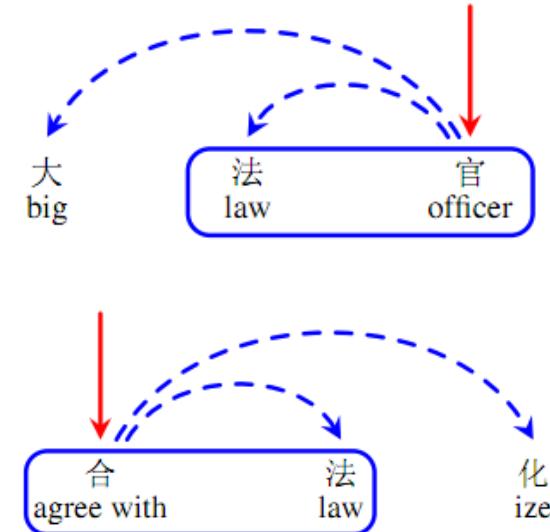


# Joint Segmentation, POS-tagging and Dependency Parsing

- New features

## Feature templates

$L_c, L_{ct}, R_c, R_{ct}, L_{lc1c}, L_{rc1c}, R_{lc1c},$   
 $L_c \cdot R_c, L_{lc1ct}, L_{rc1ct}, R_{lc1ct},$   
 $L_c \cdot R_w, L_w \cdot R_c, L_{ct} \cdot R_w,$   
 $L_{wt} \cdot R_c, L_w \cdot R_{ct}, L_c \cdot R_{wt},$   
 $L_c \cdot R_c \cdot L_{lc1c}, L_c \cdot R_c \cdot L_{rc1c},$   
 $L_c \cdot R_c \cdot L_{lc2c}, L_c \cdot R_c \cdot L_{rc2c},$   
 $L_c \cdot R_c \cdot R_{lc1c}, L_c \cdot R_c \cdot R_{lc2c},$   
 $L_{lsw}, L_{rsw}, R_{lsw}, R_{rsw}, L_{lswt},$   
 $L_{rswt}, R_{lswt}, R_{rswt}, L_{lsw} \cdot R_w,$   
 $L_{rsw} \cdot R_w, L_w \cdot R_{lsw}, L_w \cdot R_{rsw}$



- 
- Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.
- Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.



# Joint Segmentation, POS-tagging and Dependency Parsing

- Results on CTB

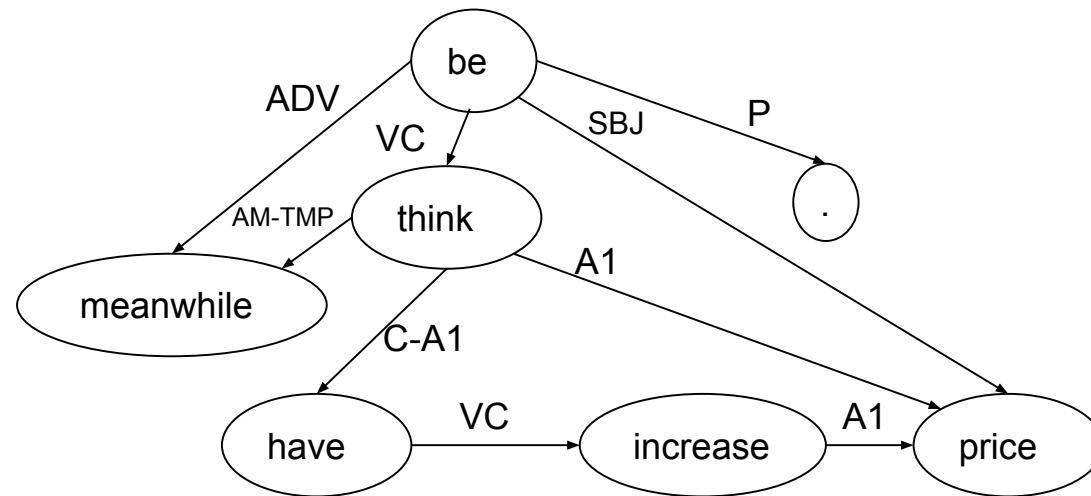
Model	CTB50				CTB60				CTB70			
	SEG	POS	DEP	WS	SEG	POS	DEP	WS	SEG	POS	DEP	WS
The arc-standard models												
STD (pipe)	97.53	93.28	79.72	–	95.32	90.65	75.35	–	95.23	89.92	73.93	–
STD (real, pseudo)	97.78	93.74	–	<b>97.40</b>	<b>95.77</b> <sup>‡</sup>	91.24 <sup>‡</sup>	–	<b>95.08</b>	<b>95.59</b> <sup>‡</sup>	90.49 <sup>‡</sup>	–	<b>94.97</b>
STD (pseudo, real)	97.67	94.28 <sup>‡</sup>	81.63 <sup>‡</sup>	–	95.63 <sup>‡</sup>	<b>91.40</b> <sup>‡</sup>	76.75 <sup>‡</sup>	–	95.53 <sup>‡</sup>	90.75 <sup>‡</sup>	75.63 <sup>‡</sup>	–
STD (real, real)	<b>97.84</b>	<b>94.62</b> <sup>‡</sup>	<b>82.14</b> <sup>‡</sup>	97.30	95.56 <sup>‡</sup>	91.39 <sup>‡</sup>	<b>77.09</b> <sup>‡</sup>	94.80	95.51 <sup>‡</sup>	<b>90.76</b> <sup>‡</sup>	<b>75.70</b> <sup>‡</sup>	94.78
Hatori+ '12	97.75	94.33	81.56	–	95.26	91.06	75.93	–	95.27	90.53	74.73	–
The arc-eager models												
EAG (pipe)	97.53	93.28	79.59	–	95.32	90.65	74.98	–	95.23	89.92	73.46	–
EAG (real, pseudo)	97.75	93.88	–	97.45	95.63 <sup>‡</sup>	91.07 <sup>‡</sup>	–	95.06	<b>95.50</b> <sup>‡</sup>	90.36 <sup>‡</sup>	–	<b>95.00</b>
EAG (pseudo, real)	97.76	<b>94.36</b> <sup>‡</sup>	81.70 <sup>‡</sup>	–	95.63 <sup>‡</sup>	91.34 <sup>‡</sup>	76.87 <sup>‡</sup>	–	95.39 <sup>‡</sup>	90.56 <sup>‡</sup>	75.56 <sup>‡</sup>	–
EAG (real, real)	<b>97.84</b>	<b>94.36</b> <sup>‡</sup>	<b>82.07</b> <sup>‡</sup>	<b>97.49</b>	<b>95.71</b> <sup>‡</sup>	<b>91.51</b> <sup>‡</sup>	<b>76.99</b> <sup>‡</sup>	<b>95.16</b>	95.47 <sup>‡</sup>	<b>90.72</b> <sup>‡</sup>	<b>75.76</b> <sup>‡</sup>	94.94

Meishan Zhang, Yue Zhang, Wanxiang Che and Ting Liu. *Character-Level Chinese Dependency Parsing*. In Proceedings of ACL 2014. Baltimore, USA, June.

Jun Hatori, Takuya Matsuzaki, Yusuke Miyao, Jun'ichi Tsujii. Incremental Joint Approach to Chinese Word Segmentation, POS Tagging, and Dependency Parsing. In the Proceedings of ACL. Jeju, Korea. 2012.

# Joint Morphology and Linearization

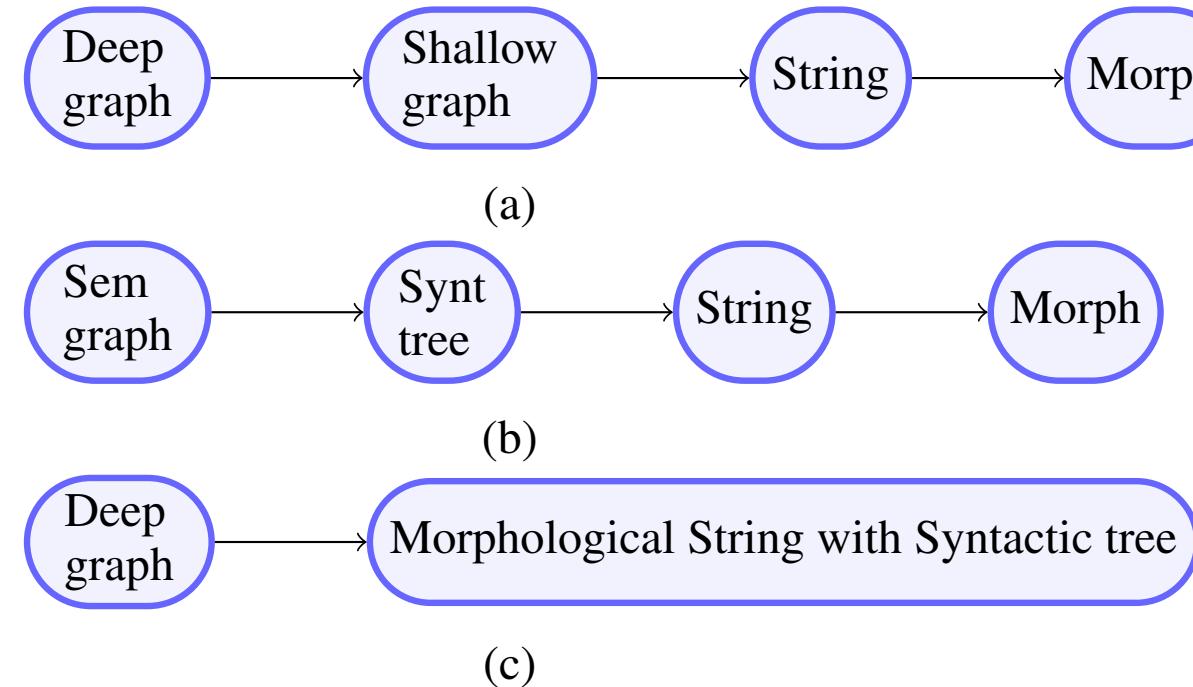
- Task



meanwhile, prices are thought to have increased.

# Joint Morphology and Linearization

- Model



- (a) NLG pipeline with deep input graph
- (b) Pipeline based on the meaning text theory
- (c) This paper



# Joint Morphology and Linearization

- Transition Actions

- SHIFT-Word-POS [SH]

- Shifts *Word* from  $\rho$ , as- signs POS to it and pushes it to top of stack as  $S_0$ ;

- LEFTARC-LABEL [LA]

- Constructs dependency arc  $S_1 \xleftarrow{LABEL} S_0$  and pops out second element from top of stack  $S_1$

- RIGHTARD-LABEL [RA]

- Constructs dependency arc  $S_1 \xrightarrow{LABEL} S_0$  and pops out top of stack  $S_0$

- INSERT [IN]

- Inserts comma at the present position

- SPLITARC-Word [SP]

- splits an arc in the input graph  $C$ , inserting a function word between the words connected by the arc.



# Joint Morphology and Linearization

- Transition Example

Sentence: *meanwhile, prices are thought to have increased.*



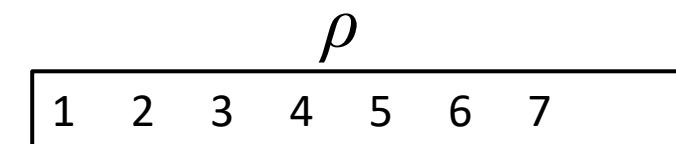
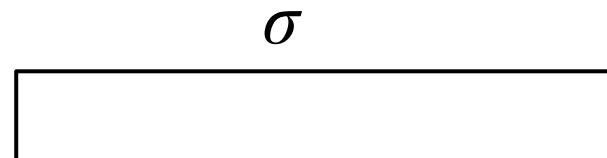
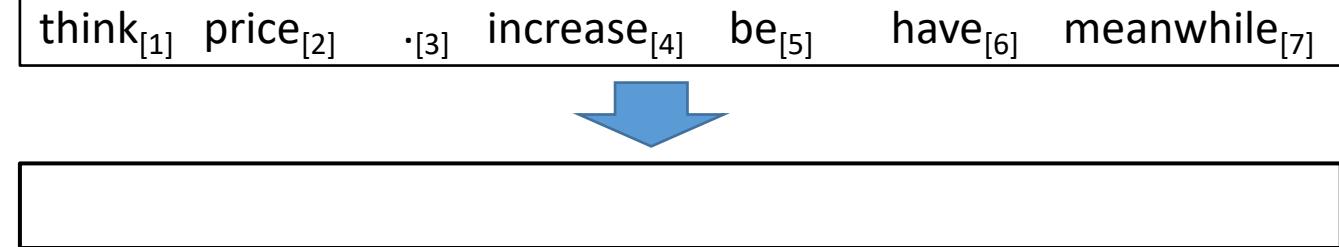
Input  
Lemmas:

think <sub>[1]</sub>	price <sub>[2]</sub>	· <sub>[3]</sub>	increase <sub>[4]</sub>	be <sub>[5]</sub>	have <sub>[6]</sub>	meanwhile <sub>[7]</sub>
----------------------	----------------------	------------------	-------------------------	-------------------	---------------------	--------------------------



# Joint Morphology and Linearization

- Transition Action





# Joint Morphology and Linearization

- Transition Action
  - SH-meanwhile

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile

$\sigma$

7

$\rho$

1 2 3 4 5 6



# Joint Morphology and Linearization

- Transition Action
  - INSERT

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile ,

$\sigma$

7

$\rho$

1 2 3 4 5 6



# Joint Morphology and Linearization

- Transition Action
  - SH-prices

think <sub>[1]</sub>	price <sub>[2]</sub>	· <sub>[3]</sub>	increase <sub>[4]</sub>	be <sub>[5]</sub>	have <sub>[6]</sub>	meanwhile <sub>[7]</sub>
Meanwhile , prices						





# Joint Morphology and Linearization

- Transition Action
  - SH-are

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile , prices are

 $\sigma$ 

7 2 5

 $\rho$ 

1 3 4 6



# Joint Morphology and Linearization

- Transition Action
  - SH-thought

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile , prices are thought

 $\sigma$ 

7 2 5 1

 $\rho$ 

3 4 6



# Joint Morphology and Linearization

- Transition Action
  - SH-to

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile , prices are thought to

 $\sigma$ 

7 2 5 1

 $\rho$ 

3 4 6



# Joint Morphology and Linearization

- Transition Action
  - SH-have

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile , prices are thought to have

 $\sigma$ 

7 2 5 1 6

 $\rho$ 

3 4



# Joint Morphology and Linearization

- Transition Action
  - SH-increased

think<sub>[1]</sub> price<sub>[2]</sub> ·<sub>[3]</sub> increase<sub>[4]</sub> be<sub>[5]</sub> have<sub>[6]</sub> meanwhile<sub>[7]</sub>

Meanwhile , prices are thought to have increased

 $\sigma$ 

7 2 5 1 6 4

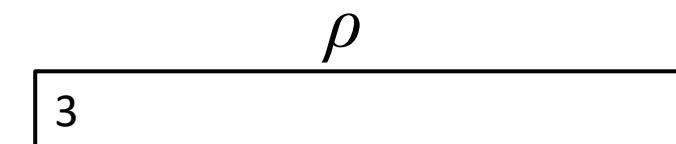
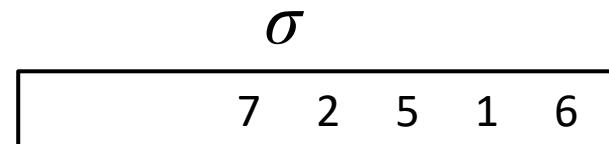
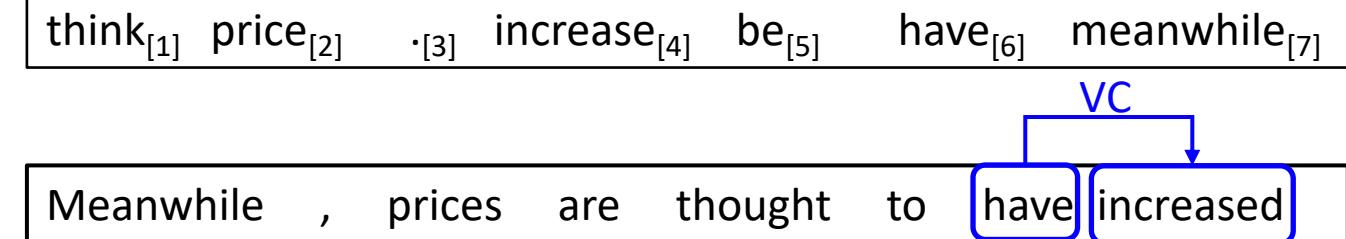
 $\rho$ 

3



# Joint Morphology and Linearization

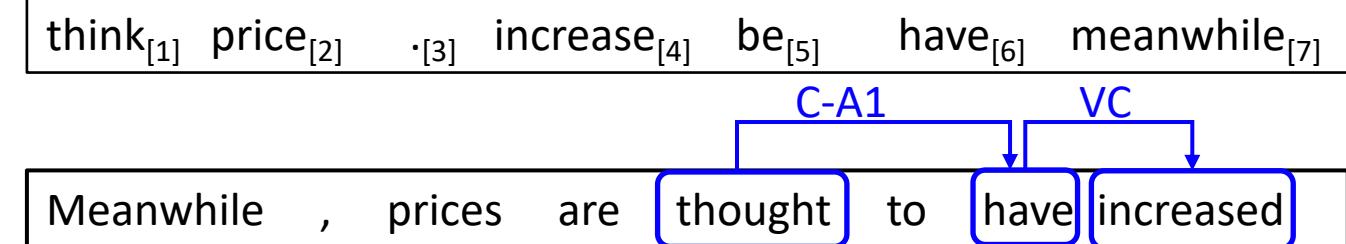
- Transition Action
  - RA ( $6 \rightarrow 4$ ) [VC]





# Joint Morphology and Linearization

- Transition Action
  - RA ( $1 \rightarrow 6$ ) [C-A1]

 $\sigma$ 

7	2	5	1	6
---	---	---	---	---

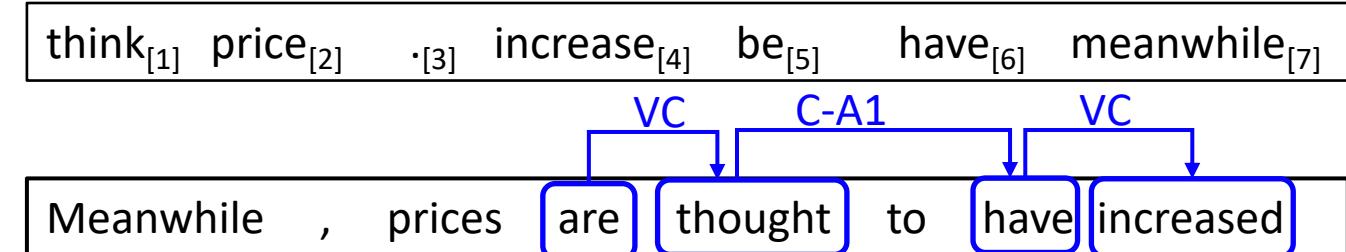
 $\rho$ 

3
---



# Joint Morphology and Linearization

- Transition Action
  - RA ( $5 \rightarrow 1$ ) [VC]

 $\sigma$ 

7	2	5	1
---	---	---	---

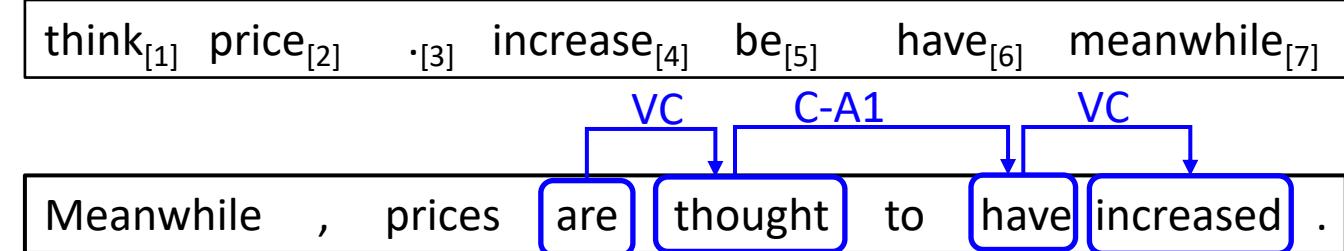
 $\rho$ 

3
---



# Joint Morphology and Linearization

- Transition Action
  - SH-.

 $\sigma$ 

7	2	5
---	---	---

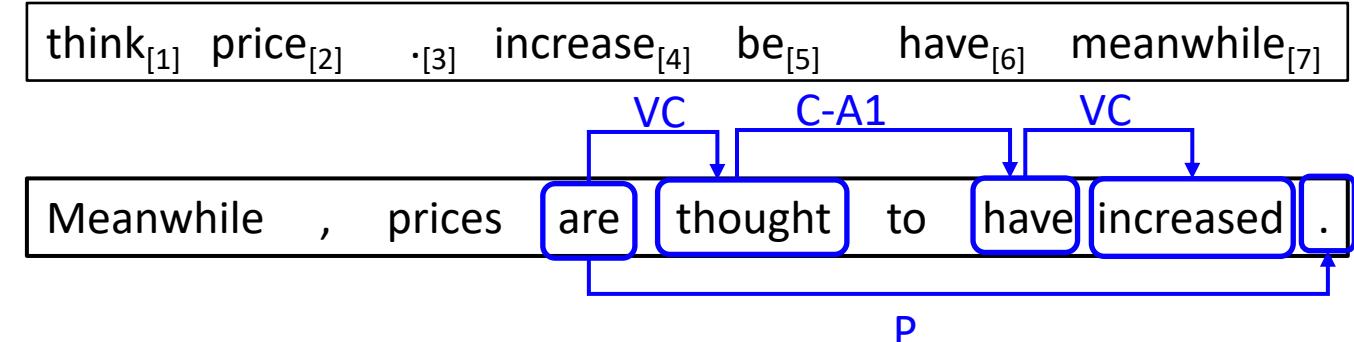
 $\rho$ 

3
---



# Joint Morphology and Linearization

- Transition Action
  - RA ( $5 \rightarrow 3$ ) [P]

 $\sigma$ 

7	2	5	3
---	---	---	---

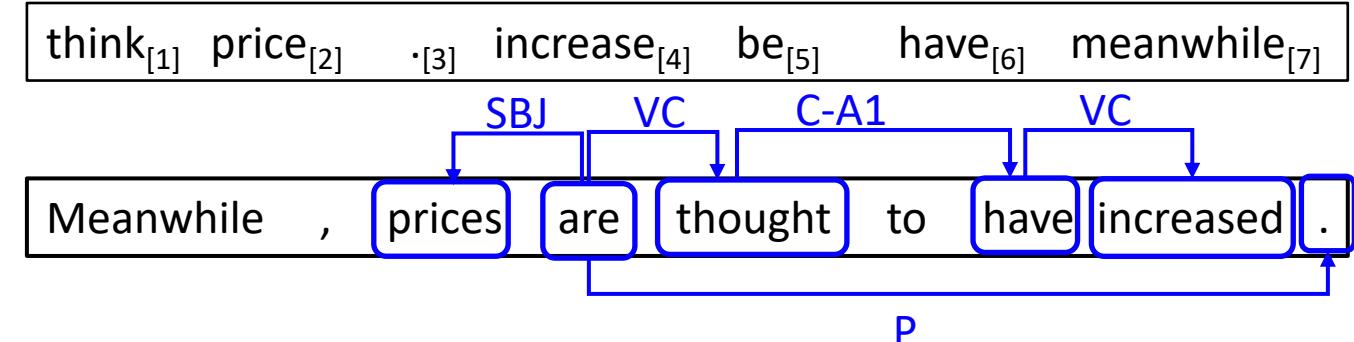
 $\rho$ 

--



# Joint Morphology and Linearization

- Transition Action
  - LA ( $2 \leftarrow 5$ ) [SBJ]


 $\sigma$ 

7	2	5
---	---	---

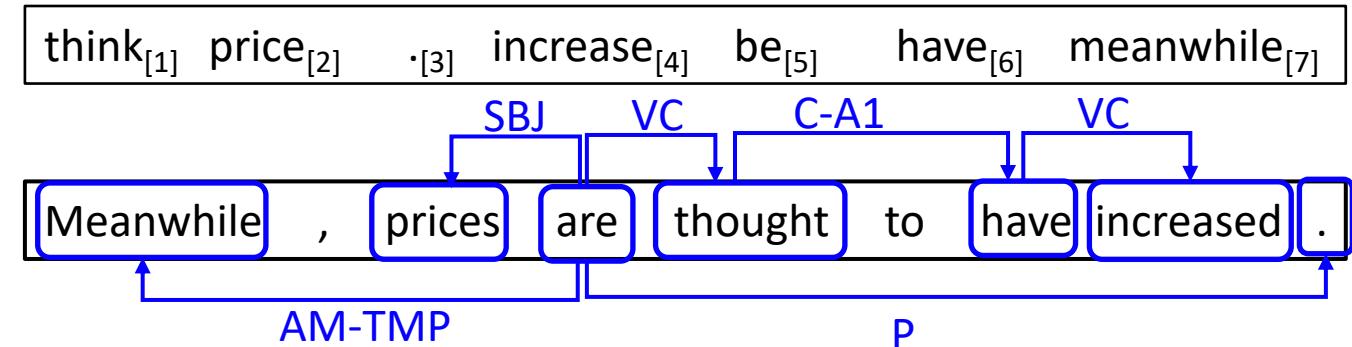
 $\rho$ 

--



# Joint Morphology and Linearization

- Transition Action
  - LA ( $7 \leftarrow 5$ ) [AM-TMP]

 $\sigma$ 

5

 $\rho$



# Joint Morphology and Linearization

- Results on dataset of the Surface Realisation Shared Task

System	BLEU Score
STUMABA-D	79.43
Pipeline	70.99
TBDIL	<b>80.49</b>



# Joint Entity and Relation Extraction

- This paper investigate joint models for simultaneously extracting drugs, diseases and adverse drug events.

**Gliclazide**<sub>drug</sub>-induced **acute hepatitis**<sub>disease</sub>



# Joint Entity and Relation Extraction

- We define the action as:
  - O, which marks the current word as not belong to either a drug or disease mention.
  - BC, which marks the current word as the beginning of a drug mention.
  - BD, which marks the current word as the beginning of a disease mention.
  - I, which marks the current word as part of a drug or disease mention but not the beginning.
- For example
  - Given a sentence: Gliclazide-induced acute hepatitis.
  - The action sequence: “BC O O BD I O “ yields the result “**Gliclazide**<sub>drug</sub>-induced **acute hepatitis**<sub>disease</sub>”



# Joint Entity and Relation Extraction

- The state of the joint model as a tuple  $\langle \text{labels}, \text{disease}, \text{drugs}, \text{ADEs} \rangle$ 
  - $\text{labels}$  is a label sequence
  - $\text{disease}$  is a list of readily-recognized disease entity mentions
  - $\text{drugs}$  is a list of readily-recognized drug entity mentions
  - $\text{ADEs}$  is a set of ADEs
- Two more actions are defined to achieve this
  - N, which indicates that a pair of entities does not have an ADE relation
  - Y, which indicates that a pair of entities has an ADE relation



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

state <labels, disease, drugs, relations>

<[],[],[],[]>

next action

BD



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD

state <labels, disease, drugs, relations>

<[BD],[],[],[]>

next action

O



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD O

state <labels, disease, drugs, relations>

<[BD,O],[Hepatitis],[],[]>

next action

O



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD O O

state <labels, disease, drugs, relations>

<[BD,O,O],[Hepatitis],[],[]>

next action

BC



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD O O BC

state <labels, disease, drugs, relations>

<[BD,O,O,BC],[Hepatitis],[],[]>

next action

O



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD O O BC O

state <labels, disease, drugs, relations>

<[BD,O,O,BC,O],[Hepatitis],[methotrexate],[]>

next action

Y



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD	O	O	BC	O
----	---	---	----	---

state <labels, disease, drugs, relations>

next action

<[BD,O,O,BC,O],[Hepatitis],[methotrexate],[(Hepatitis,methotrexate)]>	BC
---	----



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD	O	O	BC	O	BC
----	---	---	----	---	----

state <labels, disease, drugs, relations>

```
<[BD,O,O,BC,O,BC],[Hepatitis],[methotrexate],[(Hepatitis,methotrexate)]  
>
```

next action

O
---



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD	O	O	BC	O	BC	O
----	---	---	----	---	----	---

state <labels, disease, drugs, relations>

```
<[BD,O,O,BC,O,BC,O],[Hepatitis],[methotrexate,etretinate],[(Hepatitis,m  
ethotrexate)]>
```

next action

Y



# Joint Entity and Relation Extraction

- State transition examples

Hepatitis caused by methotrexate and etretinate .

BD	O	O	BC	O	BC	O
----	---	---	----	---	----	---

state <labels, disease, drugs, relations>

```
<[BD,O,O,BC,O,BC,O],[Hepatitis],[methotrexate,etretinate],[(Hepatitis,m  
ethotrexate),(Hepatitis,etretinate)]>
```

next action

<EOS>
-------



# Joint Entity and Relation Extraction

- Perceptron learning + greedy search



# Joint Entity and Relation Extraction

- Results on ADE data

Method	Entity Recognition			ADE extraction		
	P	R	F <sub>1</sub>	P	R	F <sub>1</sub>
Li <i>et al.</i> [2015]	75.9	71.6	73.6	55.2	47.9	51.1
Baseline	77.8	72.0	74.8	60.7	51.5	55.7
Discrete Joint	<b>80.0</b>	75.1	77.5	<b>65.1</b>	56.7	60.6



# Outline

- Motivation
- Statistical Models
- Deep Learning Models



# Deep Learning Models

- Neural Transition-based Models
- Neural Graph-based Models (Multi-task Learning)
  - Cross Task
  - Cross Domain
  - Cross Lingual
  - Cross Standard



# Deep Learning Models

- Neural Transition-based Models

- Neural Graph-based Models (Multi-task)

- Cross Task
- Cross Domain
- Cross Linguistic
- Cross Application

Joint Learning

Joint Search



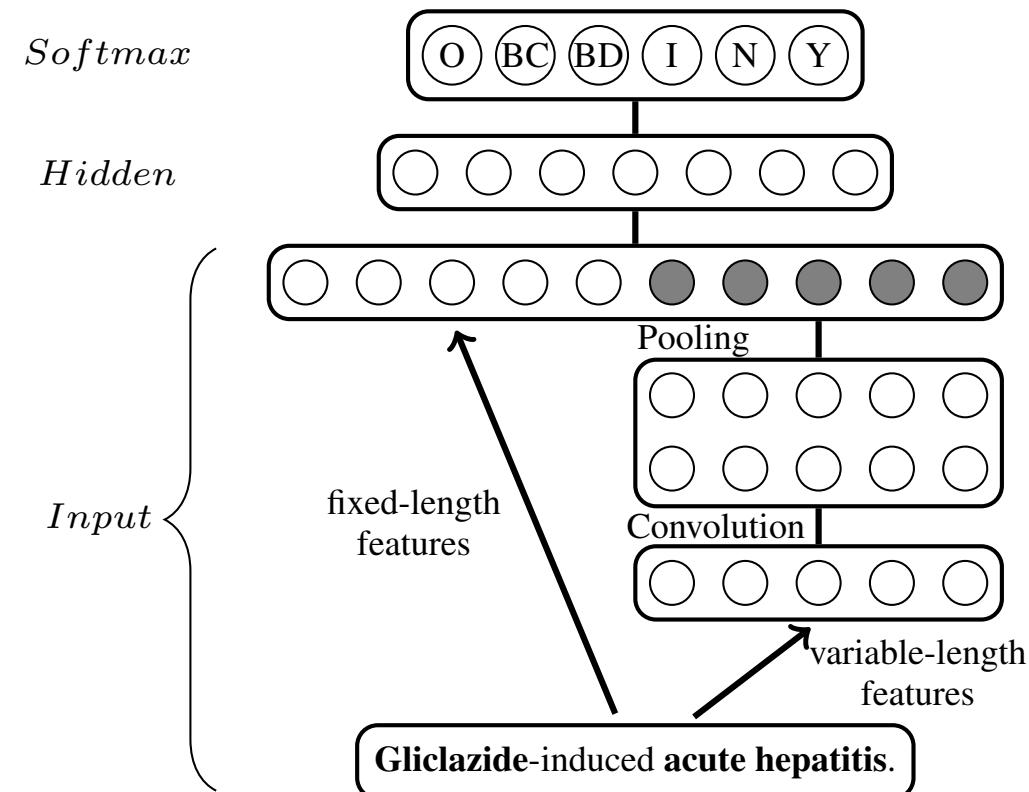
# Joint Entity and Relation Extraction

- Replacing perceptron with Neural Model.

**Gliclazide**<sub>drug</sub>-induced **acute hepatitis**<sub>disease</sub>

# Joint Entity and Relation Extraction

- Model





# Joint Entity and Relation Extraction

- Results

Method	Entity Recognition			ADE extraction		
	P	R	F <sub>1</sub>	P	R	F <sub>1</sub>
Li <i>et al.</i> [2015]	75.9	71.6	73.6	55.2	47.9	51.1
Baseline	77.8	72.0	74.8	60.7	51.5	55.7
Discrete Joint	<b>80.0</b>	75.1	77.5	<b>65.1</b>	56.7	60.6
Neural Joint	79.5	<b>79.6</b>	<b>79.5</b>	64.0	<b>62.9</b>	<b>63.4</b>

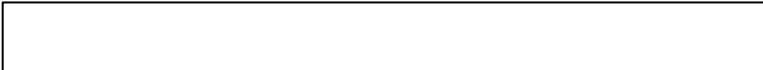


# Joint Parsing and SRL

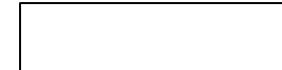
- Transition Action

all are expected to reopen soon root

Stack [S]



Buffer [M]



Queue [B]

all, are, expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - S-SHIFT

all are expected to reopen soon root

Stack [S]

Buffer [M]

Queue [B]

all

are, expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-SHIFT

all are expected to reopen soon root

Stack [S]

Buffer [M]

Queue [B]

all

all

are, expected, to, reopen, soon, root



# Joint Parsing and SRL

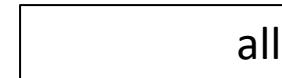
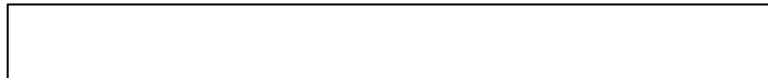
- Transition Action
  - S-LEFT (*sbj*)



Stack [S]

Buffer [M]

Queue [B]





# Joint Parsing and SRL

- Transition Action
  - S-SHIFT



Stack [S]

Buffer [M]

Queue [B]

are

all

are, expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-SHIFT



Stack [S]

are

Buffer [M]

all, are

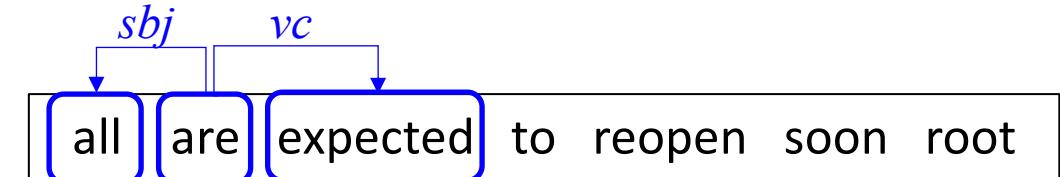
Queue [B]

expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - S-RIGHT ( $vc$ )



Stack [S]

Buffer [M]

Queue [B]

are, expected

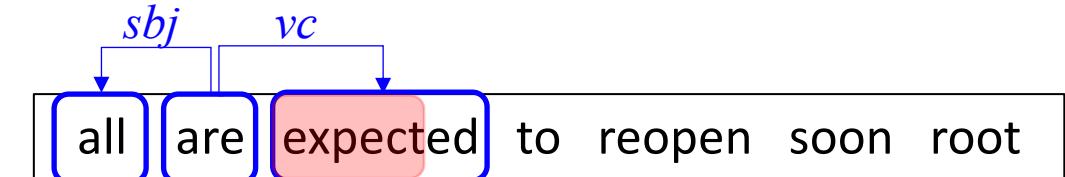
all, are

expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-PRED (**expect.01**)



Stack [S]

Buffer [M]

Queue [B]

are, expected

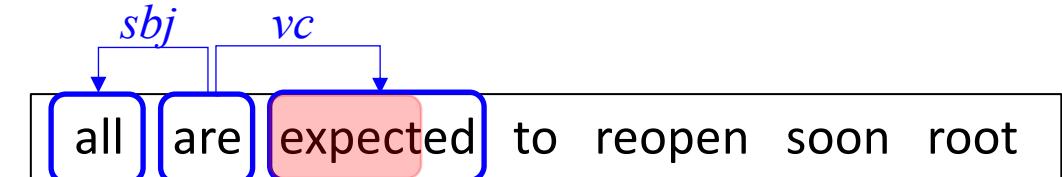
all, are

expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-REDUCE



Stack [S]

Buffer [M]

Queue [B]

are, expected

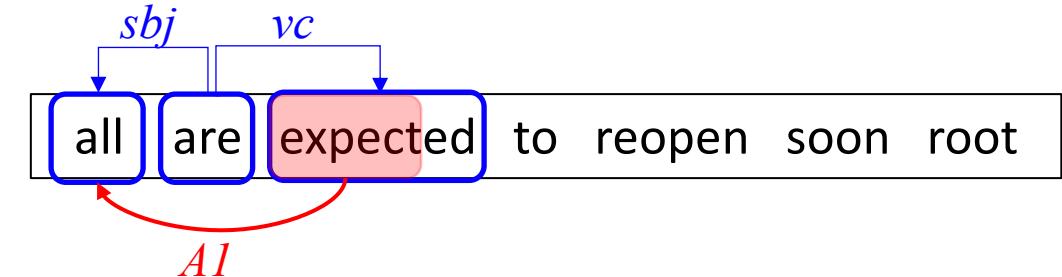
all

expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-LEFT(A1)



Stack [S]

Buffer [M]

Queue [B]

are, expected

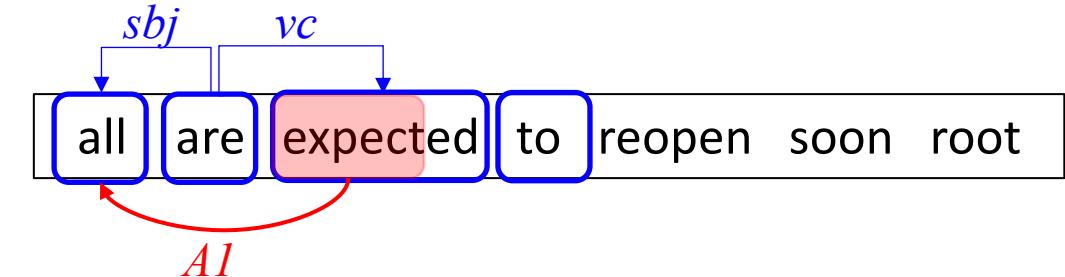
all

expected, to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-SHIFT



Stack [S]

are, expected

Buffer [M]

all, expected

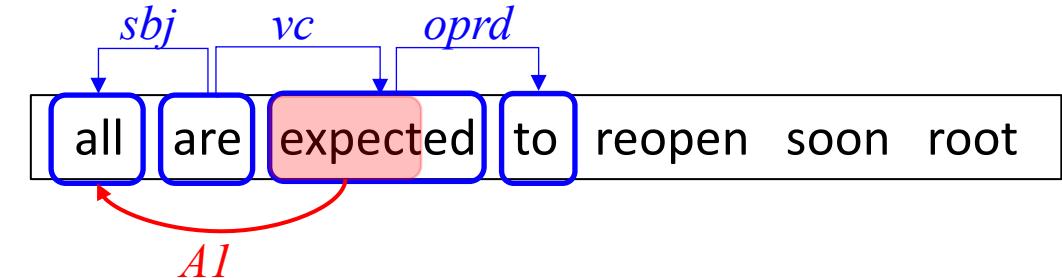
Queue [B]

to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - \*\*\*S-RIGHT (*oprд*)



Stack [S]

are, expected, to

Buffer [M]

all, expected

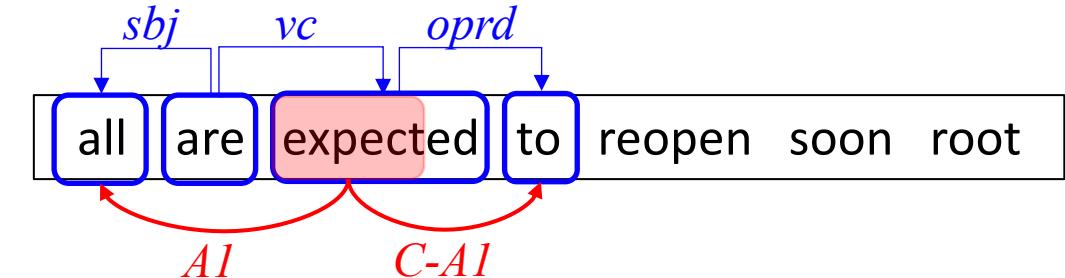
Queue [B]

to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-RIGHT (C-A1)



Stack [S]

are, expected, to

Buffer [M]

all, expected

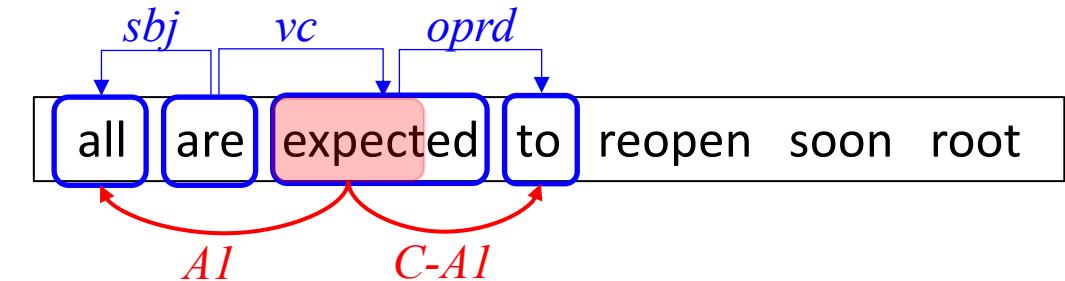
Queue [B]

to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-REDUCE



Stack [S]

are, expected, to

Buffer [M]

all

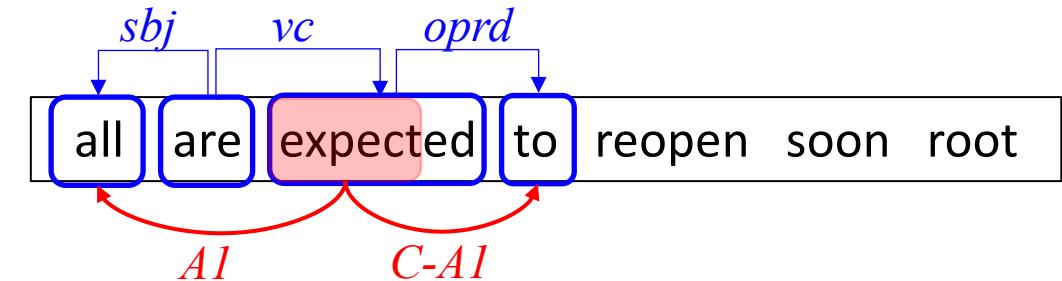
Queue [B]

to, reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-SHIFT



Stack [S]

are, expected, to

Buffer [M]

all, to

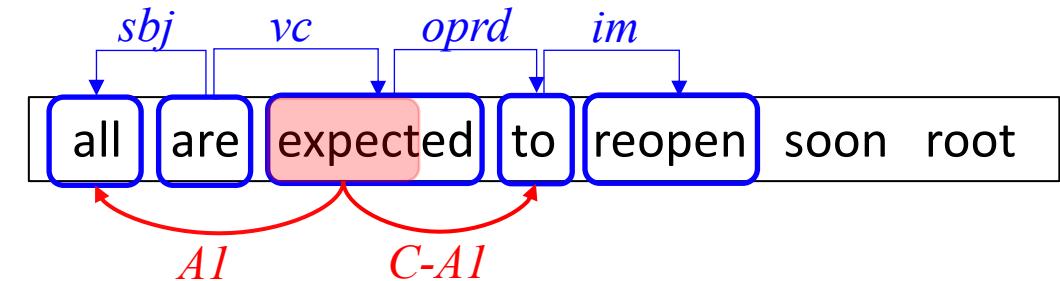
Queue [B]

reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - S-RIGHT ( $im$ )



Stack [S]

Buffer [M]

Queue [B]

are, expected, to, reopen

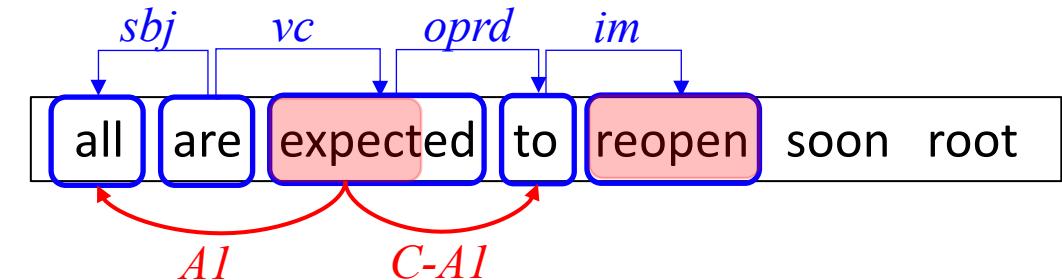
all, to

reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-PRED (*reopen.01*)



Stack [S]

Buffer [M]

Queue [B]

are, expected, to, reopen

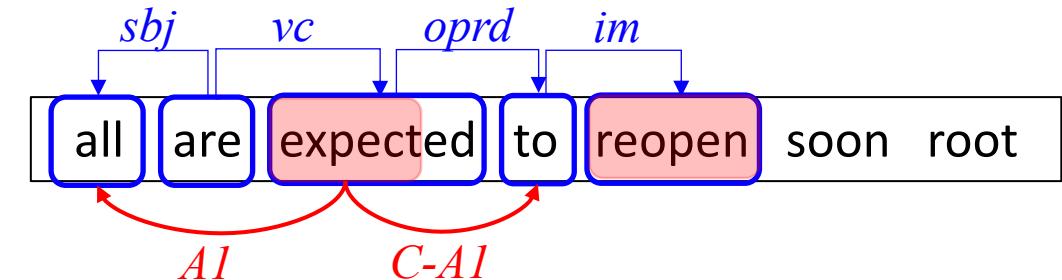
all, to

reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-REDUCE



Stack [S]

Buffer [M]

Queue [B]

are, expected, to, reopen

all

reopen, soon, root



# Joint Parsing and SRL

- Transition Action
  - M-LEFT (A1)

Stack [S]

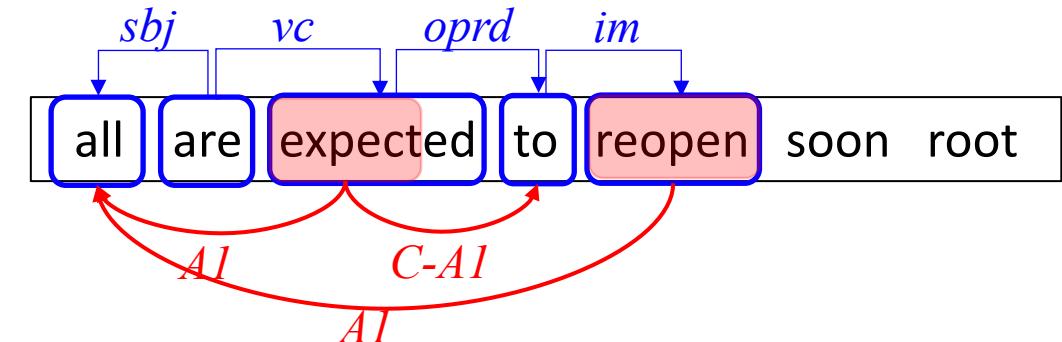
are, expected, to, reopen

Buffer [M]

all

Queue [B]

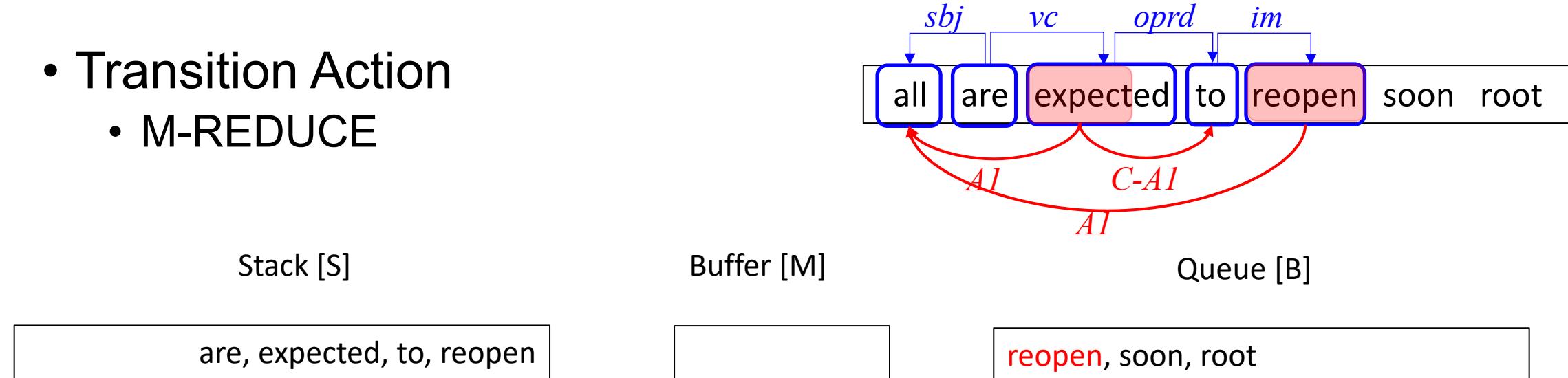
reopen, soon, root





# Joint Parsing and SRL

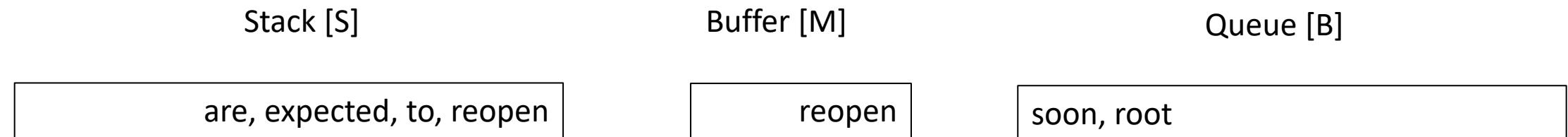
- Transition Action
  - M-REDUCE





# Joint Parsing and SRL

- Transition Action
  - M-SHIFT





# Joint Parsing and SRL

- Transition Action
  - S-RIGHT ( $tmp$ )

Stack [S]

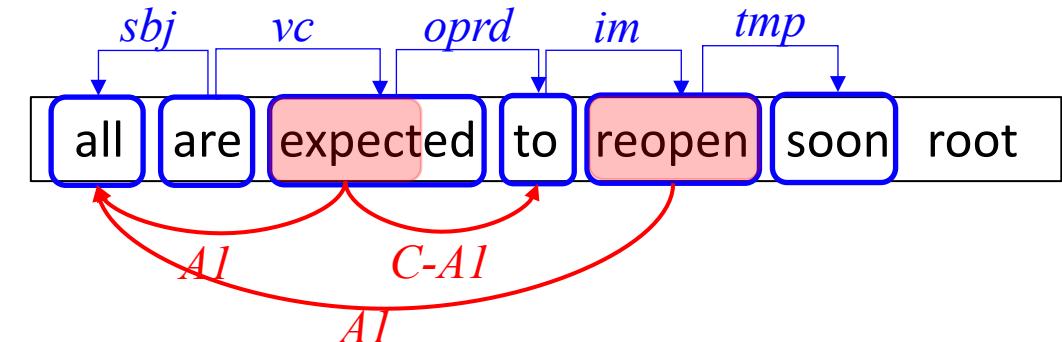
are, expected, to, reopen, soon

Buffer [M]

reopen

Queue [B]

soon, root





# Joint Parsing and SRL

- Transition Action
  - M-RIGHT (AM-TMP)

Stack [S]

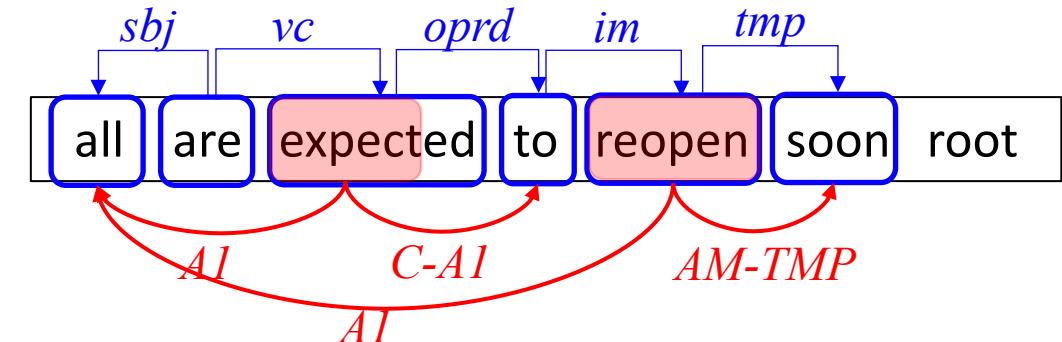
are, expected, to, reopen, soon

Buffer [M]

reopen

Queue [B]

soon, root





# Joint Parsing and SRL

- Transition Action
  - M-REDUCE

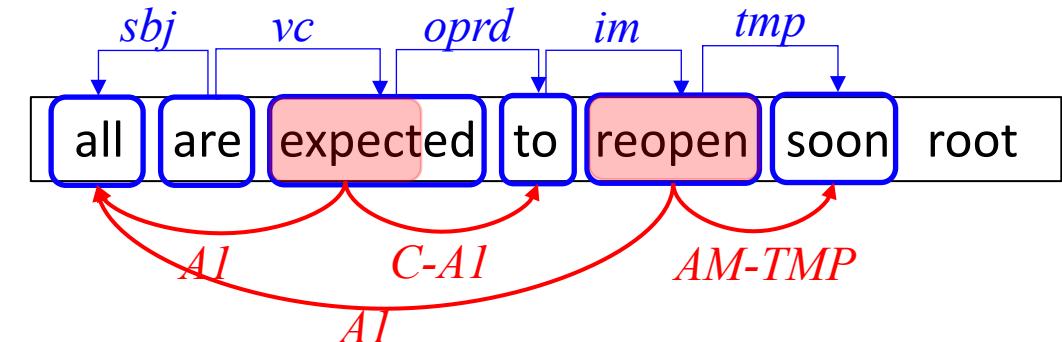
Stack [S]

are, expected, to, reopen, soon

Buffer [M]

Queue [B]

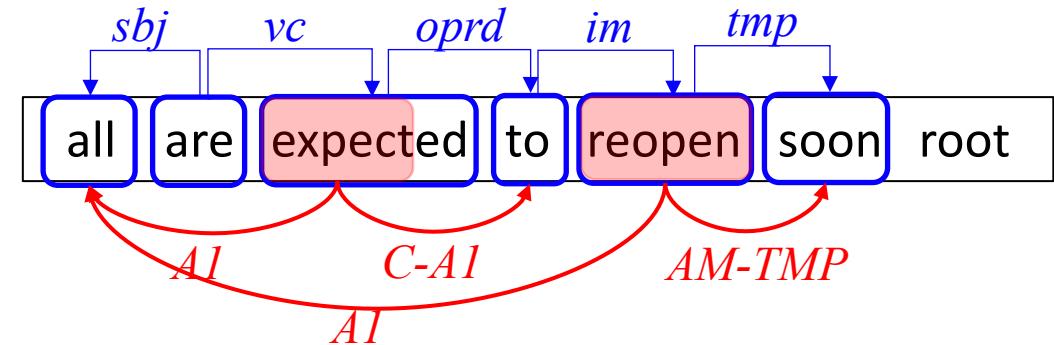
soon, root





# Joint Parsing and SRL

- Transition Action
  - M-SHIFT



Stack [S]

Buffer [M]

Queue [B]

are, expected, to, reopen

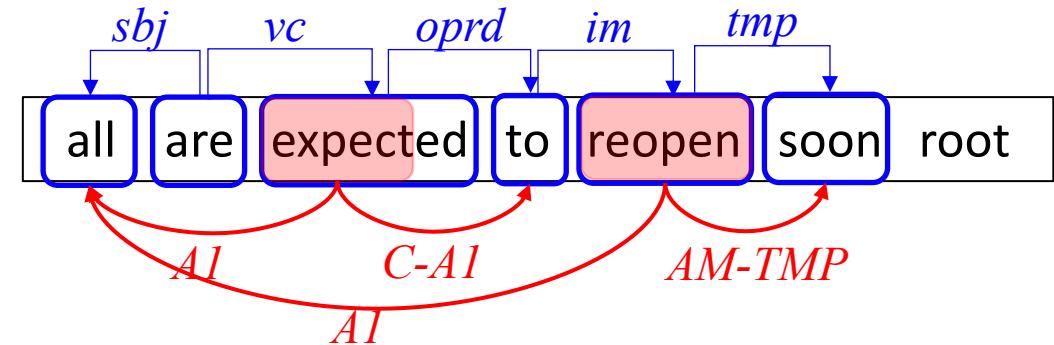
soon

root



# Joint Parsing and SRL

- Transition Action
  - S-REDUCE



Stack [S]

are, expected, to, reopen

Buffer [M]

soon

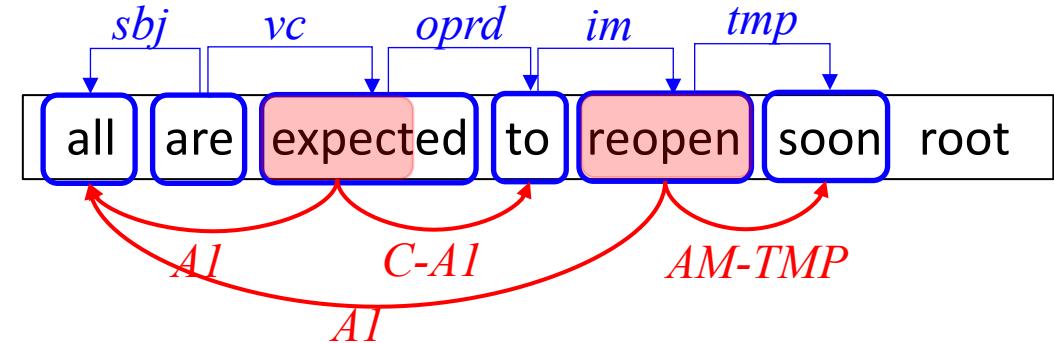
Queue [B]

root



# Joint Parsing and SRL

- Transition Action
  - S-REDUCE



Stack [S]

Buffer [M]

Queue [B]

are, expected, to

soon

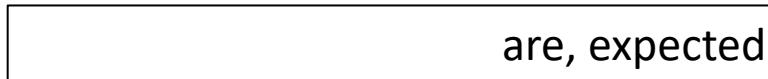
root



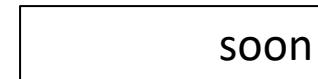
# Joint Parsing and SRL

- Transition Action
  - S-REDUCE

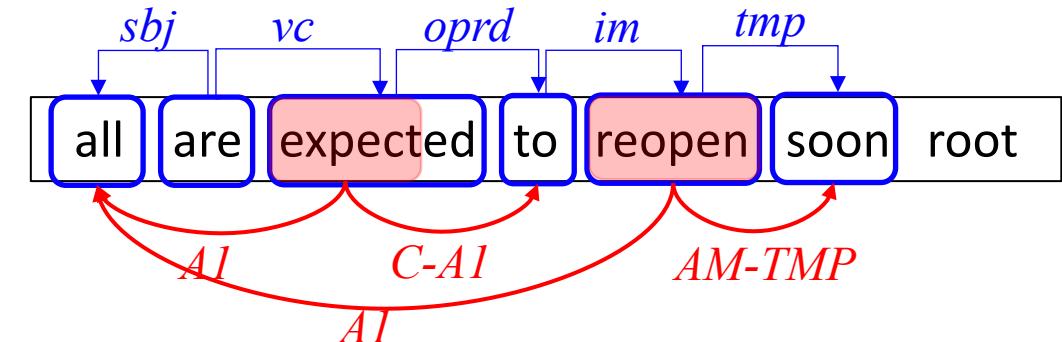
Stack [S]



Buffer [M]



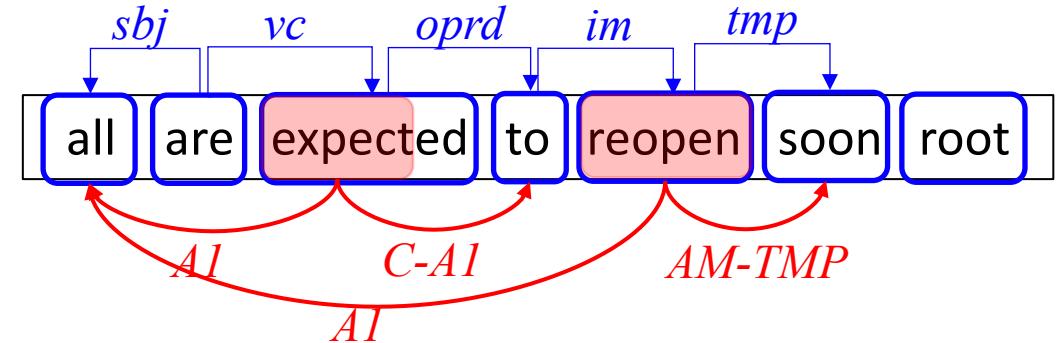
Queue [B]





# Joint Parsing and SRL

- Transition Action
  - S-REDUCE



Stack [S]

are

Buffer [M]

soon

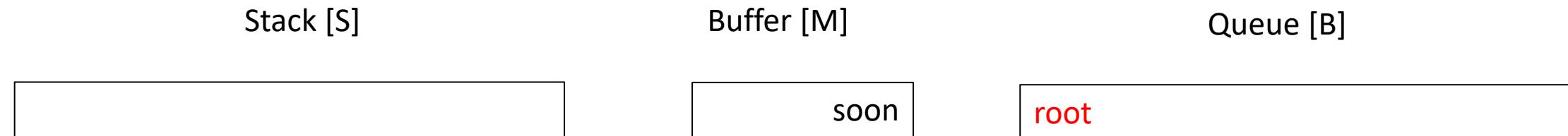
Queue [B]

root



# Joint Parsing and SRL

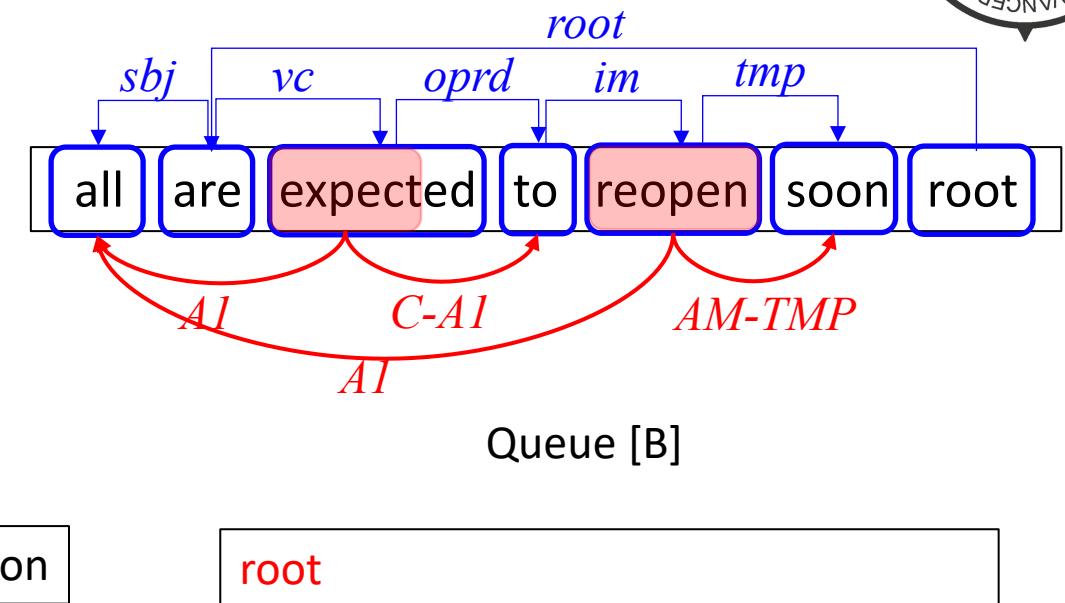
- Transition Action
  - S-LEFT (*root*)





# Joint Parsing and SRL

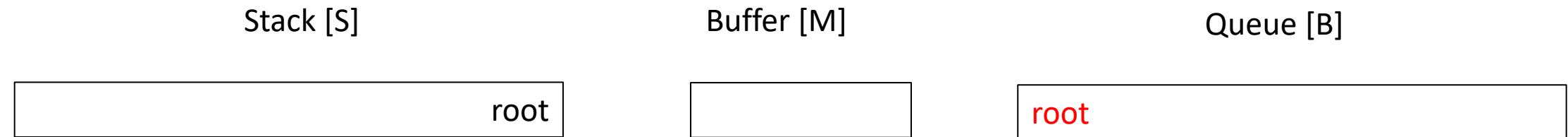
- Transition Action
  - S-SHIFT





# Joint Parsing and SRL

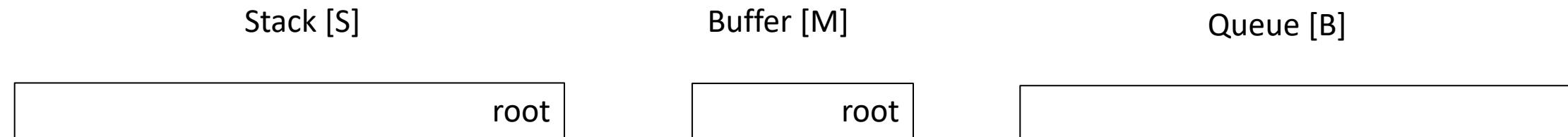
- Transition Action
  - M-REDUCE





# Joint Parsing and SRL

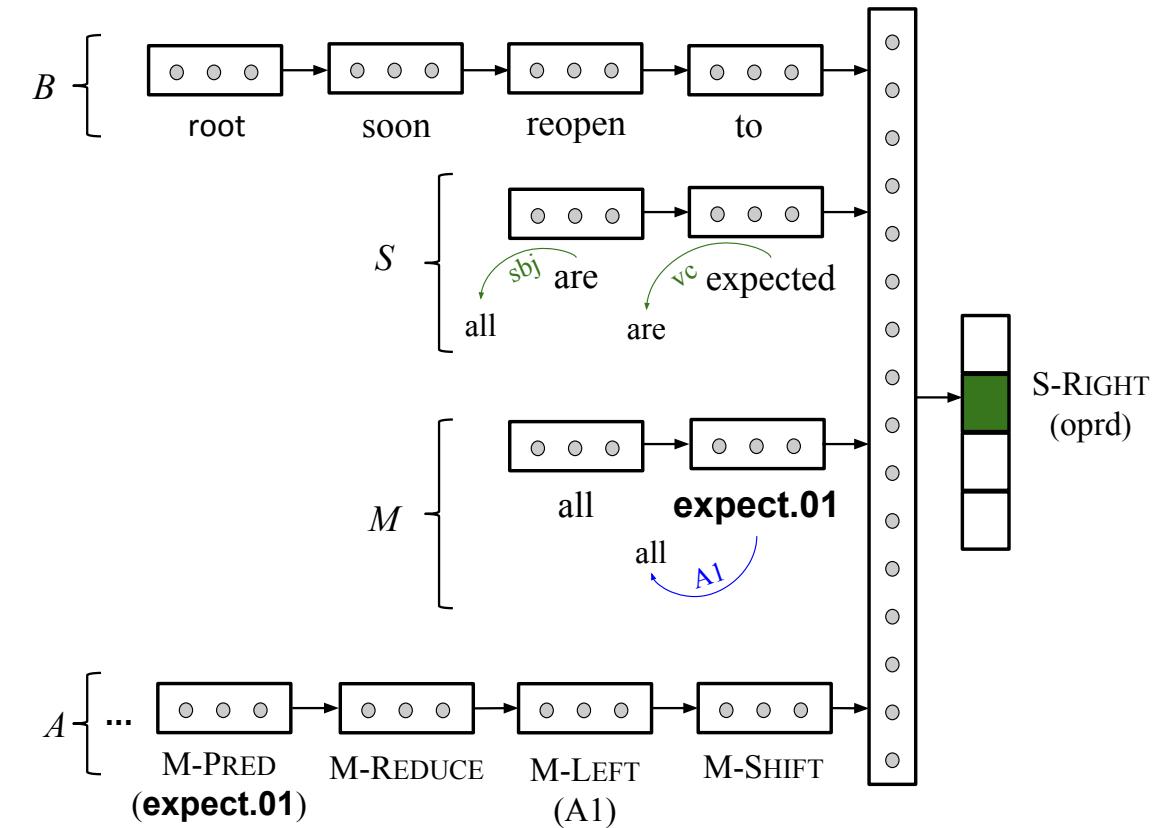
- Transition Action
  - M-SHIFT





# Joint Parsing and SRL

- Model





# Joint Parsing and SRL

- Results on CONLL

Model	LAS	Sem. $F_1$	Macro $F_1$
<i>joint models:</i>			
Lluís and Màrquez (2008)	85.8	70.3	78.1
Henderson et al. (2008)	87.6	73.1	80.5
Johansson (2009)	86.6	77.1	81.8
Titov et al. (2009)	87.5	76.1	81.8
<i>CoNLL 2008 best:</i>			
#3: Zhao and Kit (2008)	87.7	76.7	82.2
#2: Che et al. (2008)	86.7	78.5	82.7
#2: Ciaramita et al. (2008)	87.4	78.0	82.7
#1: J&N (2008)	89.3	81.6	85.5
Joint (this work)	89.1	80.5	84.9



# Joint Parsing and SRL

- Joint VS Pipeline

Model	LAS	Sem. $F_1$ (WSJ)	Sem. $F_1$ (Brown)	Macro $F_1$
<i>CoNLL'09 best:</i>				
#3 G+ '09	88.79	83.24	70.65	86.03
#2 C+ '09	88.48	85.51	73.82	87.00
#1 Z+ '09a	89.19	86.15	74.58	87.69
<i>this work:</i>				
Syntax-only	89.83			
Sem.-only		84.39	73.87	
Hybrid	89.83	84.58	75.64	87.20
Joint	89.94	84.97	74.48	87.45
<i>pipelines:</i>				
R&W '14		86.34	75.90	
L+ '15		86.58	75.57	
T+ '15		87.30	75.50	
F+ '15		87.80	75.50	

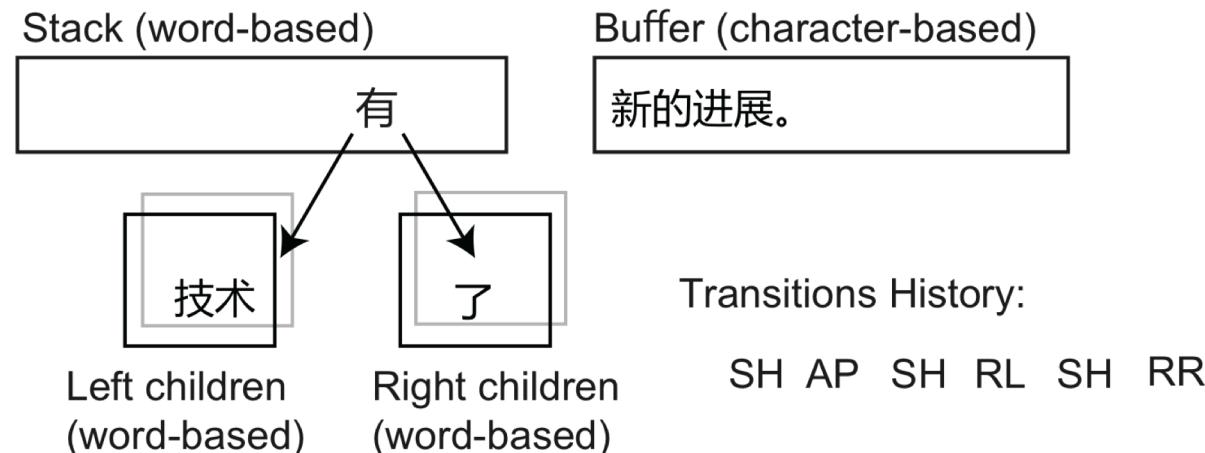


# Joint Word Segmentation, POS Tagging, and Dependency Parsing

- Model

技术有了新的进展。

Technology have made new progress.



# Joint Word Segmentation, POS Tagging and Dependency Parsing

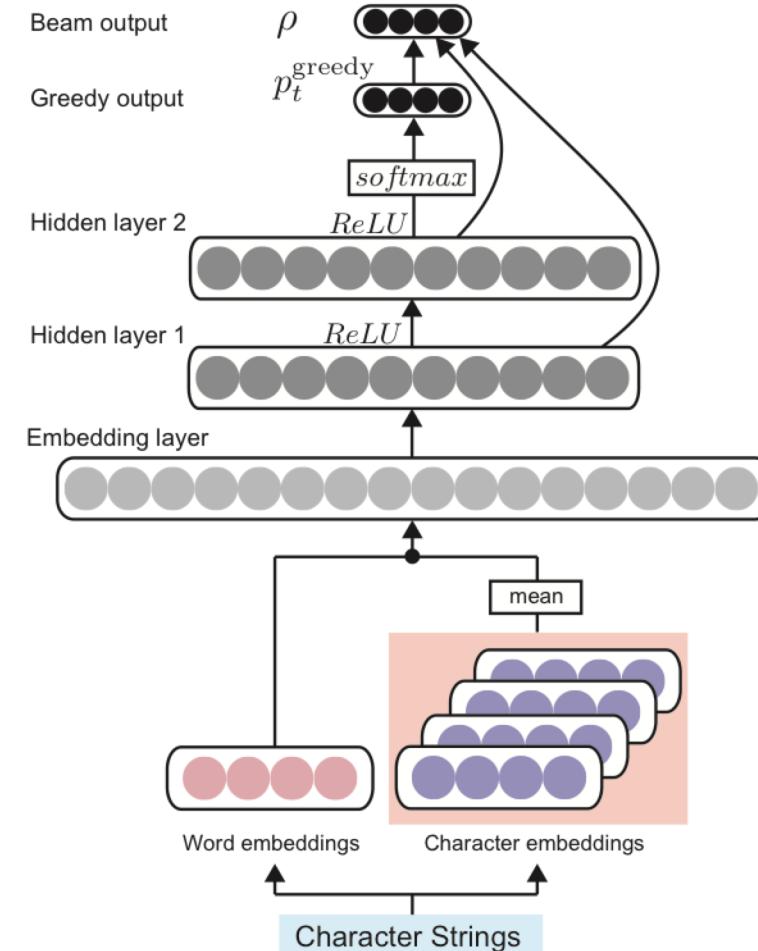


- Same transition system as introduced earlier

# Joint Word Segmentation, POS Tagging, and Dependency Parsing



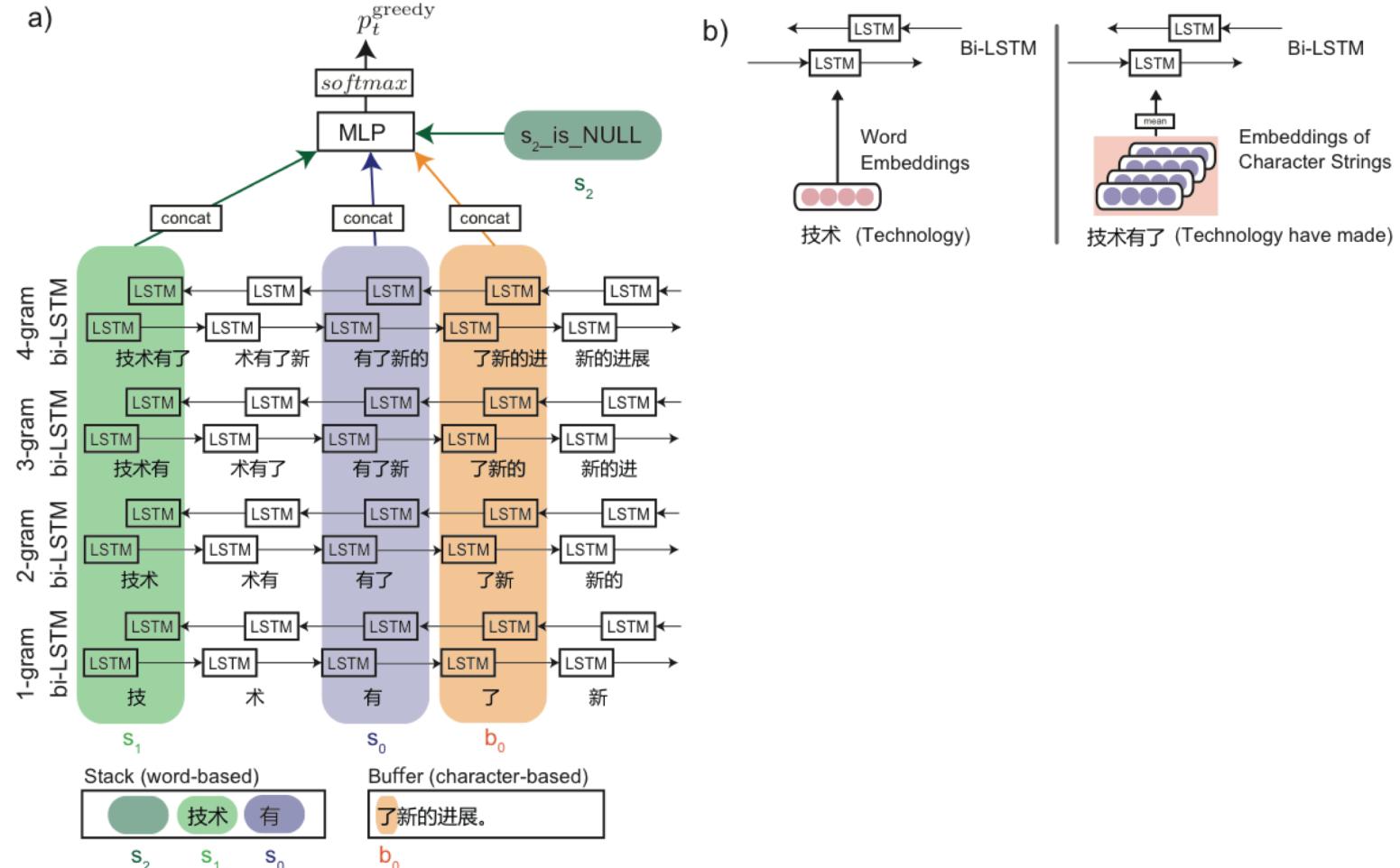
- Feed-forward NN model





# Joint Word Segmentation, POS Tagging, and Dependency Parsing

- Bi-LSTM model





# Joint Word Segmentation, POS Tagging, and Dependency Parsing

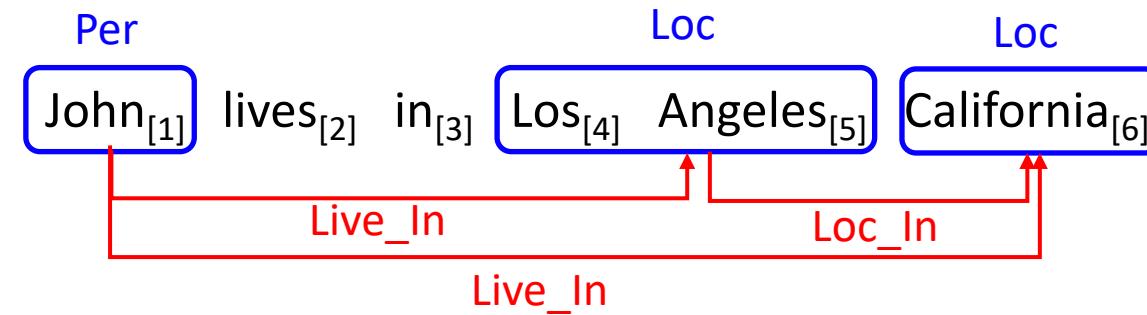
- Results on PTB

Model	Seg	POS	Dep
Hatori+12	97.75	94.33	81.56
M. Zhang+14 STD	97.67	94.28	81.63
M. Zhang+14 EAG	97.76	94.36	81.70
Y. Zhang+15	98.04	94.47	82.01
SegTagDep(g)	98.24	94.49	80.15
SegTagDep	98.37	<b>94.83<sup>‡</sup></b>	81.42 <sup>‡</sup>
SegTag+Dep	<b>98.60<sup>‡</sup></b>	94.76 <sup>‡</sup>	<b>82.60<sup>‡</sup></b>



# Joint Extraction of Entities and Relations

- Task





# Joint Extraction of Entities and Relations

- Transition Actions
  - Initialization

John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

$\sigma$   
[ ]

$\delta$   
[ ]

$e$   
[ ]

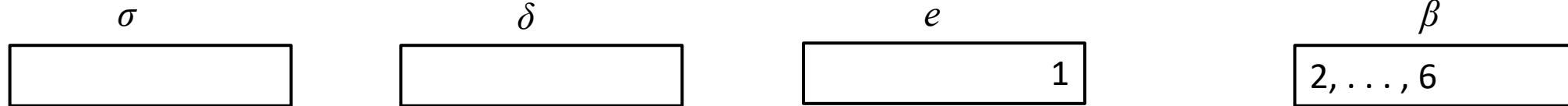
$\beta$   
[ ]  
1, ..., 6



# Joint Extraction of Entities and Relations

- Transition Actions
  - NER-SHIFT

John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

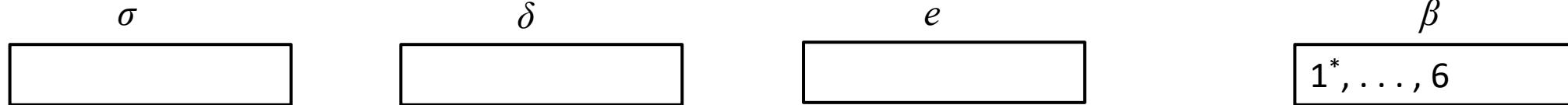




# Joint Extraction of Entities and Relations

- Transition Actions
  - NER-PER

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

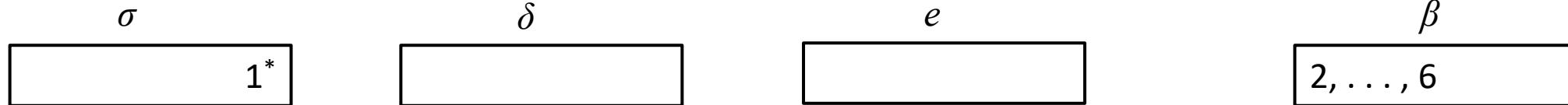




# Joint Extraction of Entities and Relations

- Transition Actions
  - NO-SHIFT

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

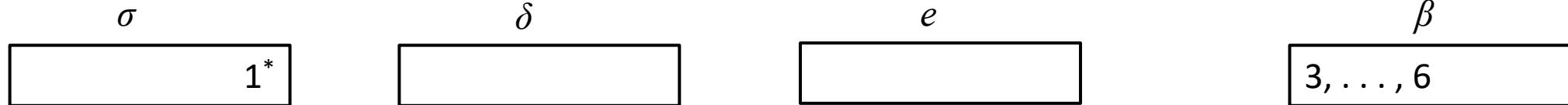




# Joint Extraction of Entities and Relations

- Transition Actions
  - O-DELETE

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

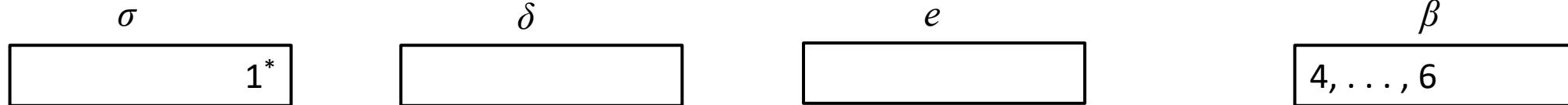




# Joint Extraction of Entities and Relations

- Transition Actions
  - O-DELETE

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

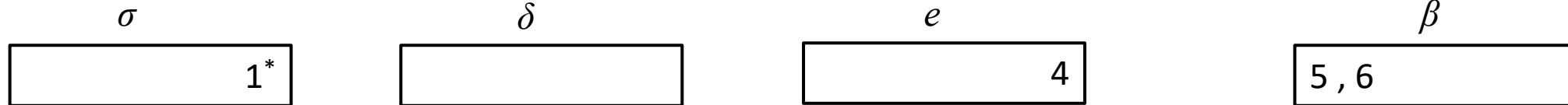




# Joint Extraction of Entities and Relations

- Transition Actions
  - NER-SHIFT

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>

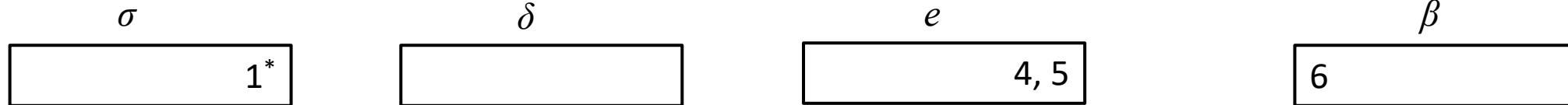




# Joint Extraction of Entities and Relations

- Transition Actions
  - NER-SHIFT

Per  
John<sub>[1]</sub> lives<sub>[2]</sub> in<sub>[3]</sub> Los<sub>[4]</sub> Angeles<sub>[5]</sub> California<sub>[6]</sub>





# Joint Extraction of Entities and Relations

- Transition Actions
    - NER-LOC

$\sigma$

$\delta$

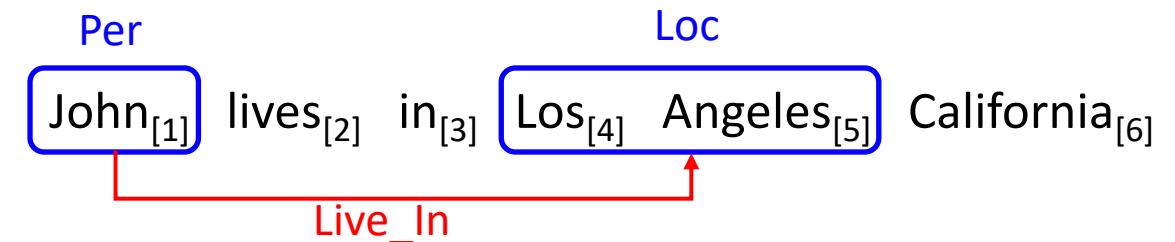
*e*

$\beta$



# Joint Extraction of Entities and Relations

- Transition Actions
  - RIGHT-SHIFT(Live\_In)



$\sigma$   
1\*, 5\*

$\delta$

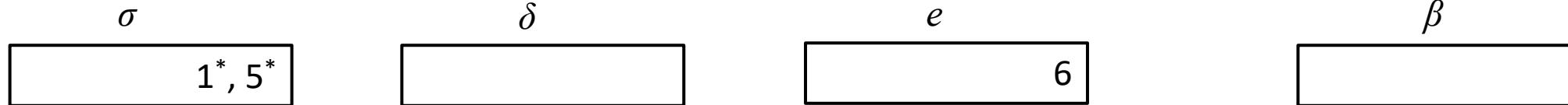
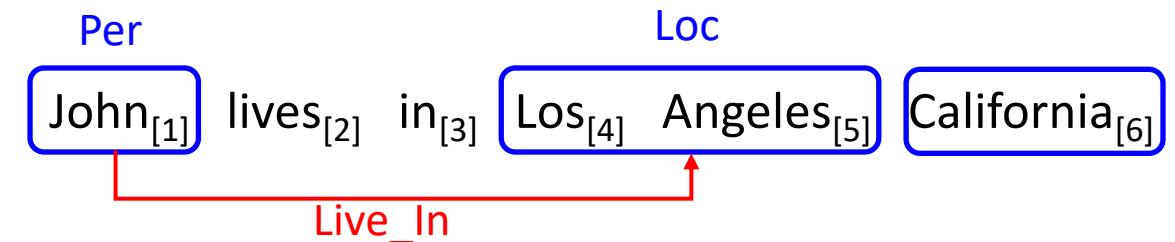
$e$

$\beta$   
6



# Joint Extraction of Entities and Relations

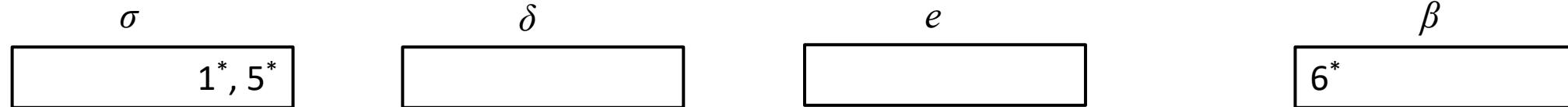
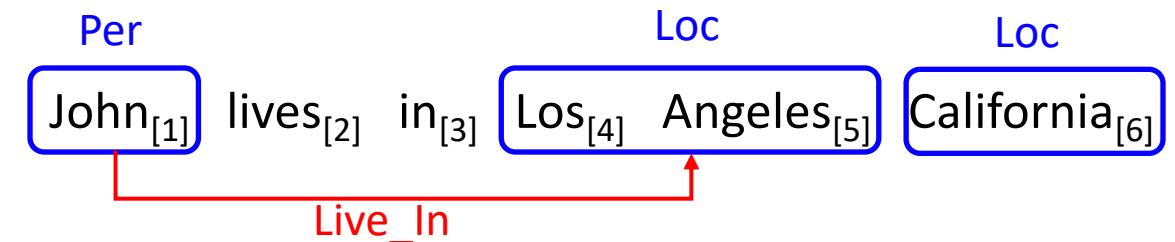
- Transition Actions
  - NER-SHIFT





# Joint Extraction of Entities and Relations

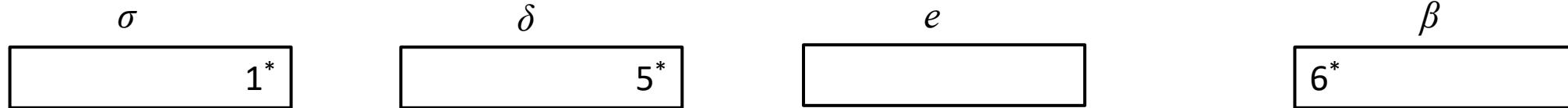
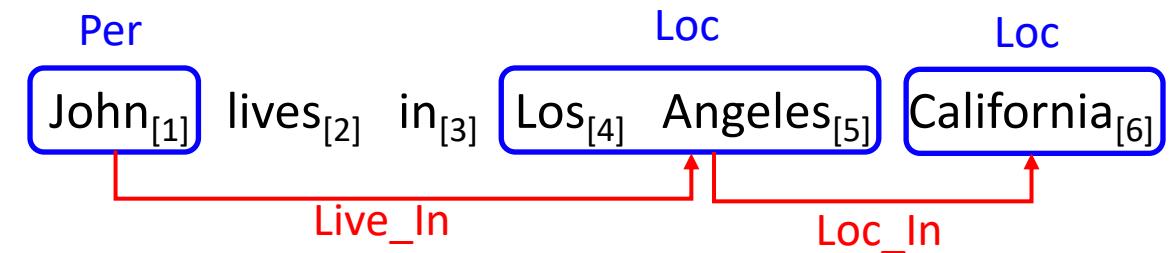
- Transition Actions
  - NER-LOC





# Joint Extraction of Entities and Relations

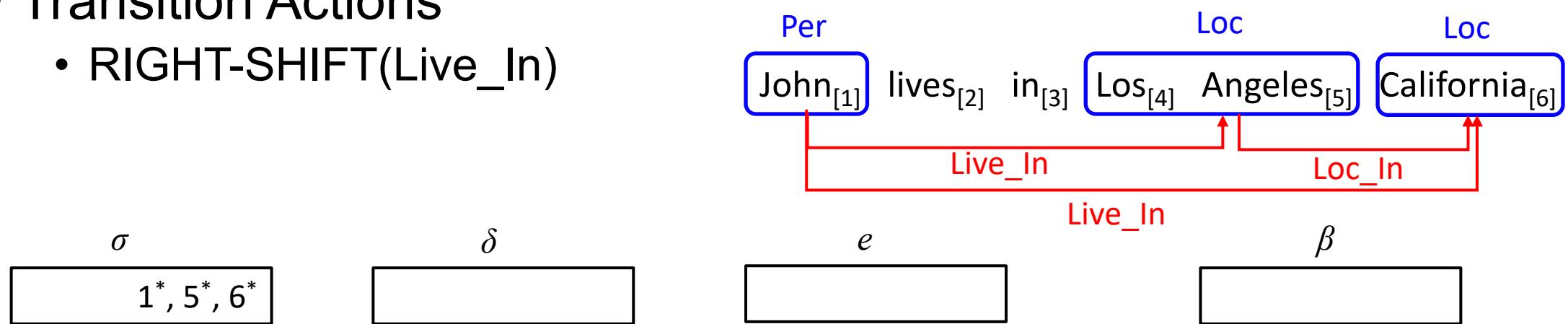
- Transition Actions
  - RIGHT-PASS(Loc\_In)





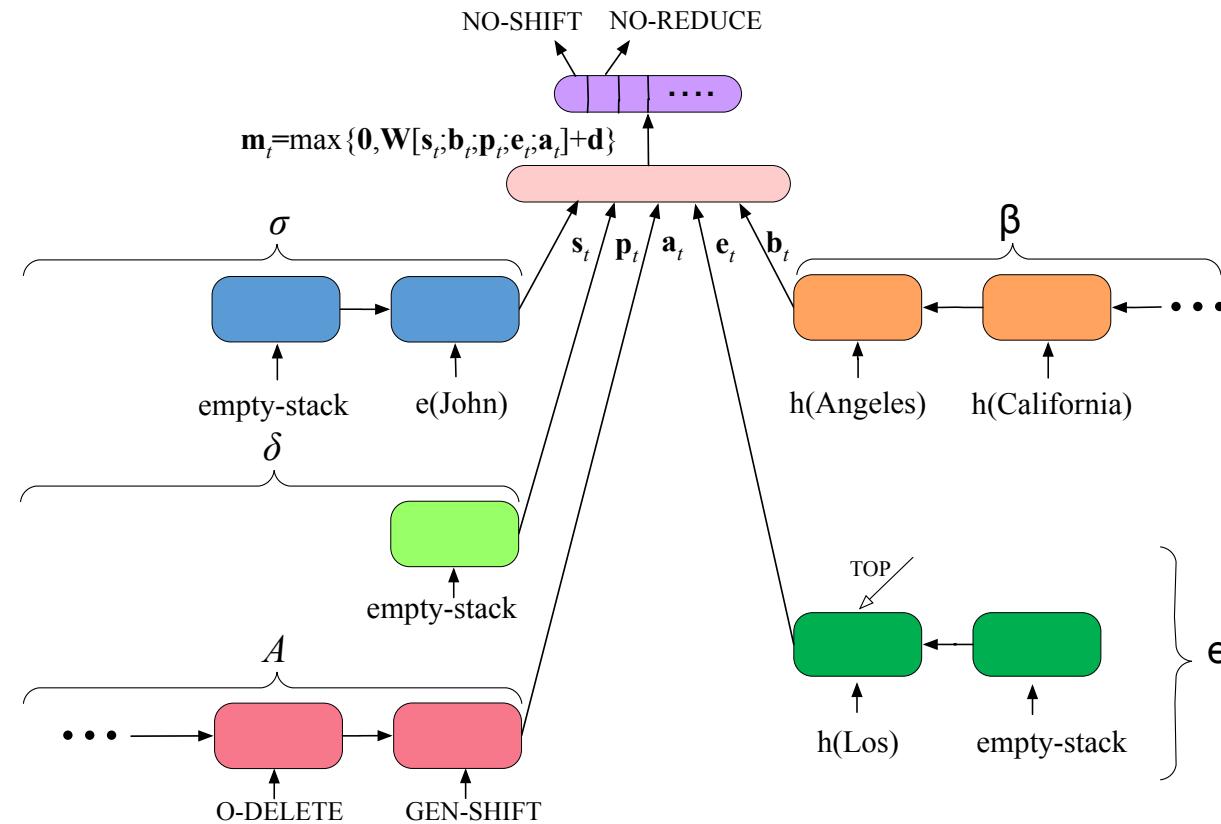
# Joint Extraction of Entities and Relations

- Transition Actions
  - RIGHT-SHIFT(Live\_In)



# Joint Extraction of Entities and Relations

- Model





# Joint Extraction of Entities and Relations

- Results on NYT

Method	Prec.	Rec.	F1
FCM [Gormley <i>et al.</i> , 2015]	55.3	15.4	24.0
DS+logistic [Mintz <i>et al.</i> , 2009]	25.8	39.3	31.1
LINE [Tang <i>et al.</i> , 2015]	33.5	32.9	33.2
MultiR [Hoffmann <i>et al.</i> , 2011]	33.8	32.7	33.3
DS-Joint [Li and Ji, 2014]	57.4	25.6	35.4
CoType [Ren <i>et al.</i> , 2017]	42.3	51.1	46.3
LSTM-LSTM-Bias	61.5	41.4	49.5
LSTM-LSTM-Bias*	60.8	41.3	49.1
<b>Our Method</b>	<b>64.3</b>	<b>42.1</b>	<b>50.9</b>



# Deep Learning Models

- Neural Transition-based Models
- Neural Graph-based Models (Multi-task Learning)
  - Cross Task
  - Cross Lingual
  - Cross Domain
  - Cross Standard

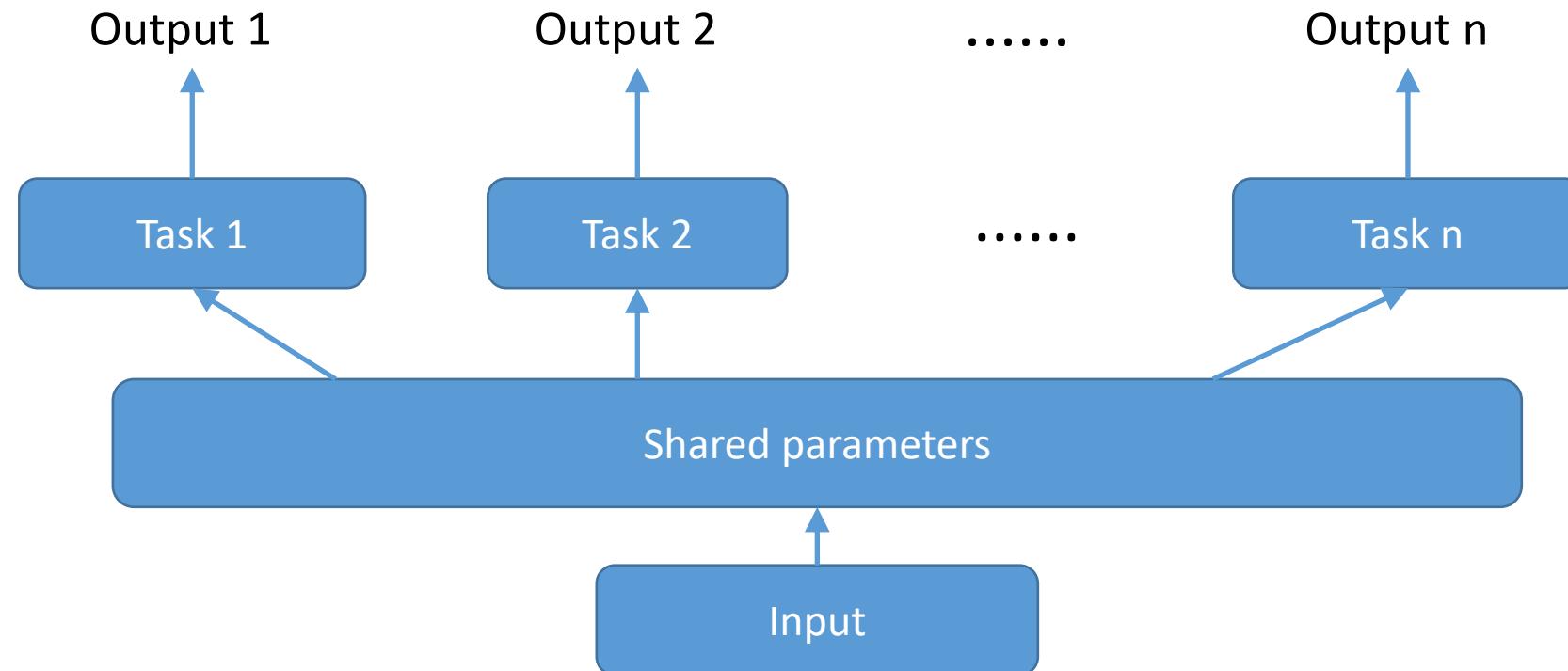


# Deep Learning Models

- Neural Transition-based Models
- Neural Graph-based Models (Multi-task)
  - Cross Task
  - Cross Lingual
  - Cross Domain
  - Cross Application

Joint Learning Separate Search

# Neural Graph-based Models (Multi-task Learning)



# Neural Graph-based Models (Multi-task Learning)



- Cross Task
- Cross Lingual
- Cross Domain
- Cross Standard

# Neural Graph-based Models (Multi-task Learning)

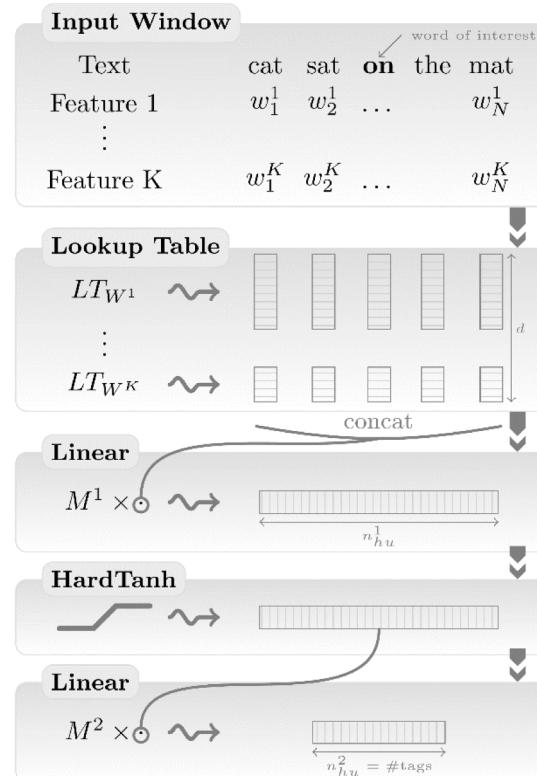


- Cross Task
- Cross Lingual
- Cross Domain
- Cross Standard



# Joint Tagging, Chunking and NER

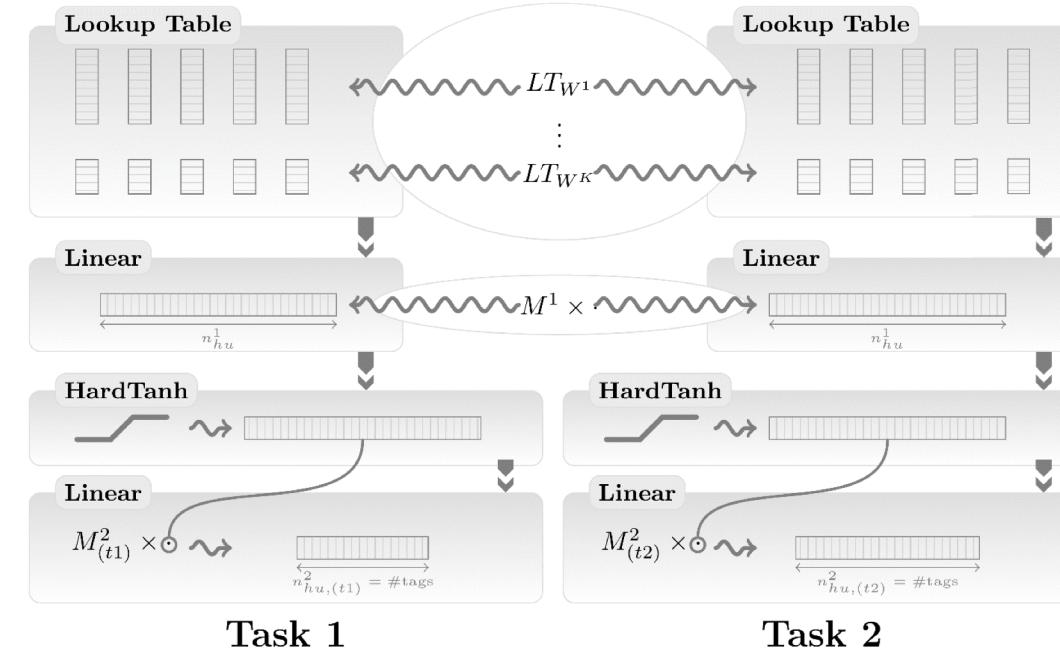
- Seminal work in NLP



Collobert, Ronan, et al. "Natural language processing (almost) from scratch." *Journal of Machine Learning Research* 12.Aug (2011): 2493-2537.

# Joint Tagging, Chunking and NER

- Multitasking between Tagging, Chunking and NER
  - Share lookup table
  - Share first linear layers





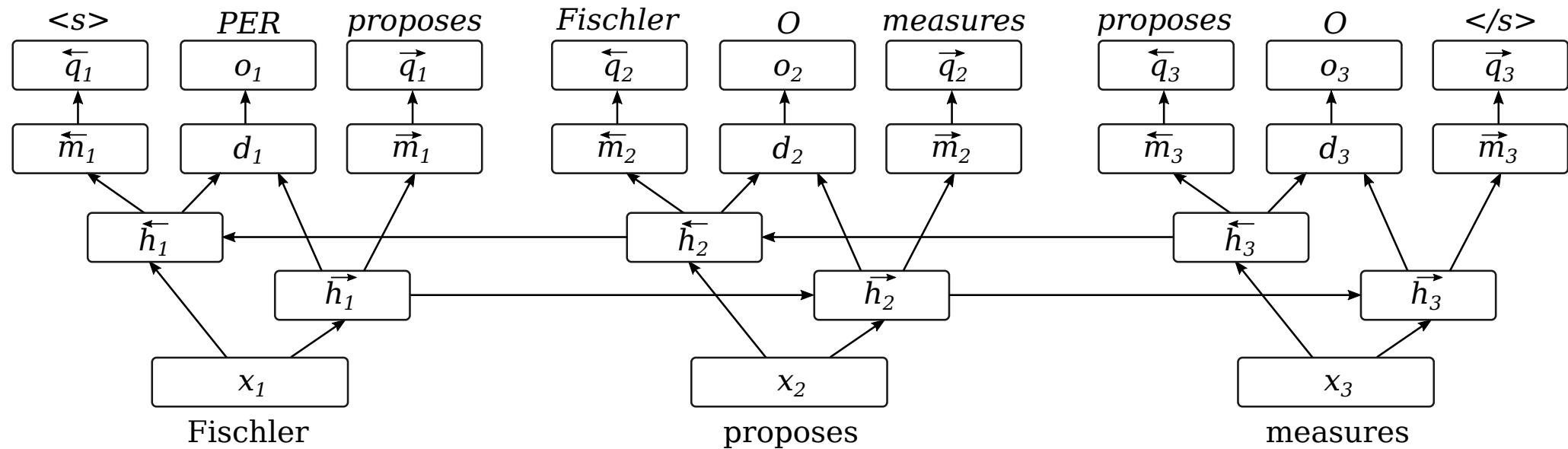
# Joint Tagging, Chunking and NER

- Results

<b>Approach</b>	<b>POS</b> (PWA)	<b>CHUNK</b> (F1)	<b>NER</b> (F1)
<b>Benchmark Systems</b>	97.24	94.29	89.31
<i>Window Approach</i>			
NN+SLL+LM2	97.20	93.63	88.67
NN+SLL+LM2+MTL	97.22	94.10	88.62

# NER and Language Modelling

- Model





# NER and Language Modelling

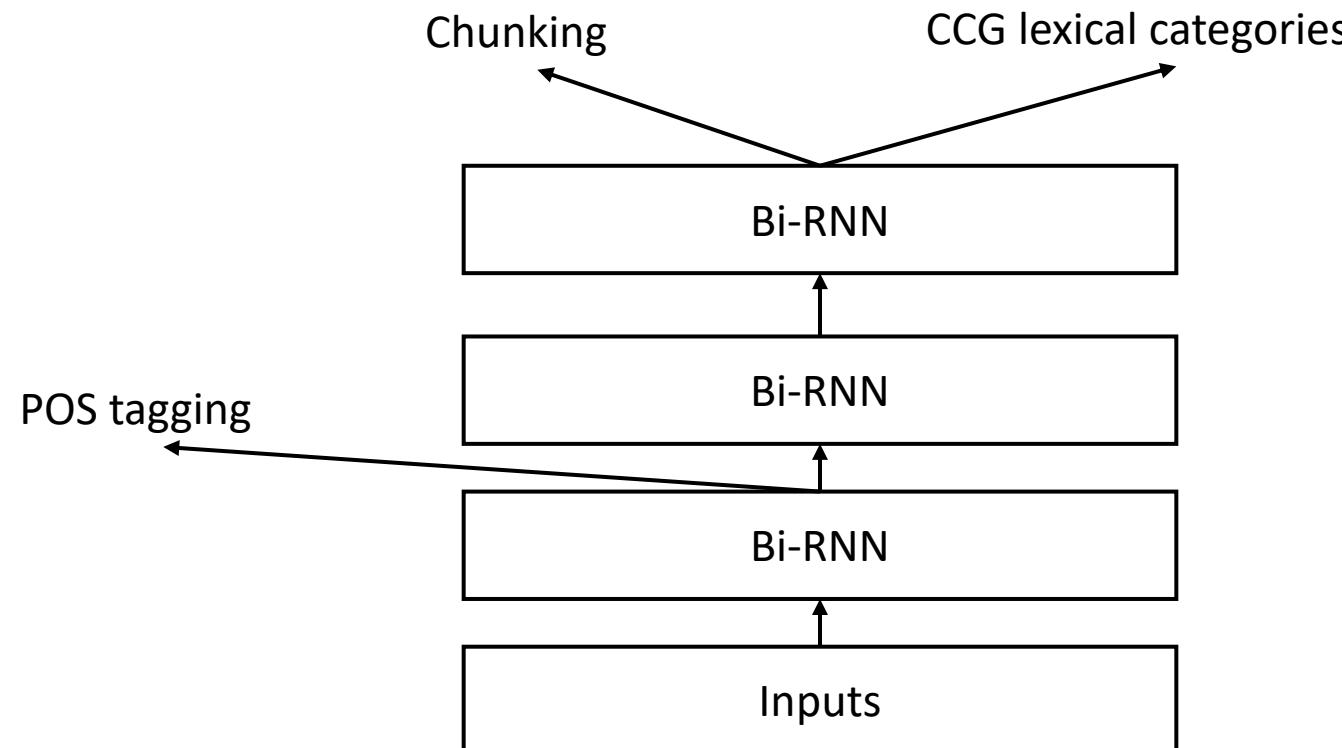
- Results

	CoNLL-00		CoNLL-03		CHEMDNER		JNLPBA	
	DEV	TEST	DEV	TEST	DEV	TEST	DEV	TEST
Baseline	92.92	92.67	90.85	85.63	83.63	84.51	77.13	72.79
+ dropout	93.40	93.15	91.14	86.00	84.78	85.67	77.61	73.16
+ LMcost	<b>94.22</b>	<b>93.88</b>	<b>91.48</b>	<b>86.26</b>	<b>85.45</b>	<b>86.27</b>	<b>78.51</b>	<b>73.83</b>

# Joint POS tagging/Chunking and CCG Super Tagging



- Model



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Søgaard, Anders, and Yoav Goldberg. "Deep multi-task learning with low level tasks supervised at lower layers." *Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*. Vol. 2. 2016.

# Joint POS tagging/Chunking and CCG Super Tagging



- Results

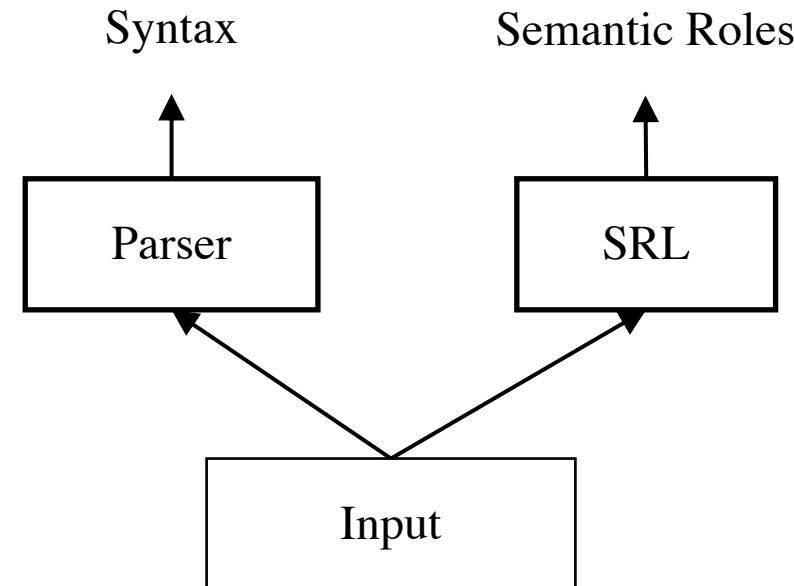
	POS	CHUNKS	CCG
BI-LSTM	-	95.28	91.04
	3	95.30	92.94
	1	<b>95.56</b>	<b>93.26</b>

- Additional tasks such as NER do not benefit from multi-task learning



# Joint Parsing and SRL

- Share only the embedding layer





# Joint Parsing and SRL

- Results on CONLL

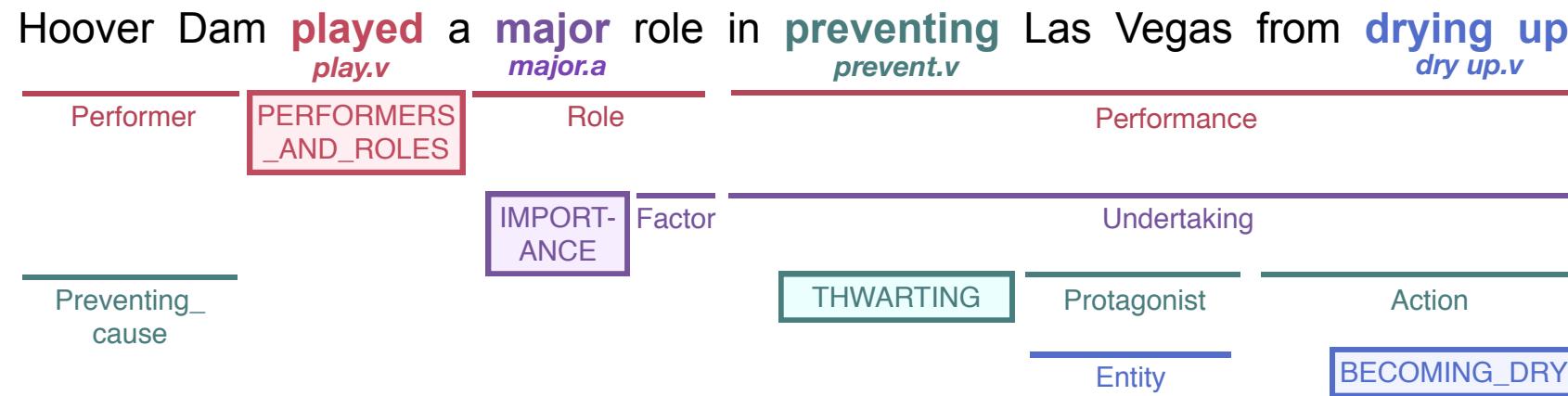
Model	F <sub>1</sub>	UAS	LAS
Bi-LSTM	72.71	-	-
S-LSTM	-	84.33	82.10
DEP→SRL( <i>lab/lstm</i> )	73.00/ <b>74.18</b>	84.33	82.10
SRL→DEP	72.71	84.75	82.62
Joint	73.84	<b>85.15</b>	<b>82.91</b>

- Sharing more layers have mixed results



# Joint Frame Semantic and Constituent Parsing

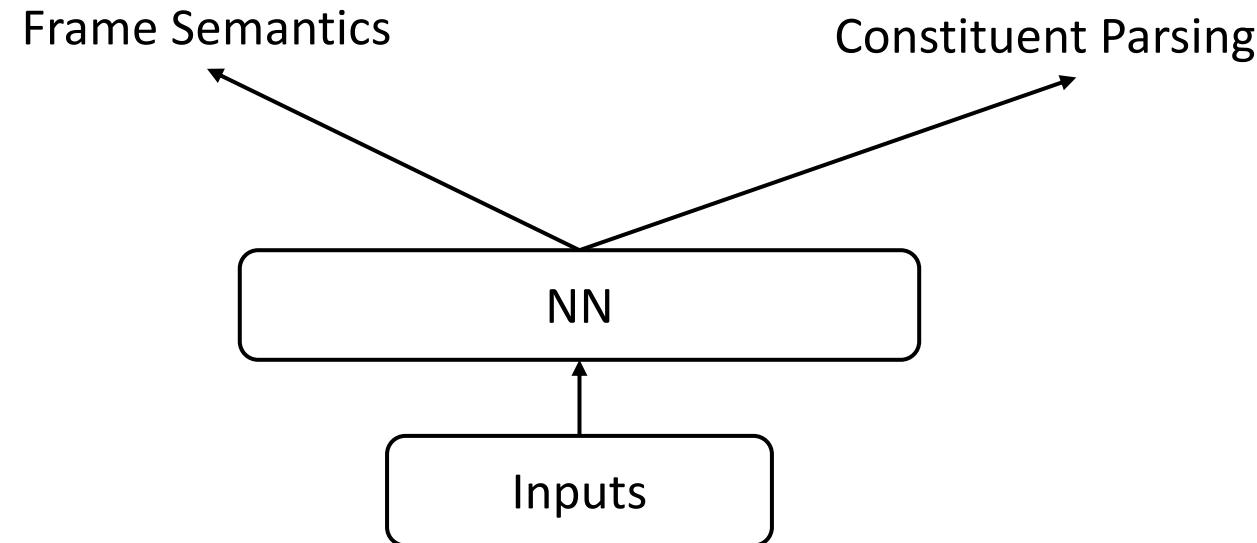
- FrameNet lexicon



# Joint Frame Semantic and Constituent Parsing



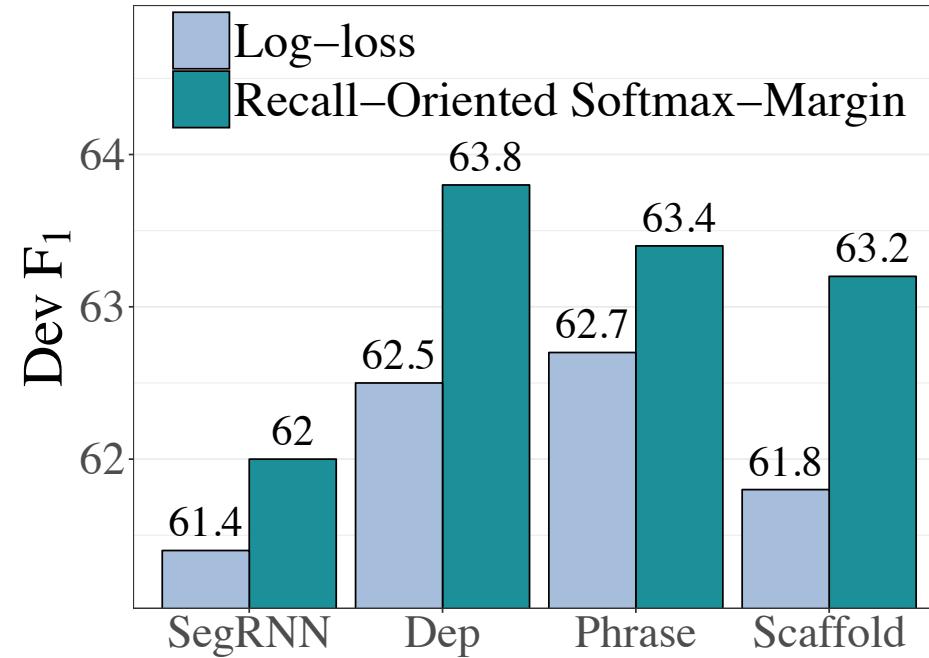
- Standard Multi-task



# Joint Frame Semantic and Constituent Parsing



- Results on FrameNet (September 2010 release)



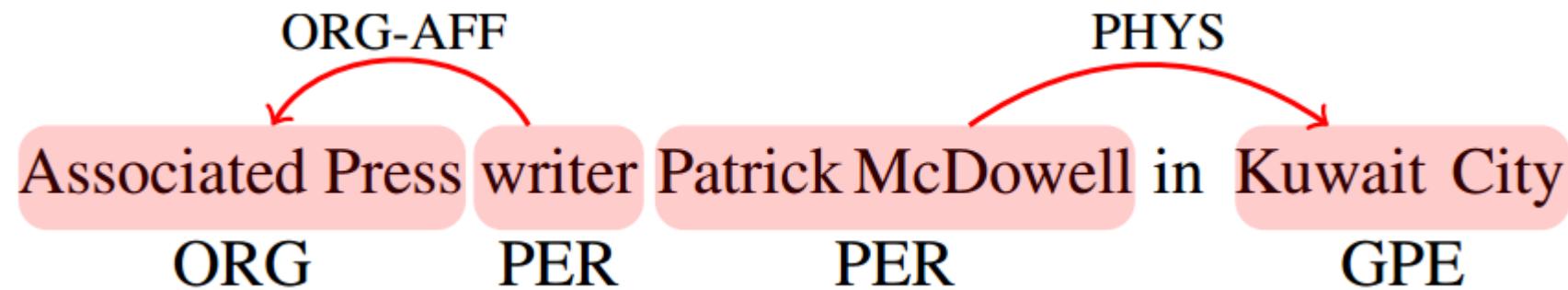
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Swayamdipta, S., Thomson, S., Dyer, C., & Smith, N. A. (2017). Frame-semantic parsing with softmax-margin segmental RNNs and a syntactic scaffold. arXiv preprint arXiv:1706.09528.



# Joint Entity and Relation Extraction

- Relation Extraction





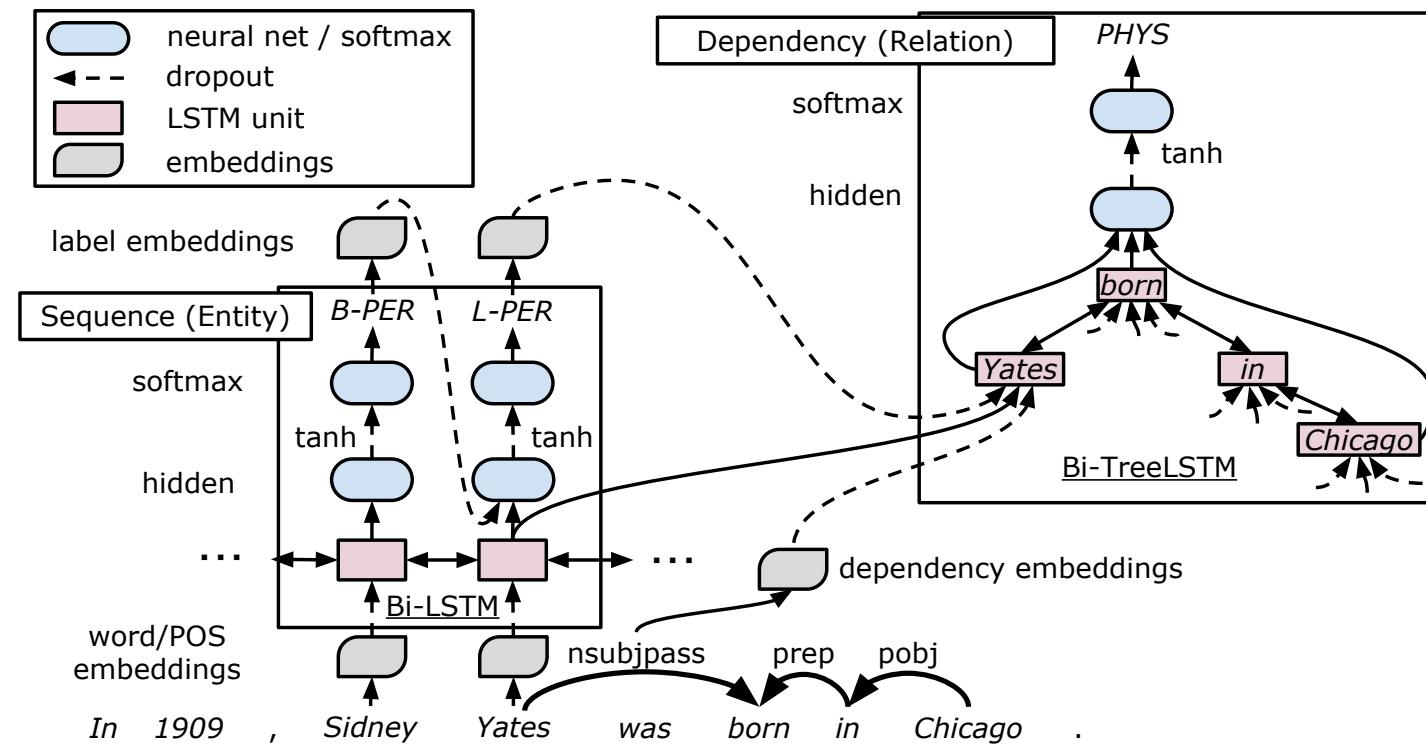
# Joint Entity and Relation Extraction

- Table-Filling

	Associated	Press	writer	Patrick	McDowell	in	Kuwait	City
Associated	1 B-ORG	9 ⊥	16 ⊥	22 ⊥	27 ⊥	31 ⊥	34 ⊥	36 ⊥
Press		2 L-ORG	10 <del>ORG-AFF</del>	17 ⊥	23 ⊥	28 ⊥	32 ⊥	35 ⊥
writer			3 U-PER	11 ⊥	18 ⊥	24 ⊥	29 ⊥	33 ⊥
Patrick				4 B-PER	12 ⊥	19 ⊥	25 ⊥	30 ⊥
McDowell					5 L-PER	13 ⊥	20 ⊥	26 PHYS
in						6 O	14 ⊥	21 ⊥
Kuwait							7 B-GPE	15 ⊥
City								8 L-GPE

# Joint Entity and Relation Extraction

- Share RNN hidden layers



Miwa, Makoto, and Mohit Bansal. "End-to-end relation extraction using lstms on sequences and tree structures." *In proceedings of ACL* (2016).



# Joint Entity and Relation Extraction

- Results on ACE

Settings	Macro-F1
No External Knowledge Resources	
Our Model (SPTree)	<b>0.844</b>
dos Santos et al. (2015)	0.841
Xu et al. (2015a)	0.840
+WordNet	
Our Model (SPTree + WordNet)	0.855
Xu et al. (2015a)	<b>0.856</b>
Xu et al. (2015b)	0.837

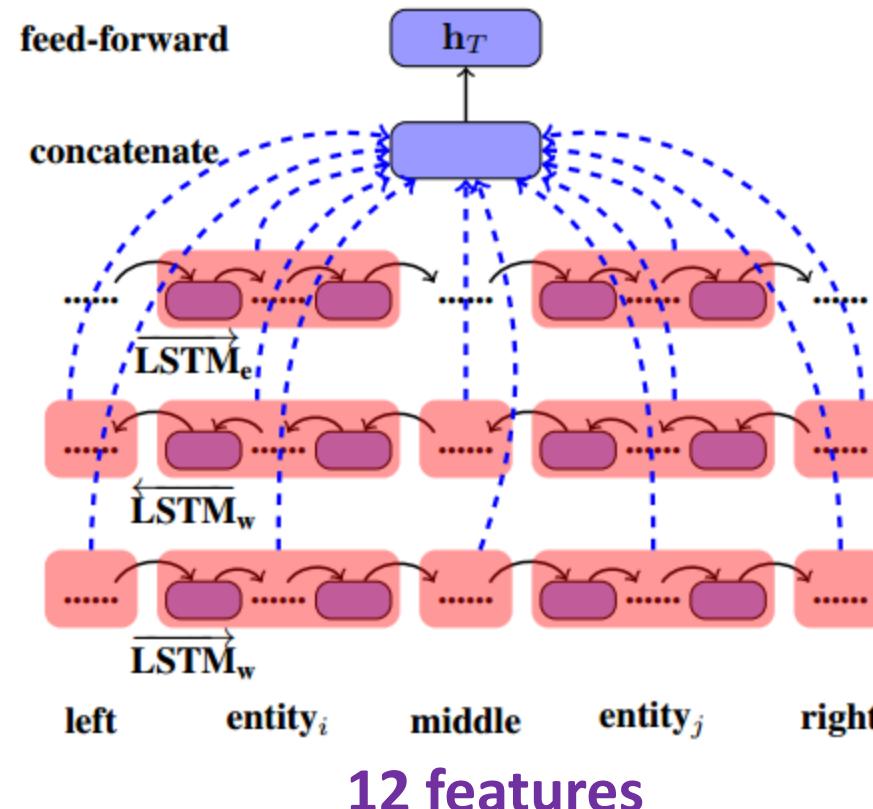


# Joint Entity and Relation Extraction

- Beam Search with Global Learning
- Syntactic Features by sharing the last hidden layer of (Dozat and Manning, 2017)

# Joint Entity and Relation Extraction

- Share RNN Encoding Layers





# Joint Entity and Relation Extraction

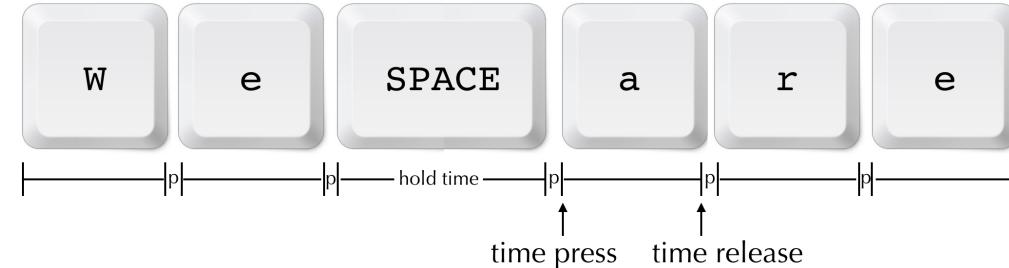
- Results on ACE05

Model	Beam	Relation F1
Local	1	50.9
Local(+SS)	1	51.2
Global	1	51.4
	3	51.8
	5	<b>52.6</b>



# Keystroke and Shallow Syntactic Parsing

- Keystroke Logging



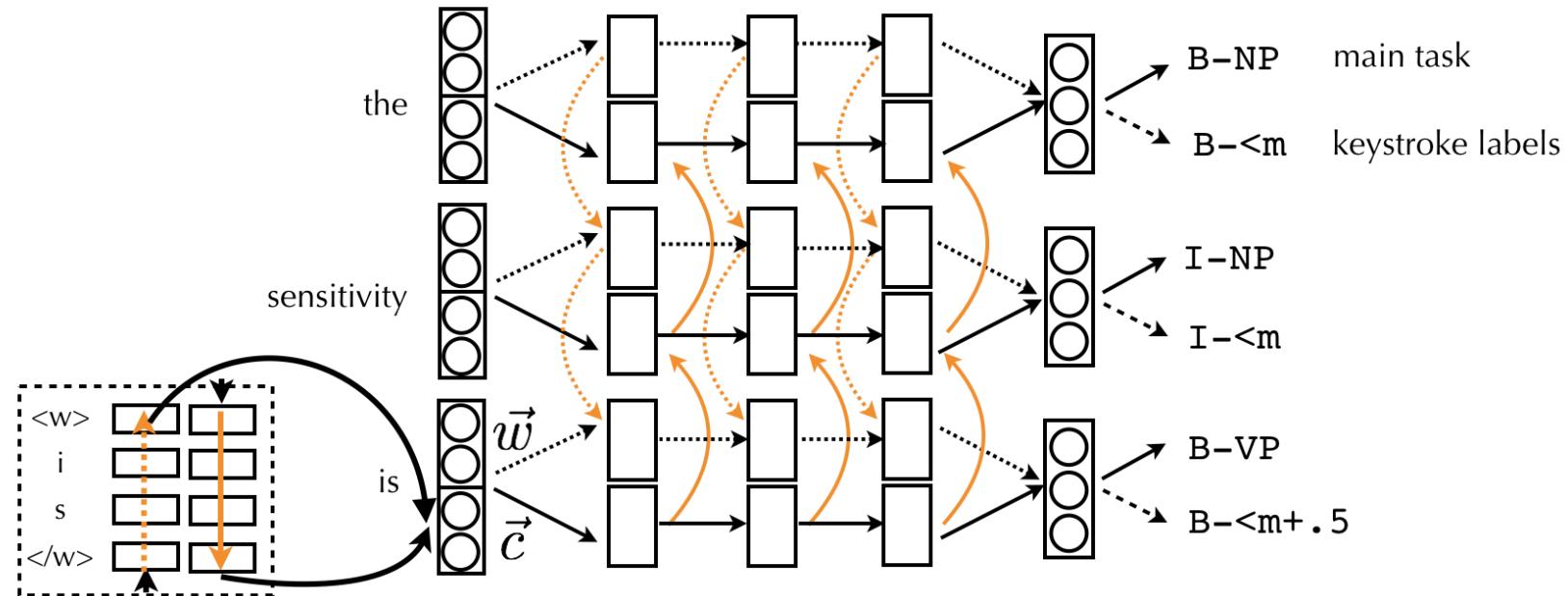
Token:	[ Coefficient	of	determination ]	[ is	a ]	[ measure	used	in ]	[ statisitcal	model ]	[ analysis ]
Pause (ms):	0	96	496	30769	96	2144	96	80	2975	240	680

B-<m		B-<m+1		B-<m		I-<m		B-<m+.5		I-<m+.5		B->m+1
the		closer		the		number		is		to		1

Aggregate statistics

# Keystroke and Shallow Syntactic Parsing

- Model





# Keystroke and Shallow Syntactic Parsing

- Results

sentences	TRAIN	DEV	TEST
CoNLL 2000	8936	–	2012
FOSTER	–	269	250
RITTER	–	–	2364
CCG	39604	1913	2407

	FOSTER.DEV	FOSTER.TEST	RITTER	CCG
Baseline	73.93	73.61	66.65	92.41
+PAUSE	<b>74.63<sup>†</sup></b>	<b>74.32<sup>†</sup></b>	<b>66.91<sup>†</sup></b>	<b>92.62<sup>†</sup></b>
<i>p</i> -values	<0.01	<0.01	<0.01	<0.048

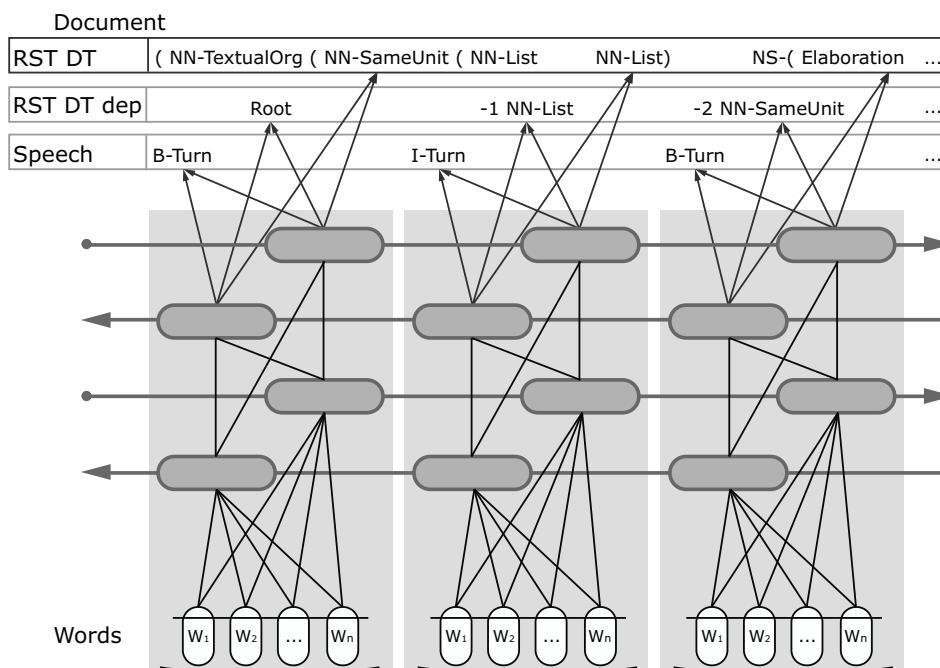
Chunking and CCG data



# RST Discourse Parser

- Many tasks

	Task	# Doc	# Labels
Main task	Constituent	322	1955
	Nuclearity	322	284
	Relation	322	1159
	Dependency	322	708
	Fine grained	322	2,700
Other views	Aspect	208	4
	Factuality	208	7
	Modality	208	10
	Polarity	208	3
	Tense	208	7
Other tasks	Coreference	2,361	4
	PDTB	2,065	35
	Speech	446	2



Braud, Chloé, Barbara Plank, and Anders Søgaard. "Multi-view and multi-task training of RST discourse parsers." Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers. 2016.



# RST Discourse Parser

- Results on RST Discourse Treebank

System	RSTFin	Fact	Speech	Asp	RSTDep	Nuc+lab	Mod	Pol	PDTB	Coref	Ten	Span	Nuclearity	Relation
Prior work														
DPLP concat	-	-	-	-	-	-	-	-	-	-	-	82.08	<b>71.13</b>	61.63
DPLP general	-	-	-	-	-	-	-	-	-	-	-	81.60	70.95	<b>61.75</b>
Our work														
Hier-LSTM	-	-	-	-	-	-	-	-	-	-	-	81.39	64.54	49.15
MTL-Hier-LSTM	✓	-	-	-	-	-	-	-	-	-	-	82.88	67.46	53.25
MTL-Hier-LSTM	-	✓	-	-	-	-	-	-	-	-	-	83.40	67.16	52.10
MTL-Hier-LSTM	-	-	✓	-	-	-	-	-	-	-	-	83.26	67.51	51.75
MTL-Hier-LSTM	-	-	-	✓	-	-	-	-	-	-	-	83.69	66.25	51.25
MTL-Hier-LSTM	-	-	-	-	✓	-	-	-	-	-	-	81.25	65.34	51.24
MTL-Hier-LSTM	-	-	-	-	-	✓	-	-	-	-	-	82.09	65.68	51.12
MTL-Hier-LSTM	-	-	-	-	-	-	✓	-	-	-	-	81.66	65.31	50.58
MTL-Hier-LSTM	-	-	-	-	-	-	-	✓	-	-	-	82.01	65.29	50.11
MTL-Hier-LSTM	-	-	-	-	-	-	-	-	✓	-	-	81.61	63.10	48.89
MTL-Hier-LSTM	-	-	-	-	-	-	-	-	-	✓	-	80.26	63.35	47.70
MTL-Hier-LSTM	-	-	-	-	-	-	-	-	-	-	✓	81.33	62.34	47.57
Best combination	-	-	-	-	✓	✓	✓	-	✓	-	-	<b>83.62</b>	69.77	55.11
Human annotation	-	-	-	-	-	-	-	-	-	-	-	88.70	77.72	65.75

Braud, Chloé, Barbara Plank, and Anders Søgaard. "Multi-view and multi-task training of RST discourse parsers." Proceedings of COLING 2016, the 26th International Conference on Computational Linguistics: Technical Papers. 2016.



# Joint Entity and Sentiment Extraction

---

So excited to meet my [**baby Farah**]<sub>+</sub> !!!

---

[**Baseball Warehouse**]<sub>+</sub> : easy to understand information.

---

The [**#Afghan #Parlaiment Speaker**]<sub>-</sub> should Resign .

---

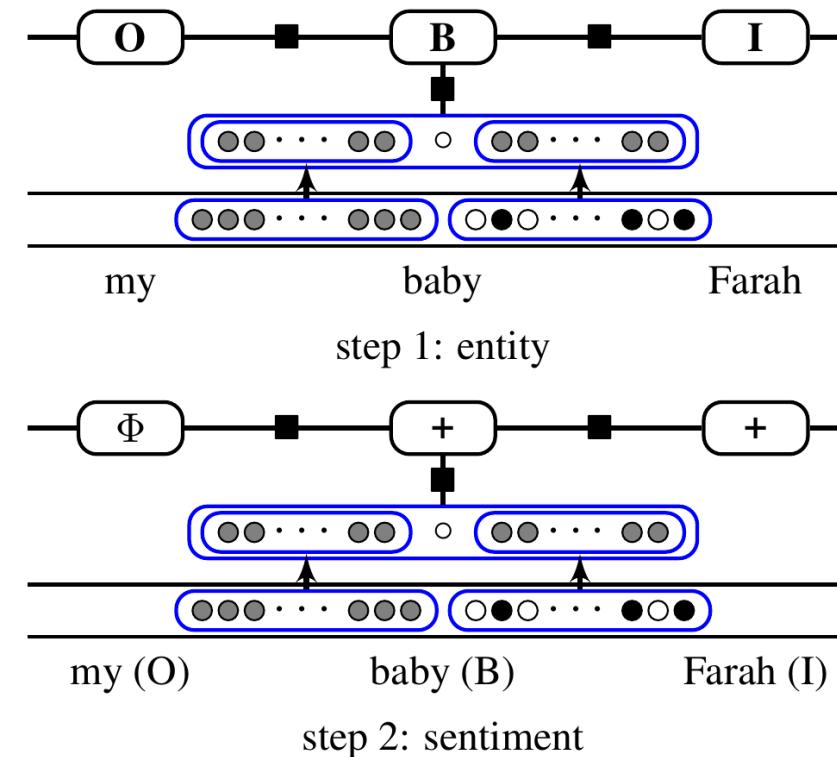
Saw [**Erykah Badu**]<sub>-</sub> last night , vile venue unfortunately .

---

[**AW service**]<sub>0</sub> will be back at work .

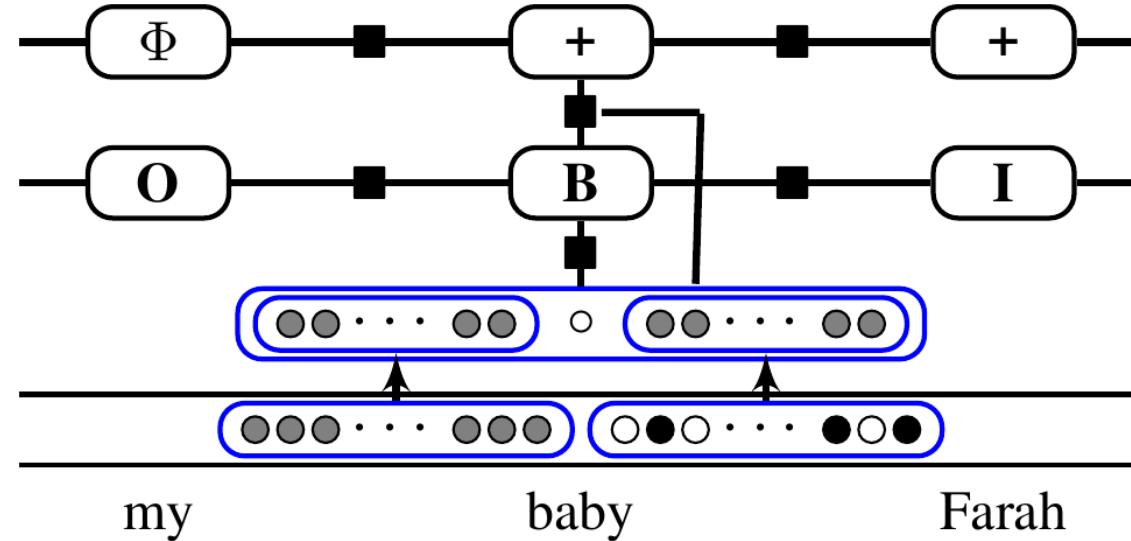
# Joint Entity and Sentiment Extraction

- Pipeline



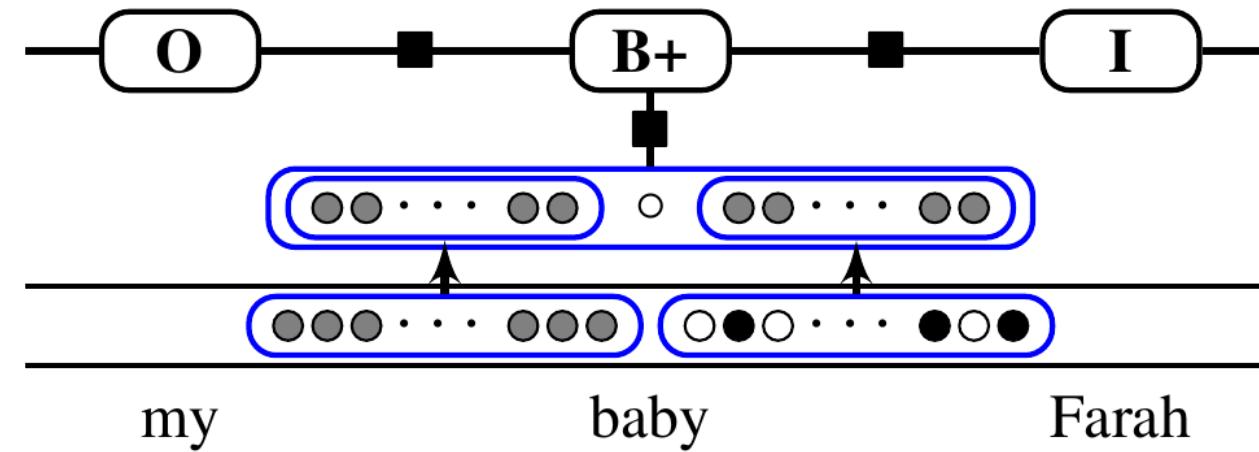
# Joint Entity and Sentiment Extraction

- Joint



# Joint Entity and Sentiment Extraction

- Collapsed





# Joint Entity and Sentiment Extraction

- Results

Model	English						Spanish					
	Entity			SA			Entity			SA		
	P	R	F	P	R	F	P	R	F	P	R	F
<b>Pipeline</b>												
discrete	59.37	34.83	43.84	42.97	25.21	31.73	<b>70.77</b>	47.75	57.00	<b>46.55</b>	31.38	37.47
neural	53.64	44.87	48.67	37.53	31.38	34.04	65.59	47.82	55.27	41.50	30.27	34.98
integrated	<b>60.69</b>	<b>51.63</b>	<b>55.67</b>	<b>43.71</b>	<b>37.12</b>	<b>40.06</b>	70.23	<b>62.00</b>	<b>65.76</b>	45.99	<b>40.57</b>	<b>43.04</b>
<b>Joint</b>												
discrete	59.55	34.06	43.30	43.09	24.67	31.35	71.08	47.56	56.96	46.36	31.02	37.15
neural	54.45	42.12	47.17	37.55	28.95	32.45	65.05	47.79	55.07	40.28	29.58	34.09
integrated	<b>61.47</b>	<b>49.28</b>	<b>54.59</b>	<b>44.62</b>	<b>35.84</b>	<b>39.67</b>	<b>71.32</b>	<b>61.11</b>	<b>65.74</b>	<b>46.67</b>	<b>39.99</b>	<b>43.02</b>
<b>Collapsed</b>												
discrete	<b>64.16</b>	26.03	36.95	<b>48.35</b>	19.64	27.86	73.18	35.11	47.42	<b>49.85</b>	23.91	32.30
neural	58.53	37.25	45.30	43.12	27.44	33.36	67.43	43.2	52.64	42.61	27.27	33.25
integrated	63.55	<b>44.98</b>	<b>52.58</b>	46.32	<b>32.84</b>	<b>38.36</b>	<b>73.51</b>	<b>53.3</b>	<b>61.71</b>	47.69	<b>34.53</b>	<b>40.00</b>



# Identifying beneficial task relations

- Not all tasks are mutually beneficial !

	CCG	CHU	COM	FNT	POS	HYP	KEY	MWE	SEM	STR
CCG		1.4	0.45	0.58	1.8	0.24	0.3	0.45	1.4	0.84
CHU	-0.052		-0.15	-0.12	-0.45	-0.5	-0.22	-0.27	-0.099	-0.32
COM	-5	1.3		1.3	-1.4	-2.4	-4.8	0.82	-3	-0.63
FNT	-5.8	-1	-6.1		-9.4	-5.7	-3.6	-9.4	-3	-0.68
POS	4.9	2.9	1.9	0.9		-0.85	-0.26	1.3	3.4	2.9
HYP	12	4	-11	9.2	22		1.5	-7.7	23	8.1
KEY	5.7	3.2	-1	-0.43	-1.3	-2.6		-4.7	0.59	0.69
MWE	18	20	7.4	5.5	1.6	-3.8	-5.8		16	8.6
SEM	-5	-0.76	-1.2	-0.81	-0.85	-1.3	-0.83	-1.1		-1.7
STR	-1.7	1.5	-0.26	-0.72	0.037	-1.5	-1.4	-1.6	1.7	

Bingel, Joachim, and Anders Søgaard. "Identifying beneficial task relations for multi-task learning in deep neural networks." arXiv preprint arXiv:1702.08303 (2017).

Hector Martínez Alonso and Barbara Plank. 2017. Multitask learning for semantic sequence prediction under varying data conditions. In EACL.

Mou, Lili, et al. "How transferable are neural networks in nlp applications?." arXiv preprint arXiv:1603.06111 (2016).



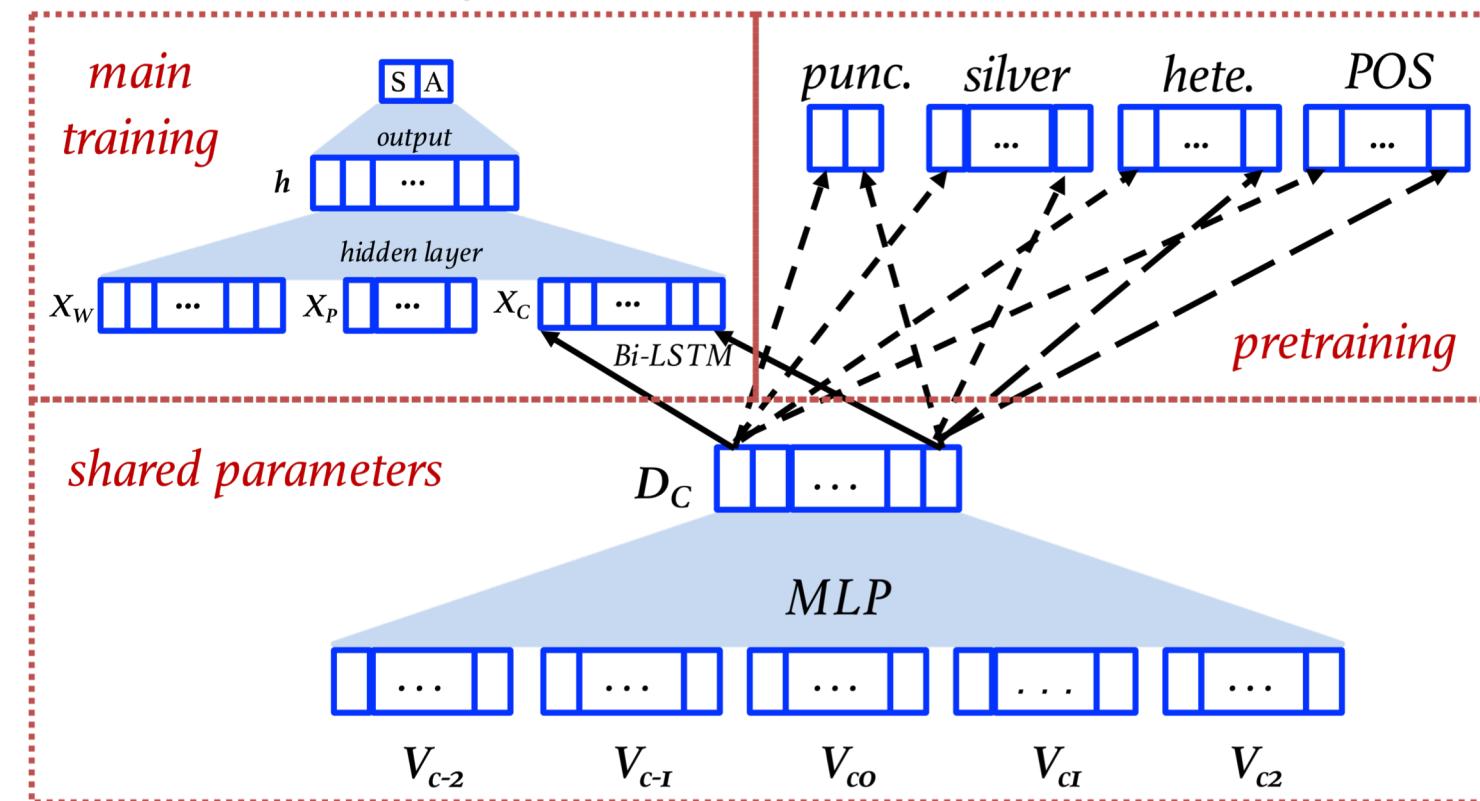
# Pre-training

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Jie Yang, Yue Zhang, Fei Dong. Neural Word Segmentation with Rich Pretraining. In Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics (2017)

# Word Segmentation

- Rich Multi-task pretraining of character window representations





# Word Segmentation

- Results

Models	P	R	F
Baseline	95.3	95.5	95.4
Punc. pretrain	96.0	95.6	95.8
Auto-seg pretrain	95.8	95.6	95.7
Multitask pretrain	<b>96.4</b>	<b>96.0</b>	<b>96.2</b>
<a href="#">Sun and Xu (2011)</a> baseline	95.2	94.9	95.1
<a href="#">Sun and Xu (2011)</a> multi-source semi	95.9	95.6	95.7
<a href="#">Zhang et al. (2016b)</a> neural	95.3	94.7	95.0
<a href="#">Zhang et al. (2016b)*</a> hybrid	96.1	95.8	96.0
<a href="#">Chen et al. (2015a)</a> window	95.7	95.8	95.8
<a href="#">Chen et al. (2015b)</a> char LSTM	96.2	95.8	96.0
<a href="#">Zhang et al. (2014)</a> POS and syntax	–	–	95.7
<a href="#">Wang et al. (2011)</a> statistical semi	95.8	95.8	95.8
<a href="#">Zhang and Clark (2011)</a> statistical	95.5	94.8	95.1



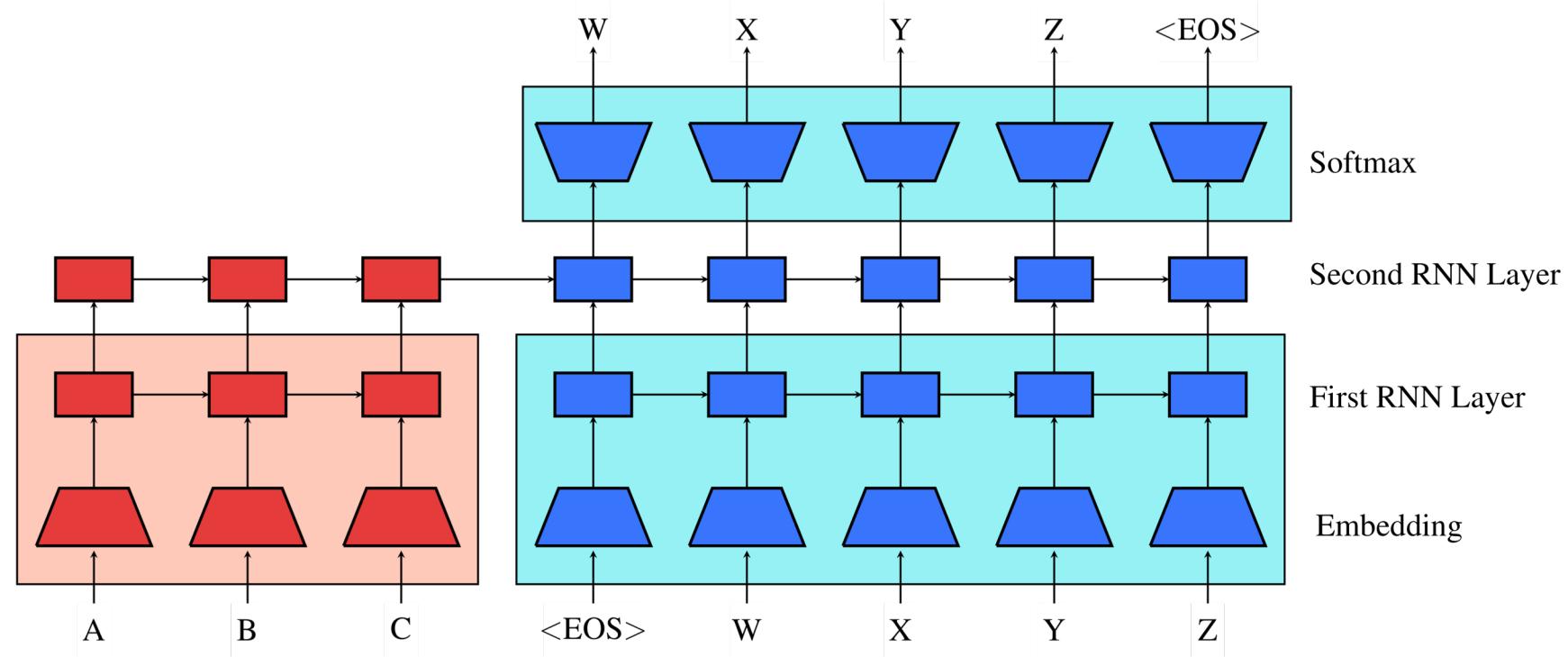
# Word Segmentation

- Results

F1 measure	PKU	MSR	AS	CityU	Weibo
Multitask pretrain	<b>96.3</b>	97.5	<b>95.7</b>	<b>96.9</b>	<b>95.5</b>
Cai and Zhao (2016)	95.5	96.5	—	—	—
Zhang et al. (2016b)	95.1	97.0	—	—	—
Zhang et al. (2016b)*	95.7	<b>97.7</b>	—	—	—
Pei et al. (2014)	95.2	97.2	—	—	—
Sun et al. (2012)	95.4	97.4	—	—	—
Zhang and Clark (2007)	94.5	97.2	94.6	95.1	—
Zhang et al. (2006)	95.1	97.1	95.1	95.1	—
Sun et al. (2009)	95.2	97.3	—	94.6	—
Sun (2010)	95.2	96.9	95.2	95.6	—
Wang et al. (2014)	95.3	97.4	95.4	94.7	—
Xia et al. (2016)	—	—	—	—	95.4

# Language Translation and Language Modelling

- Language Model Pretrain for both the source and target





# Language Translation and Language Modelling

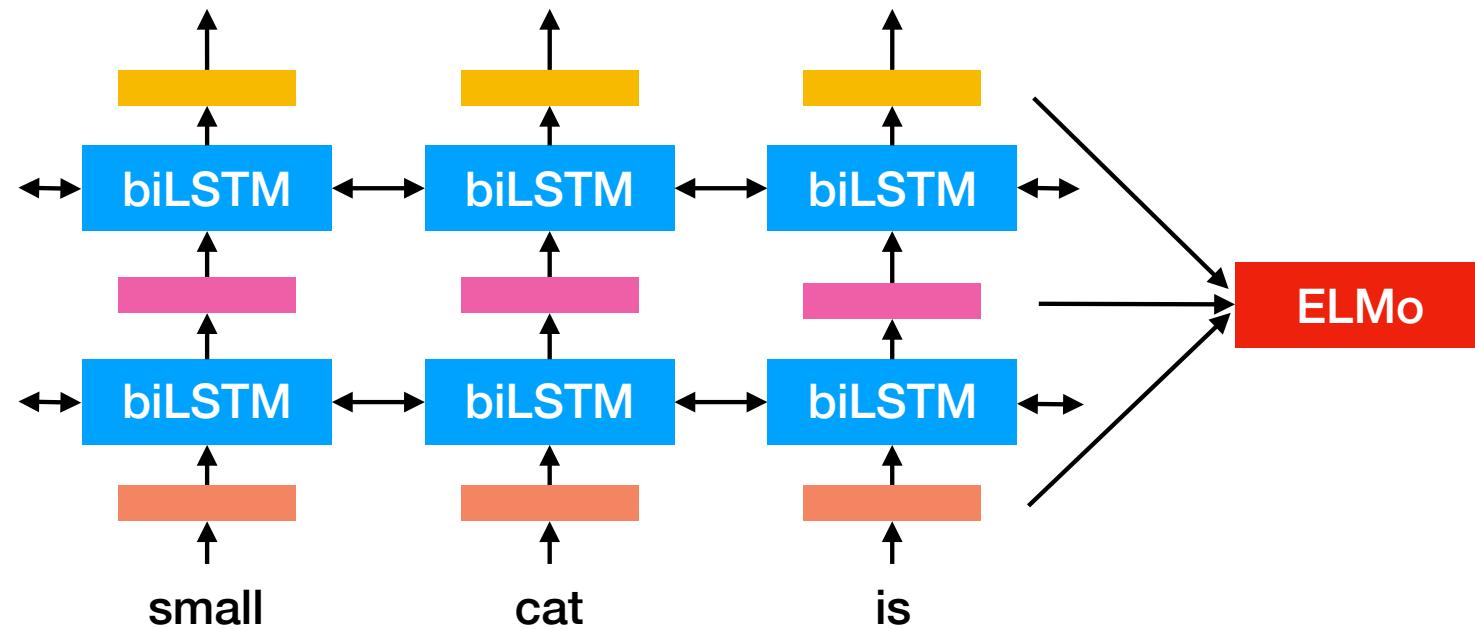
- Results on WMT

System	ensemble?	BLEU	
		newstest2014	newstest2015
Phrase Based MT (Williams et al., 2016)	-	21.9	23.7
Supervised NMT (Jean et al., 2015)	single	-	22.4
Edit Distance Transducer NMT (Stahlberg et al., 2016)	single	21.7	24.1
Edit Distance Transducer NMT (Stahlberg et al., 2016)	ensemble 8	22.9	25.7
Backtranslation (Sennrich et al., 2015a)	single	22.7	25.7
Backtranslation (Sennrich et al., 2015a)	ensemble 4	23.8	26.5
Backtranslation (Sennrich et al., 2015a)	ensemble 12	<b>24.7</b>	27.6
No pretraining	single	21.3	24.3
Pretrained seq2seq	single	<b>24.0</b>	<b>27.0</b>
Pretrained seq2seq	ensemble 5	<b>24.7</b>	<b>28.1</b>



# Language Model Pretraining

- Embeddings from Language Models (ELMo)





# Language Model Pretraining

- Results

TASK	PREVIOUS SOTA	OUR BASELINE	ELMO + BASELINE	INCREASE (ABSOLUTE/ RELATIVE)
SQuAD	Liu et al. (2017)	84.4	81.1	85.8
SNLI	Chen et al. (2017)	88.6	88.0	$88.7 \pm 0.17$
SRL	He et al. (2017)	81.7	81.4	84.6
Coref	Lee et al. (2017)	67.2	67.2	70.4
NER	Peters et al. (2017)	$91.93 \pm 0.19$	90.15	$92.22 \pm 0.10$
SST-5	McCann et al. (2017)	53.7	51.4	$54.7 \pm 0.5$

# Neural Graph-based Models (Multi-task Learning)



- Cross Task
- Cross Lingual
- Cross Domain
- Cross Standard

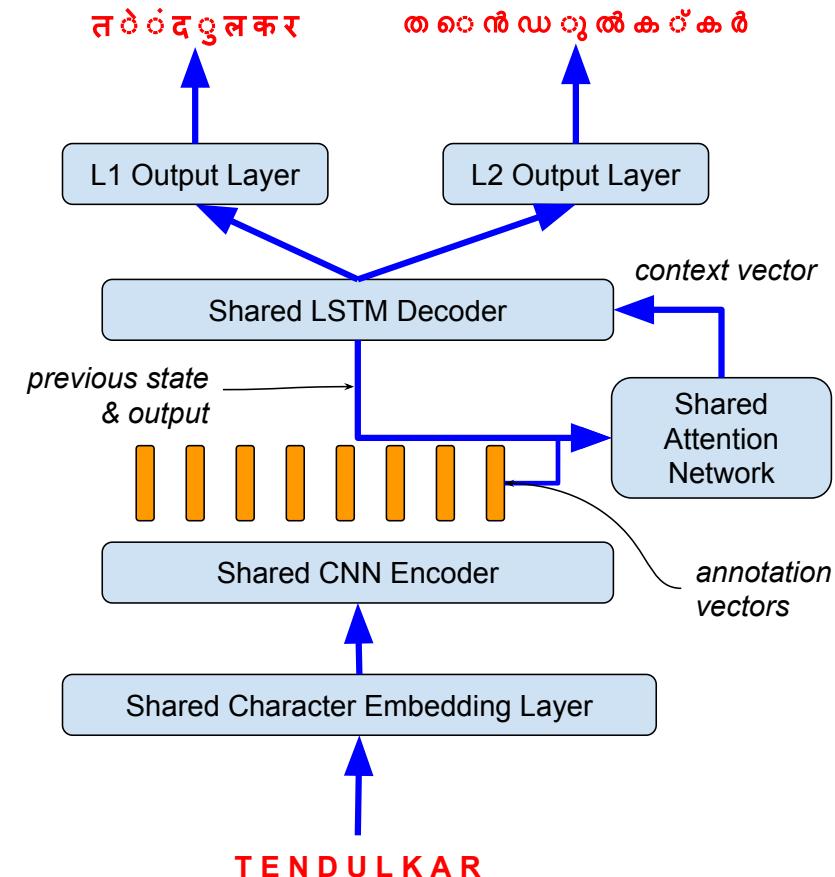


# Multi-lingual Neural Transliteration

- Orthographically similar languages
  - (i) highly overlapping phoneme sets.
  - (ii) mutually compatible orthographic systems.
  - (iii) similar grapheme to phoneme mappings.

# Multi-lingual Neural Transliteration

- Standard multi-task





# Multi-lingual Neural Transliteration

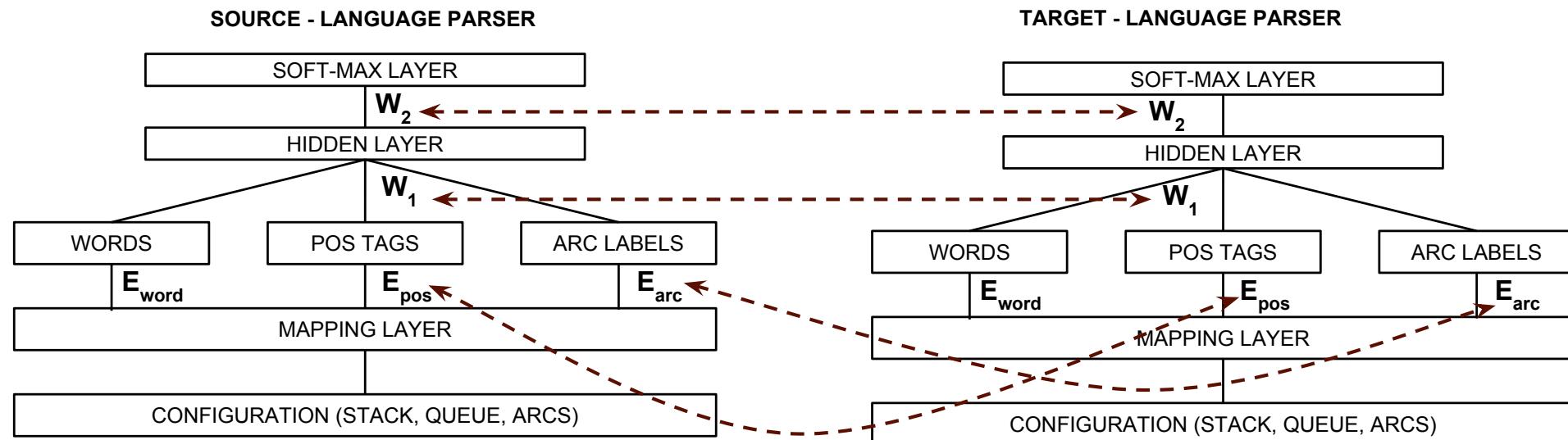
- Results on NEWS 2015

Pair	P	B	M	Pair	P	B	M
<b>Similar Source and Target Languages</b>							
<i>Indic-Indic (45.5%)</i>							
bn-hi	<b>29.74</b>	19.08	27.69	kn-bn	28.59	24.04	<b>37.47</b>
bn-kn	17.62	18.14	<b>27.74</b>	kn-ta	34.89	30.85	<b>38.30</b>
hi-bn	29.92	25.46	<b>39.15</b>	ta-hi	<b>29.07</b>	19.24	28.97
hi-ta	25.15	28.62	<b>38.70</b>	ta-kn	26.99	19.86	<b>29.06</b>
<b>Similar Source Languages</b>							
<i>Slavic-Arabic (55.8%)</i>				<i>Indic-English (24.2%)</i>			
cs-ar	38.91	37.10	<b>59.17</b>	bn-en	<b>55.23</b>	48.93	54.01
pl-ar	34.70	34.80	<b>44.83</b>	hi-en	49.19	38.26	<b>51.11</b>
sk-ar	43.26	37.49	<b>62.21</b>	kn-en	42.79	33.77	<b>47.70</b>
sl-ar	41.90	36.74	<b>62.04</b>	ta-en	<b>33.93</b>	23.22	25.93
<b>Similar Target Languages</b>							
<i>Arabic-Slavic (176.8%)</i>				<i>English-Indic (1.1%)</i>			
ar-cs	15.41	12.08	<b>36.76</b>	en-bn	42.90	41.70	<b>46.10</b>
ar-pl	13.68	12.26	<b>24.21</b>	en-hi	60.50	<b>64.10</b>	60.70
ar-sk	15.24	13.82	<b>38.72</b>	en-kn	48.70	52.00	<b>53.90</b>
ar-sl	18.31	13.63	<b>44.35</b>	en-ta	52.90	<b>57.80</b>	55.30

Comparison of bilingual (B) and multilingual (M) neural models as well as bilingual PBSMT (P) models (top-1 accuracy %). Figure in brackets for each dataset shows average increase in transliteration accuracy for multilingual neural model over bilingual neural model. Best accuracies for each language pair in **bold**.

# Low resource dependency parsing

- Transferred Parameters  $E_{word}^{en}, E_{pos}^{en}, E_{arc}^{en}, W_1^{en}, W_2^{en}$





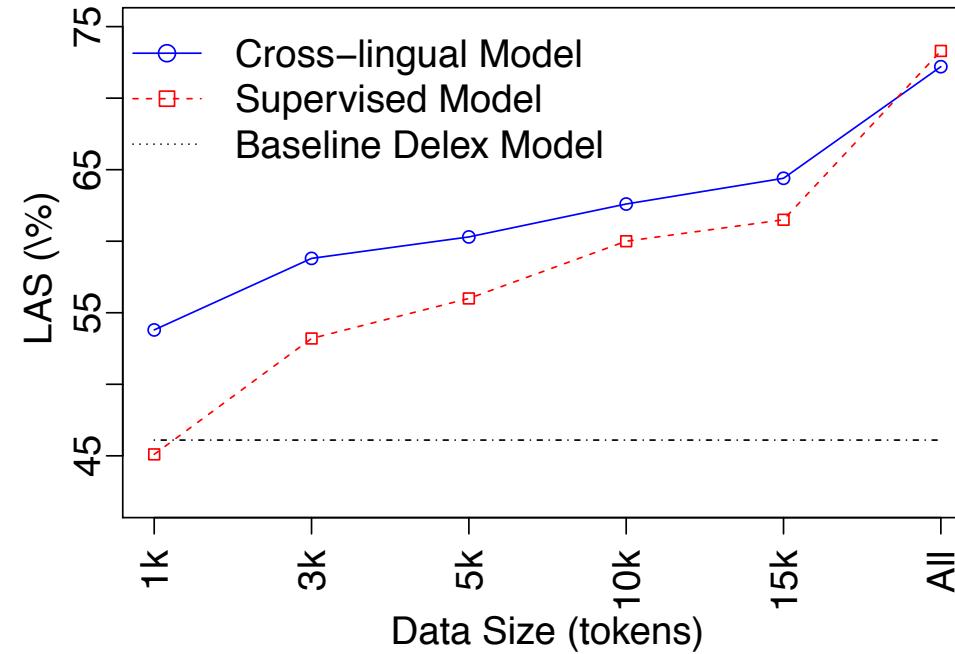
# Low resource dependency parsing

“ To allow parameter sharing between languages we could jointly train the parser on the source and target language simultaneously. However, we leave this for **future work**. First we train a lexicalized neural network parser on the source resource-rich language (English), as described in Section 2. ”

$$\begin{aligned} \mathcal{L} = & \sum_{i=1}^N \log P(y^{(i)}|x^{(i)}) - \frac{\lambda_1}{2} \left[ \|W_1^{pos} - W_1^{en:pos}\|_F^2 \right. \\ & + \|W_1^{arc} - W_1^{en:arc}\|_F^2 + \|W_2 - W_2^{en}\|_F^2 \Big] \\ & - \frac{\lambda_2}{2} \left[ \|E_{pos} - E_{pos}^{en}\|_F^2 + \|E_{arc} - E_{arc}^{en}\|_F^2 \right] \end{aligned}$$

# Low resource dependency parsing

- Results



Save human label effort



# Multi-lingual parser

- ‘Future Work’ mentioned in the previous work.
- Seven languages jointly trained
- Words: Cross-lingual embeddings and cross-lingual word cluster
- Languages: Language embeddings!



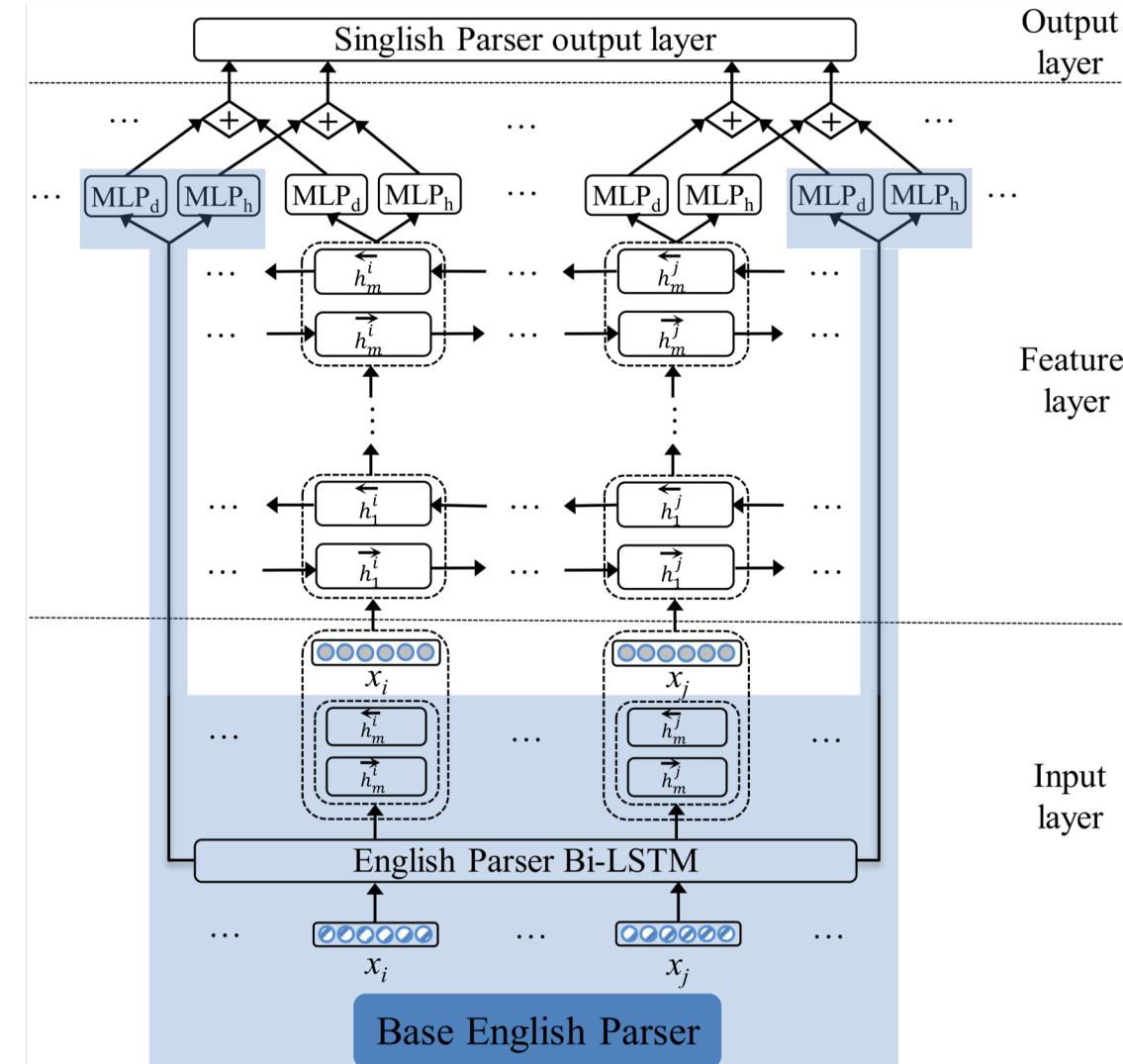
# Multi-lingual parser

- Results on UD Treebank

LAS	target language							average
	de	en	es	fr	it	pt	sv	
monolingual	<b>79.3</b>	<b>85.9</b>	83.7	81.7	88.7	85.7	83.5	84.0
MALOPA	70.4	69.3	72.4	71.1	78.0	74.1	65.4	71.5
+lexical	76.7	82.0	82.7	81.2	87.6	82.1	81.2	81.9
+language ID	78.6	84.2	83.4	<b>82.4</b>	<b>89.1</b>	84.2	82.6	83.5
+fine-grained POS	78.9	85.4	<b>84.3</b>	<b>82.4</b>	89.0	<b>86.2</b>	<b>84.5</b>	<b>84.3</b>

# Singlish Parsing

- Variation on Parameter Sharing





# Singlish Parsing

- Results

System	Accuracy
ENG-on-SIN	81.39%
Base-ICE-SIN	78.35%
Stack-ICE-SIN	<b>89.50%</b>

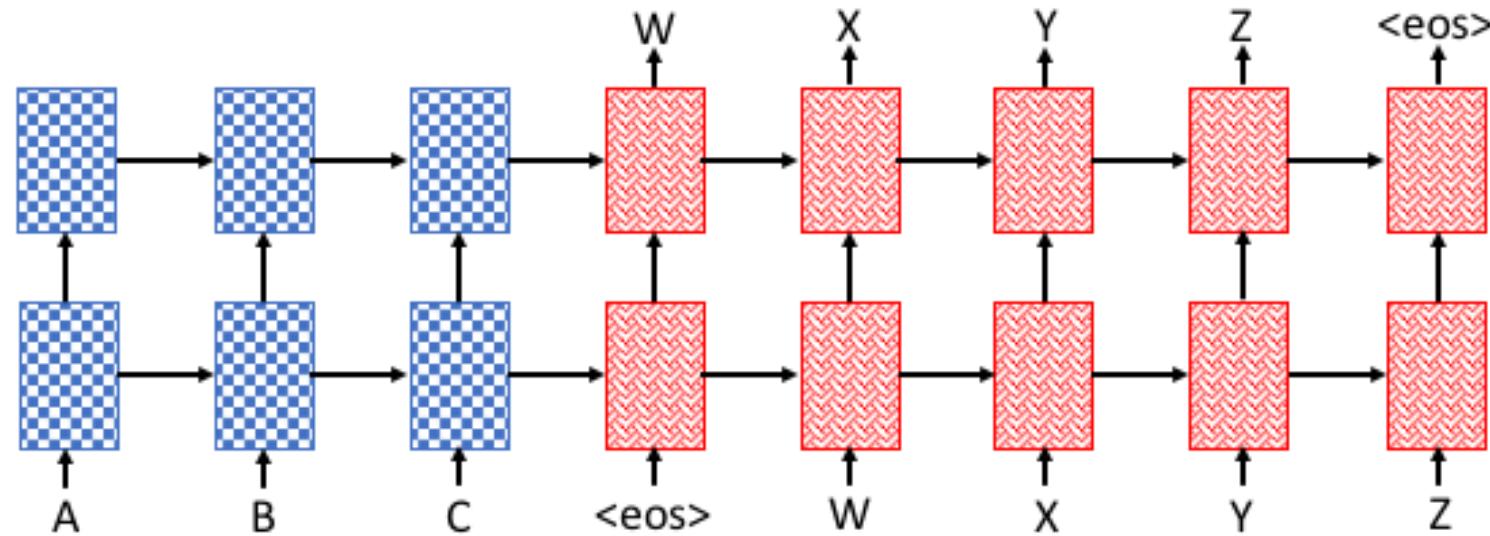
POS tagging

Trained on	System	UAS	LAS
English	ENG-on-SIN	75.89	65.62
Singlish	Baseline	75.98	66.55
	Base-Giga100M	77.67	67.23
	Base-GloVe6B	78.18	68.51
	Base-ICE-SIN	79.29	69.27
Both	ENG-plus-SIN	82.43	75.64
	Stack-ICE-SIN	<b>84.47</b>	<b>77.76</b>

Dependency Parsing

# Low resource neural machine translation

- Variation on model structure: Rich Resource( $\text{EN} \rightarrow \text{FR}$ ) pretraining, low resource ( $\text{EN} \rightarrow \text{UZ}$ ) fine-tuning





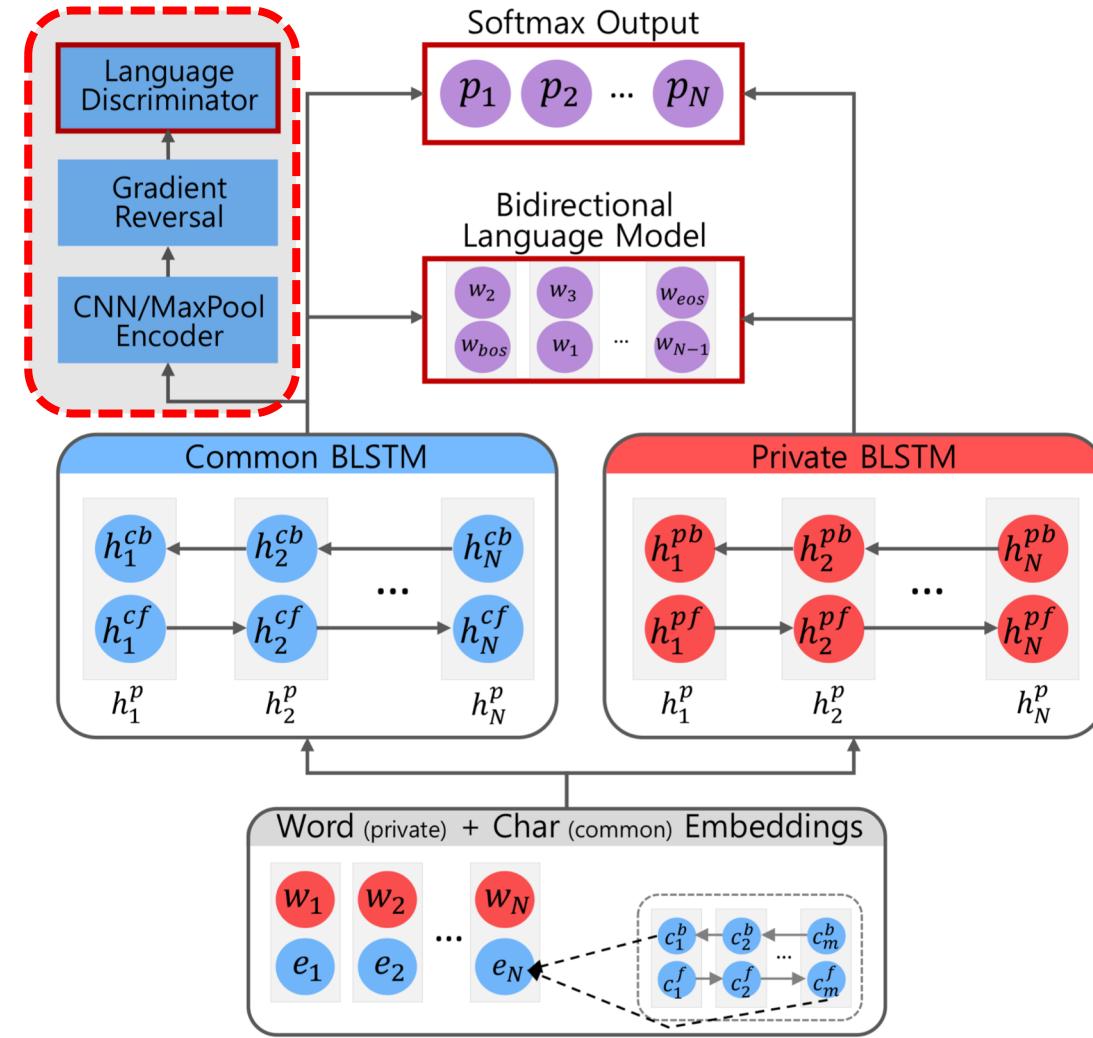
# Low resource neural machine translation

- Results

Language Pair	Parent	Train Size	BLEU ↑	PPL ↓
Uzbek–English	None	1.8m	10.7	22.4
	French–English	1.8m	<b>15.0 (+4.3)</b>	<b>13.9</b>
French'–English	None	1.8m	13.3	28.2
	French–English	1.8m	<b>20.0 (+6.7)</b>	<b>10.9</b>

# Cross-lingual

- Adversarial training
- Language model auxiliary task





# Cross-lingual

- Results on UD treebank

Language Family	Language	Target only		Source (English) → Target				
		p	p,l	p,l	c,l	p,c,l	c,l+a	p,c,l+a
Germanic	Swedish	87.43	90.49	<b>91.02</b>	90.45	90.48	90.72	90.70
	Danish	86.42	90.00	90.74	90.69	90.02	90.16	<b>90.79</b>
	Dutch	76.76	82.24	<b>82.61</b>	82.46	82.10	82.58	82.15
	German	86.25	88.95	89.10	88.69	88.93	88.08	<b>89.68</b>
	Avg	84.22	87.92	<b>88.37</b>	88.07	87.88	87.88	88.33
Slavic	Slovenian	87.02	89.97	90.29	90.00	90.32	89.58	<b>90.59</b>
	Polish	82.10	84.13	85.21	85.41	85.30	85.46	<b>85.50</b>
	Slovak	76.22	81.03	82.95	<b>83.40</b>	82.68	82.70	83.17
	Bulgarian	87.32	<b>92.81</b>	92.68	92.07	92.30	92.20	92.39
	Avg	83.16	86.98	87.78	87.72	87.65	87.48	<b>87.91</b>
Romance	Romanian	88.67	<b>91.44</b>	<b>91.44</b>	90.87	91.22	90.85	91.37
	Portuguese	90.66	93.73	93.55	93.90	93.81	93.58	<b>94.20</b>
	Italian	89.78	93.99	93.82	93.27	93.46	93.51	<b>94.00</b>
	Spanish	85.91	<b>91.07</b>	90.59	90.59	<b>91.07</b>	90.17	90.88
	Avg	88.76	92.56	92.35	92.16	92.39	92.03	<b>92.61</b>
Indo-Iranian	Persian	90.64	<b>92.40</b>	91.98	91.97	92.12	92.18	91.83
Uralic	Hungarian	89.14	90.65	91.45	91.48	90.91	<b>91.52</b>	90.72
	Total Avg	86.02	89.49	89.82	89.66	89.62	89.52	<b>89.86</b>

# Neural Graph-based Models (Multi-task Learning)

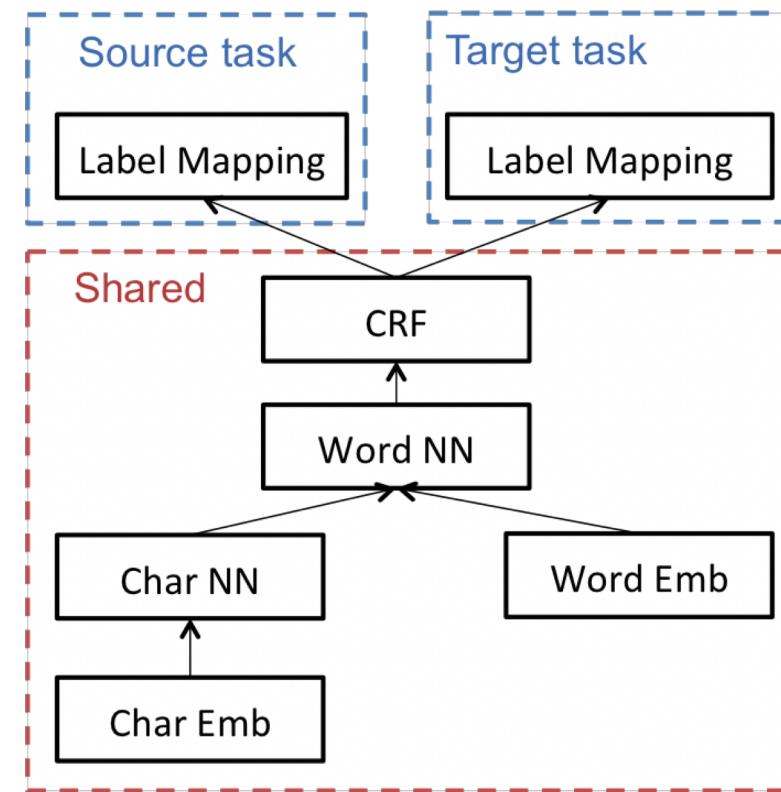


- Cross Task
- Cross Lingual
- Cross Domain
- Cross Standard



# Sequence Tagging

- Standard Multi-task





# Sequence Tagging

- Results

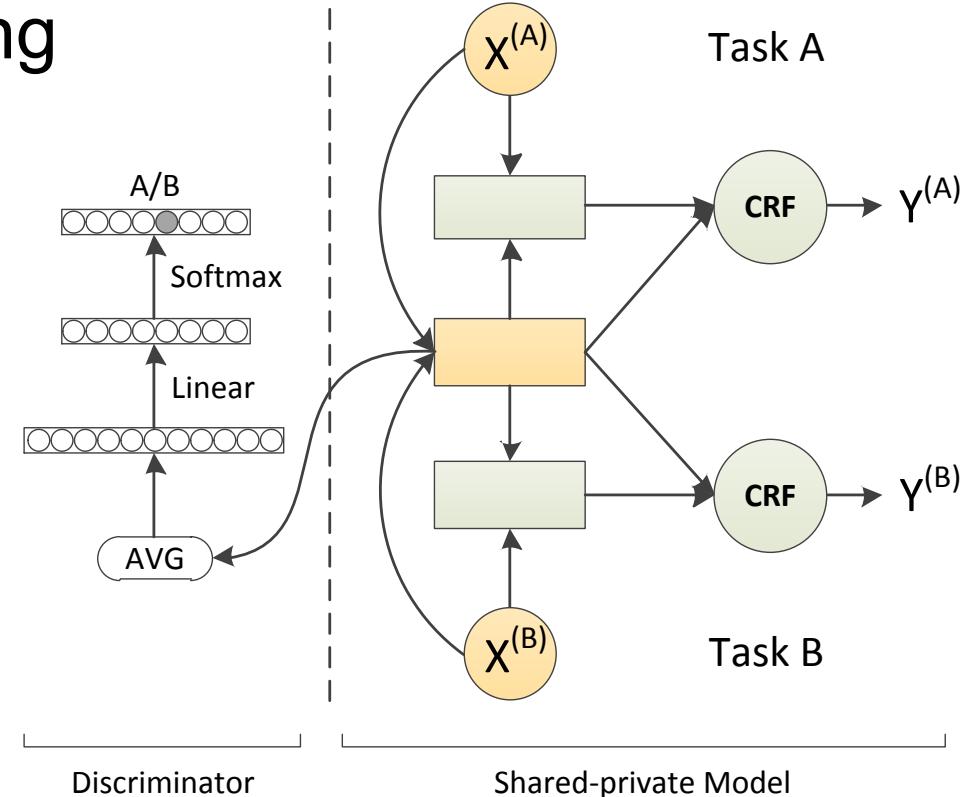
Source	Target	Model	Setting	Transfer	No Transfer	Delta
PTB	Twitter/0.1	T-A	dom	83.65	74.80	8.85
CoNLL03	Twitter/0.1	T-A	dom	43.24	34.65	8.59
PTB	CoNLL03/0.01	T-B	app	74.92	68.64	6.28
PTB	CoNLL00/0.01	T-B	app	86.73	83.49	3.24
CoNLL03	PTB/0.001	T-B	app	87.47	84.16	3.31
Spanish	CoNLL03/0.01	T-C	ling	72.61	68.64	3.97
CoNLL03	Spanish/0.01	T-C	ling	60.43	59.84	0.59

PTB	Genia/0.001	T-A	dom	92.62	83.26	9.36
CoNLL03	Genia/0.001	T-B	dom&app	87.47	83.26	4.21
Spanish	Genia/0.001	T-C	dom&app&ling	84.39	83.26	1.13
PTB	Genia/0.001	T-B	dom	89.77	83.26	6.51
PTB	Genia/0.001	T-C	dom	84.65	83.26	1.39

# Chinese Word Segmentation

- Adversarial training





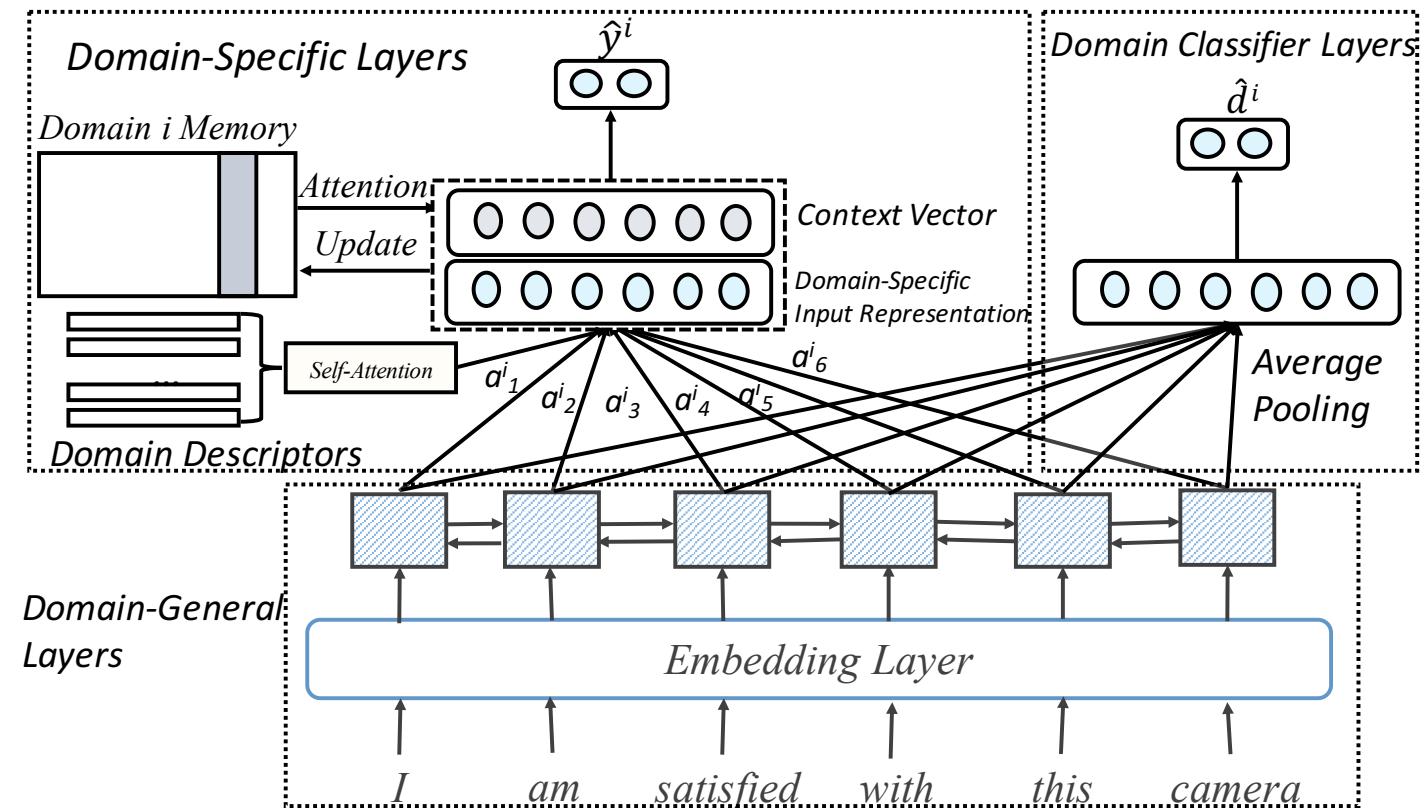
# Chinese Word Segmentation

- Results

Adversarial Multi-Criteria Learning										
Model-I+ADV	P	95.95	94.17	94.86	96.02	93.82	95.39	92.46	96.07	94.84
	R	96.14	95.11	93.78	96.33	94.70	95.70	93.19	96.01	95.12
	F	<b>96.04</b>	94.64	<b>94.32</b>	<b>96.18</b>	<b>94.26</b>	<b>95.55</b>	<b>92.83</b>	96.04	<b>94.98</b>
	OOV	71.60	73.50	72.67	82.48	77.59	81.40	63.31	77.10	74.96
Model-II+ADV	P	96.02	94.52	94.65	96.09	93.80	95.37	92.42	95.85	94.84
	R	95.86	94.98	93.61	95.90	94.69	95.63	93.20	96.07	94.99
	F	95.94	<b>94.75</b>	94.13	96.00	94.24	95.50	92.81	95.96	94.92
	OOV	72.76	75.37	73.13	82.19	77.71	81.05	62.16	76.88	75.16
Model-III+ADV	P	95.92	94.25	94.68	95.86	93.67	95.24	92.47	96.24	94.79
	R	95.83	95.11	93.82	96.10	94.48	95.60	92.73	96.04	94.96
	F	95.87	94.68	94.25	95.98	94.07	95.42	92.60	<b>96.14</b>	94.88
	OOV	70.86	72.89	72.20	81.65	76.13	80.71	63.22	77.88	74.44

# Multi-domain Sentiment Classification

- Adversarial training
- Domain Embeddings
- Memory Network





# Multi-domain Sentiment Classification

- Results

Dataset	In domain						Cross domain										
	MTRL	Mix	Multi	DSR	DSR-sa	DSR-ctx	DSR-at	MTRL	Mix	MDA	Multi	FEMA	NDA	DSR	DSR-sa	DSR-ctx	DSR-at
Apparel	0.883	0.912	0.921	0.927	0.928	0.92	<b>0.938*</b>	0.828	0.843	0.863	0.854	0.865	0.873	0.882	0.899	0.896	<b>0.909*</b>
Electronics	0.853	0.881	<b>0.899</b>	0.884	0.879	0.883	0.891	0.804	0.826	0.836	0.849	0.845	0.834	0.857	0.859	0.861	<b>0.875*</b>
Office	0.863	0.88	0.89	0.903	0.914	0.925	<b>0.933*</b>	0.824	0.825	0.818	0.824	0.843	0.839	0.854	0.876	0.883	<b>0.894*</b>
Automotive	0.842	0.864	0.873	0.886	0.891	0.902	<b>0.917*</b>	0.791	0.786	0.791	0.797	0.816	0.826	0.835	0.847	0.857	<b>0.867*</b>
Gourmet	0.814	0.838	0.84	0.852	0.856	0.858	<b>0.863*</b>	0.777	0.775	0.764	0.784	0.796	0.803	0.814	0.826	<b>0.832</b>	0.828
Outdoor	0.853	0.889	0.899	0.903	0.907	0.915	<b>0.927*</b>	0.785	0.796	0.805	0.815	0.836	0.829	0.856	0.861	0.867	<b>0.887*</b>
Baby	0.816	0.853	0.86	0.875	0.877	0.892	<b>0.91*</b>	0.803	0.816	0.814	0.821	0.834	0.84	0.845	0.878	0.873	<b>0.895*</b>
Grocery	0.862	0.886	0.898	0.907	0.911	0.917	<b>0.933*</b>	0.806	0.817	0.826	0.846	0.846	0.862	0.88	0.873	0.865	<b>0.886*</b>
Software	0.851	0.876	0.88	0.893	0.898	0.904	<b>0.92*</b>	0.795	0.811	0.816	0.836	0.845	0.836	0.85	0.862	0.884	<b>0.897*</b>
Beauty	0.816	0.843	0.8567	0.862	0.867	0.864	<b>0.889*</b>	0.756	0.768	0.775	0.785	0.795	0.804	0.812	0.812	0.838	<b>0.851*</b>
Health	0.871	0.901	0.904	0.896	0.897	0.896	<b>0.907</b>	0.785	0.807	0.819	0.832	0.845	0.848	0.843	0.834	0.857	<b>0.871*</b>
Sports	0.851	0.883	0.899	0.889	0.882	0.895	<b>0.9</b>	0.759	0.768	0.775	0.784	0.816	0.819	0.821	0.836	0.848	<b>0.864*</b>
Book	0.743	0.803	0.79	0.804	0.809	0.815	<b>0.822*</b>	0.694	0.705	0.716	0.723	0.745	0.743	0.751	0.758	0.779	<b>0.798*</b>
Jewelry	0.816	0.891	0.881	0.893	0.891	0.894	<b>0.909*</b>	0.762	0.769	0.774	0.785	0.795	0.808	0.815	0.835	0.857	<b>0.874*</b>
Camera	0.912	0.937	0.968	0.966	0.959	0.968	<b>0.989*</b>	0.869	0.878	0.886	0.896	0.894	0.908	0.917	0.925	0.942	<b>0.963*</b>
Kitchen	0.815	0.858	0.863	0.875	0.887	0.894	<b>0.913*</b>	0.759	0.768	0.775	0.776	0.794	0.818	0.826	0.856	0.865	<b>0.884 *</b>
Toy	0.823	0.863	0.875	0.881	0.884	0.88	<b>0.892*</b>	0.814	0.824	0.815	0.803	0.813	0.832	0.826	0.843	0.845	<b>0.857*</b>
Phone	0.879	0.936	0.94	0.943	<b>0.949*</b>	0.941	0.933	0.805	0.813	0.808	0.818	0.821	0.833	0.836	0.856	0.874	<b>0.894*</b>
Magazine	0.835	0.874	0.872	0.883	0.895	0.917	<b>0.937*</b>	0.805	0.819	0.817	0.816	0.83	0.841	0.845	0.857	0.871	<b>0.896*</b>
Video	0.851	0.873	0.882	0.891	0.896	0.912	<b>0.925*</b>	0.754	0.774	0.794	0.795	0.815	0.822	0.834	0.845	0.855	<b>0.875*</b>
Games	0.867	0.886	0.89	0.883	0.886	0.887	<b>0.9*</b>	0.681	0.684	0.708	0.718	0.723	0.734	0.746	0.765	<b>0.781</b>	0.778
Music	0.752	0.782	0.8	0.798	0.8	0.798	<b>0.81*</b>	0.775	0.769	0.779	0.784	0.795	0.824	0.815	0.823	0.842	<b>0.858*</b>
Dvd	0.795	0.826	0.834	0.847	0.854	0.867	<b>0.889*</b>	0.801	0.794	0.804	0.794	0.814	0.827	0.835	0.845	0.851	<b>0.875*</b>
Instrument	0.873	0.943	<b>0.957*</b>	0.896	0.906	0.898	0.9	0.814	0.805	0.813	0.815	0.825	0.836	0.833	0.835	0.845	<b>0.865*</b>
Tools	0.887	0.915	0.931	0.928	0.93	0.932	<b>0.94*</b>	0.805	0.814	0.828	0.835	0.846	0.857	0.864	0.866	0.873	<b>0.897*</b>
<b>Average</b>	0.841	0.875	0.884	0.887	0.89	0.895	<b>0.907*</b>	0.786	0.794	0.801	0.807	0.82	0.827	0.835	0.847	0.858	<b>0.873*</b>

Qi Liu, Yue Zhang, Jiangming Liu, 2018. Learning Domain Representation for Multi-domain Sentiment Classification. In Proceedings of 16th Annual Conference of the North American Chapter of the Association for Computational Linguistics (NAACL), New Orleans, Louisiana, June.

# Neural Graph-based Models (Multi-task Learning)



- Cross Task
- Cross Lingual
- Cross Domain
- Cross Standard



# POS tagging

- Same language, different standard

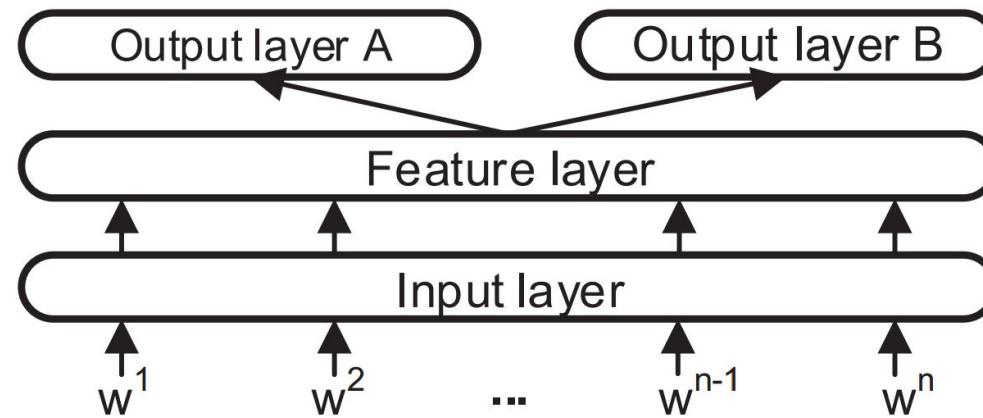
CTB:	中国	最大	氨纶丝	生产	基地	在	连云港	建成	。
	NR	JJ	NN	NN	NN	P	NR	VV	PU



PD:	第四	条	防震	减灾	工作	,	应当	纳入	国民经济	和	社会	发展	计划	。
	m	q	vn	vn	vn	w	v	v	n	c	n	vn	n	w

# POS tagging

- Standard neural multi-view model





# POS tagging

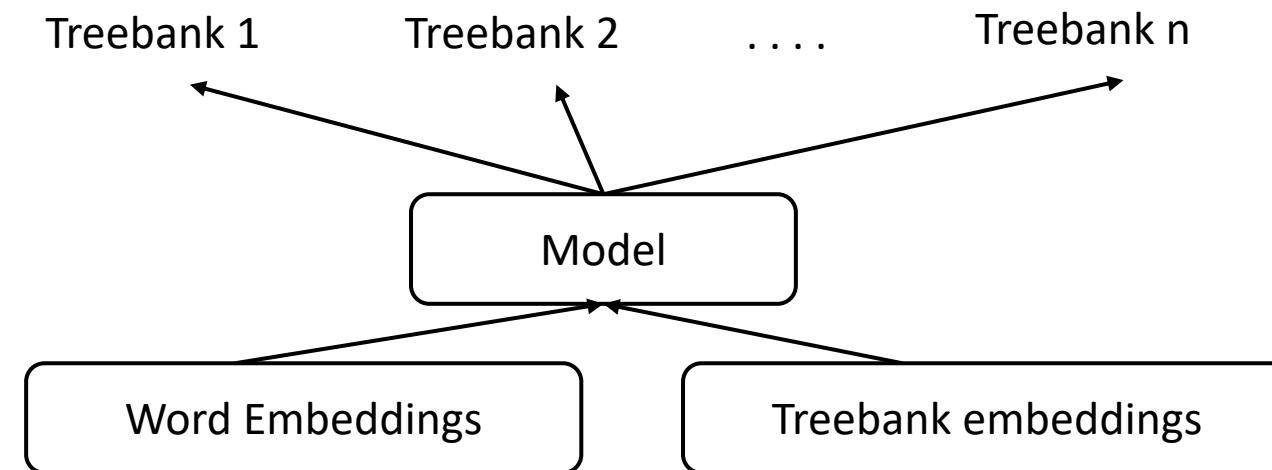
- Results

System	Accuracy
CRF Baseline (Li et al., 2015)	94.10
CRF Stacking (Li et al., 2015)	94.81
CRF Multi-view (Li et al., 2015)	95.00
NN Baseline	94.24
NN Stacking	94.74
NN Feature Stacking	95.01
NN Feature Stacking & Fine-tuning	95.32
NN Multi-view	95.40
Integrated NN Multi-view & Stacking	<b>95.53</b>



# Dependency parsing

- Same language with multiple treebanks
- Treebank embeddings





# Dependency parsing

- Results

Language	Treebank	Size	Same treebank test set				PUD test set			
			SINGLE	CONCAT	C+FT	TB-EMB	SINGLE	CONCAT	C+FT	TB-EMB
Czech	PDT	68495	86.7	87.5 <sup>+</sup>	<b>88.3*</b>	87.2 <sup>+</sup>	<b>81.7</b>		81.6	81.2
	CAC	23478	86.0	87.8 <sup>+</sup>	88.1 <sup>+</sup>	<b>88.5*</b>	75.0	<b>81.7</b>	81.3	81.1
	FicTree	10160	84.3	89.3 <sup>+</sup>	<b>89.5*</b>	89.2 <sup>+</sup>	66.1		79.8	80.3
	CLTT	860	72.5	86.2 <sup>+</sup>	<b>86.9*</b>	86.0 <sup>+</sup>	42.1		80.8	80.9
English	EWT	12543	82.2	82.1	82.5	<b>83.0</b>	80.7		81.7*	<b>81.9*</b>
	LinES	2738	72.1	76.7 <sup>+</sup>	<b>77.3*</b>	<b>77.3*</b>	62.6	80.0	75.9	74.5
	ParTUT	1781	80.5	83.5 <sup>+</sup>	85.4 <sup>+</sup>	<b>85.7*</b>	68.0		78.1	76.9
Finnish	FTB	14981	76.4 <sup>×</sup>	74.4	80.1*	<b>80.6*</b>	46.7	73.0	54.6	53.1
	TDT	12217	78.1 <sup>×</sup>	70.6	<b>80.6*</b>	80.3*	78.6 <sup>×</sup>		<b>81.3*</b>	80.9*
French	FTB	14759	83.2	83.2	83.9*	<b>84.1*</b>	72.0		76.7	74.1
	GSD	14554	84.5	84.1	85.3	<b>85.6*</b>	79.1	79.4	80.2*	<b>80.3*</b>
	Sequoia	2231	84.0	86.0 <sup>+</sup>	<b>89.8*</b>	89.1*	69.5		78.1	77.6
	ParTUT	803	79.8	80.5	89.1*	<b>90.3*</b>	63.4		78.8	77.5
Italian	ISDT	12838	87.7	<b>87.9</b>	87.7	87.6	85.4		85.7	86.0
	PoSTWITA	2808	71.4	76.7 <sup>+</sup>	76.8 <sup>+</sup>	<b>77.0*</b>	68.5	86.0	85.7	85.3
	ParTUT	1781	83.4	89.2 <sup>+</sup>	<b>89.3*</b>	88.8 <sup>+</sup>	77.4		85.8 <sup>+</sup>	<b>86.1*</b>
Portuguese	GSD	9664	88.3	87.3	89.0*	<b>89.1*</b>	74.0	76.8 <sup>+</sup>	75.2	74.9
	Bosque	8331	84.7	84.2	86.2 <sup>×</sup>	<b>86.3*</b>	75.2		77.5 <sup>+</sup>	<b>77.6<sup>+</sup></b>
Russian	SynTagRus	48814	90.2 <sup>×</sup>	89.4	<b>90.4*</b>	<b>90.4*</b>	66.0	68.7	66.3	66.4
	GSD	3850	74.7 <sup>×</sup>	73.4	79.8*	<b>80.8*</b>	70.1 <sup>×</sup>		77.6*	<b>78.0*</b>
Spanish	AnCora	14305	87.2 <sup>×</sup>	86.2	87.5 <sup>×</sup>	<b>87.6*</b>	75.2	79.9	77.7	76.4
	GSD	14187	84.7	83.0	85.8 <sup>×</sup>	<b>86.2*</b>	79.8		80.8 <sup>+</sup>	<b>80.9*</b>
Swedish	Talbanken	4303	79.6	79.1	80.2	<b>80.6*</b>	70.3	72.0 <sup>+</sup>	73.2*	<b>73.6*</b>
	LinES	2738	74.3	76.8	<b>77.3*</b>	77.1 <sup>+</sup>	64.0		70.0	69.0
Average			81.4	82.7 <sup>+</sup>	<b>84.9*</b>	<b>84.9*</b>	77.9	77.5	80.0*	<b>80.1*</b>

Thanks!