WestlakeNLP

Natural Language Processing

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WESTLAKE UNIVERSITY

WestlakeNLP

Chapter 11

Transition-based Methods for Structured Prediction

Contents

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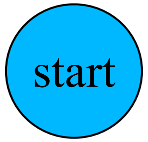
A Transition System

WestlakeNLP

- A different view from graph-based models for structured prediction
  - Encodes rich unbounded features without complexity constraints
  - A general framework that is easy to adapt to different tasks
- Maps output building process into a state transducer
  - State —— S_i
    - Corresponds to partial results during decoding
  - Action —— a_i
    - The operations that can be applied for state transition
    - Construct output incrementally

A Transition System

- **Automata:**
  - State —— S_i
  - Action —— a_i



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WestlakeNLP

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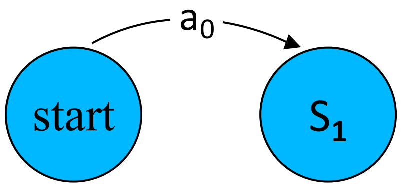

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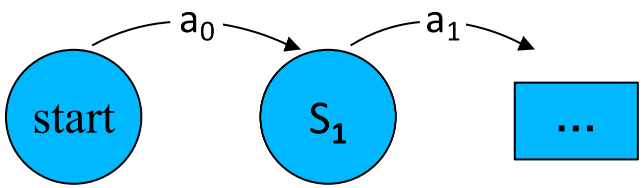

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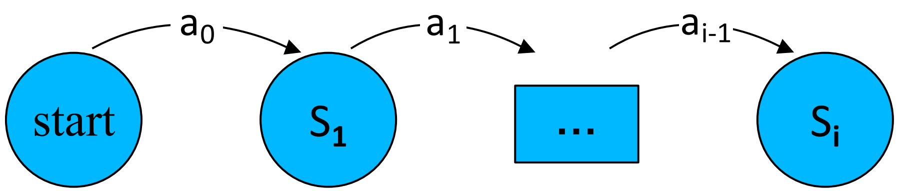

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WestlakeNLP

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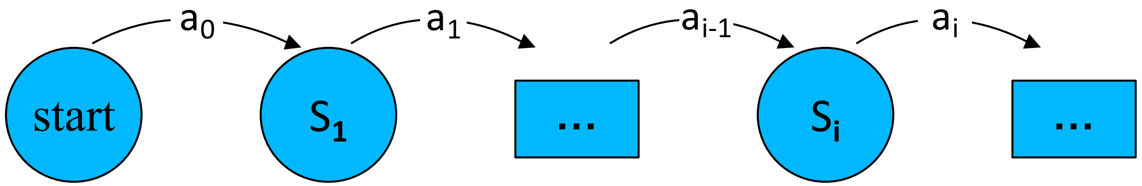

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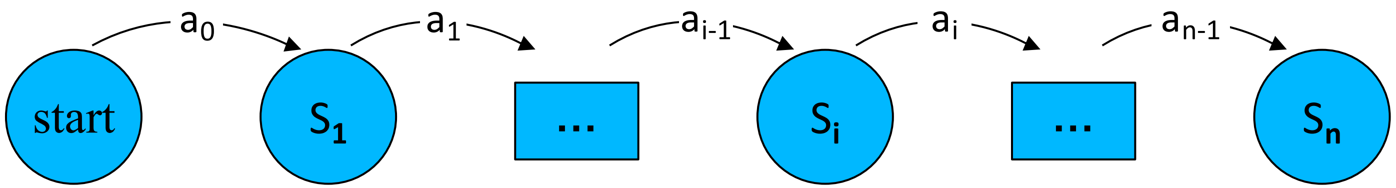

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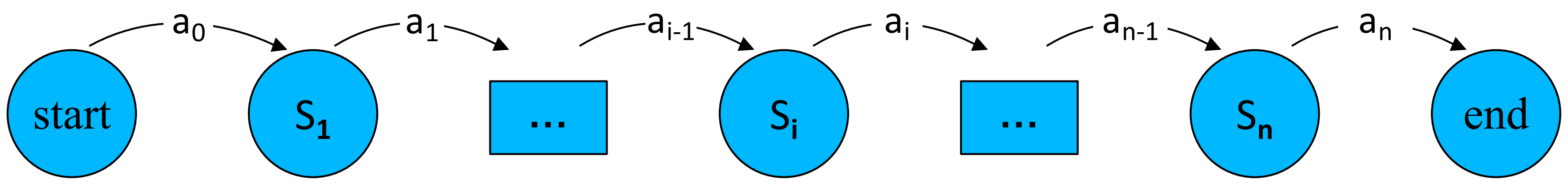

Transition-based structured prediction

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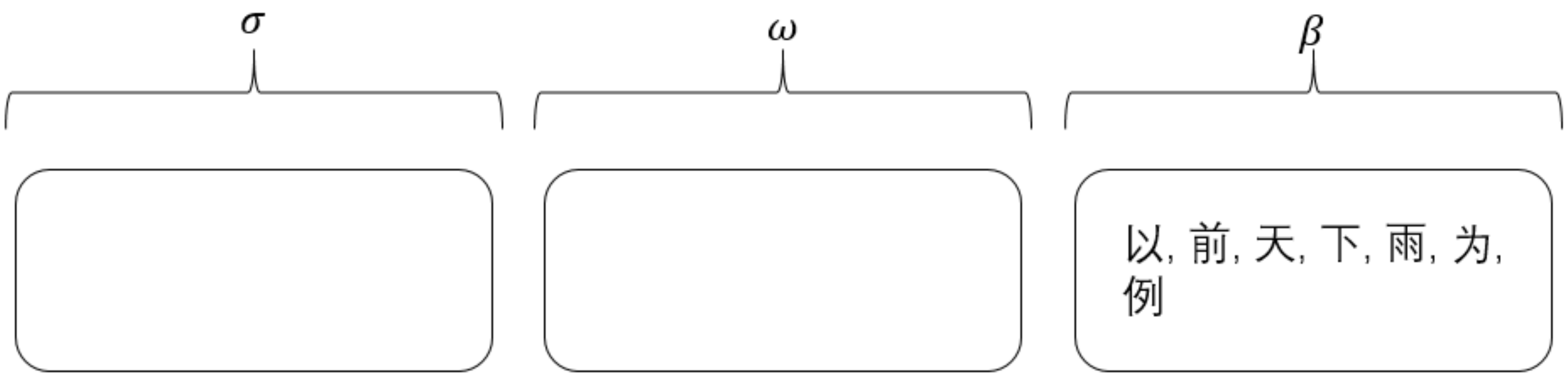
Transition-based structured prediction is a state transition process.

Automata:

- State
  - Start state —— an empty structure
  - End state —— the output structure
  - Intermediate state —— partially constructed structures
- Transition actions
  - Incremental steps that build output structures, change one state to another

Example (Word Segmentation)

- Input："以(take) 前(before) 天(day) 下(fall) 雨(rain) 为(be) 例(example)"



Next Action: ***SEP***

σ: partial output w: current partial word β: list of next incoming characters

Example (Word Segmentation)

WestlakeNLP

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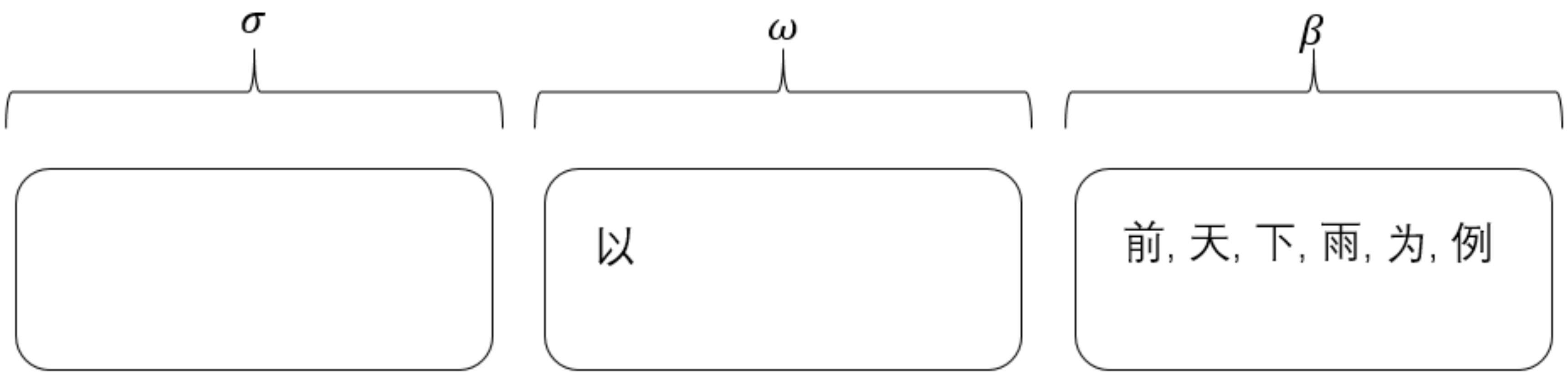

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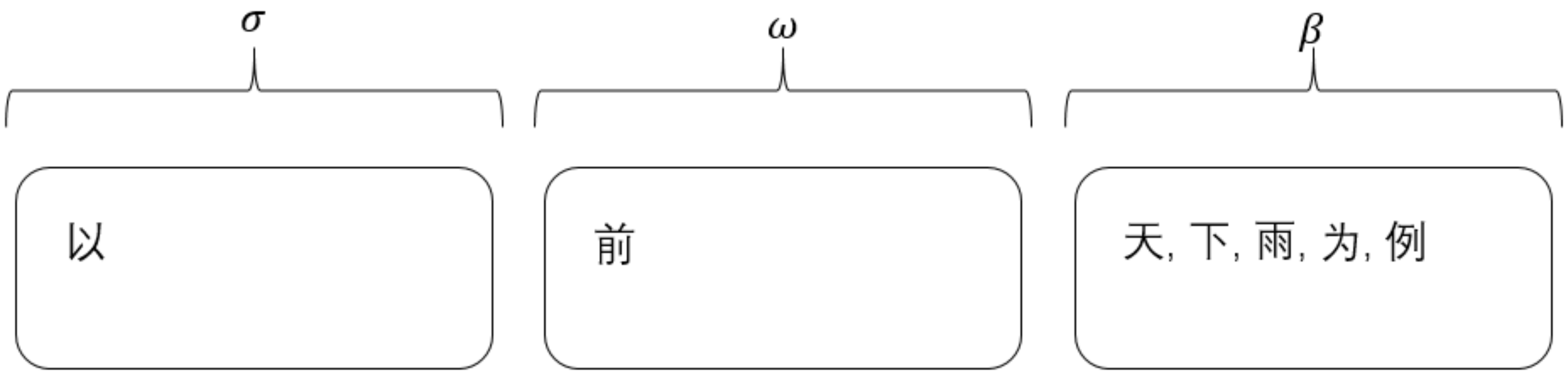

Next Action: ***APP***

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Example (Word Segmentation)

WestlakeNLP

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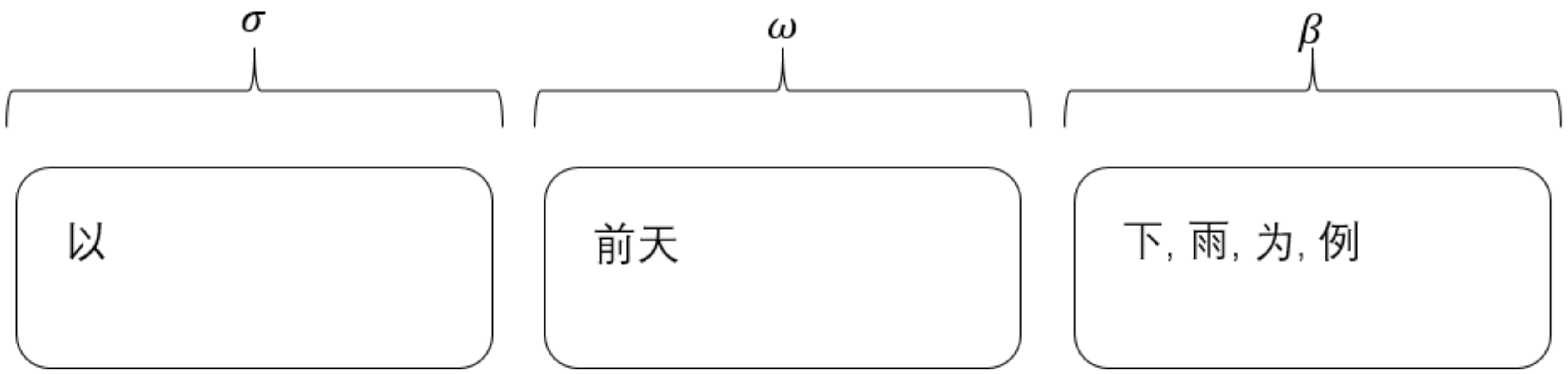

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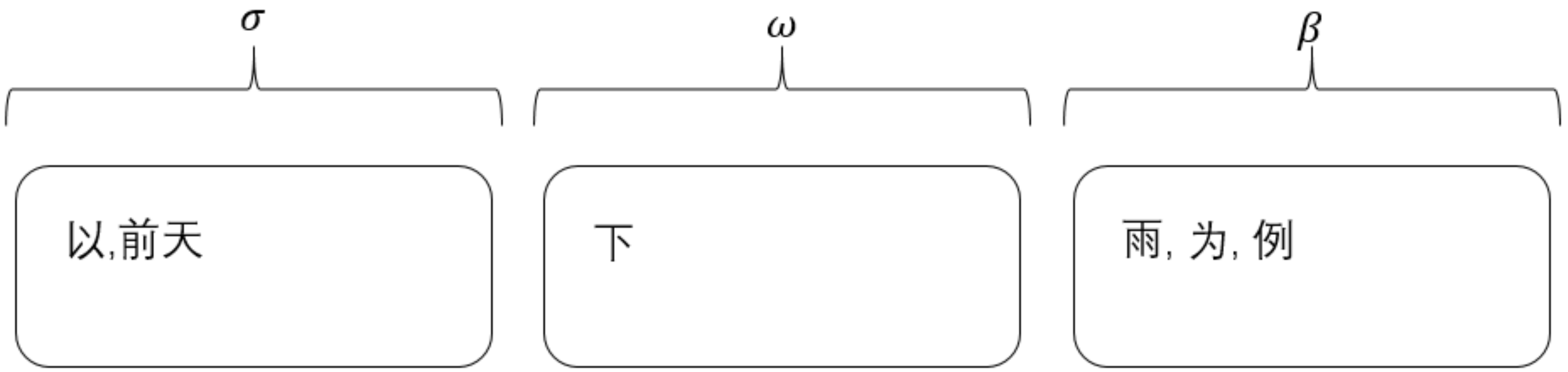

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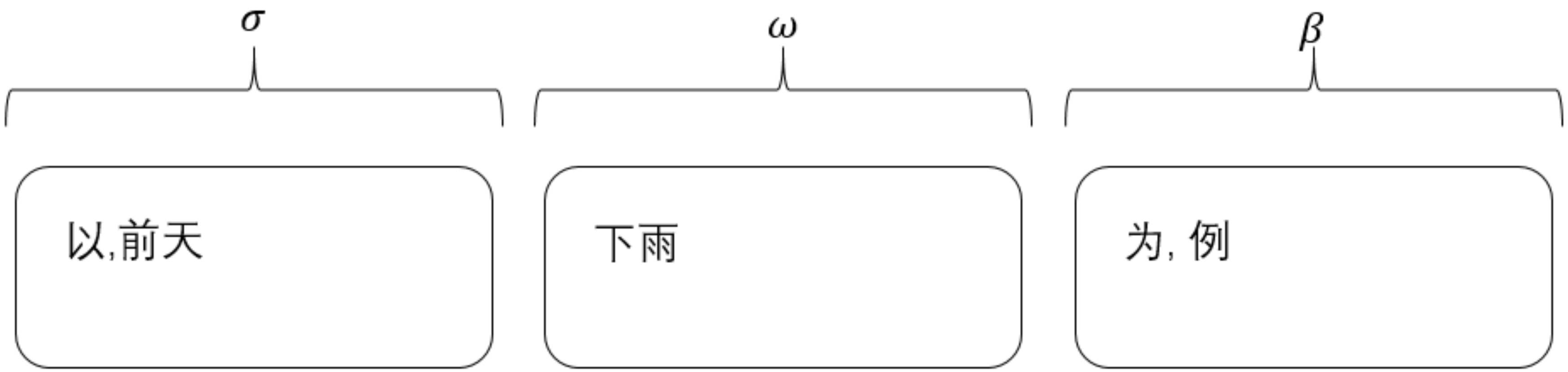

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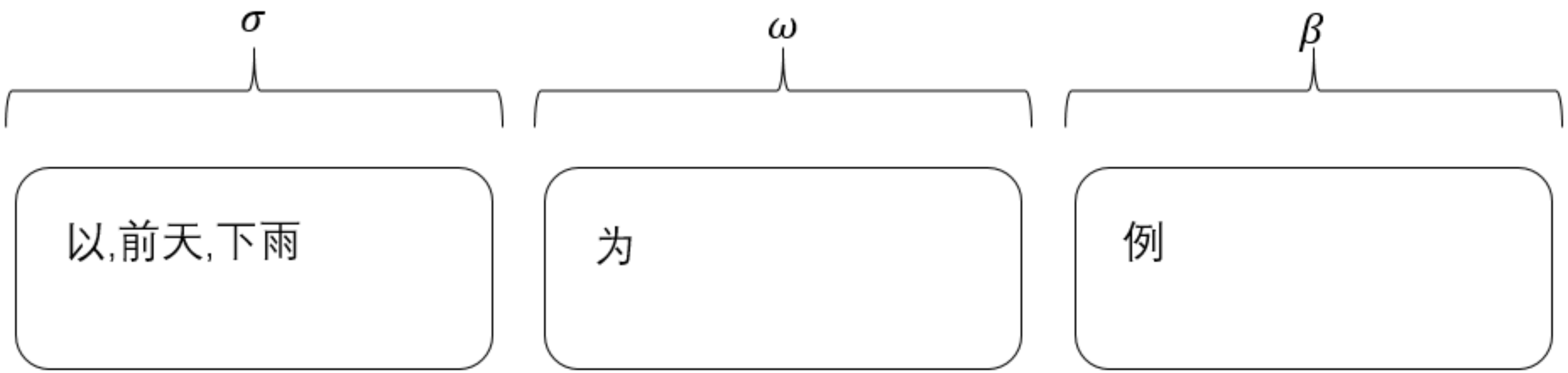

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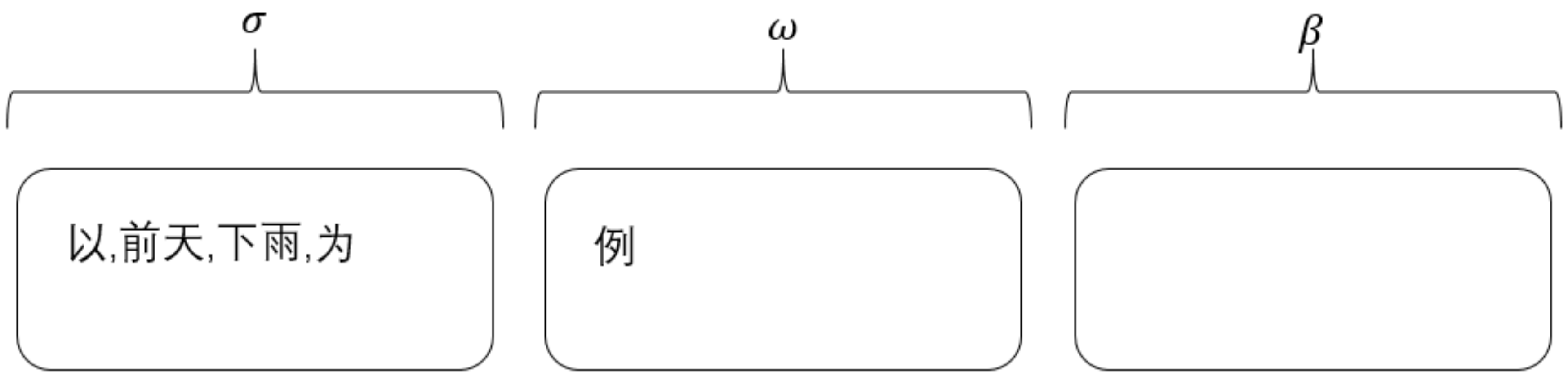
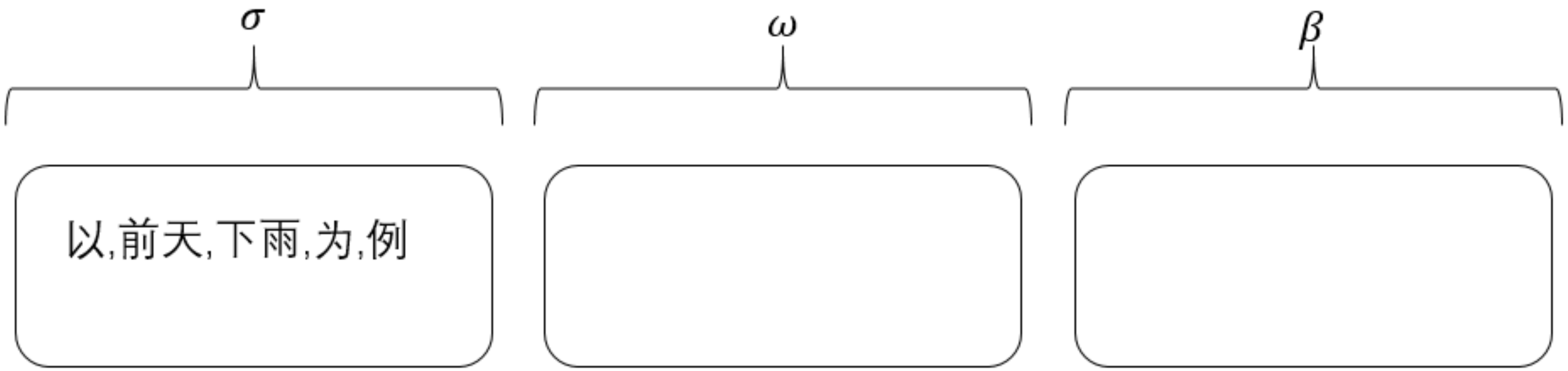


Next Action: ***FIN***

σ: partial output w: current partial word β: list of next incoming characters

Example (Word Segmentation)

- Input："以(take) 前(before) 天(day) 下(fall) 雨(rain) 为(be) 例(example)"



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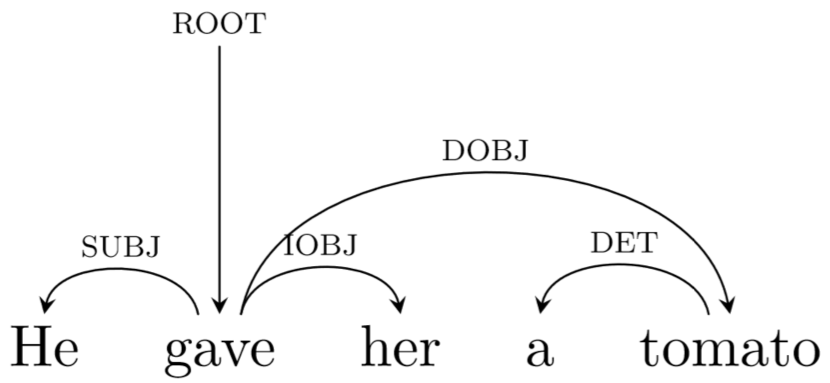
Example (Dependency Parsing)



Example (Dependency Parsing)

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$$\overbrace{\boxed{\phantom{\text{He does it}}}}^{\sigma} \quad \overbrace{\boxed{\text{He does it here}}}^{\beta}$$

σ: stack $\qquad$ β: buffer

Example (Dependency Parsing)

- NEXT ACTION: $Shift$

$$\overbrace{\boxed{\phantom{\text{He does it here}}}}^{\sigma} \quad \overbrace{\boxed{\text{He does it here}}}^{\beta}$$

σ: stack β: buffer

Example (Dependency Parsing)

WestlakeNLP

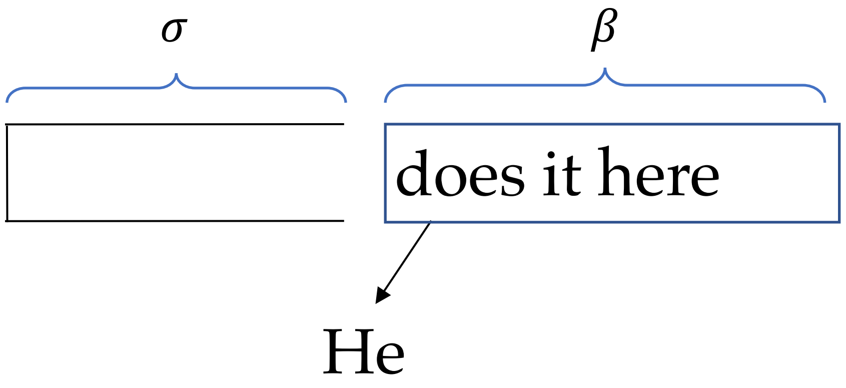
- NEXT ACTION: $Left - Arc$

$$\overbrace{\boxed{\text{He}}}^{\sigma} \quad \overbrace{\boxed{\text{does it here}}}^{\beta}$$

σ: stack β: buffer

Example (Dependency Parsing)

- NEXT ACTION: $Shift$



σ: stack β: buffer

Example (Dependency Parsing)

WestlakeNLP

- NEXT ACTION: $Right - Arc$

σ β

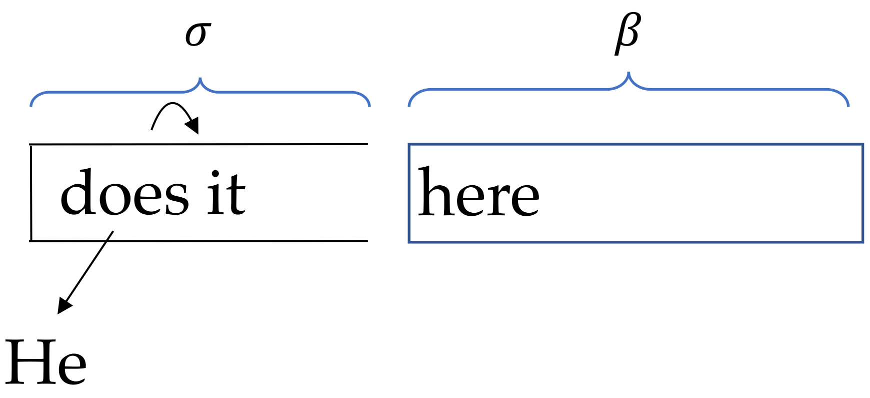
does | it here

He

σ: stack β: buffer

Example (Dependency Parsing)

- NEXT ACTION: *Reduce*



σ: stack β: buffer

Example (Dependency Parsing)

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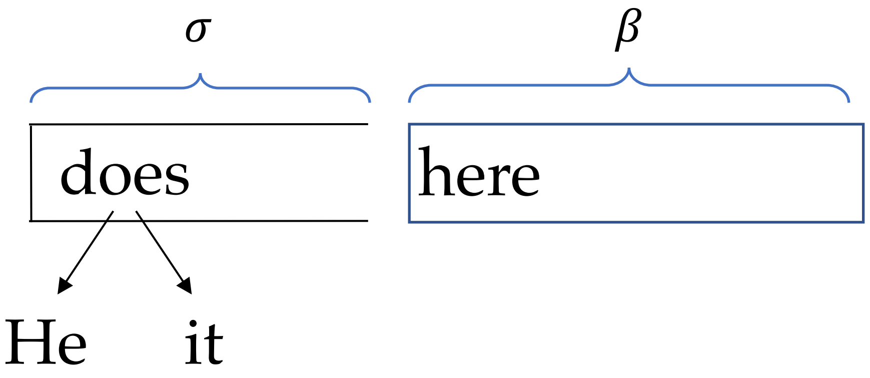
- NEXT ACTION: $Right - Arc$



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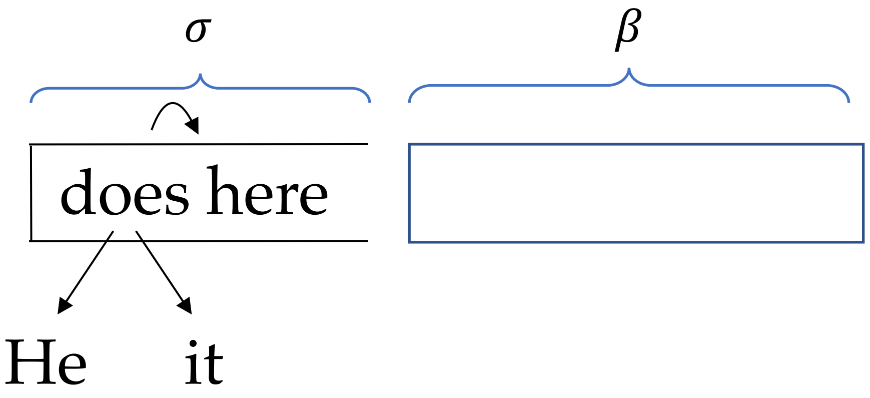
Example (Dependency Parsing)

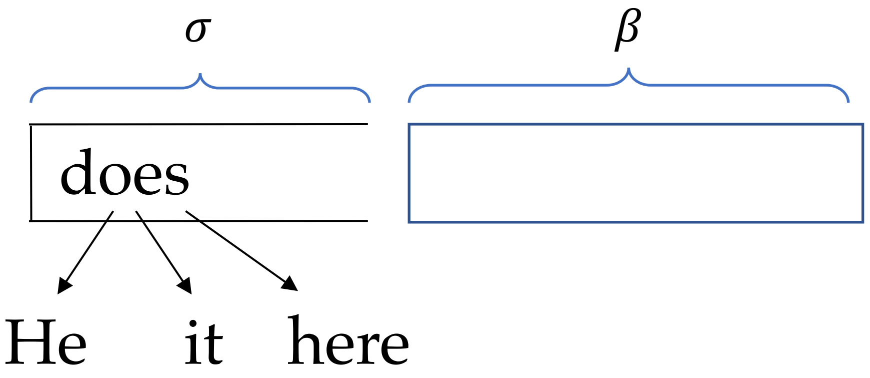
- NEXT ACTION: *Reduce*



σ: stack β: buffer

Example (Dependency Parsing)

- NEXT ACTION: *Finish*



σ: stack β: buffer

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Transition-based Modeling

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- Given a state s_{i-1}, our goal is to disambiguate all possible actions $a_i \in$POSSIBLEACTIONS(s_{i-1}) by using a discriminative model to score transition actions:

$$score(a_i|s_{i-1}) = \vec{\theta} \cdot \vec{\phi}(s_{i-1}, a_i)$$

- $\vec{\theta}$: model parameter vector
- $\vec{\phi}(s_{i-1}, a_i)$: feature vector on the input-output pair (s_{i-1}, a_i)

Greedy Local Method

- Training
  - Training dataset $D = \{(X_i, Y_i)\}|_{i=1}^{N}$

    break down

  - A sequence of gold transitions: $\left(s_{j-1}^{(i)}, a_j^{(i)}\right)$

    merge all the state-action pairs

  - A training set for the discriminative model
- Testing
  - Start from initial state $s_0(X)$
  - Repeatedly find $\hat{a}_i = argmax_{\alpha}\vec{\theta} \cdot \vec{\phi}(s_{i-1}, \alpha)$

Greedy Local Method

WestlakeNLP

- NEXT ACTION: $Shift$

σ β

He does it here

σ: stack β: buffer

Greedy Local Method

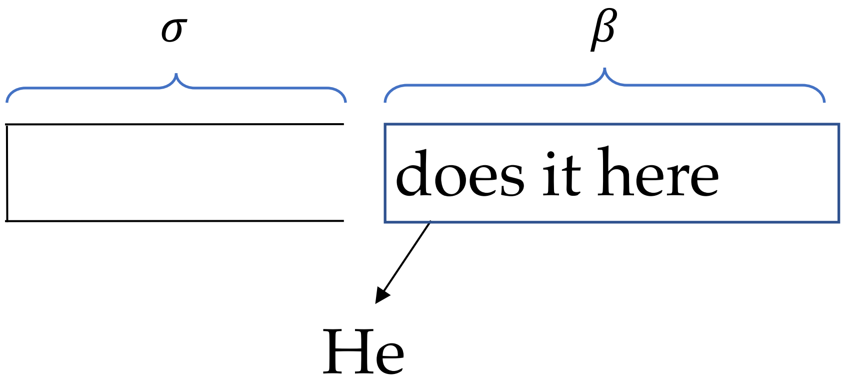
- NEXT ACTION: $Left - Arc$

$$\overbrace{\boxed{\text{He}}}^{\sigma} \quad \overbrace{\boxed{\text{does it here}}}^{\beta}$$

σ: stack β: buffer

Greedy Local Method

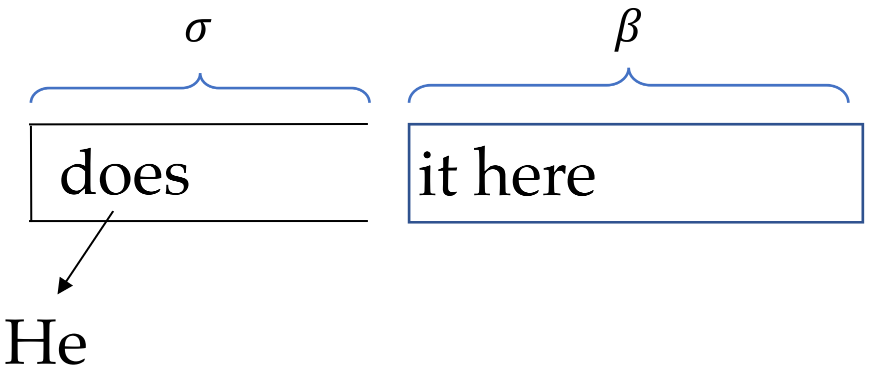
- NEXT ACTION: $Shift$



σ: stack β: buffer

Greedy Local Method

- NEXT ACTION: $Right - Arc$



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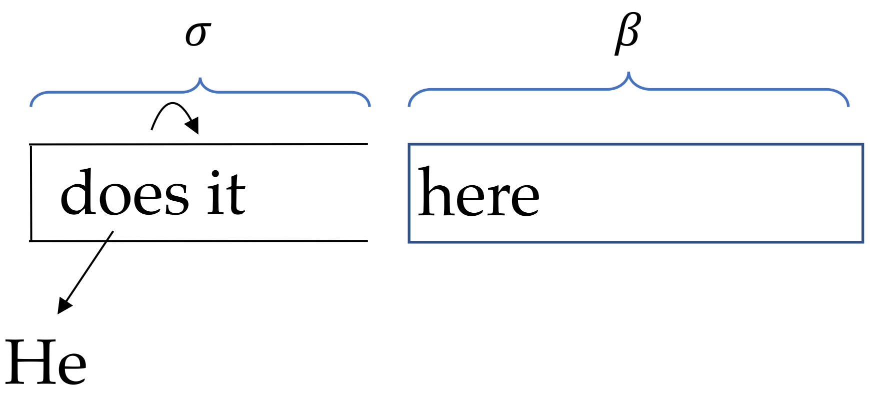
Greedy Local Method

- NEXT ACTION: *Reduce*



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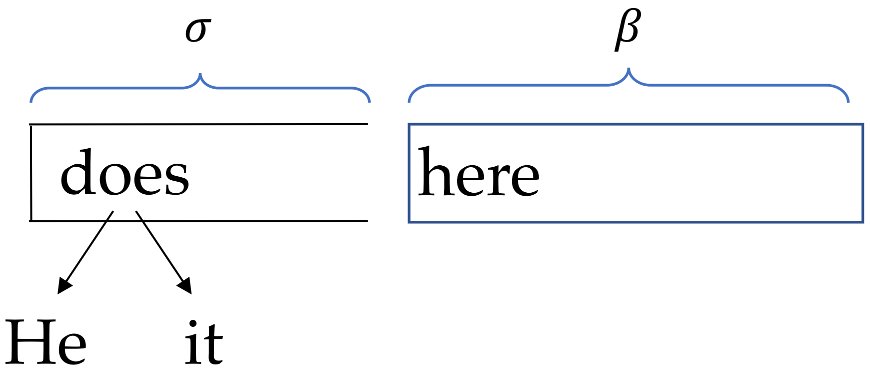

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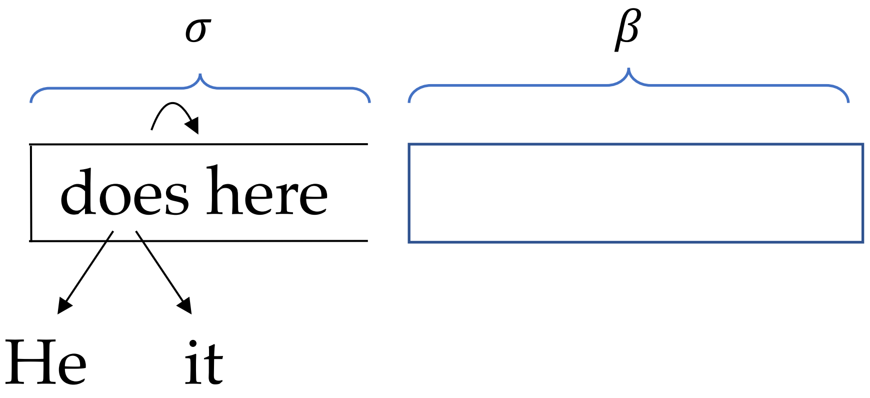

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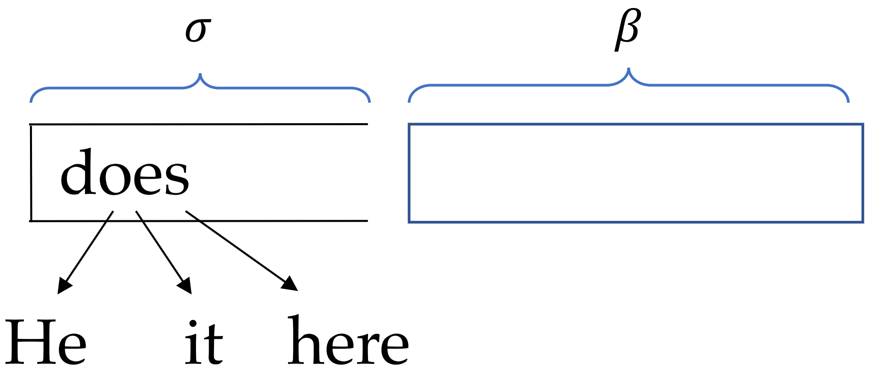


σ: stack β: buffer

Greedy Local Method

- An Example

He does it here

Greedy Local Method

WestlakeNLP

- An Example

He does it here $\xrightarrow{S}$ He does it here

Greedy Local Method

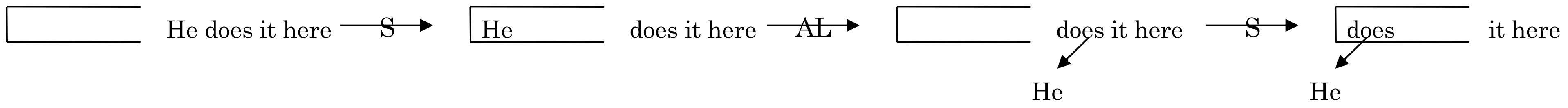
- An Example

[ ] He does it here $\xrightarrow{S}$ [He] does it here $\xrightarrow{AL}$ [ ] does it here

He

Greedy Local Method

- An Example



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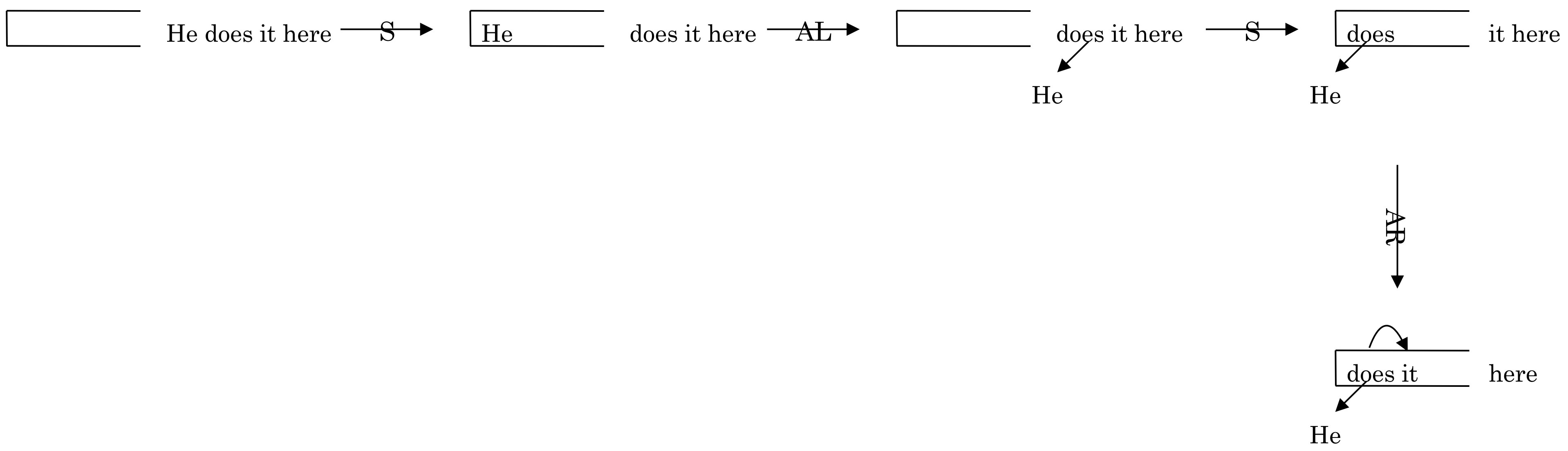

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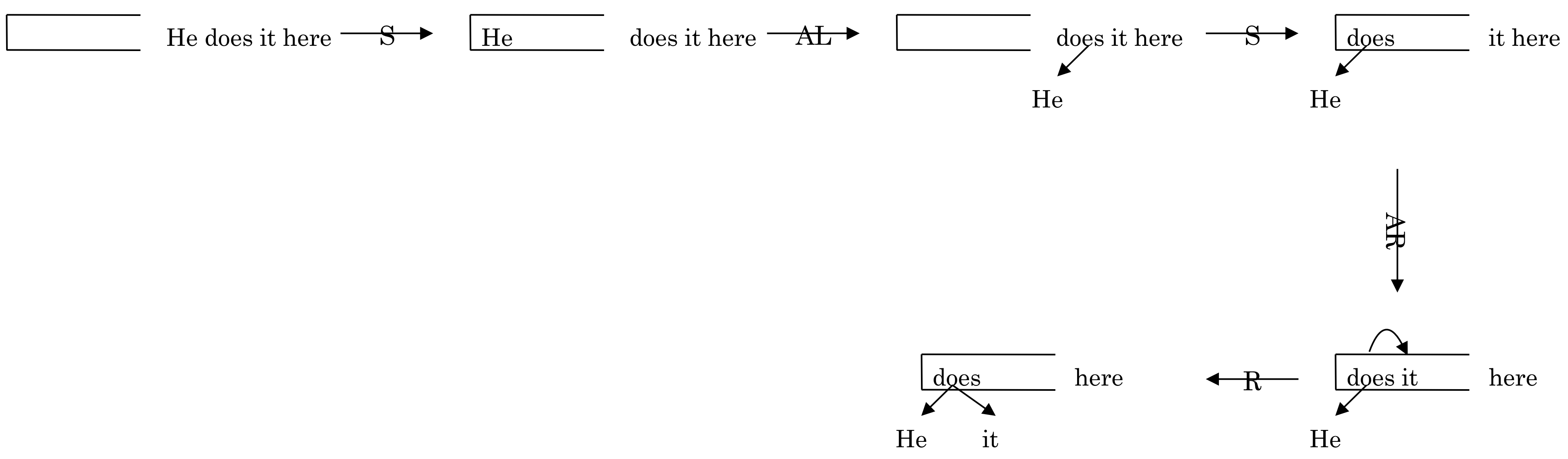

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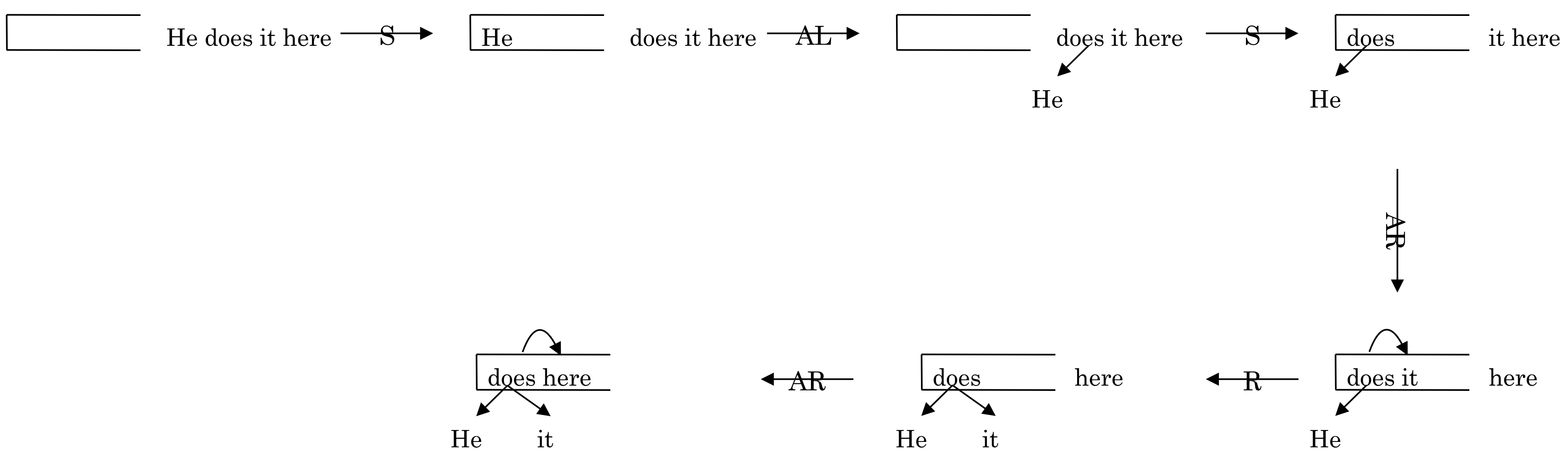
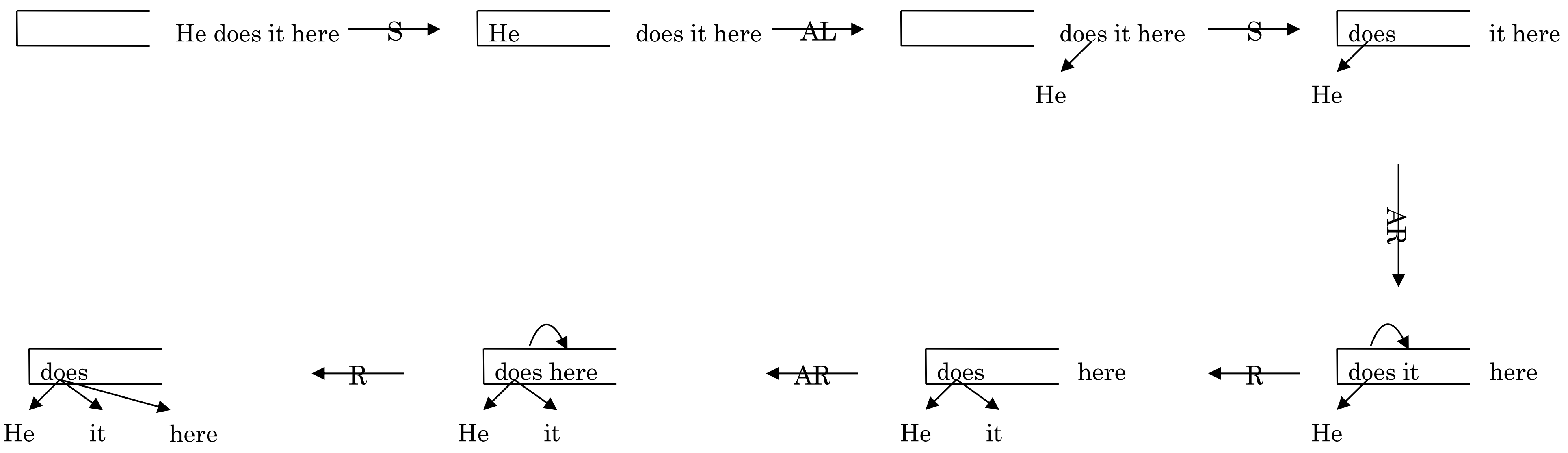


Greedy Local Method

WestlakeNLP

- An Example



Problem of Greedy Local Modeling

WestlakeNLP

- In a globally optimal action sequence, each action may not necessarily be the optimal choice locally.
- Result in error propagation.
- Model does not see incorrect states during training.

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WestlakeNLP

Problem of Greedy Local Modeling

WestlakeNLP

- In a globally optimal action sequence, each action may not necessarily be the optimal choice locally.
- Result in error propagation.

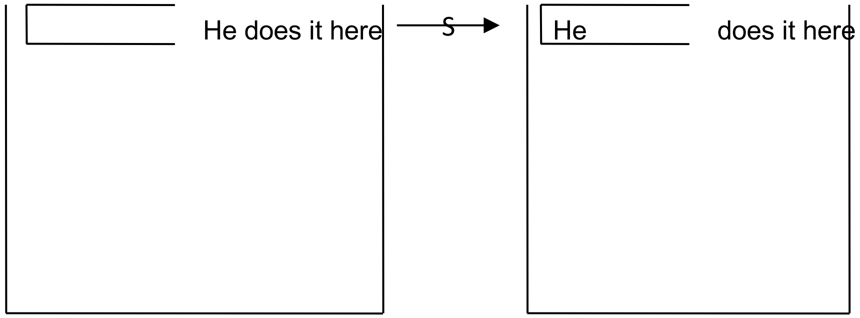
Solution:

- Beam search use a globally trained model:
  - Given an input X, a global transition-based model calculates $score(A|X)$ directly, where $A_{1:|A|} = a_1 a_2 \ldots a_{|A|}$ is a sequence of transition actions a_i for building an output structure for X.

Beam search decoding example

He does it here

Beam search decoding example



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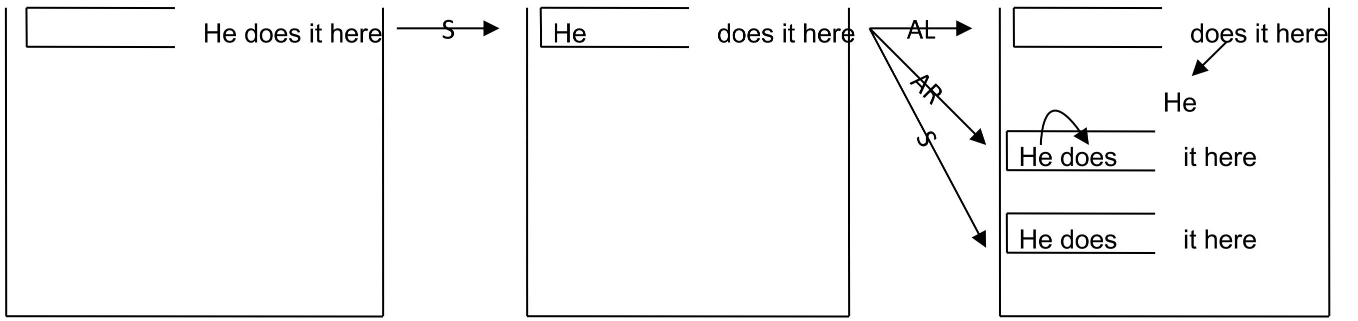

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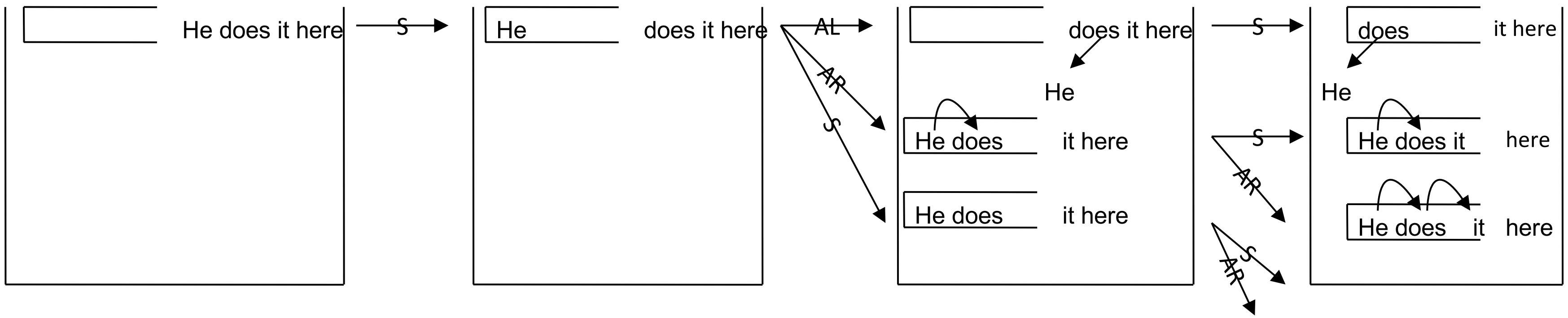

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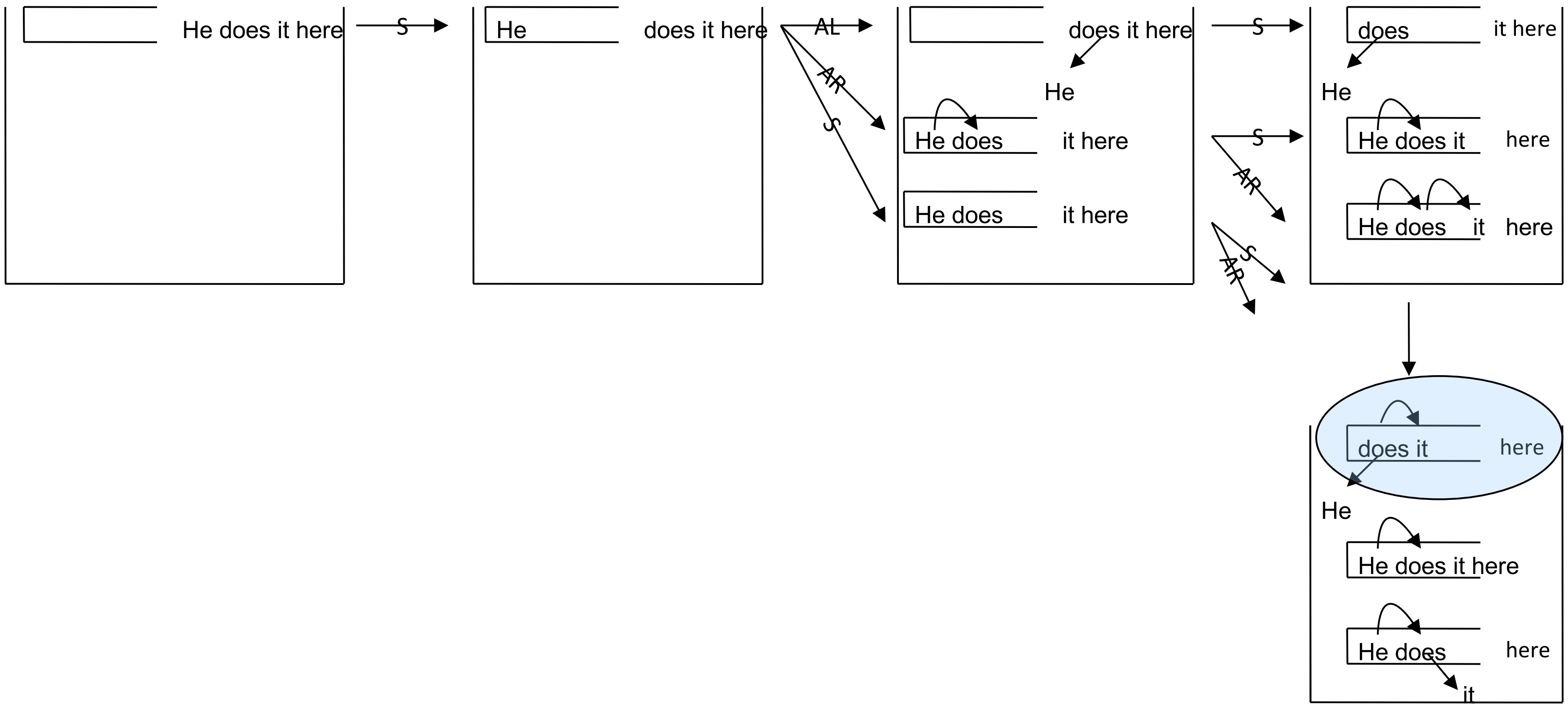

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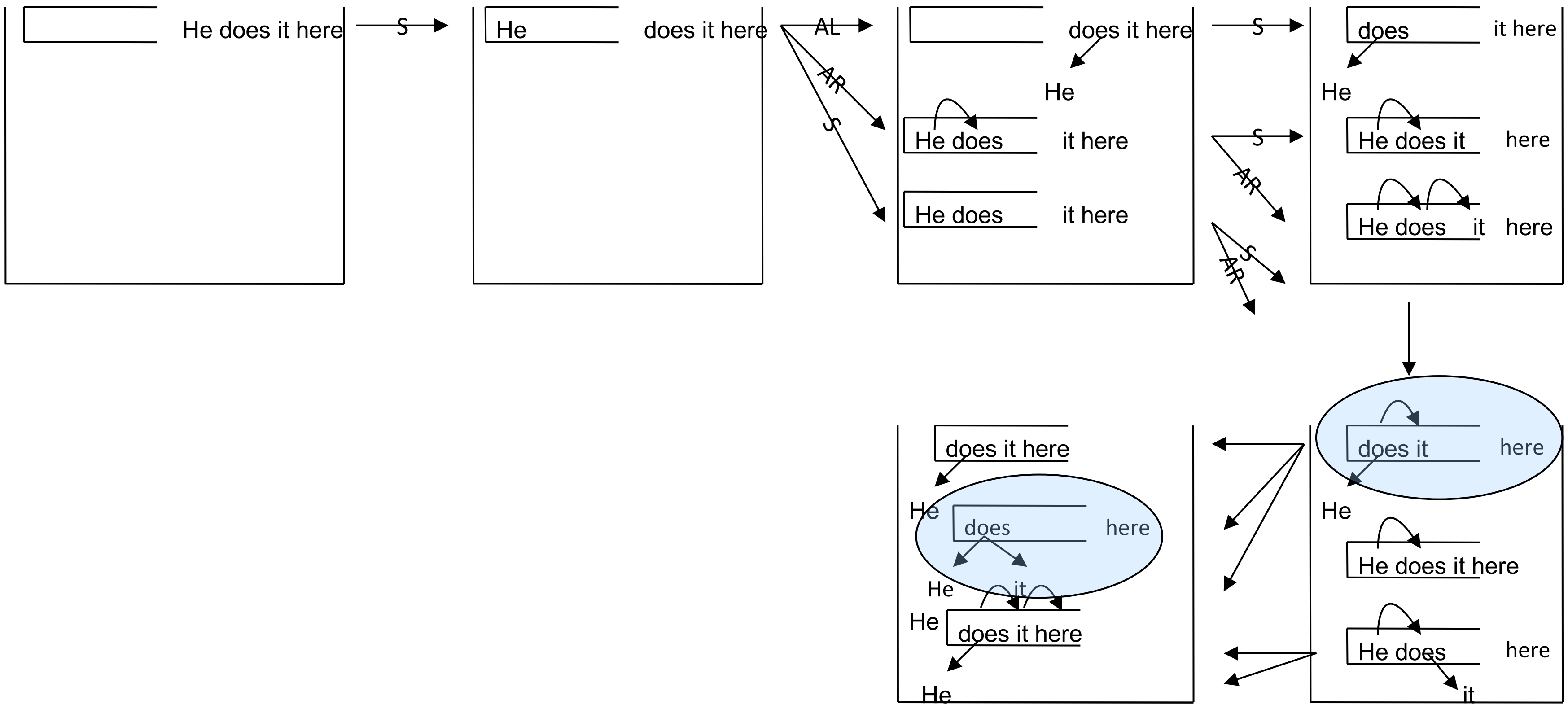

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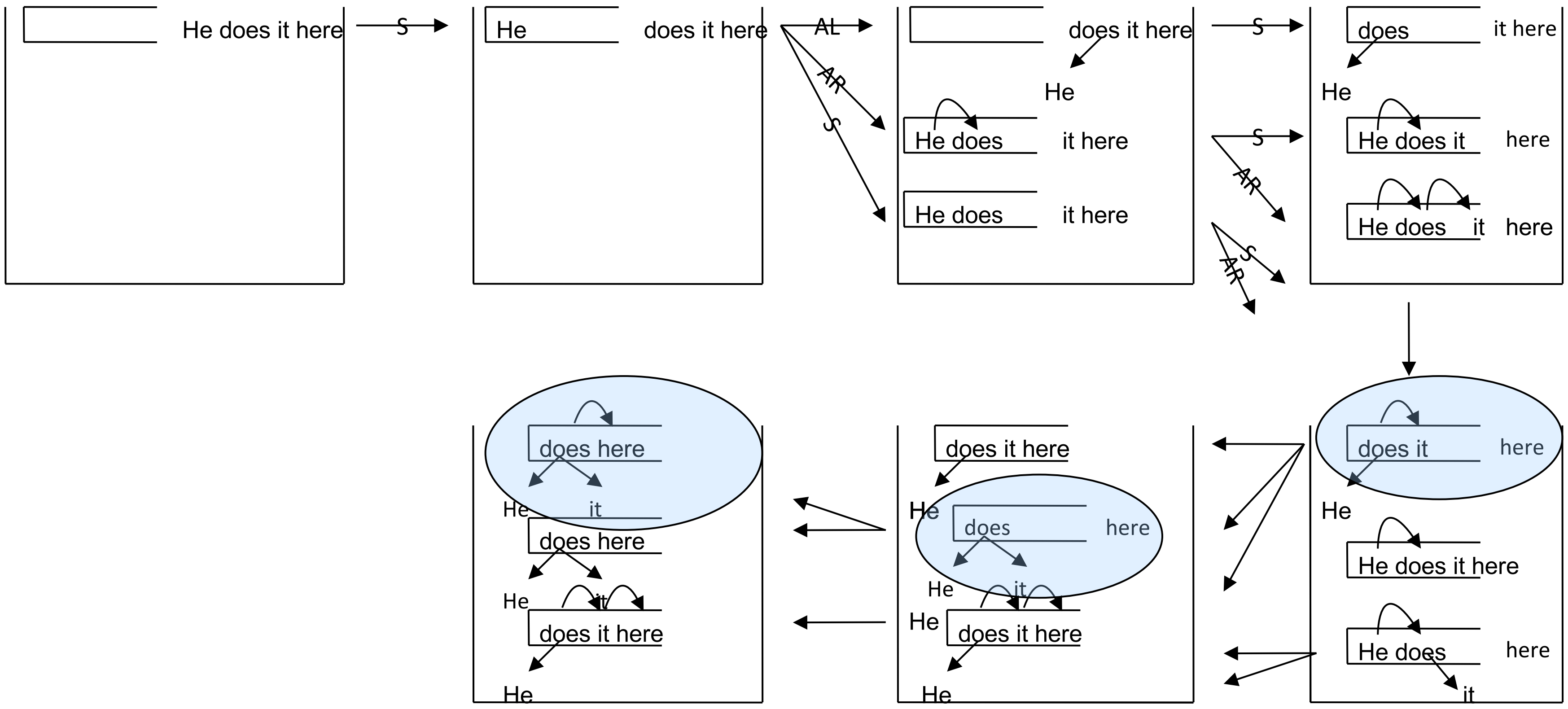

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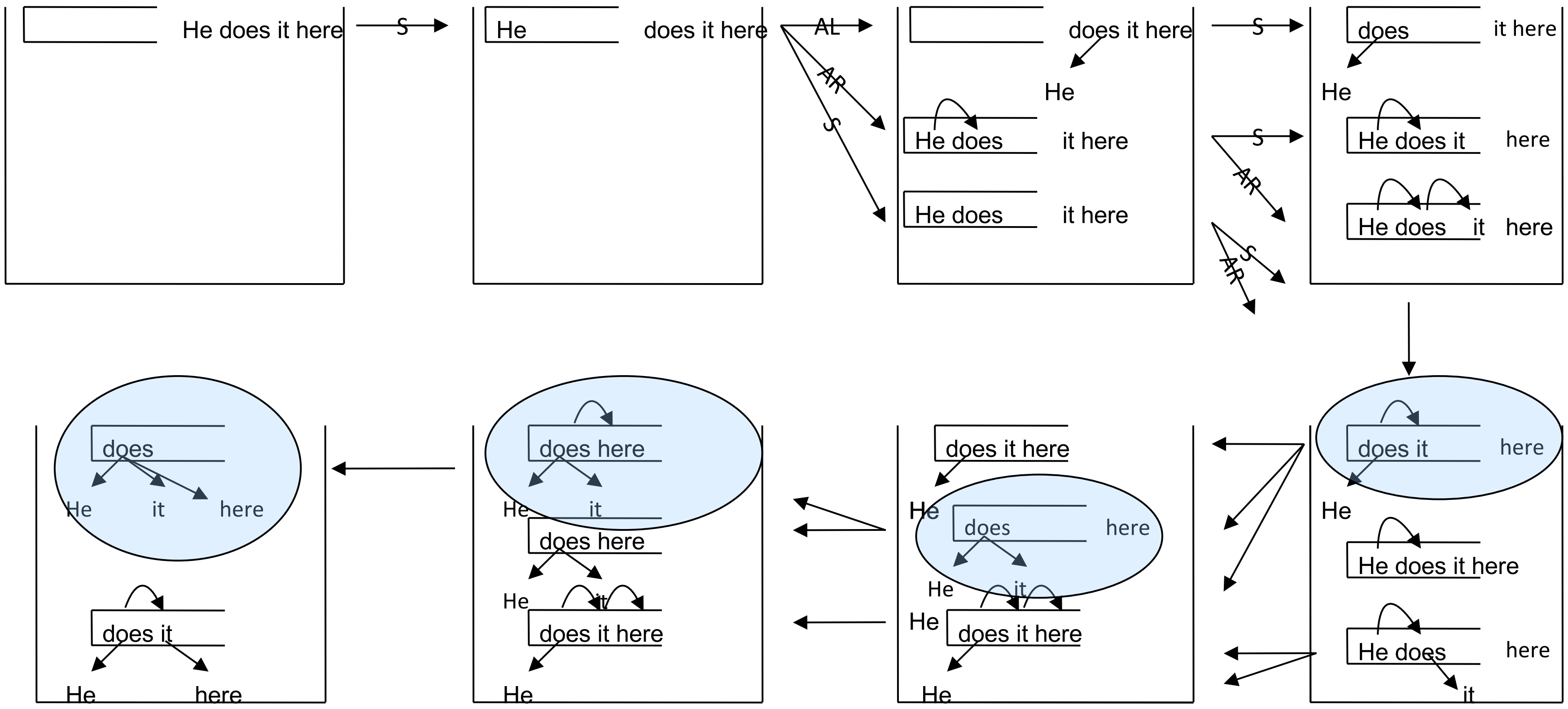

Solution

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- Use global linear model to calculate $score(A|X)$

$$score(A|X) = \vec{\theta} \cdot \vec{\phi}(A, X)$$

decompose $\vec{\phi}(A|X)$ for incremental decoding

$\vec{\phi}(A|X) = \sum_{i=1}^{|A|} \vec{\phi}(a_i, s_{i-1})$

$$score(A|X) = \vec{\theta} \cdot \vec{\phi}(A, X) = \vec{\theta} \cdot \left(\sum_{i=1}^{|A|} \vec{\phi}(a_i, s_{i-1})\right)$$

$$= \sum_{i=1}^{|A|} \left(\vec{\theta}\right\} \cdot \left\{\vec{\phi}(a_i, s_{i-1})\right)$$

Beam search decoding algorithm

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Inputs: $\vec{\theta}$ —discriminative linear model parameters;
X — task input;
K — beam size;
Initialization: $agenda \leftarrow [(\textsc{StartState}(X), 0)]$;
Algorithm:
while **not** $\textsc{AllTerminal}(agenda)$ **do**
  $to\_expand \leftarrow agenda$;
  $agenda \leftarrow []$;
  for $(state, score) \in to\_expand$ **do**
    for $a \in \textsc{PossibleActions}(state)$ **do**
      $new\_state \leftarrow \textsc{Expand}(state, a)$;
      $new\_score \leftarrow score + \vec{\theta} \cdot \vec{\phi}(state, a)$;
      $\textsc{Append}(agenda, (new\_state, new\_score))$;
  $agenda \leftarrow \textsc{Top-k}(agenda, K)$;
Output: $\textsc{Top-k}(agenda, 1)[0]$;

Beam search decoding example

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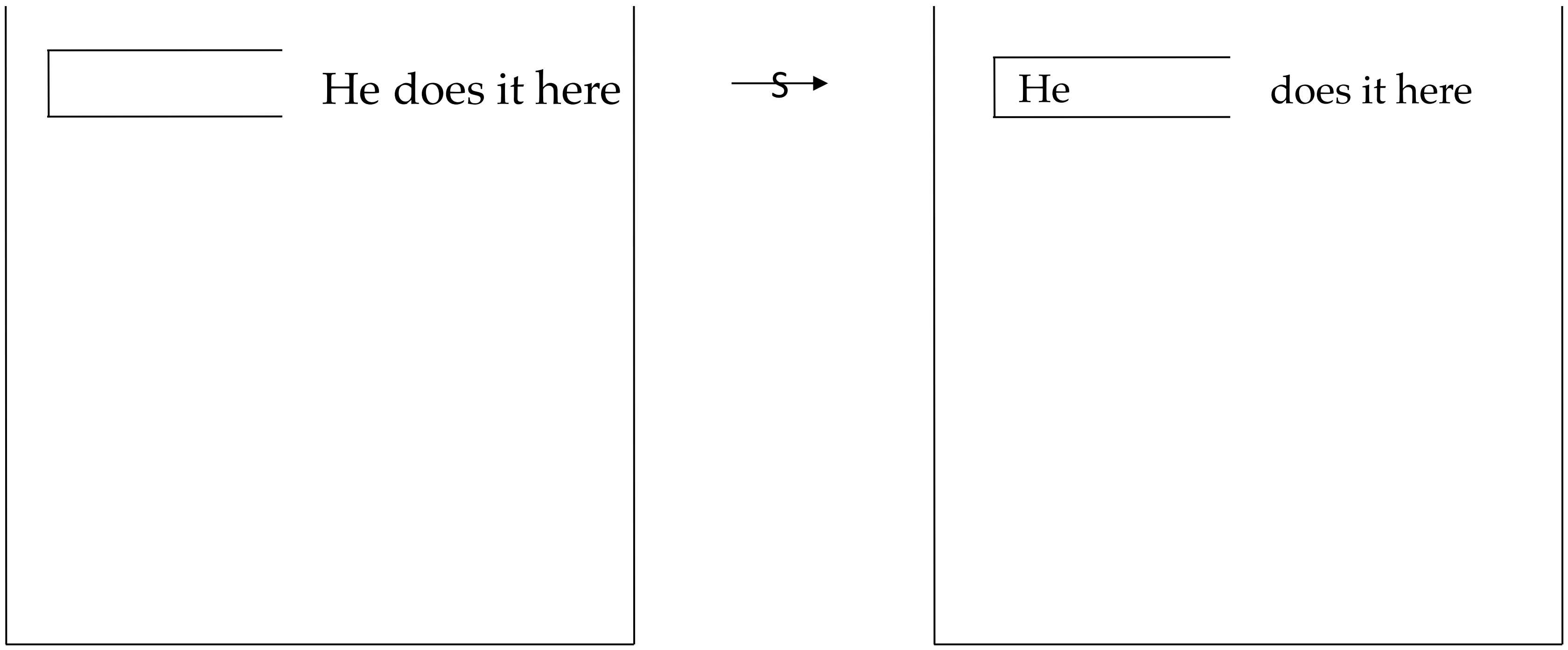
- Dependency parsing

He does it here

Beam search decoding example

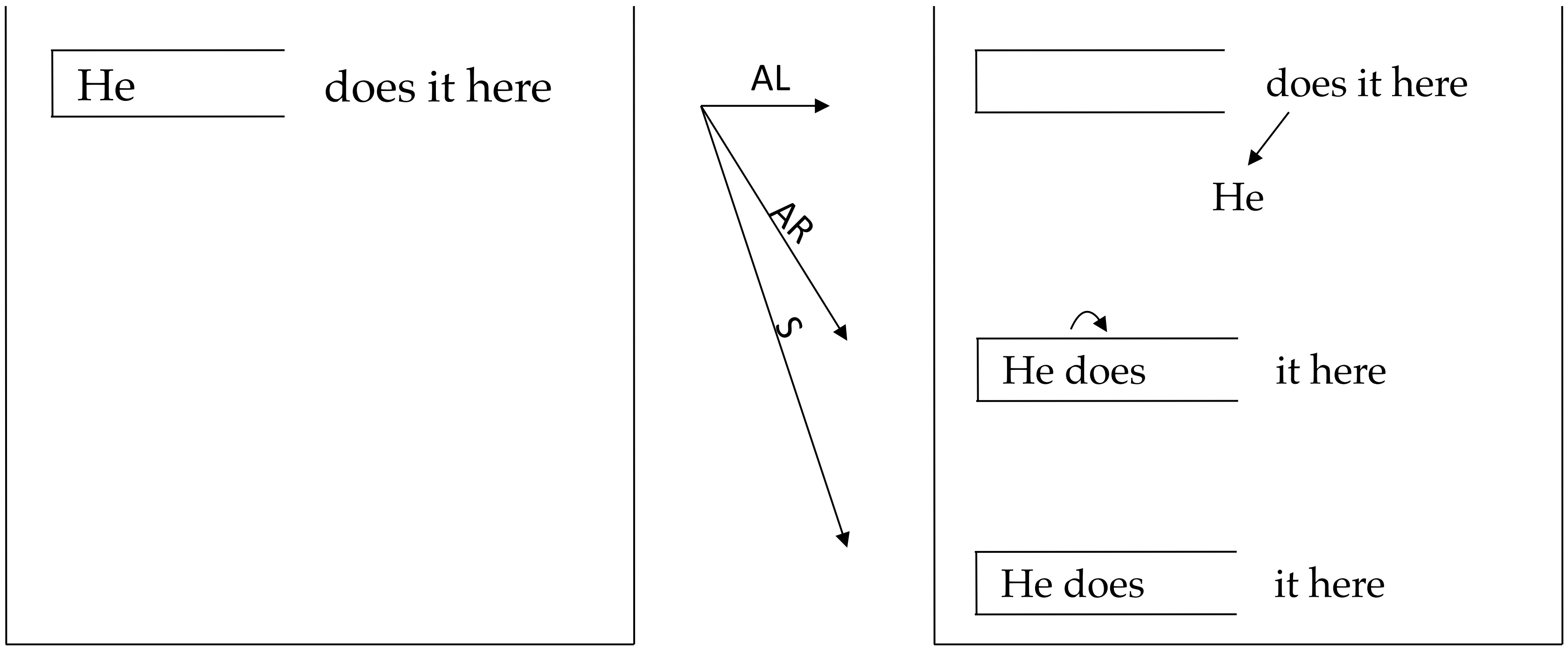
- Dependency parsing



S-SHIFT

Beam search decoding example

- Dependency parsing

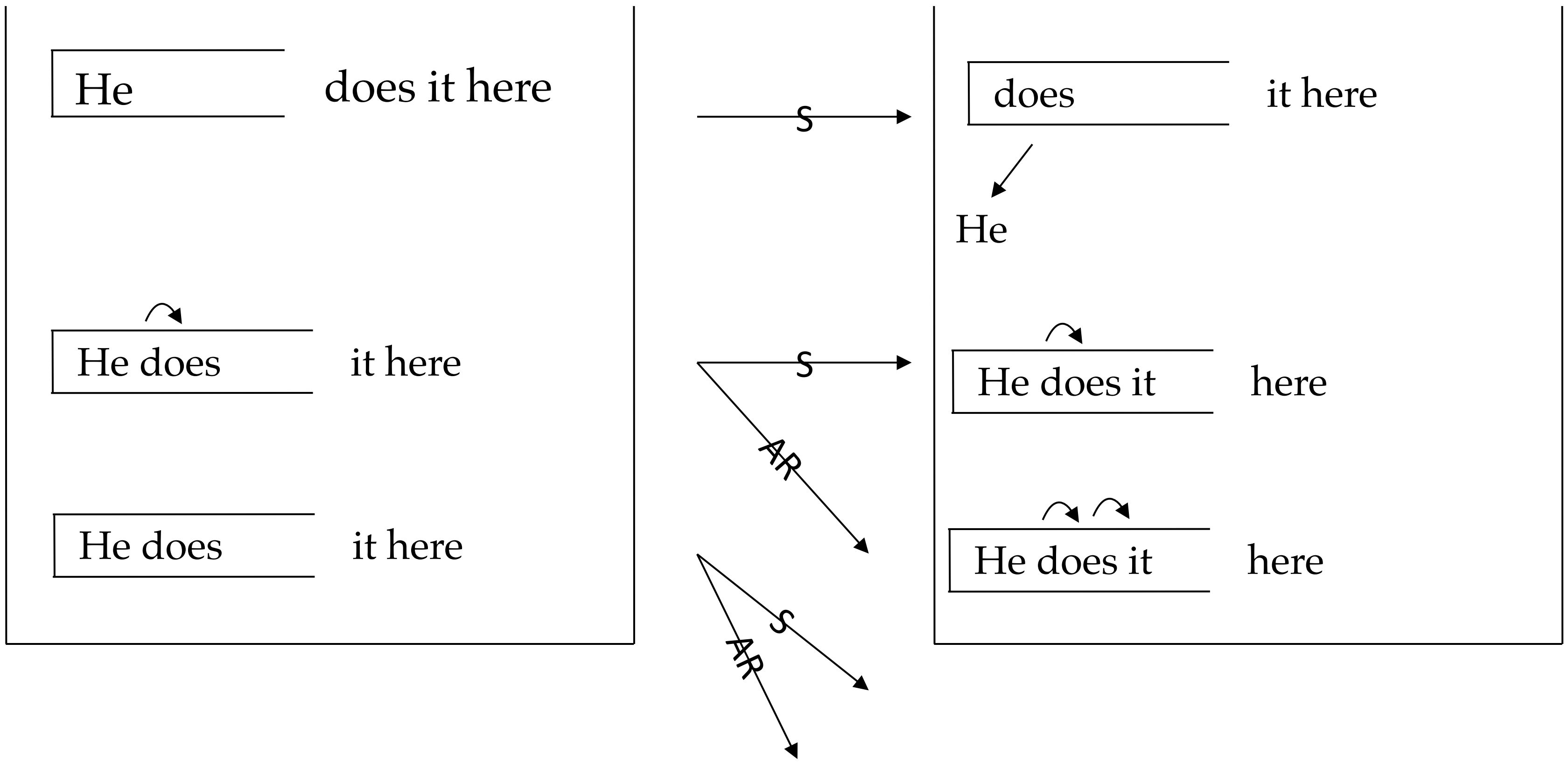


AL—LEFT-ARC

AR—RIGHT-ARC

Beam search decoding example

- Dependency parsing



Beam search decoding example

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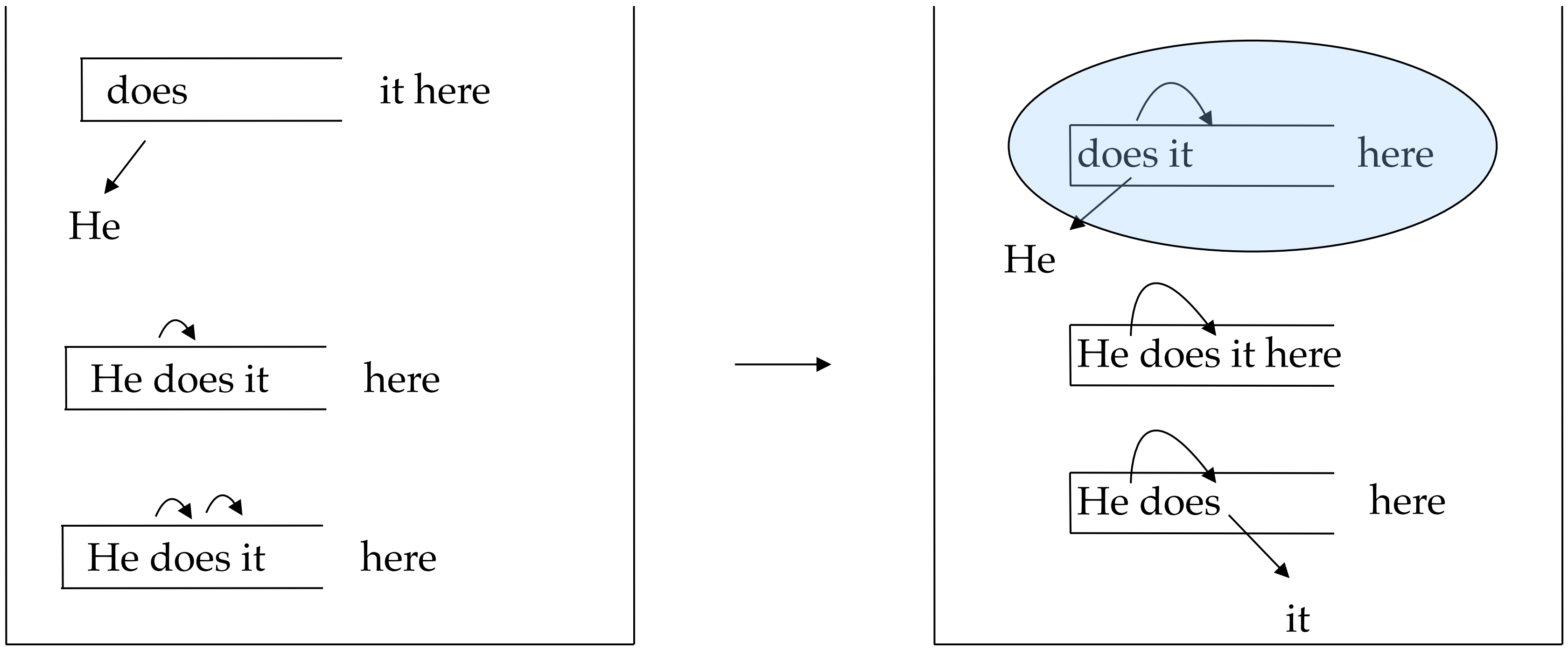

Beam search decoding example

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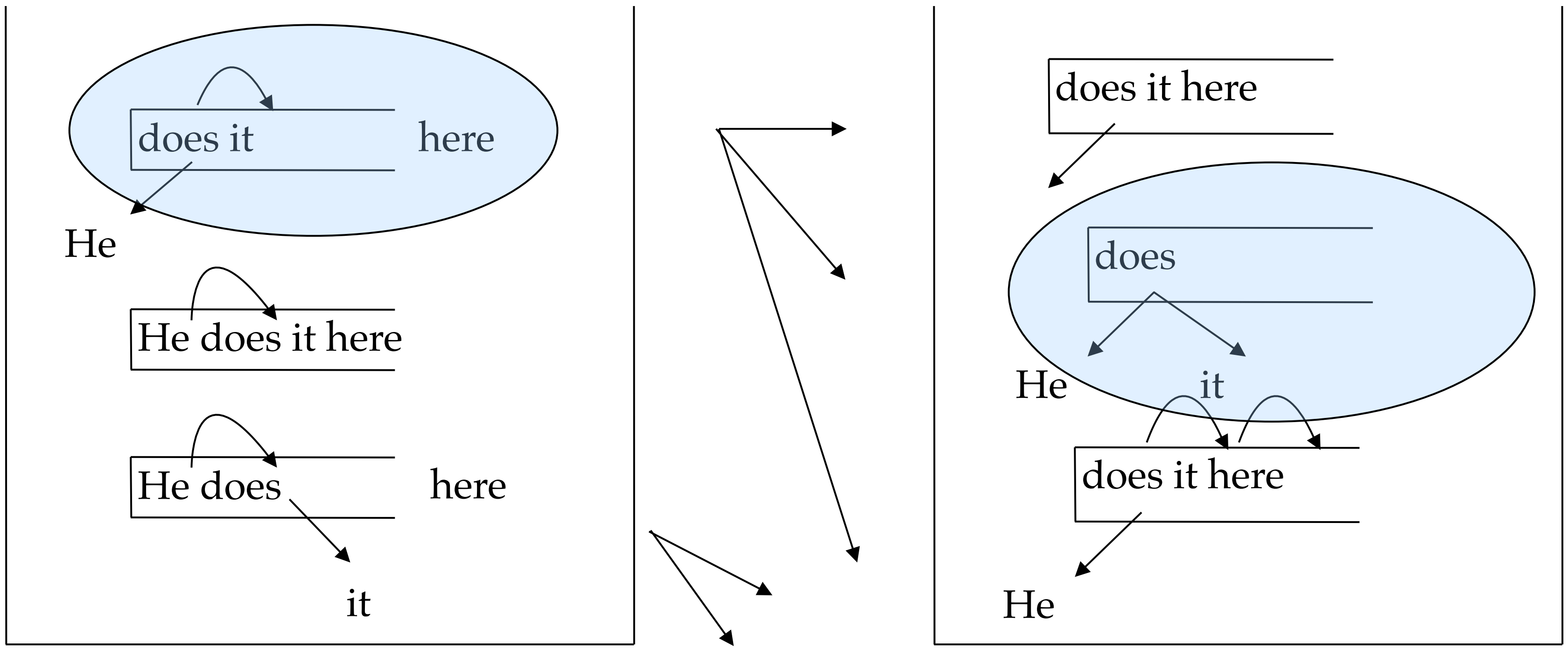
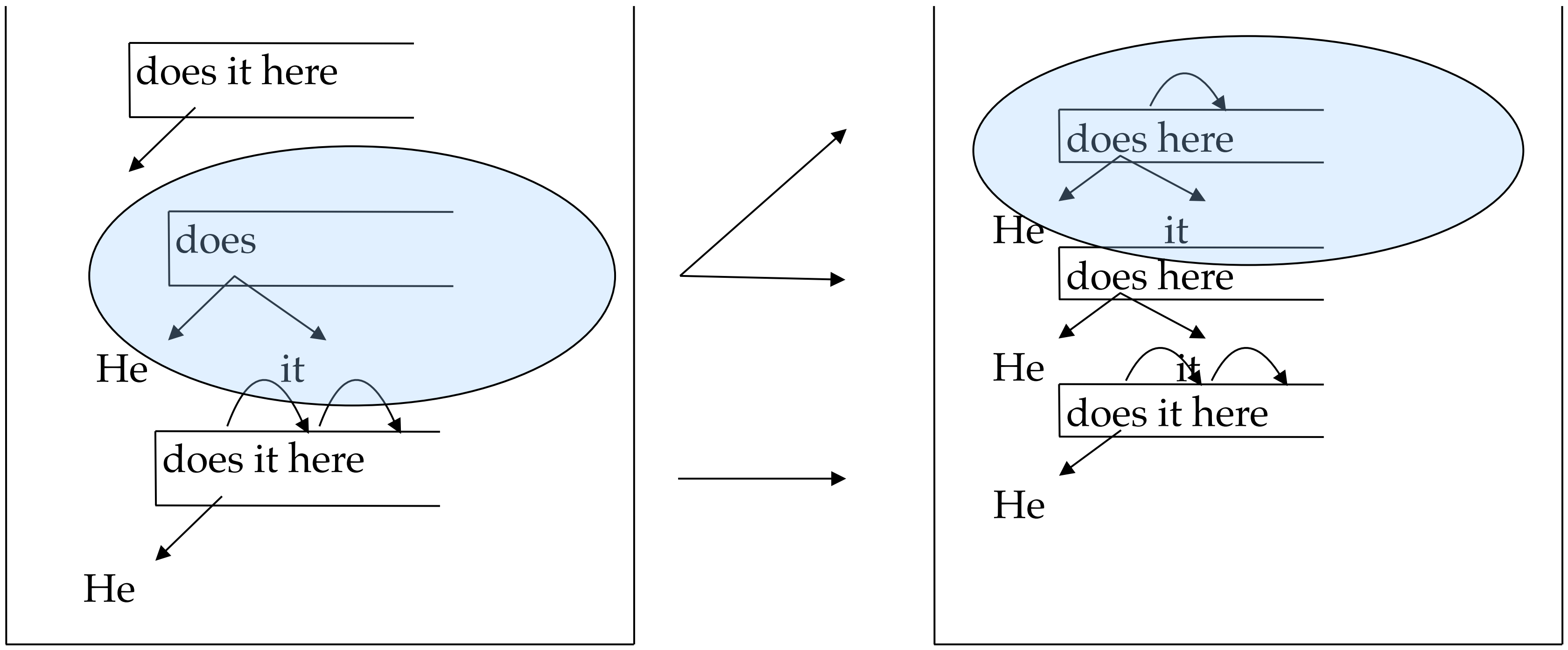
- Dependency parsing



Beam search decoding example

- Dependency parsing



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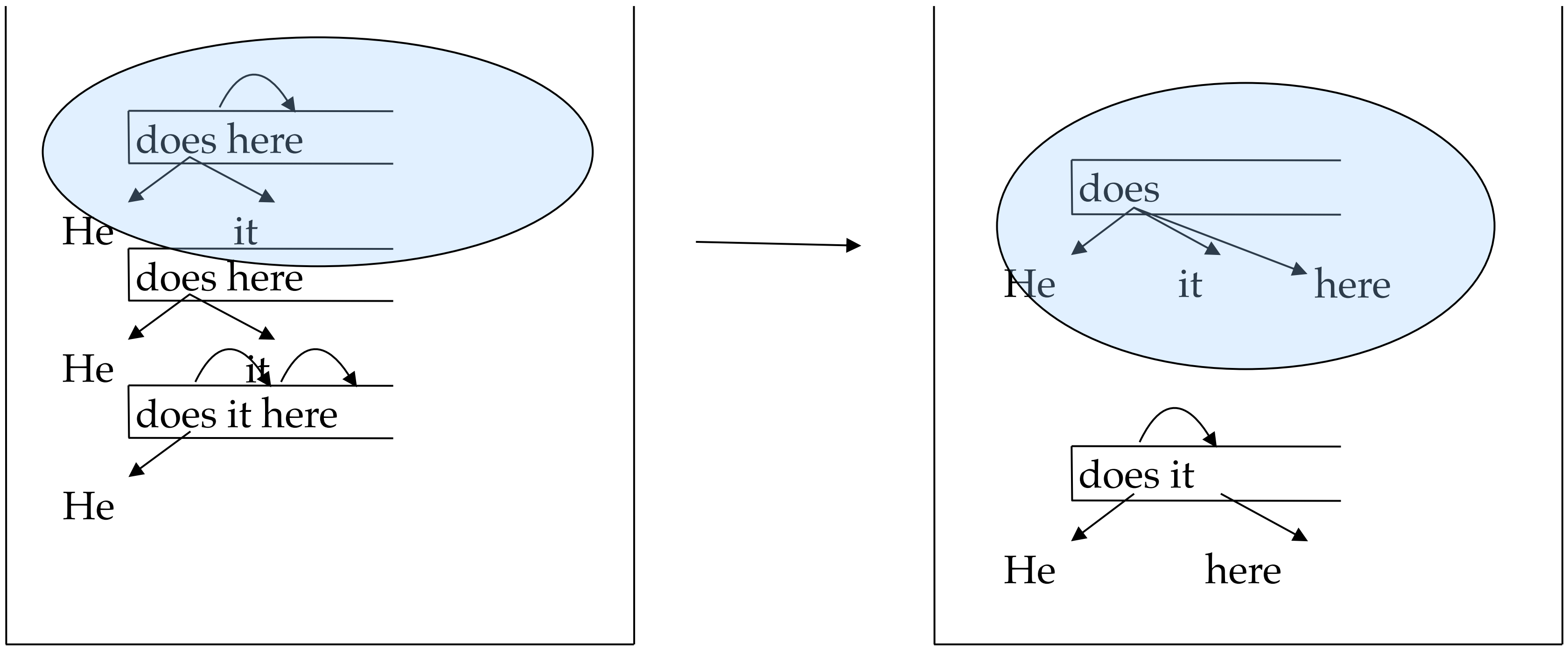

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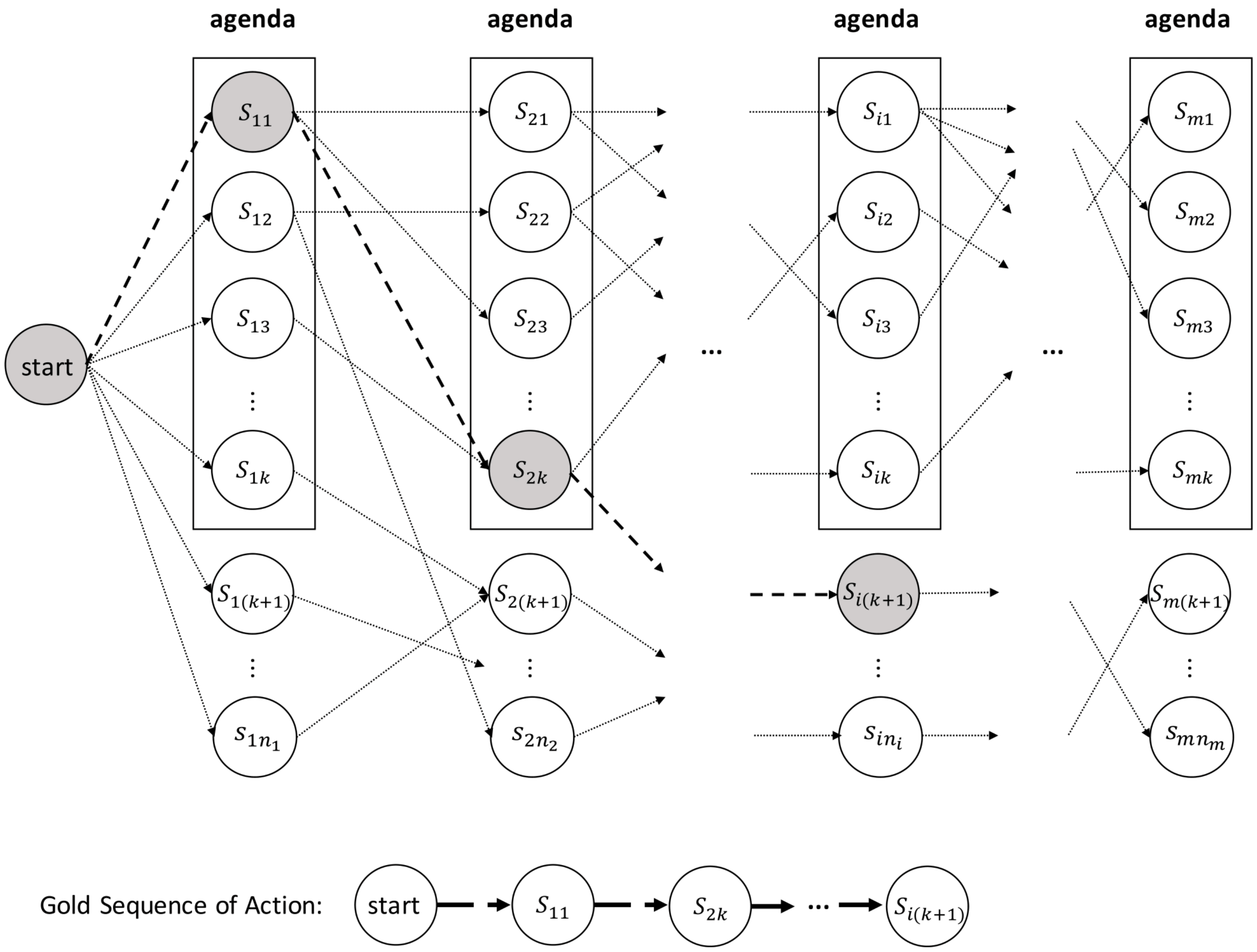

Beam search training algorithm

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Inputs: D — gold standard training set;
K — beam size;
T — number of training iterations;
Initialisation: $\vec{\theta} \leftarrow 0$;
Algorithm:
for $t \in [1, \ldots, T]$ **do**
  for $(X, Y) \in D$ **do**
    $G \leftarrow$ GoldActionSeq(X, Y);
    $agenda \leftarrow$ [(StartState(X), 0)];
    $gold\_state \leftarrow$ StartState(X);
    $i \leftarrow 0$;
    while not AllTerminal$(agenda)$ **do**
      $i \leftarrow i + 1$;
      $to\_expand \leftarrow agenda$;
      $agenda \leftarrow []$;
      for $(state, score) \in to\_expand$ **do**
        for $a \in$ PossibleActions$(state)$ **do**
          $new\_state \leftarrow$ Expand$(state, a)$;
          $new\_score \leftarrow score + \vec{\theta} \cdot \vec{\phi}(state, a)$;
          Append$(agenda, (new_state, new_score))$;
      $agenda \leftarrow$ Top-k$(agenda, K)$;
      $gold\_state \leftarrow$ Expand$(gold_state, G[i])$;
      if not Contain$(agenda, gold_state)$ **then**
        $pos \leftarrow gold\_state$;
        $neg \leftarrow$ Top-k$(agenda, 1)[0]$;
        $\vec{\theta} \leftarrow \vec{\theta} + \vec{\phi}(pos) - \vec{\phi}(neg)$;
        continue((W, G) $\in D$)
    if $gold\_state \neq$ Top-k$(agenda, 1)[0]$ **then**
      $\vec{\theta} \leftarrow \vec{\theta} + \vec{\phi}(gold_state) - \vec{\phi}($Top-k$(agenda, 1)[0])$;
Output: $\vec{\theta}$;

Contents

WestlakeNLP

Transition-based constituent parsing

WestlakeNLP

- Three steps in transition-based modeling
  - Find the state transition process
  - Define global feature vector
  - Apply the standard learning and search framework

Transition-based constituent parsing

WestlakeNLP

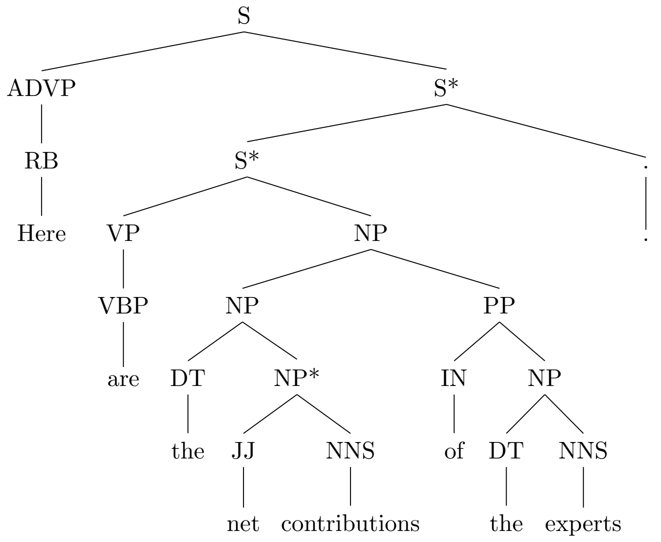
- **State**

  σ: stack of partially constituent outputs.

  β: buffer of the next incoming words.

- **actions**

  SHIFT, REDUCE-L/R-X, UNARY-X, IDLE



Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

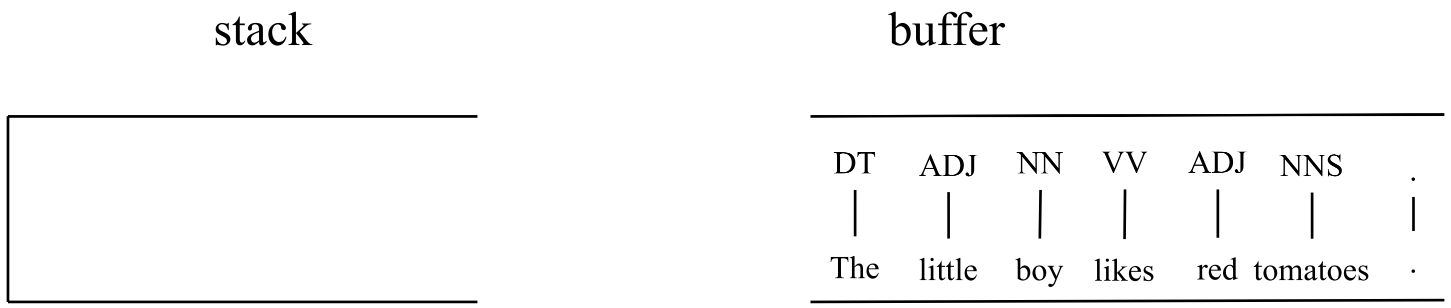
Axiom: Goal:	$([\,],\ W_{1:n})$ $(\sigma,\ [\,])$	SHIFT:	$\dfrac{(\sigma,\ w_0\|\beta)}{(\sigma\|w_0,\ \beta)}$
REDUCE-L-X:	$\dfrac{(\sigma\|s_1\|s_0,\ \beta)}{\left(\sigma\middle\| \begin{array}{c} \text{X} \\ \swarrow \quad \diagdown \\ s_1 \qquad s_0 \end{array},\ \beta\right)}$	REDUCE-R-X:	$\dfrac{(\sigma\|s_1\|s_0,\ \beta)}{\left(\sigma\middle\| \begin{array}{c} \text{X} \\ \diagup \quad \searrow \\ s_1 \qquad s_0 \end{array},\ \beta\right)}$
UNARY-X:	$\dfrac{(\sigma\|s_0,\ \beta)}{\left(\sigma\middle\| \begin{array}{c} \text{X} \\ \downarrow \\ s_0 \end{array},\ \beta\right)}$	IDLE:	$\dfrac{(\sigma,\ [\,])}{(\sigma,\ [\,])}$

Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

- Example
  - Shift



Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

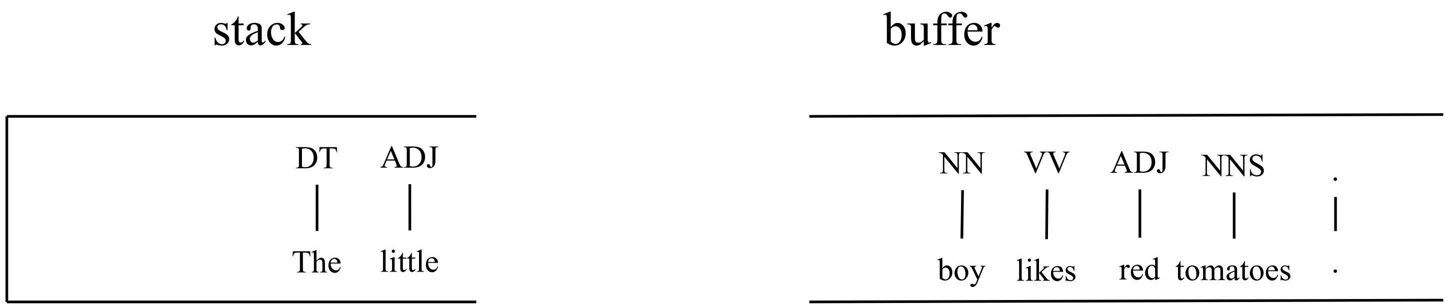
- Example
  - Shift

Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

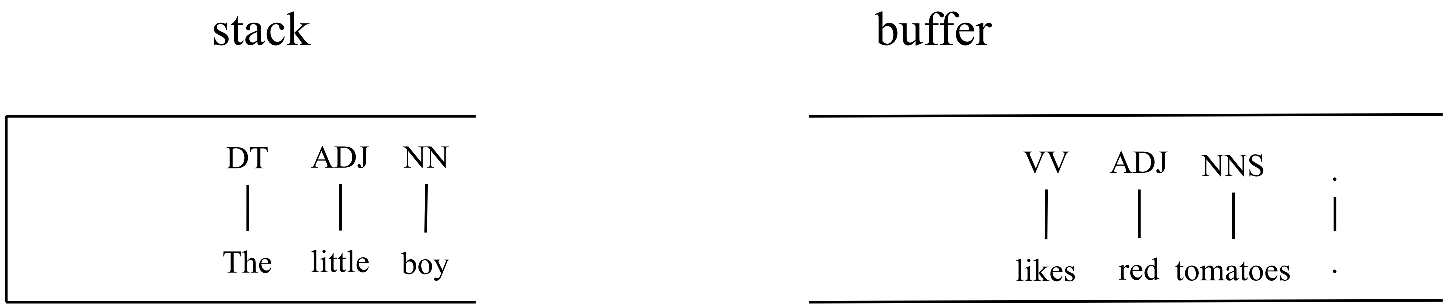
- Example
  - Shift



Transition-based constituent parsing

Shift-reduce constituent parsing

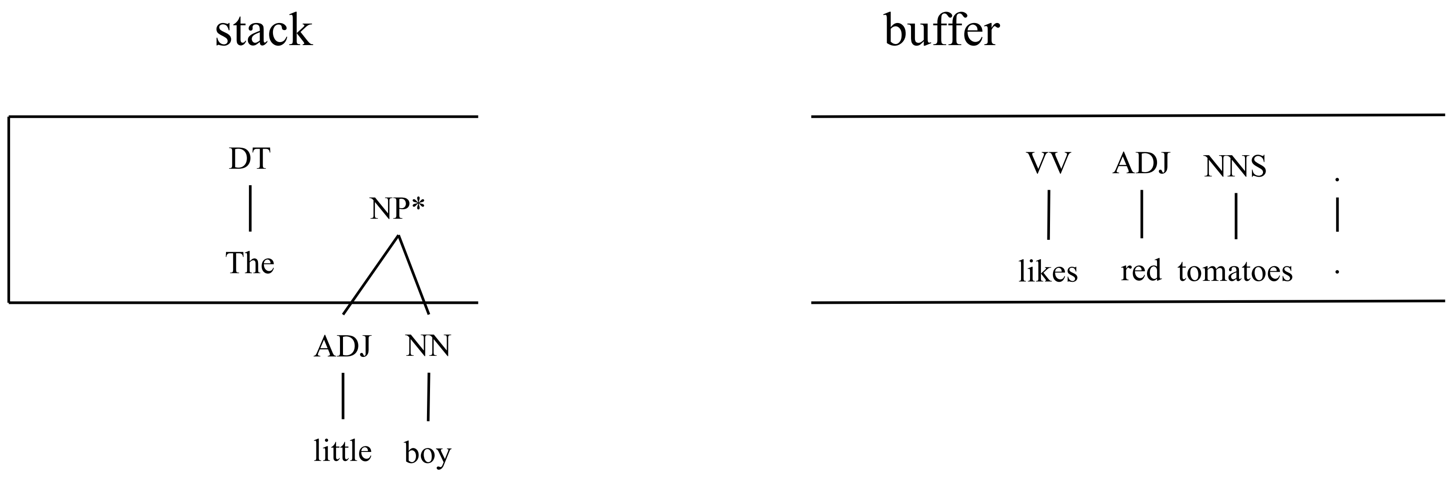
- Example
  - Reduce-R-NP



Transition-based constituent parsing

Shift-reduce constituent parsing

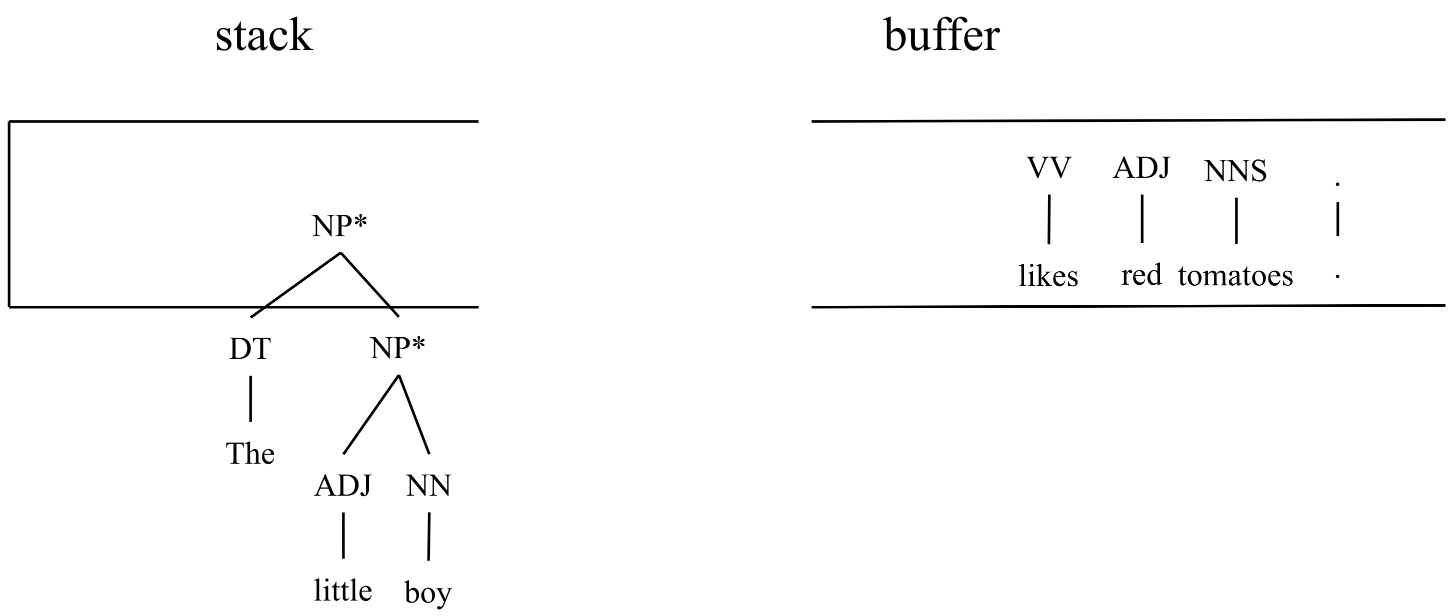
- Example
  - Reduce-R-NP



Transition-based constituent parsing

Shift-reduce constituent parsing

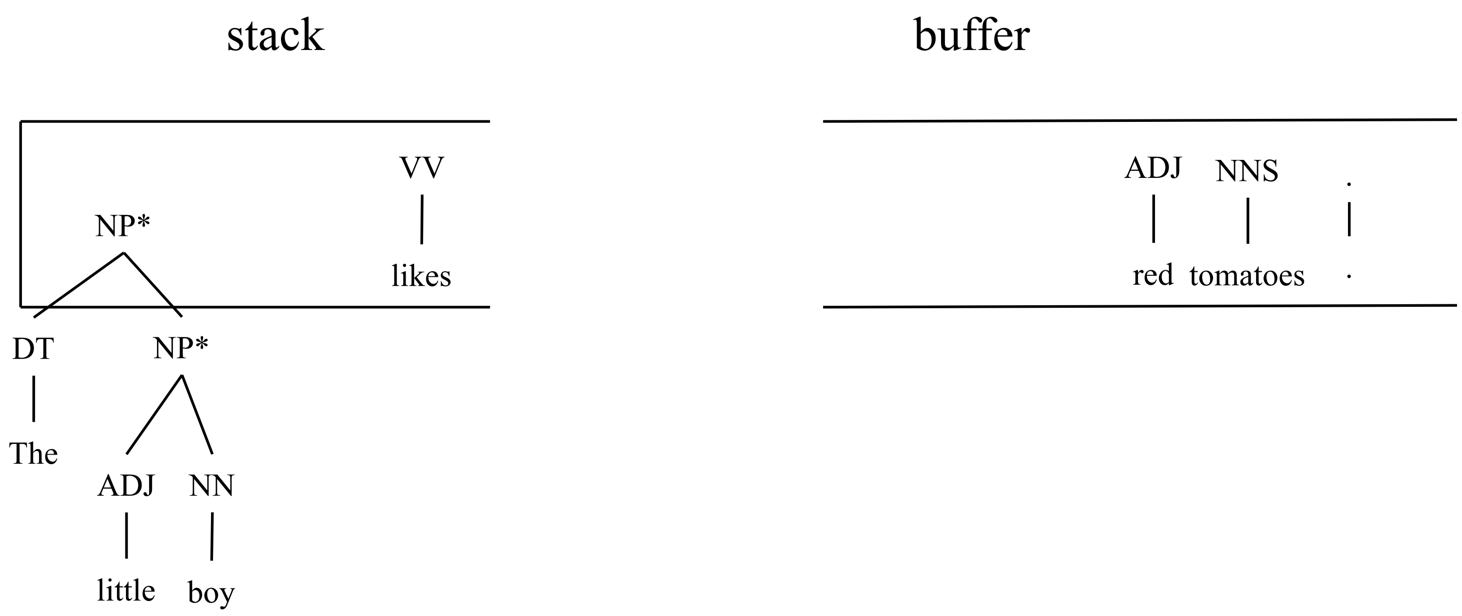
- Example
  - Shift



Transition-based constituent parsing

Shift-reduce constituent parsing

- Example
  - Shift

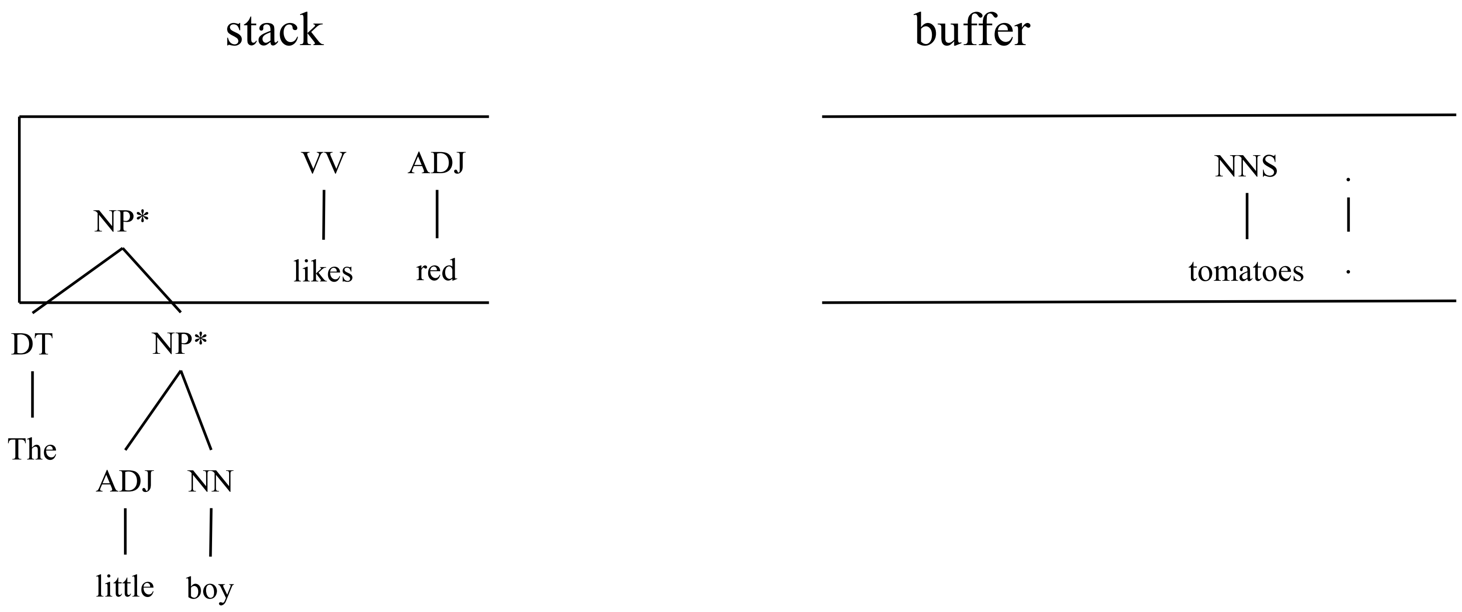


Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

- Example
  - Shift

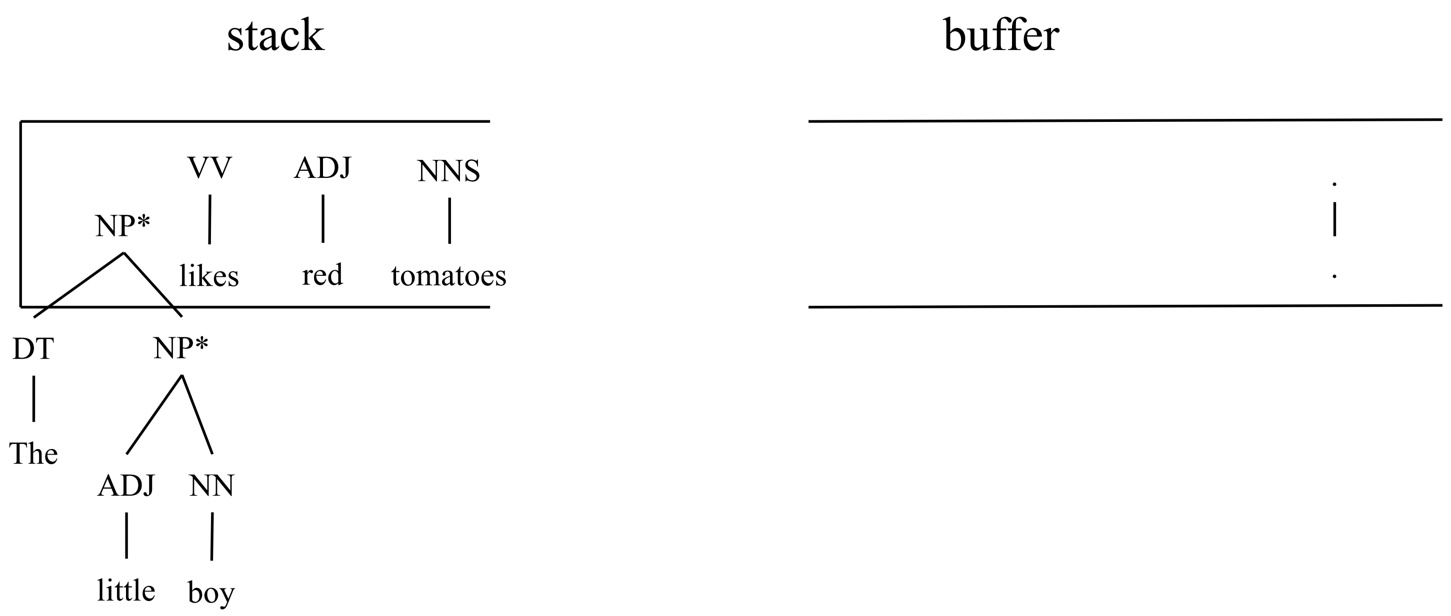


Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

- Example
  - Reduce-R-NP

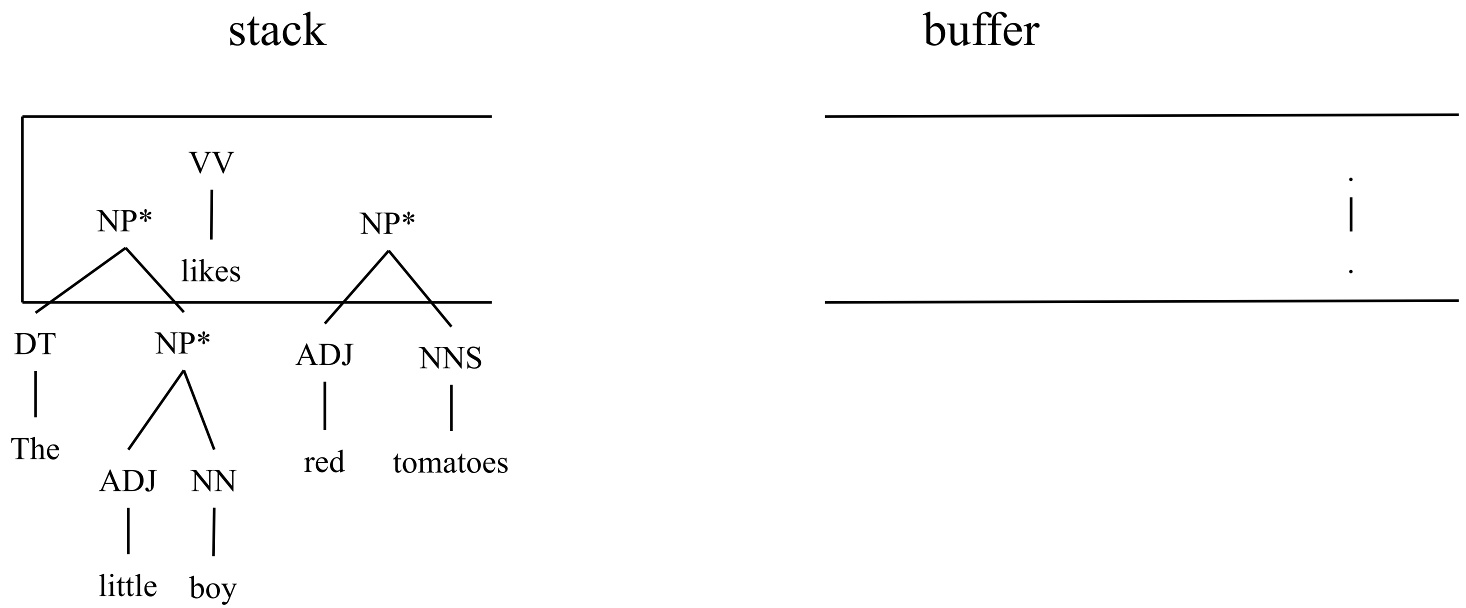


Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

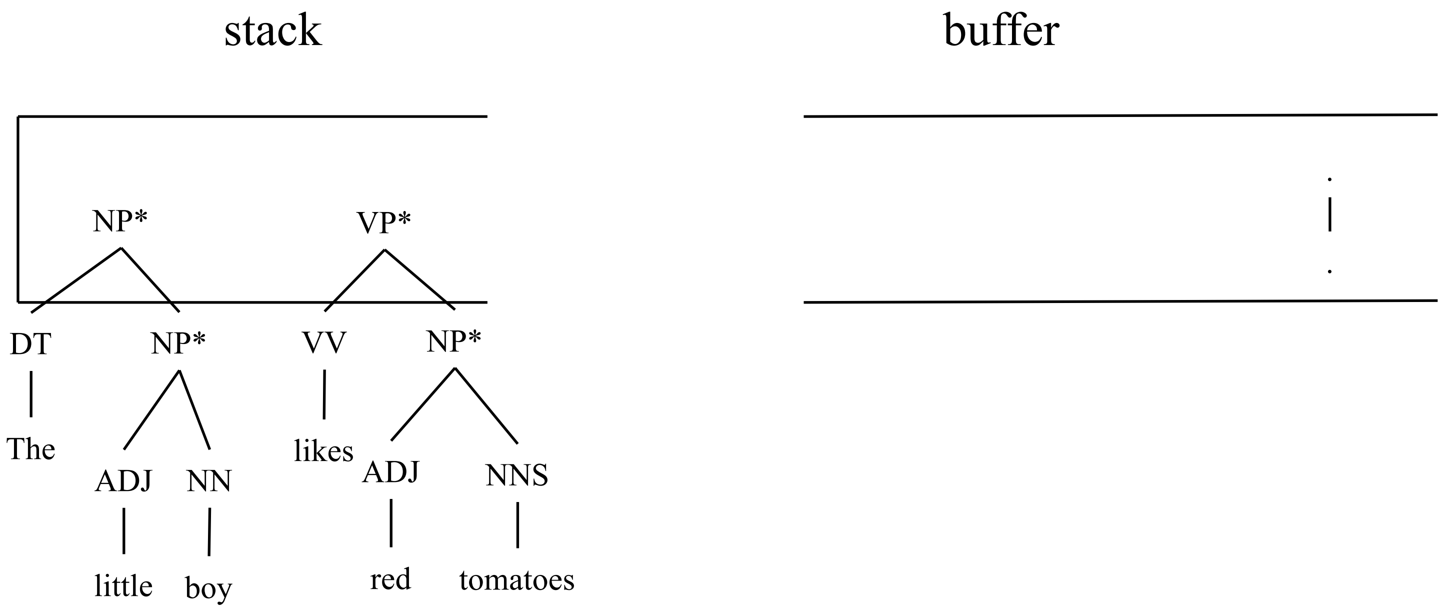
- Example
  - Reduce-L-VP



Transition-based constituent parsing

Shift-reduce constituent parsing

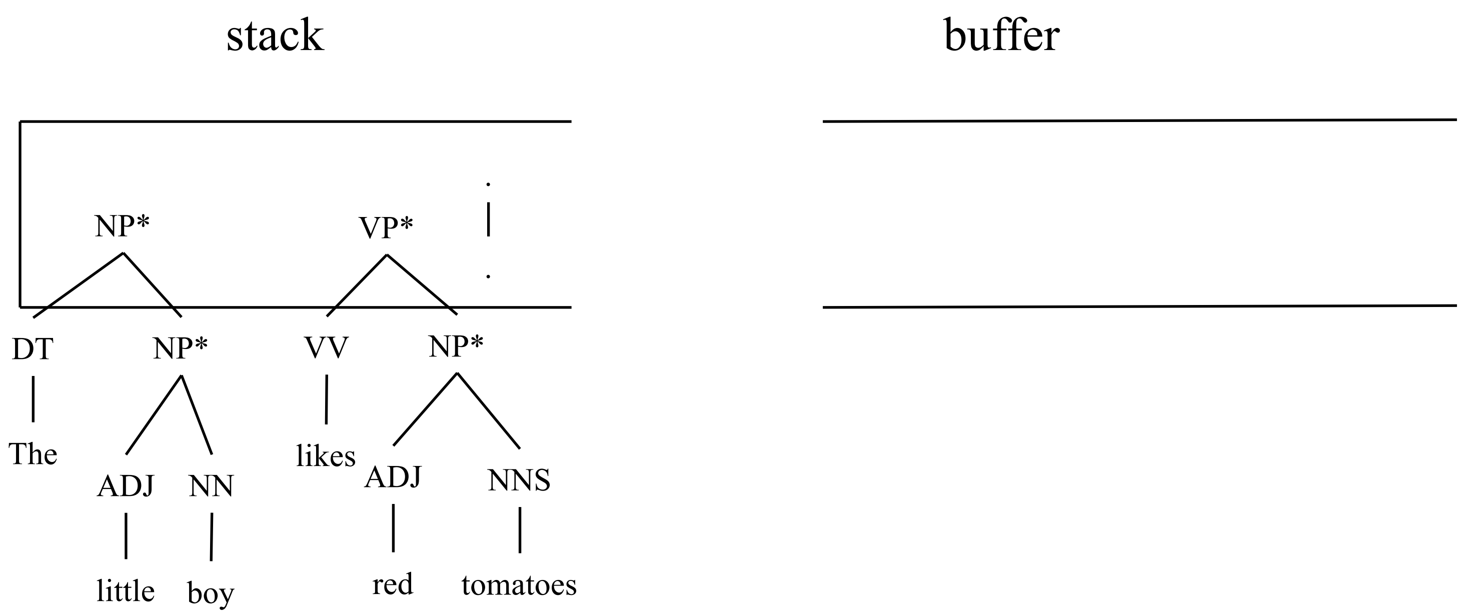
- Example
  - Shift



Transition-based constituent parsing

Shift-reduce constituent parsing

- Example
  - Reduce-L-S

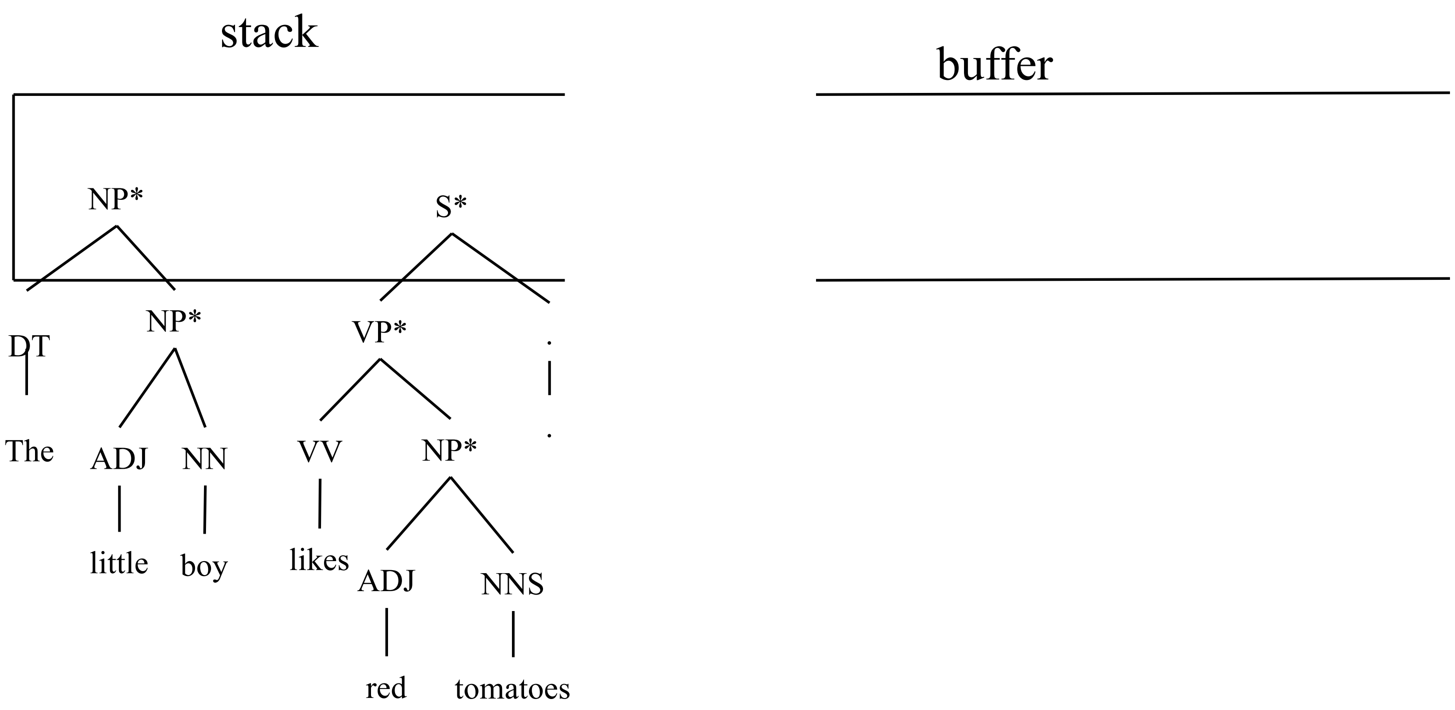


Transition-based constituent parsing

WestlakeNLP

Shift-reduce constituent parsing

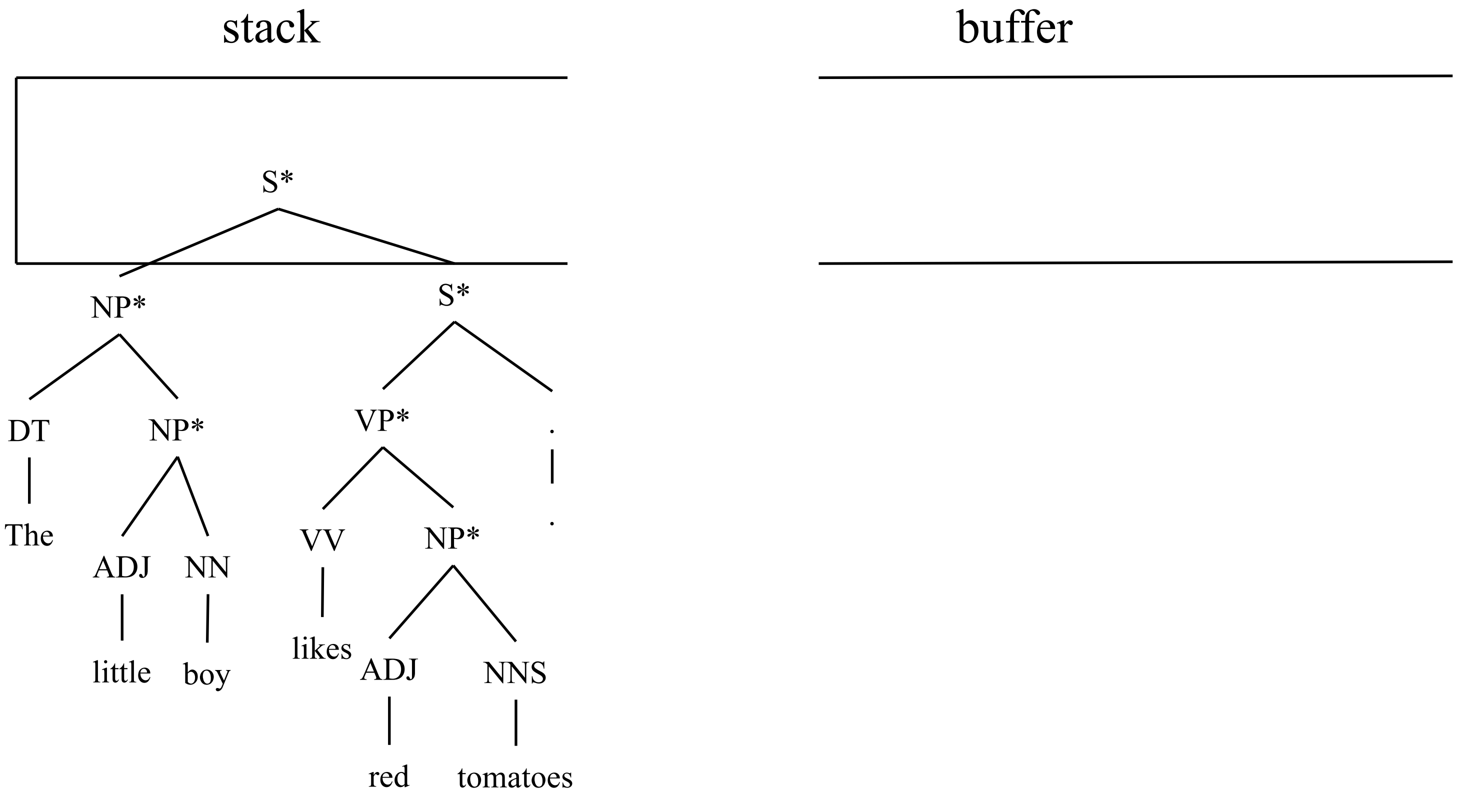
- Example
  - Reduce-R-S



Transition-based constituent parsing

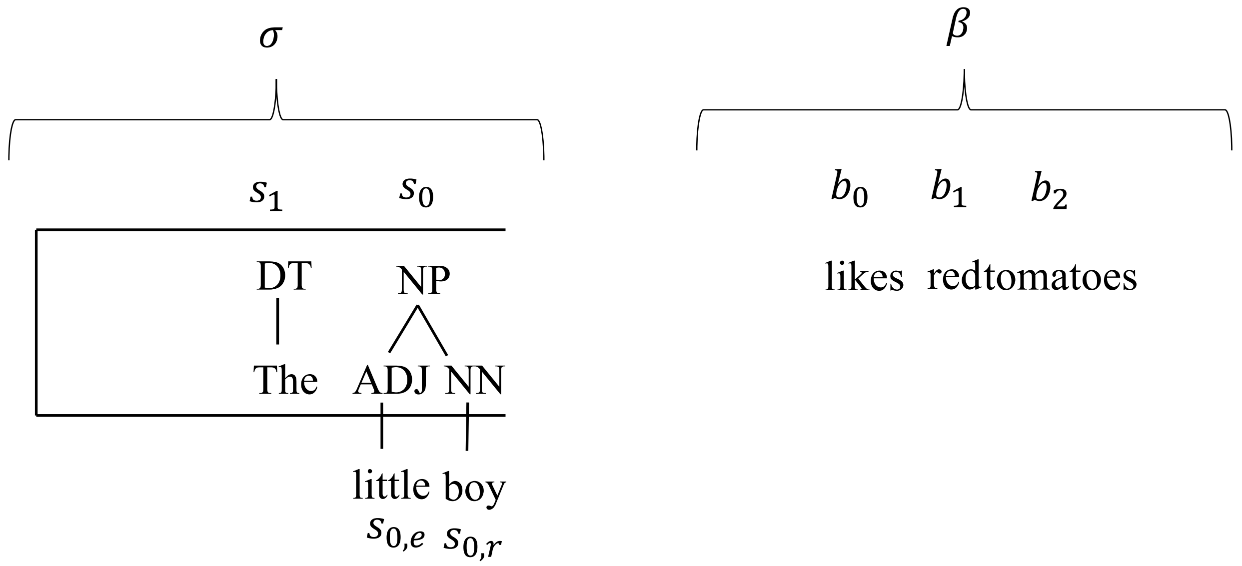
Shift-reduce constituent parsing

- Example
  - Terminate



Transition-based constituent parsing

- **Feature Templates for Shift-reduce Constituent Parser**
- Example state



Transition-based constituent parsing

WestlakeNLP

- **Feature Templates for Shift-reduce Constituent Parser**

Feature type	Feature Template
unigrams	s_0ps_0c, s_0ws_0c, s_1ps_1c, s_1ws_1c, s_2ps_2c, s_2ws_2c, s_3ps_3c, s_3ws_3c, b_0wb_0p, b_1wb_1p, b_2wb_2p, b_3wb_3p, $s_{0.l}ws_{0.l}c$, $s_{0.r}ws_{0.r}c$, $s_{0.u}ws_{0.u}c$, $s_{1.l}ws_{1.l}c$, $s_{1.r}ws_{1.r}c$, $s_{1.u}ws_{1.u}c$
bigrams	s_0ws_1w, s_0ws_1c, s_0cs_1w, s_0cs_1c, s_0wb_0w, s_0wb_0p, s_0cb_0w, s_0cb_0p, b_0wb_1w, b_0wb_1p, b_0pb_1w, b_0pb_1p, s_1wb_0w, s_1wb_0p, s_1cb_0w, s_1cb_0p
trigrams	$s_0cs_1cs_2c$, $s_0ws_1cs_2c$, $s_0cs_1wb_0p$, $s_0cs_1cs_2w$, $s_0cs_1cb_0p$, $s_0ws_1cb_0p$, $s_0cs_1wb_0p$, $s_0cs_1cb_0w$

s_i: top node of the stack; b_i: front word on the buffer; xw: the word form of x;

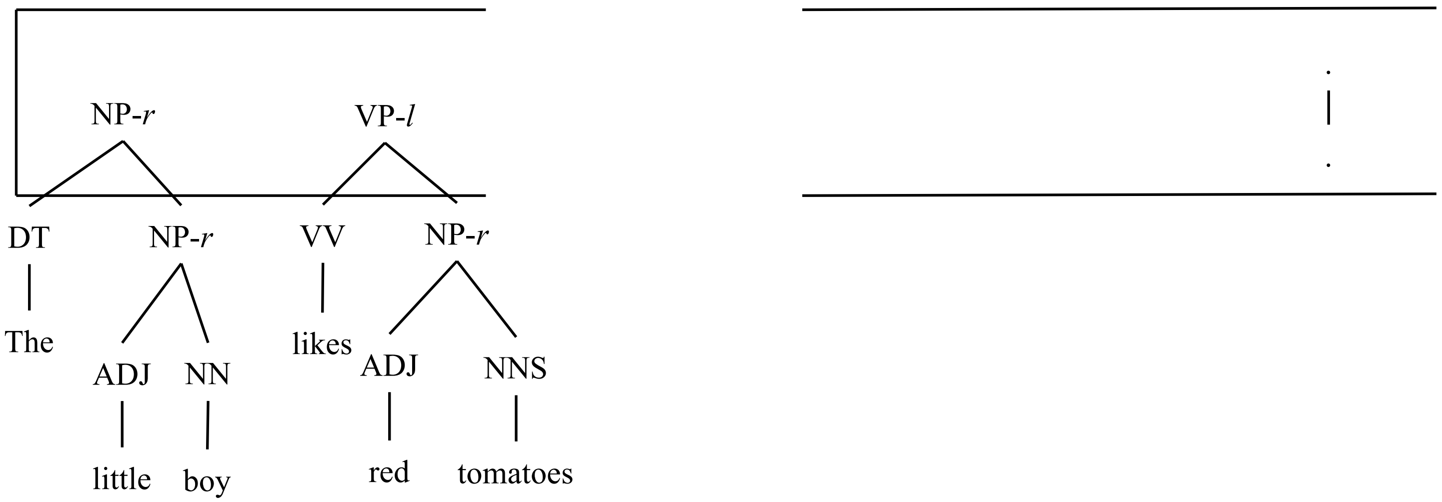
xp: the POS tag; xc: the constituent label of a non-terminal node x;

xl, xr, xu: the left child, the right child and the unary child of x, respectively.

Transition-based constituent parsing

- **Feature Templates for Shift-reduce Constituent Parser**
- Example

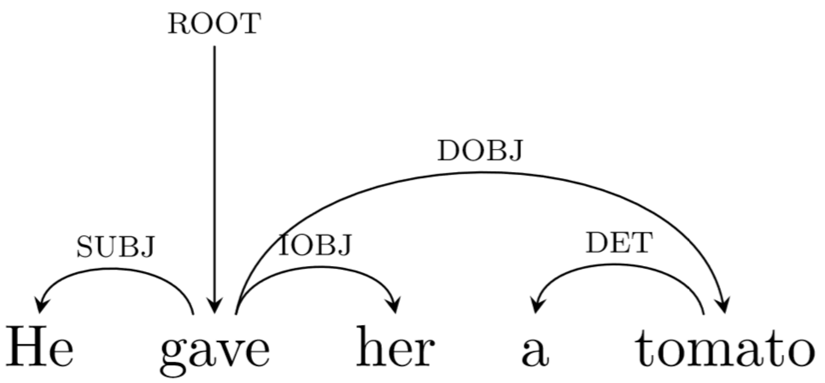
In the 10-th step of the example sentence "*The little boy likes red tomatoes*", the $s_0\ ps_0c$ feature is VBZ | VP and the s_1ps_1c feature is NN | NP.



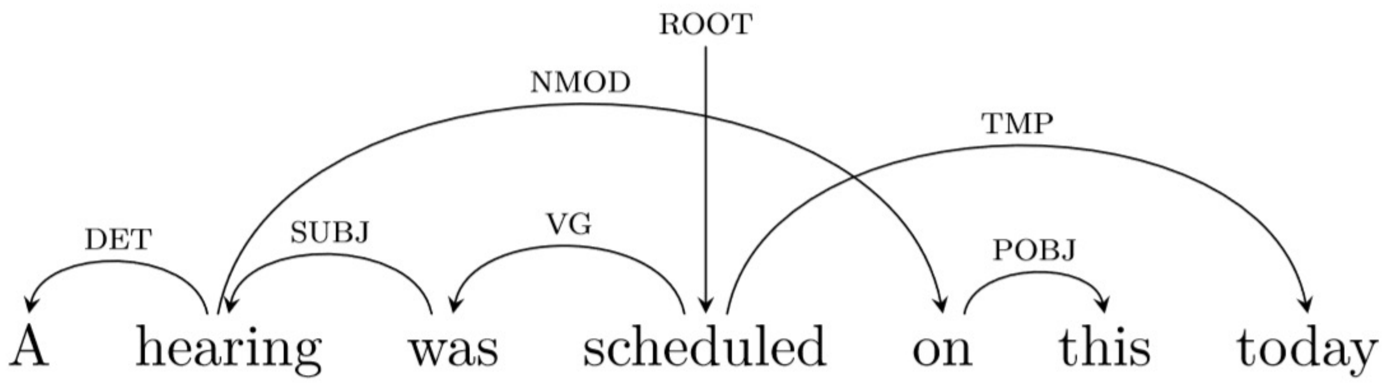
Contents

Shift-reduce dependency parsing

- Projective dependency tree



- Non-projective dependency tree



Contents

WestlakeNLP

Shift-reduce dependency parsing

- Arc-standard Parsing
  - **State**

    σ: stack of partially dependency outputs.

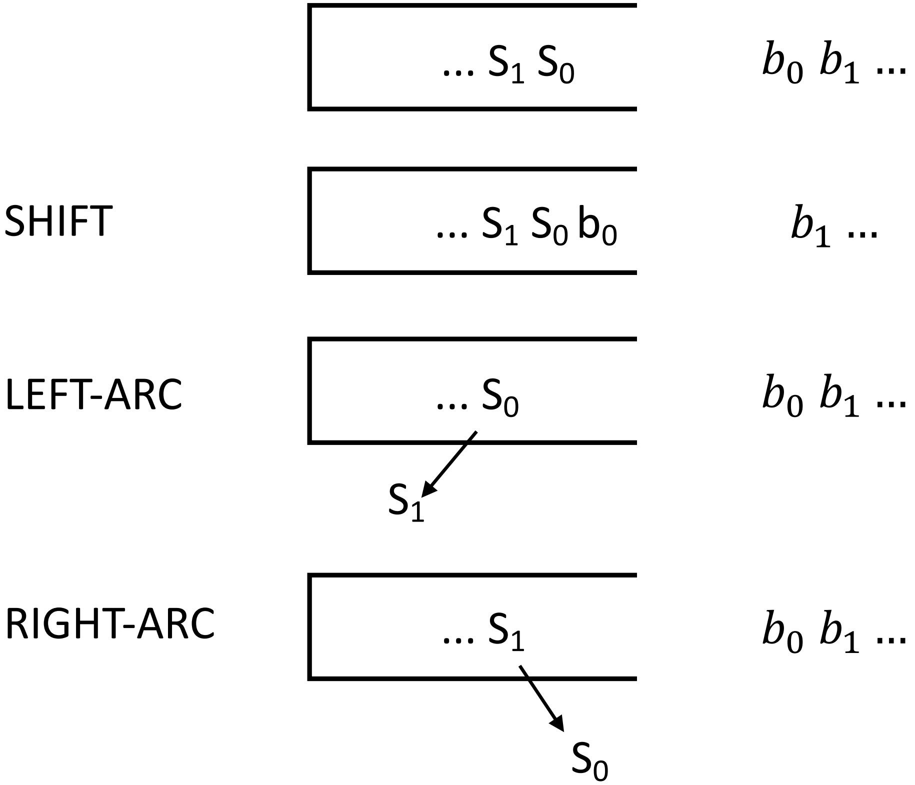
    β: buffer of the next incoming words.

  - **actions**

    SHIFT, LEFT-ARC-X, RIGHT-ARC-X

Shift-reduce dependency parsing

Actions



Shift-reduce dependency parsing

Arc-standard Dependency Parsing

Axiom:	$([\,],\ W_{1:n},\ \phi)$	LEFT-ARC-X:	$\dfrac{(\sigma\|s_1\|s_0,\ \beta,\ A)}{(\sigma\|s_0,\ \beta,\ A \cup \{s_1 \overset{X}{\curvearrowleft} s_0\})}$
Goal:	$([s_0],\ [\,],\ A)$		
SHIFT:	$\dfrac{(\sigma,\ b_0\|\beta,\ A)}{(\sigma\|b_0,\ \beta,\ A)}$	RIGHT-ARC-X:	$\dfrac{(\sigma\|s_1\|s_0,\ \beta,\ A)}{(\sigma\|s_1,\ \beta,\ A \cup \{s_1 \overset{X}{\curvearrowright} s_0\})}$

$State$: (σ, β, A);

σ: $stack$; β: $buffer$; A: $the\ set\ of\ dependency\ arcs\ that\ have\ been\ constructed$

Arc-standard dependency parsing

Example

Sentence “He gave her a tomato”

Next action: SHIFT

He gave her a tomato

Arc-standard dependency parsing

WestlakeNLP

Example

Sentence "He gave her a tomato"

Next action: SHIFT

He

gave her a tomato

Arc-standard dependency parsing

Example

Sentence “He gave her a tomato”

Next action: LEFT-ARC-SUBJ

He gave

her a tomato

Arc-standard dependency parsing

Example

Sentence “He gave her a tomato”

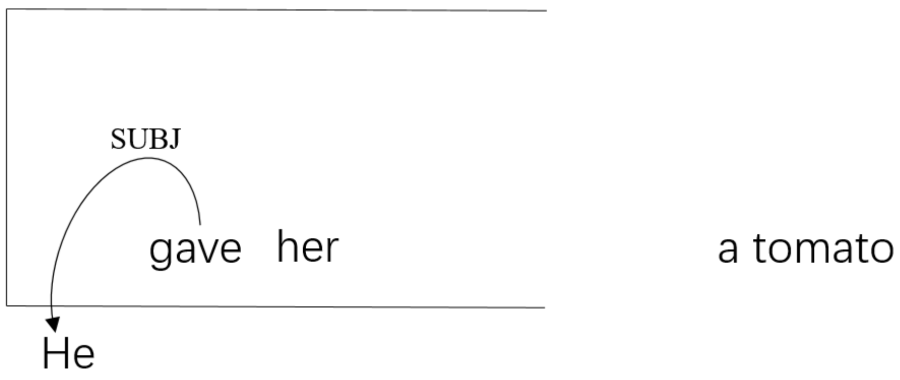
Next action: SHIFT

Arc-standard dependency parsing

Example

Sentence “He gave her a tomato”

Next action: RIGHT-ARC-IOBJ



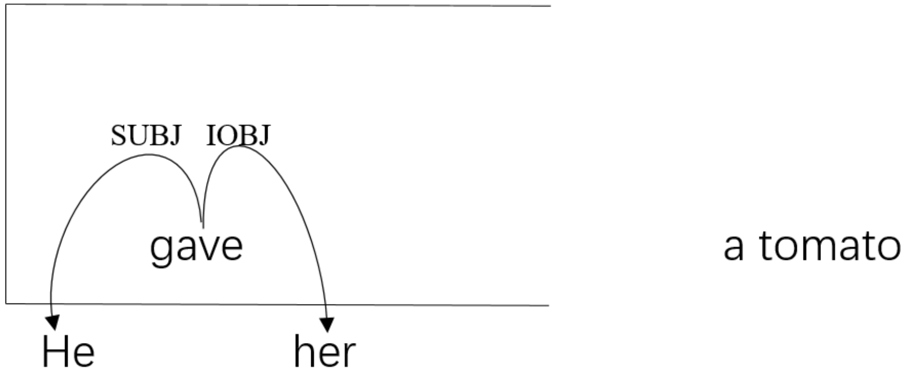
Arc-standard dependency parsing

WestlakeNLP

Example

Sentence “He gave her a tomato”

Next action: SHIFT

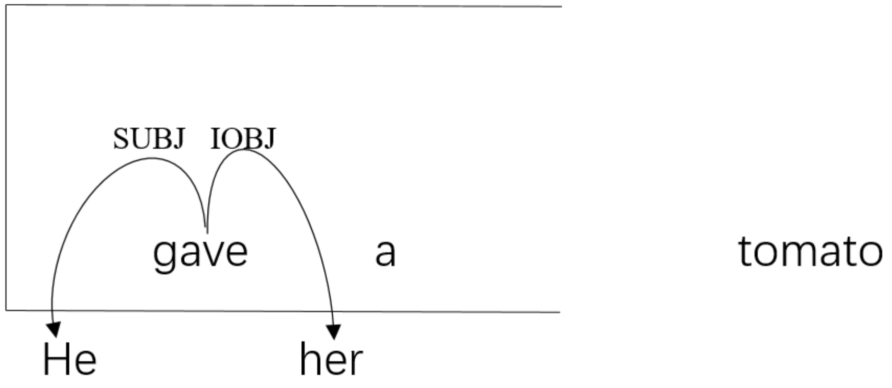


Arc-standard dependency parsing

Example

Sentence “He gave her a tomato”

Next action: SHIFT

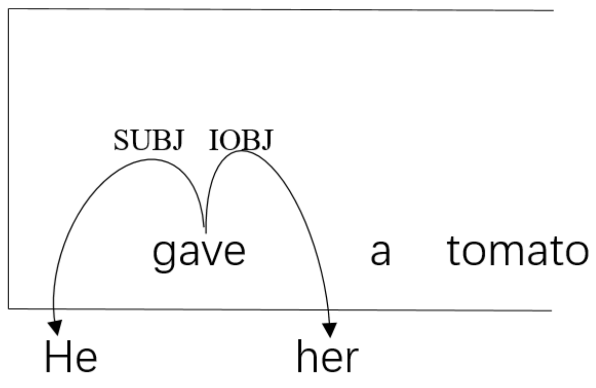


Arc-standard dependency parsing

Example

Sentence "He gave her a tomato"

Next action: LEFT-ARC-DET

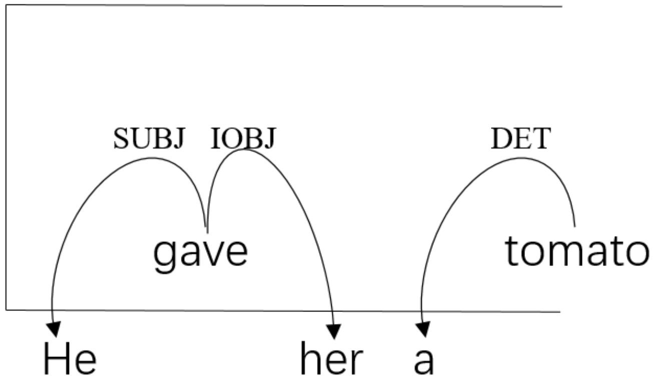


Arc-standard dependency parsing

Example

Sentence "He gave her a tomato"

Next action: RIGHT-ARC-DOBJ



Arc-standard dependency parsing

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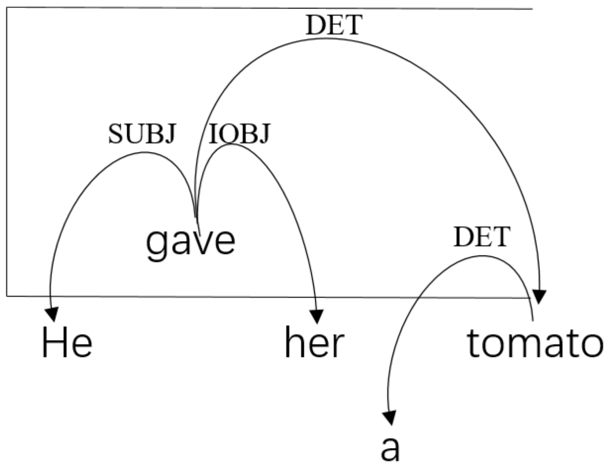
Example

Sentence "He gave her a tomato"

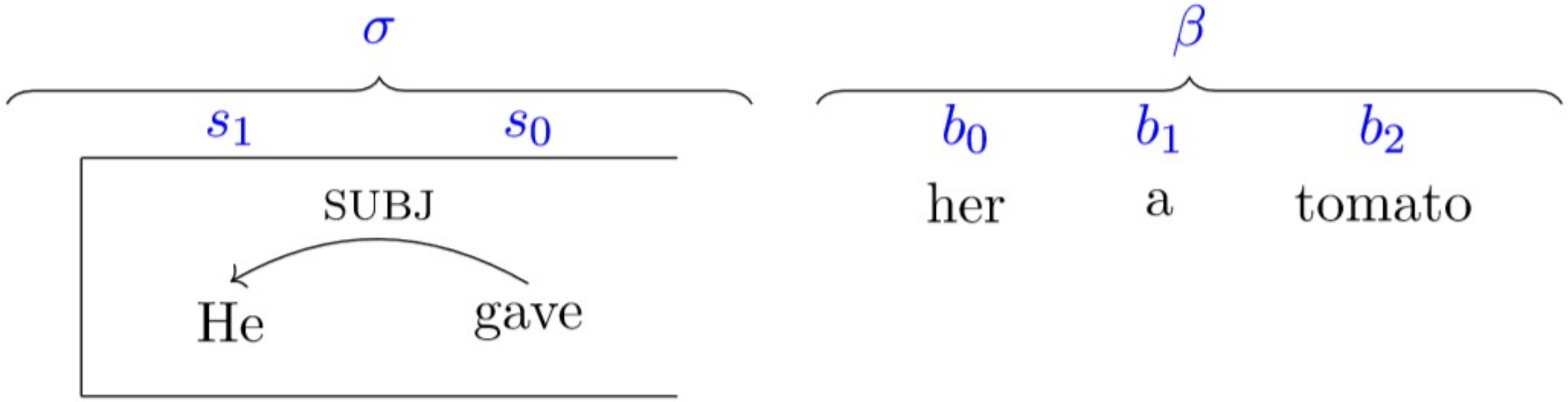
Next action: END



Shift-reduce dependency parsing

Arc-standard Dependency Parsing

- Example state



Arc-standard dependency parsing

WestlakeNLP

Feature Templates for arc-standard dependency parsing

Feature Type	Feature Template	Feature Type	Feature Template
from single words	s_0wp; s_0w; s_0p; b_0wp; b_0w; b_0p; b_1wp; b_1w; b_1p; b_2wp; b_2w; b_2p;	valency	s_0wv_r; s_0pv_r; s_0wv_l; s_0pv_l; b_0wv_l; b_0pv_l;
from word pairs	s_0wpb_0wp; s_0wpb_0w; s_0wpb_0p; s_0wb_0wp; s_0pb_0wp; s_0wb_0w; s_0pb_0p; b_0pb_1p;	unigrams	$s_{0.h}w$; $s_{0.h}p$; $s_{0.l}$; $s_{0.l}w$; $s_{0.l}p$; $s_{0.l}l$; $s_{0.r}w$; $s_{0.r}p$; $s_{0.r}l$; $b_{0.l}w$; $b_{0.l}p$; $b_{0.l}l$;
from three words	$b_0pb_1pb_2p$; $s_0pb_0pb_1p$; $s_{0.h}ps_0pb_0p$; $s_0ps_{0.l}pb_0p$; $s_0ps_{0.r}pb_0p$; $s_0pb_0pb_{0.l}p$;	third-order	$s_{0.h_2}w$; $s_{0.h_2}p$; $s_{0.h}l$; $s_{0.l_2}p$; $s_{0.l_2}l$; $s_{0.r_2}w$; $s_{0.r_2}p$; $s_{0.r_2}l$; $b_{0.l_2}w$; $b_{0.l_2}p$; $b_{0.l_2}l$; $s_0ps_{0.l}ps_{0.l_2}p$; $s_0ps_{0.r}ps_{0.r_2}p$; $s_0ps_{0.h}ps_{0.h_2}p$; $b_0pb_{0.l}pb_{0.l_2}p$;
distance	s_0wd; s_0pd; b_0wd; b_0pd; s_0wb_0wd; s_0pb_0pd;	label set	s_0ws_r; s_0ps_r; s_0ws_l; s_0ps_l; n_0ws_l; n_0ps_l

Contents

Shift-reduce dependency parsing

WestlakeNLP

- Arc-eager Parsing
  - **State**

    σ: stack of partially constituent outputs.

    β: buffer of the next incoming words.

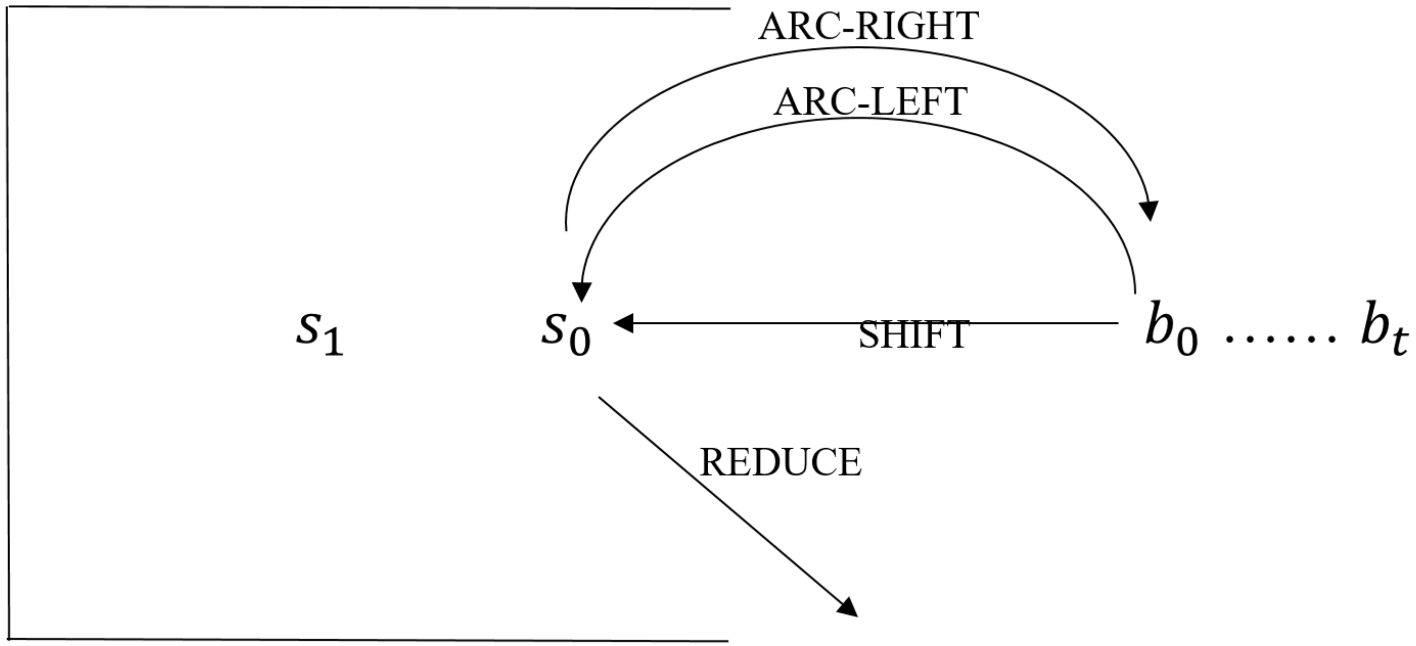
  - **actions**

    SHIFT, LEFT-ARC-X, RIGHT-ARC-X, REDUCE

Shift-reduce dependency parsing

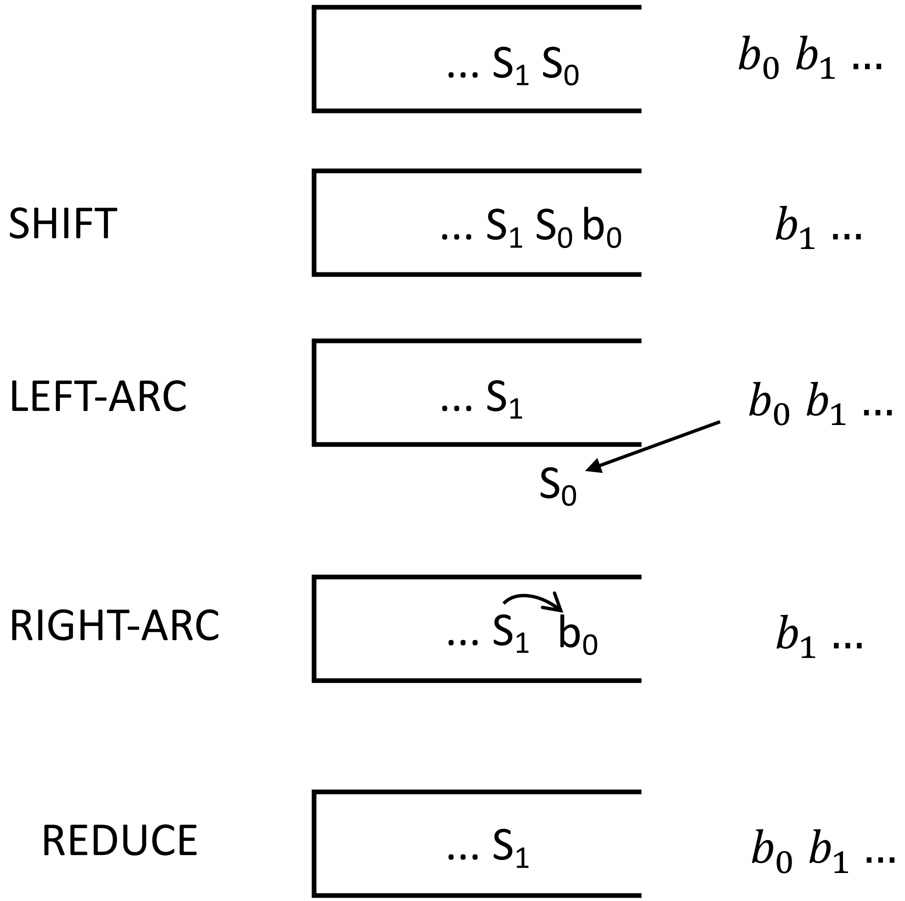
Arc-eager dependency parsing

- Example



Shift-reduce dependency parsing

Actions



Shift-reduce dependency parsing

Arc-eager dependency parsing

Axiom: $([\,],\ W_{1:n},\ \phi)$

Goal: $([s_0],\ [\,],\ A)$

$$\textsc{Shift}:\ \frac{(\sigma,\ b_0|\beta,\ \phi)}{(\sigma|b_0,\ \beta,\ \phi)}$$

$$\textsc{Left-Arc-X}:\ \frac{(\sigma|s_0,\ b_0|\beta,\ A),\ \text{such that}\ \neg\left(\exists(k,\textsc{l})\ w_k \overset{\textsc{l}}{\curvearrowright} s_0 \in A\right)}{(\sigma,\ b_0|\beta,\ A \cup \{s_0 \overset{\textsc{x}}{\curvearrowleft} b_0\})}$$

$$\textsc{Right-Arc-X}:\ \frac{(\sigma|s_0,\ b_0|\beta,\ A)}{(\sigma|s_0|b_0,\ \beta,\ A \cup \{s_0 \overset{\textsc{x}}{\curvearrowright} b_0\})}$$

$$\textsc{Reduce}:\ \frac{(\sigma|s_0,\ \beta,\ A),\ \text{such that}\ \left(\exists(k,\textsc{l})\ w_k \overset{\textsc{l}}{\curvearrowright} s_0 \in A\right)}{(\sigma,\ \beta,\ A)}$$

Main differences comparing with arc-standard:

- $Left-Arc-X/Right-Arc-X$: construct a dependency arc from the front word on the buffer to the top word on the stack, but not as that (from the top two words on the stack) in arc-standard.
- *Reduce*: pop the top word off the stack.

Example (Dependency Parsing)

- NEXT ACTION: $Shift$

$\overbrace{\boxed{\qquad\qquad\qquad}}^{\sigma} \quad \overbrace{\boxed{\text{He does it here}}}^{\beta}$

σ: stack $\qquad$ β: buffer

Example (Dependency Parsing)

- NEXT ACTION: $Left - Arc - SUBJ$

$$\underbrace{\boxed{\text{He}}}_{\sigma} \quad \underbrace{\boxed{\text{does it here}}}_{\beta}$$

σ: stack β: buffer

Example (Dependency Parsing)

- NEXT ACTION: $Shift$

σ β

does it here

He

σ: stack β: buffer

Example (Dependency Parsing)

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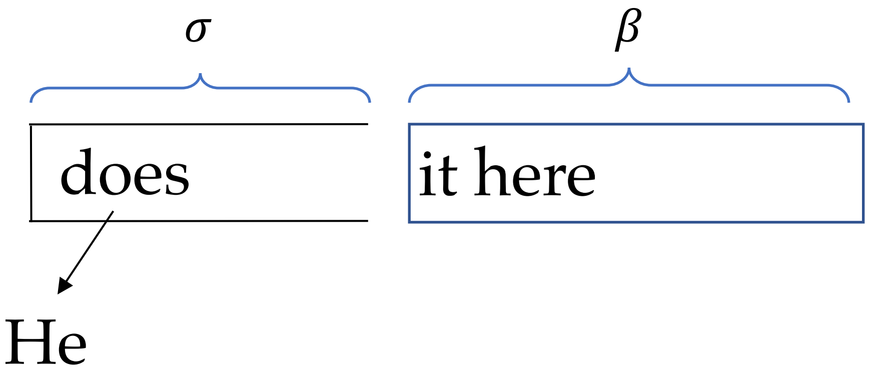
- NEXT ACTION: $Right - Arc - OBJ$



σ: stack β: buffer

Example (Dependency Parsing)

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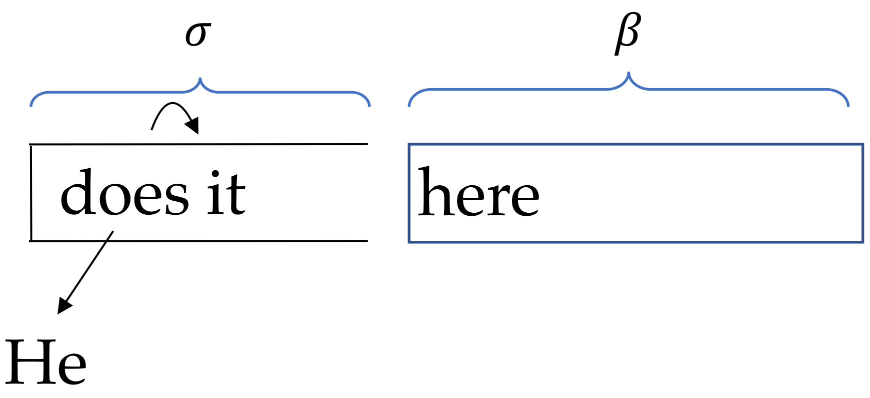
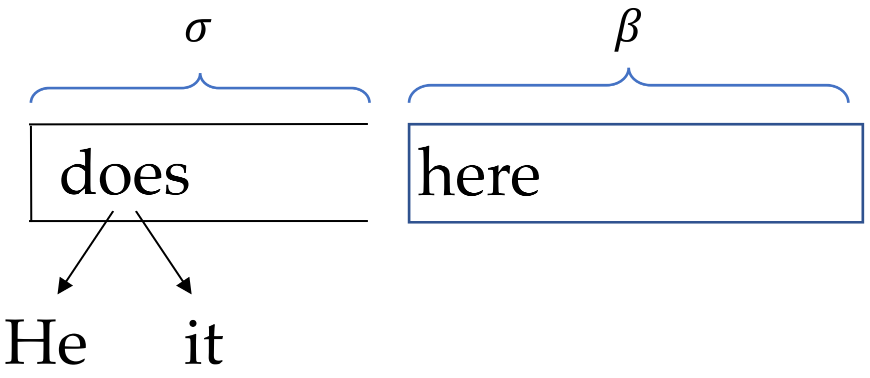
- NEXT ACTION: *Reduce*



σ: stack β: buffer

Example (Dependency Parsing)

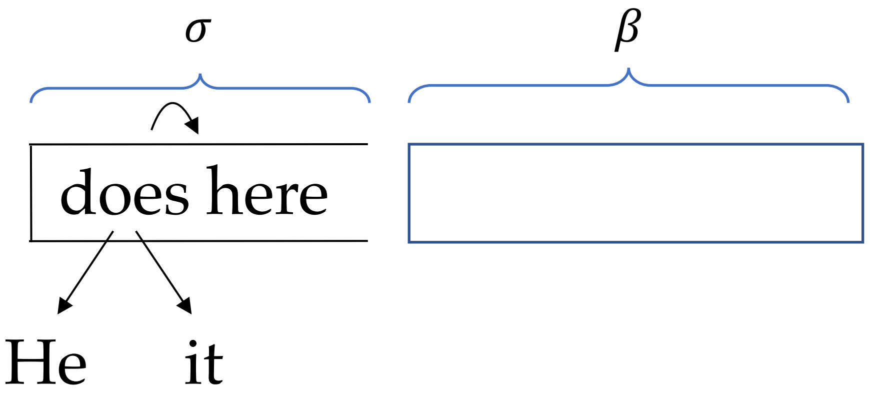
- NEXT ACTION: $Right - Arc - MOD$



σ: stack β: buffer

Example (Dependency Parsing)

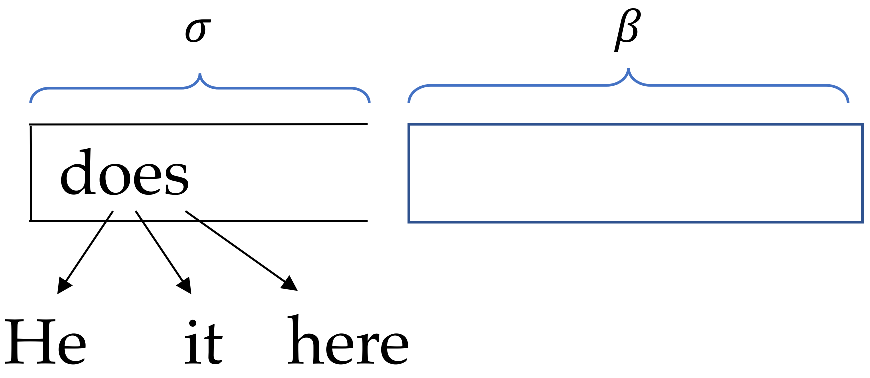
- NEXT ACTION: *Reduce*



σ: stack β: buffer

Example (Dependency Parsing)

- NEXT ACTION: *Finish*



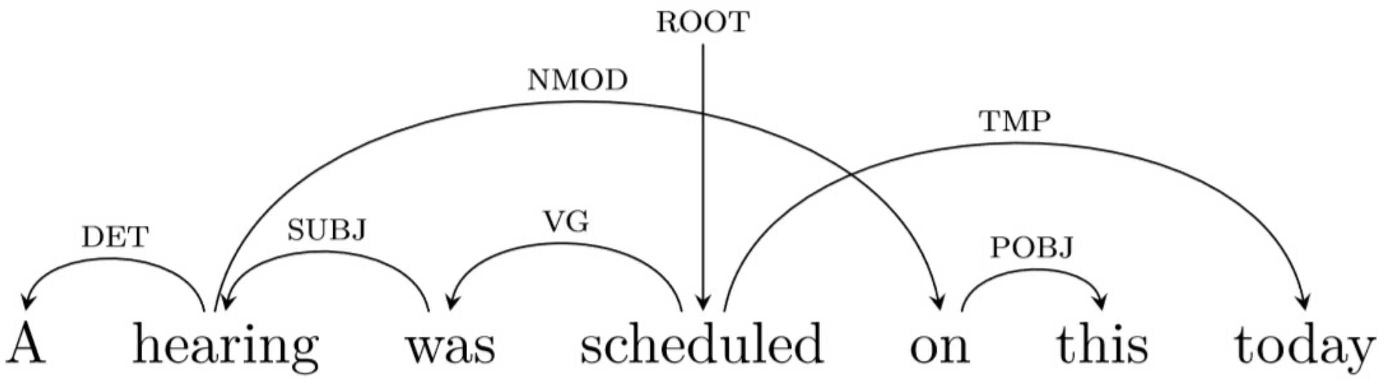
σ: stack $\qquad$ β: buffer

Contents

WestlakeNLP

Shift-reduce dependency parsing

- **The Swap Action and Non-projective Trees**
- To allow constructing non-projective trees, the arc-standard system can be extended by adding a new action:
  - *Swap*: remove the second top word from the stack, pushing it onto the buffer front.



Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

Axiom:	$([\,],\ W_{1:n},\ \phi)$	LEFT-ARC-X:	$\dfrac{([\sigma\|s_1\|s_0],\ \beta,\ A)}{([\sigma\|s_0],\ \beta,\ A \cup \{s_1 \overset{X}{\curvearrowleft} s_0\})}$
Goal:	$([s_0],\ [\,],\ A)$		
SHIFT:	$\dfrac{(\sigma,\ [b_0\|\beta],\ \phi)}{([\sigma\|b_0],\ \beta,\ \phi)}$	RIGHT-ARC-X:	$\dfrac{([\sigma\|s_1\|s_0],\ \beta,\ A)}{([\sigma\|s_1],\ \beta,\ A \cup \{s_1 \overset{X}{\curvearrowright} s_0\})}$
		SWAP:	$\dfrac{([\sigma\|s_1\|s_0],\ \beta,\ A),\ \text{such that } \mathrm{IDX}(s_1) < \mathrm{IDX}(s_0)}{([\sigma\|s_0],\ [s_1\|\beta],\ A)}$

State: (σ, β, A); σ: stack; β: buffer; A: the set of dependency arcs that have been constructed; $IDX(w)$: return the index of w in the sentence $W_{1:n}$.

Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT

A hearing was scheduled on this today

Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT

A

hearing was scheduled on this today

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: LEFT-ARC-DET

A hearing	was scheduled on this today

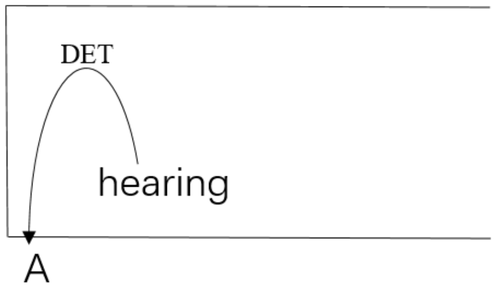
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT



was scheduled on this today

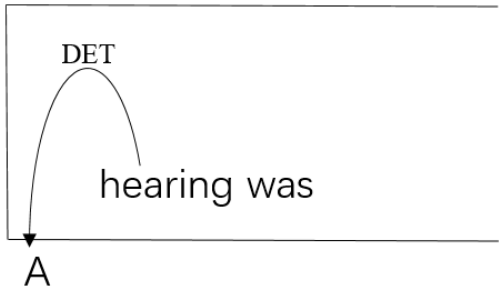
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT



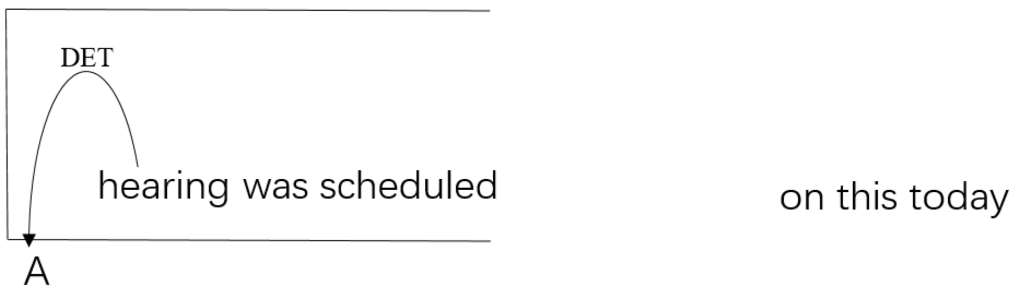
scheduled on this today

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT



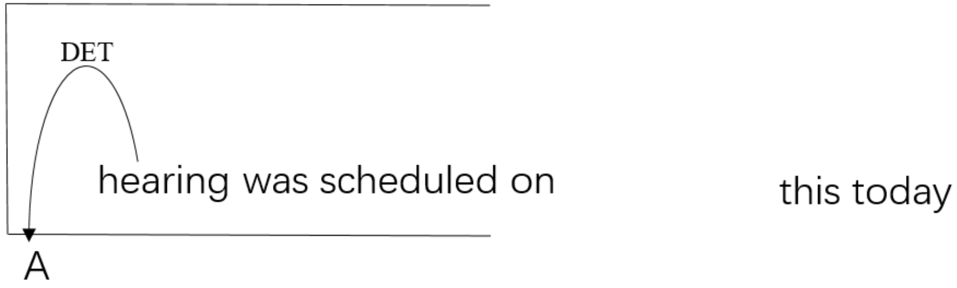
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SWAP

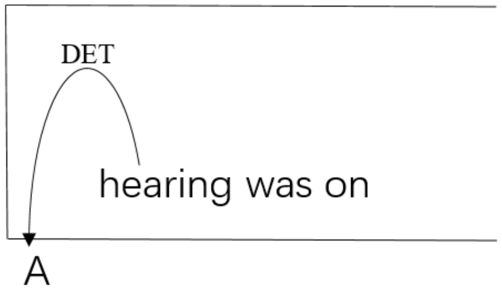


Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SWAP



scheduled this today

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

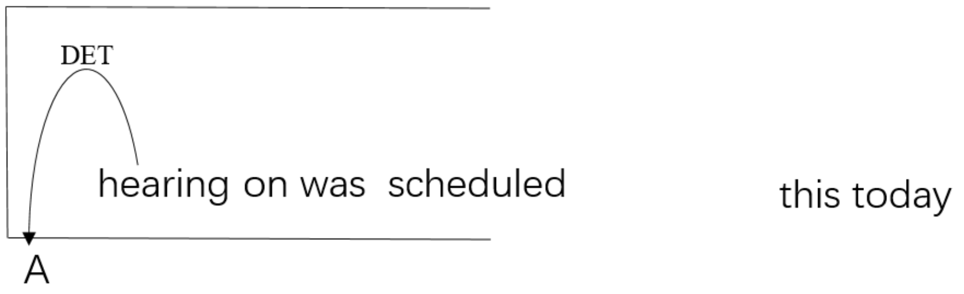
  Next action: SHIFT

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT

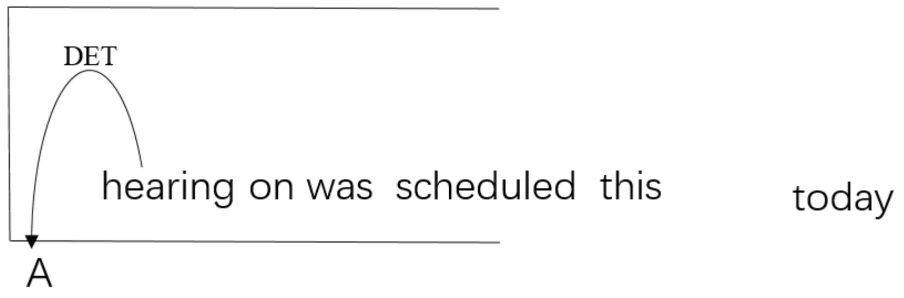


Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SWAP



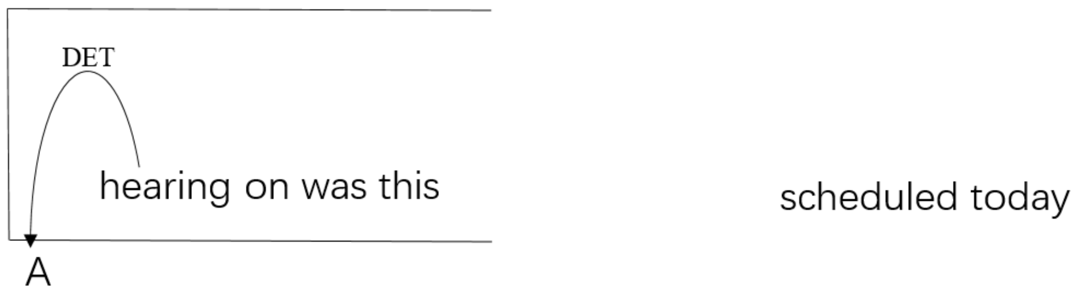
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SWAP



Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: RIGHT-ARC-POBJ

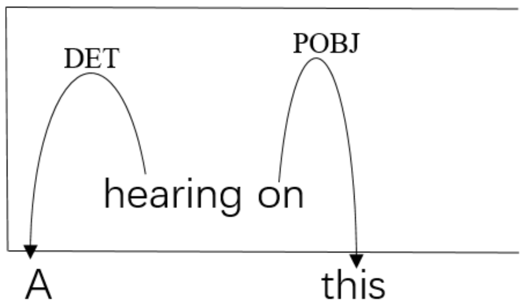
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: RIGHT-ARC-NMOD



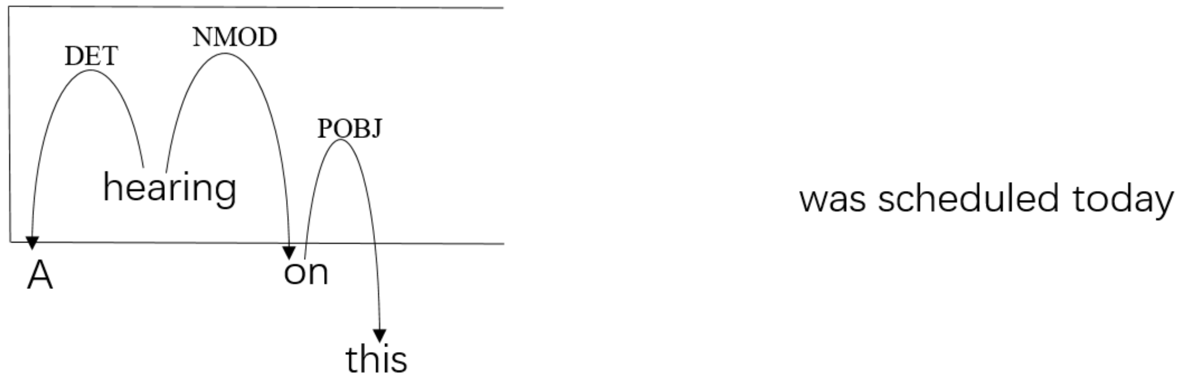
was scheduled today

Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT



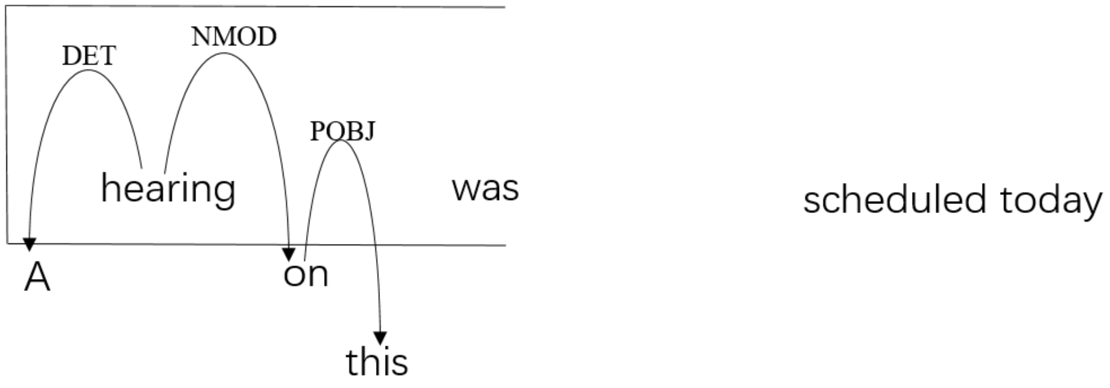
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: LEFT-ARC-SUBJ



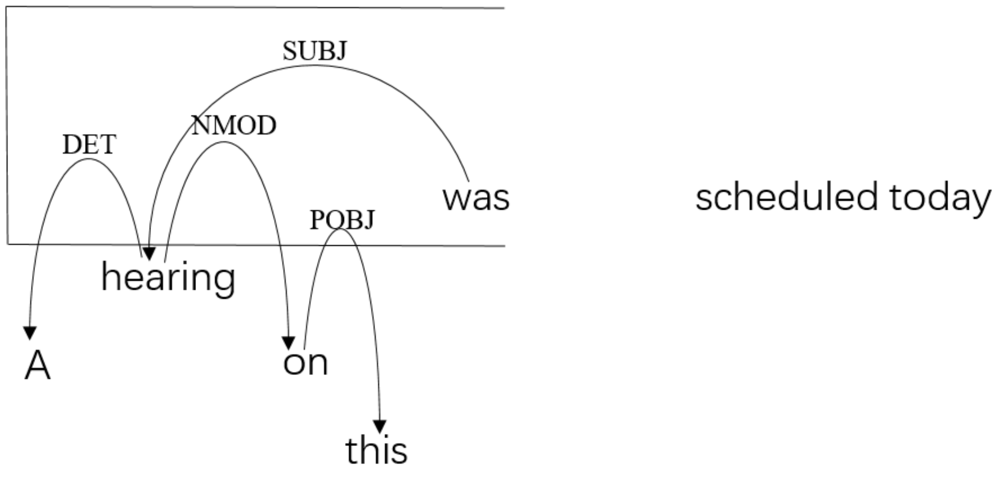
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT



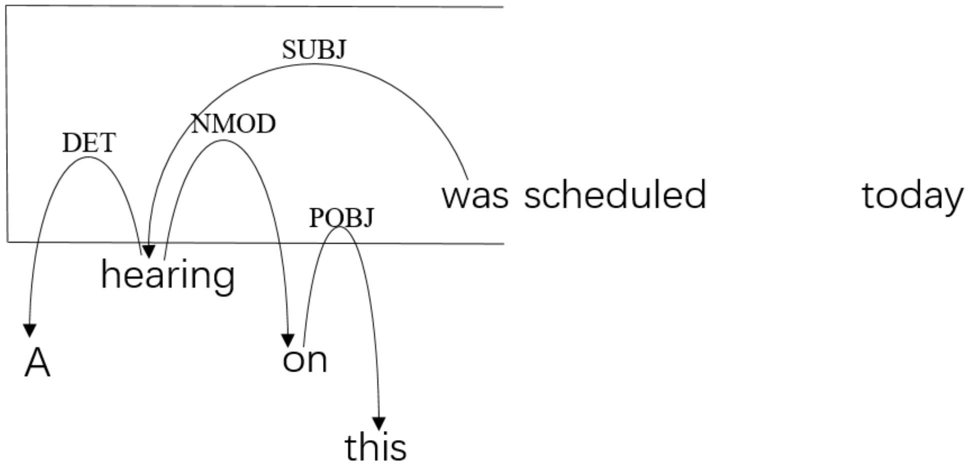
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: SHIFT

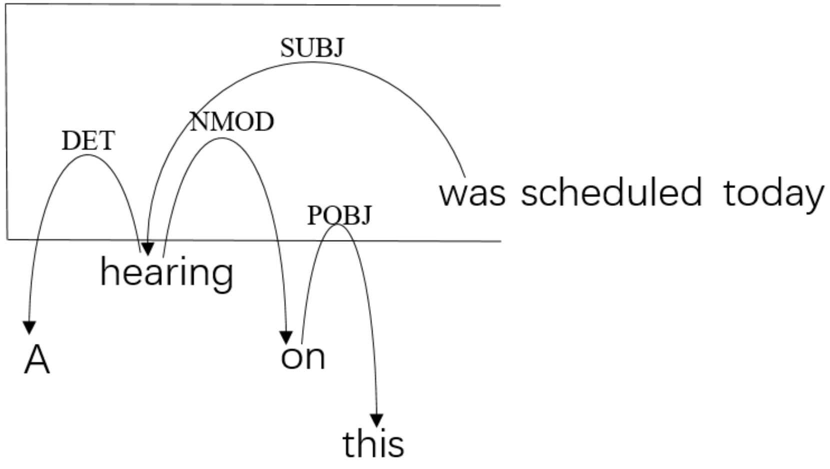


Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: RIGHT-ARC-TMP

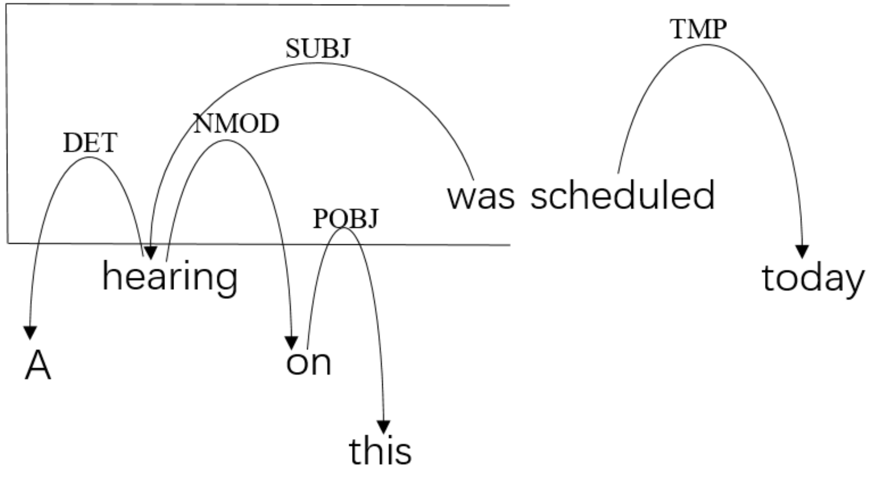


Shift-reduce dependency parsing

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: LEFT-ARC-VG



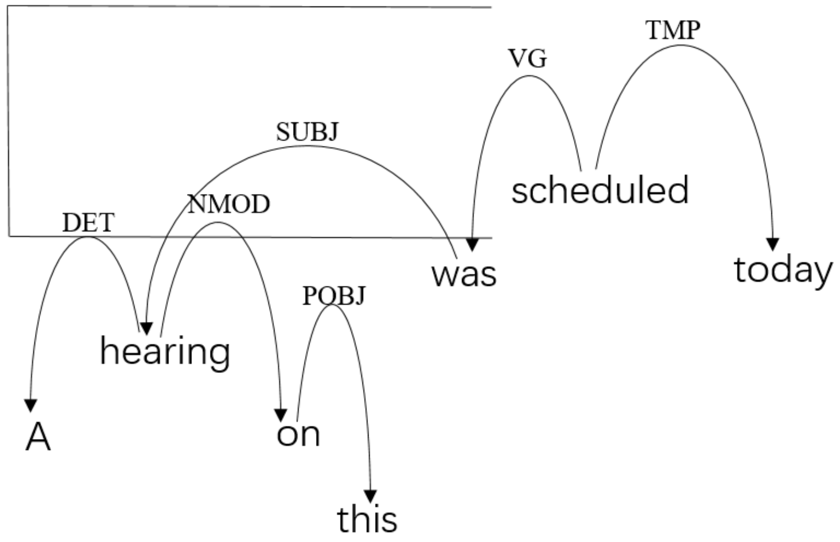
Shift-reduce dependency parsing

WestlakeNLP

Arc-standard Dependency Parsing with Swap Action

- Example

Next action: END



Contents

Joint Models

WestlakeNLP

- Motivations
  - Cross-task information sharing
  - Reduction of error propagation
- Example
  - For joint POS-tagging and syntactic parsing, the $SHIFT$ action of arc-standard algorithm can be replaced with $SHIFT - X$ action, where X refers to the POS label.

Joint Models

WestlakeNLP

Joint POS-tagging and Dependency Parsing

- Input: $W_{1:n} = w_1, \dots, w_n$
- Output: $(T_{1:n}, A)$, where t_i is POS for w_i.
- The arc-standard algorithm can be extended by replacing $SHIFT$ action with $SHIFT - X$ action
    - $SHIFT - X$, which removes the front word from the buffer, assigning the POS label X to the word, and pushing it onto the stack.

Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: SHIFT——PRP

Stack [S]

Buffer [B]

He_1 won_2 the_3 game_4

Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: SHIFT——VBD

Stack [S]	Buffer [B]
$\text{He}_{1/\text{PRP}}$	won_2 the_3 game_4

Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: LEFT——ARC——NSUBJ

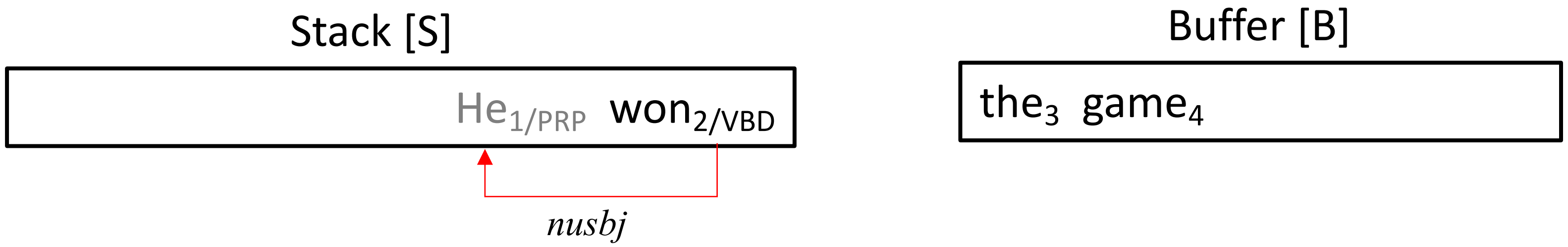
Stack [S]	Buffer [B]
$\text{He}_{1/\text{PRP}}$ won_2	the_3 game_4

Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: SHIFT——DT

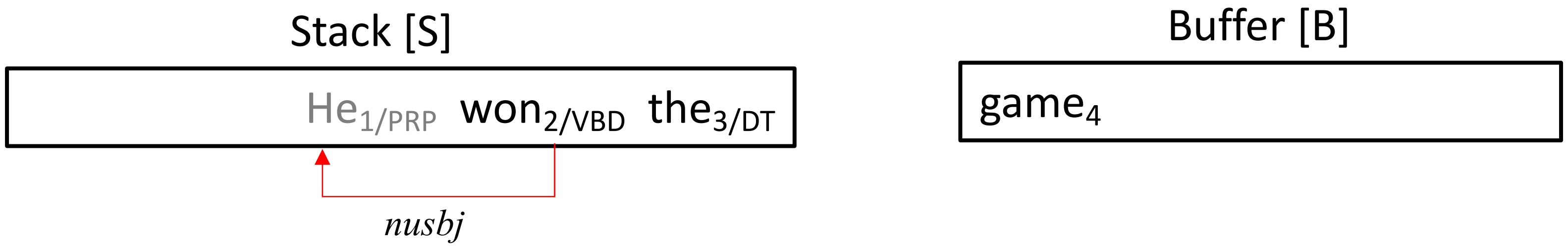


Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: SHIFT——NN



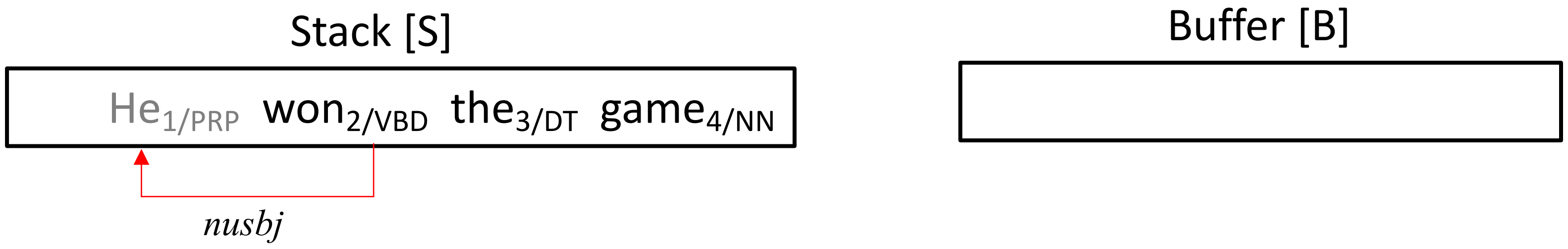
Joint Models

WestlakeNLP

Joint POS-tagging and Dependency Parsing

- Example

Next action: LEFT——ARC——DET

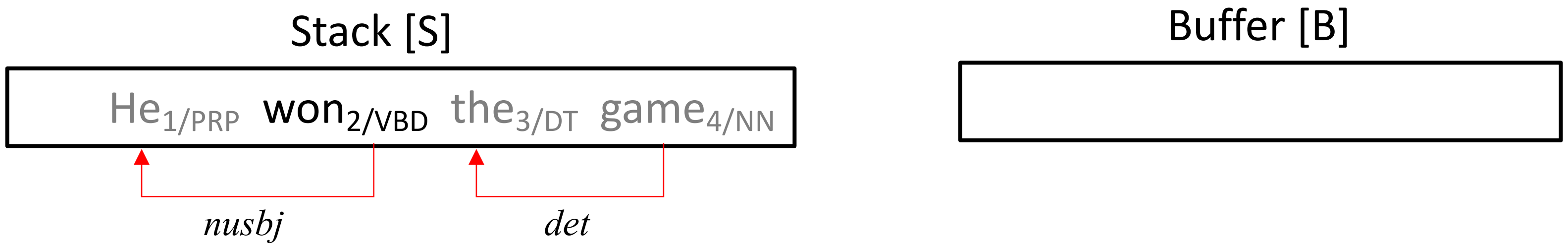


Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: RIGHT——ARC——DOBJ

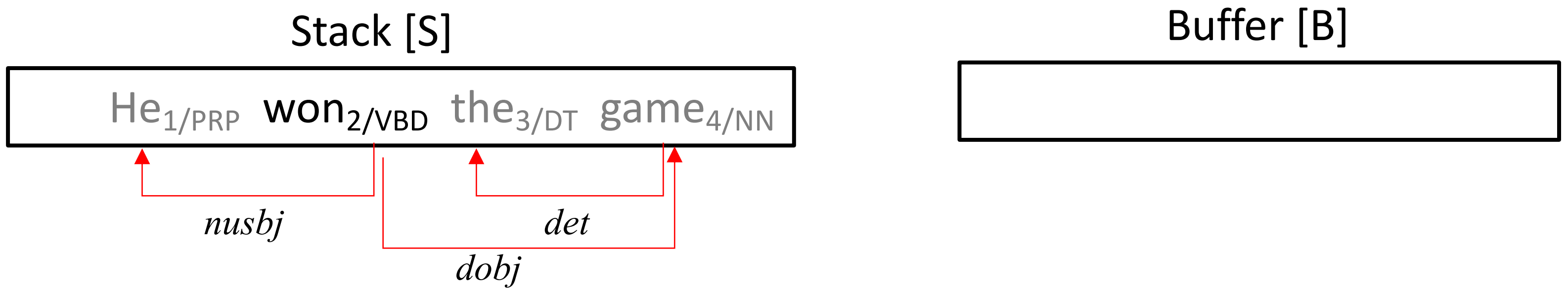


Joint Models

Joint POS-tagging and Dependency Parsing

- Example

Next action: END



Joint Models

WestlakeNLP

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Input: $C_{1:n} = C_1 \dots C_n$
- Output: $(W_{1:m}, T_{1:m}, A)$ where $w_1 \dots w_m$ are words, $t_1 \dots t_n$ are POS, and A is the set of dependency arcs.
- State:

  σ -- partially built outputs

  δ -- words

  β -- incoming characters

  A_c -- character dependencies

  A_w -- word dependencies

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

Axiom:		$([\,],\ [\,],\ C_{1:n},\ \phi,\ \phi)$
Goal:		$([S_0],\ [\,],\ [\,],\ A_c,\ A_w)$
LEFT-ARC-C:	$(\sigma,\ \delta\|d_0,\ b_0\|\beta,\ A_c,\ A_w)$ such that $\neg(\exists d \in \delta, d \curvearrowright d_0 \in A_c)$	$(\sigma,\ \delta,\ b_0\|\beta,\ A_c \cup \{d_0 \curvearrowleft b_0\},\ A_w)$
LEFT-ARC-X:	$(\sigma\|s_0,\ [d_0],\ \beta,\ A_c,\ A_w)$ such that $\neg(\exists s \in \sigma, s \overset{l}{\curvearrowright} s_0 \in A_w)$	$(\sigma,\ [d_0],\ \beta,\ A_c,\ A_w \cup \{s_0 \curvearrowleft d_0\})$
SHIFT:	$(\sigma,\ [d_0],\ \beta,\ A_c,\ A_w)$	$(\sigma\|d_0,\ [\,],\ \beta,\ A_c,\ A_w)$
SHIFT-C:	$(\sigma,\ \delta,\ b_0\|\beta,\ A_c,\ A_w)$	$(\sigma,\ \delta\|b_0,\ \beta,\ A_c,\ A_w)$
RIGHT-ARC-C:	$(\sigma,\ \delta\|d_0,\ b_0\|\beta,\ A_c,\ A_w)$	$(\sigma,\ \delta\|d_0\|b_0,\ \beta,\ A_c \cup \{d_0 \curvearrowright b_0\},\ A_w)$
RIGHT-ARC-X:	$(\sigma\|s_0,\ [d_0],\ \beta,\ A_c,\ A_w \cup \{s_0 \curvearrowright d_0\})$	$(\sigma\|s_0\|d_0,\ [\,],\ \beta,\ A_c,\ A_w)$
POP-X:	$(\sigma,\ [d_0],\ \beta,\ A_c,\ A_w)$	$(\sigma,\ [\textsc{Subtree}(d_0, A_c)/X],\ \beta,\ A_c,\ A_w)$
REDUCE-C:	$(\sigma,\ \delta\|d_0,\ \beta,\ A_c,\ A_w)$ such that $\exists d \in \delta,\ d \curvearrowright d_0 \in A_c$	$(\sigma,\ \delta,\ \beta,\ A_c,\ A_w)$
REDUCE:	$(\sigma\|s_0,\ \delta,\ \beta,\ A_c,\ A_w)$ such that $\exists s \in \sigma, s \curvearrowright s_0 \in A_w$	$(\sigma,\ \delta,\ \beta,\ A_c,\ A_w)$

State: $(\sigma, \delta, \beta, A\_c, A\_w)$ σ: stack; β:buffer; δ: partial-word buffer;

A_c: the set of character dependencies; A_w: the set of word dependencies

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
0			我，来，到，会，客，室			*SHIFT-C*

我, 来, 到, 会, 客, 室

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
1		我	来，到，会，客，室			*POP-PN*

我

来, 到, 会, 客, 室

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
2		我/PN	来，到，会，客，室			*SHIFT-W*

我/PN

来, 到, 会, 客, 室

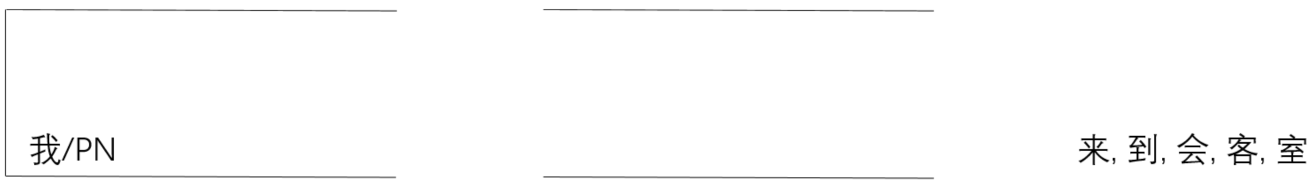
Joint Models

WestlakeNLP

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
3	我/PN		来，到，会，客，室			*SHIFT-C*



Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
4	我/PN	来	到，会，客，室			*LEFTARC-C*

我/PN

来

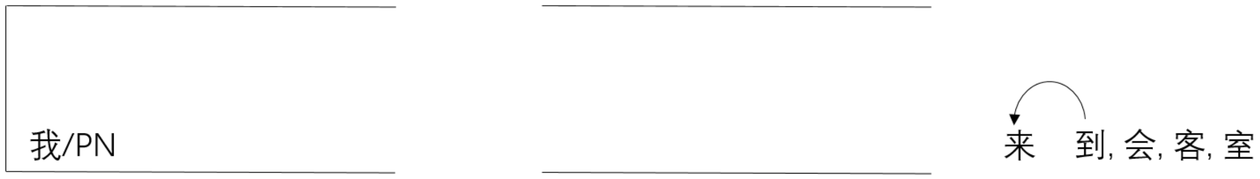
到, 会, 客, 室

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
5	我/PN		到，会，客，室	来← 到		*SHIFT*

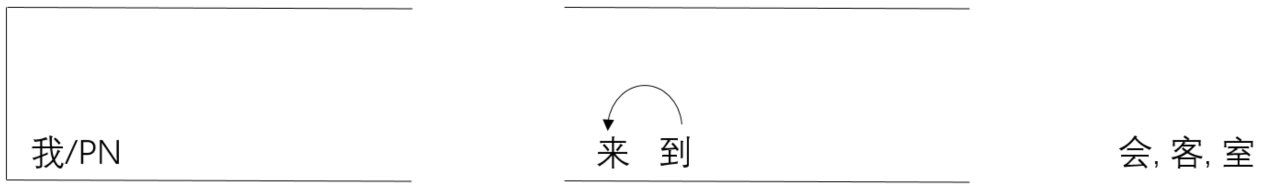


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
6	我/PN	到	到，会，客，室	来← 到		*POP-VV*

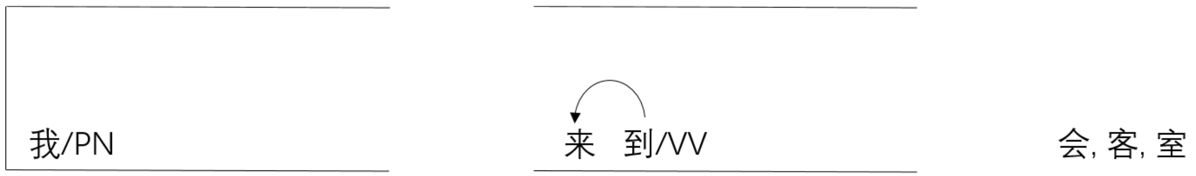


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
7	我/PN	来到/VV	会，客，室	来← 到		*LEFTARC-SUBJ*

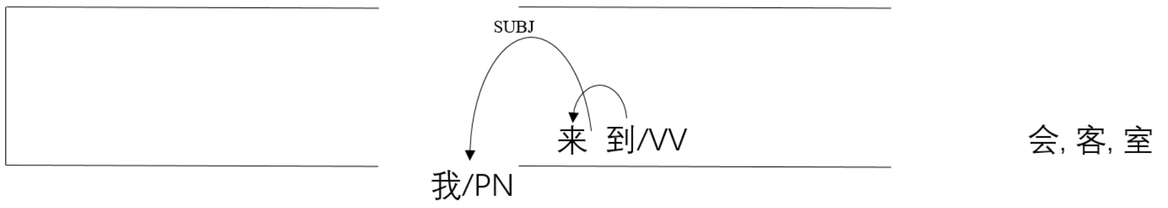


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
8		来到/VV	会，客，室	来← 到	我/PN$\leftarrow_{SUBJ}$ 来到/VV	*SHIFT*

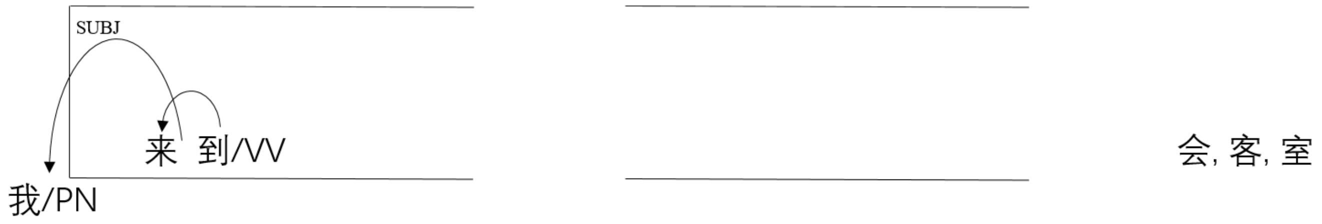


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
9	来到/VV		会，客，室	来← 到	我/PN $\xleftarrow{SUBJ}$ 来到/VV	*SHIFT-C*



Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

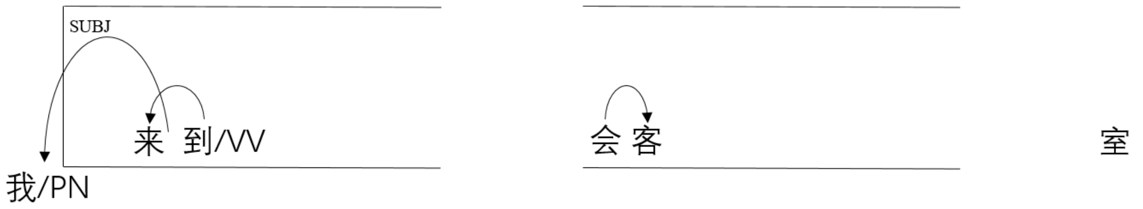
$Step$	σ	δ	β	A_c	A_w	$Action$
10	来到/VV	会	客，室	来← 到	我/PN$\leftarrow_{SUBJ}$ 来到/VV	$RIGHTARC\text{-}C$

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
11	来到/VV	会，客	室	来← 到，会→客	我/PN$\leftarrow$ *SUBJ* 来到/VV	*REDUCE-C*

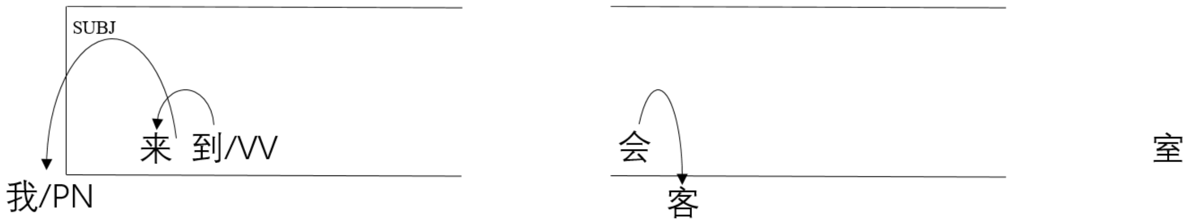


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
12	来到/VV	会	室	来$\leftarrow$ 到，会$\rightarrow$客	我/PN$\xleftarrow{\textsc{subj}}$ 来到/VV	*LEFTARC-C*

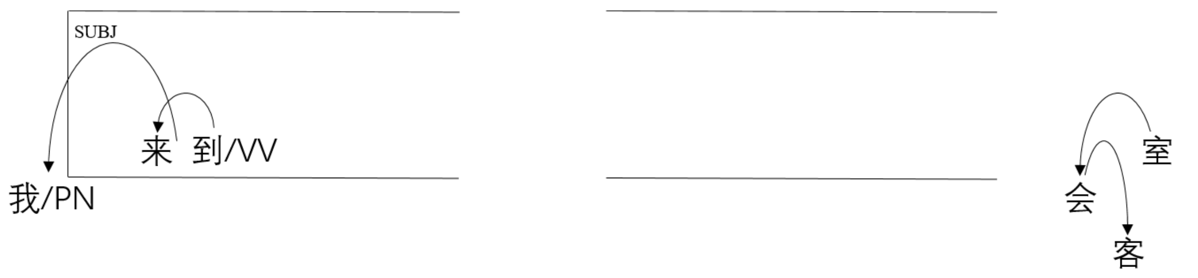


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

$Step$	σ	δ	β	A_c	A_w	$Action$
13	来到/VV		室	来← 到，会→客，会←室	我/PN$\leftarrow_{SUBJ}$ 来到/VV	$SHIFT\text{-}C$

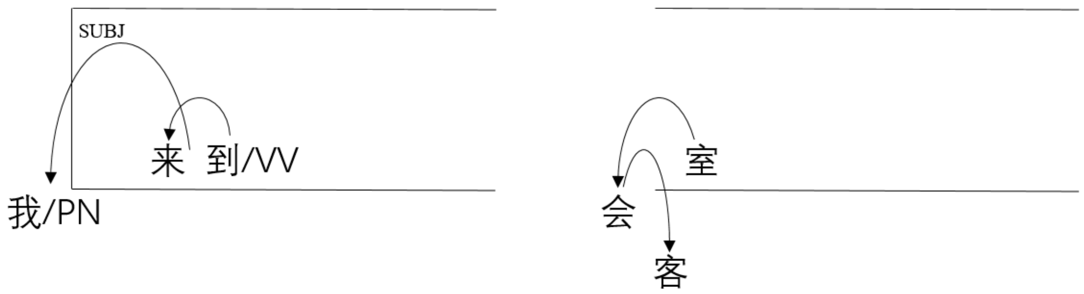


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

$Step$	σ	δ	β	A_c	A_w	$Action$
14	来到/VV	室		来← 到，会→客，会←室	我/PN$\leftarrow_{SUBJ}$ 来到/VV	$POP\text{-}NN$



Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

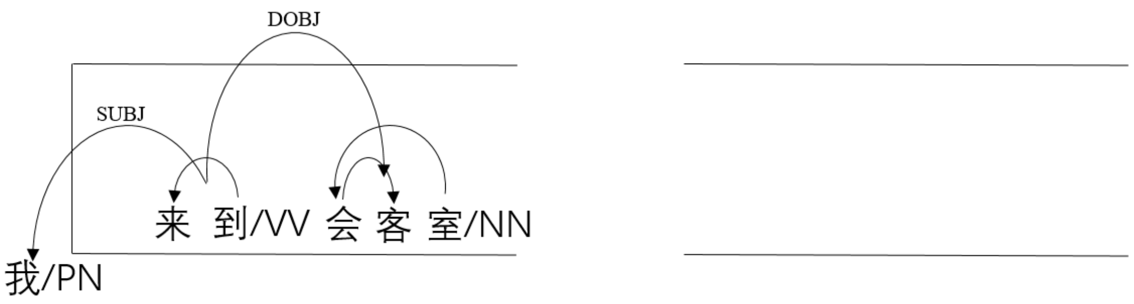
Step	σ	δ	β	A_c	A_w	*Action*
15	来 到/VV	会客 室/NN		来← 到，会→客，会 ←室	我/PN$\leftarrow_{SUBJ}$ 来 到/VV	*RIGHTARC-DOBJ*

Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
16	来到/VV，会客室/NN			来← 到，会→客，会←室	我/PN← *SUBJ* 来到/VV，来到/VV *DOBJ* →会客室/NN	*REDUCE*

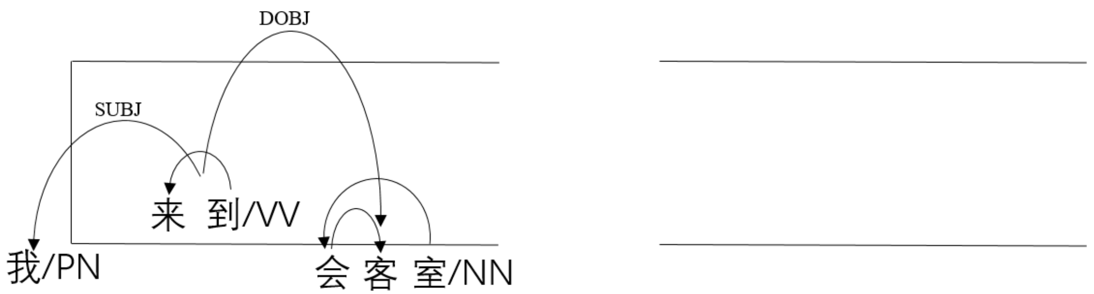


Joint Models

Joint Word Segmentation, POS-tagging and Dependency Parsing

- Example

Step	σ	δ	β	A_c	A_w	*Action*
17	来 到/VV			来← 到，会→客，会 ←室	我/PN← *SUBJ* 来到/VV，来到/VV *DOBJ* →会客室/NN	*END*



Summary

- What is transition-based method?
- Apply transition-based methods on different tasks.
- Joint modeling with transition-based methods.