



# Shift-Reduce Parsing

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Adapted from material by Jimmy Lin and Jason Eisner

## Shift-Reduce Parsing

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- Alternative to arc-factored models
- Cognitively plausible
- Better at short-range dependencies

## Example

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ROOT Economic news had little effect on financial markets .

## Example

---

ROOT Economic ← news had little effect on financial markets .

## Example

---

ROOT Economic ← news ← had little effect on financial markets .

## Example

---

ROOT Economic ← news ← had little ← effect on financial markets .

## Example

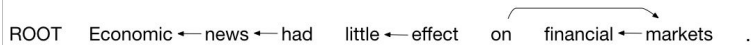
---

ROOT Economic ← news ← had little ← effect on financial ← markets .

## Example

---

ROOT   Economic ← news ← had   little ← effect   on   financial ← markets   .

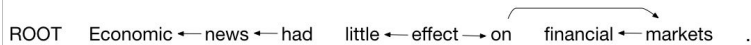




## Example

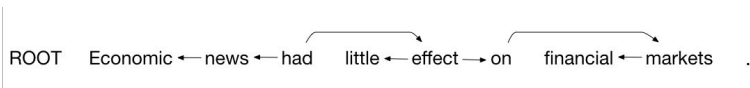
---

ROOT   Economic ← news ← had   little ← effect → on   financial ← markets   .



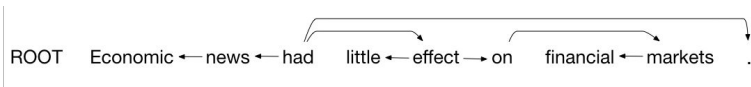
## Example

---



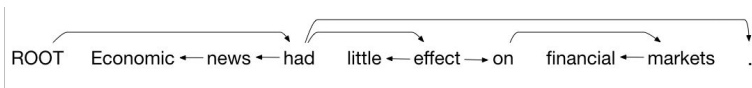
## Example

---



## Example

---



## Components

---

- Process a sentence word by word from a **buffer**
- You can temporarily place store words on a **stack**
- As you process you can either:

## Components

---

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  - *Shift*: Move a word from the buffer to the stack

## Components

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- Process a sentence word by word from a **buffer**
- You can temporarily place store words on a **stack**
- As you process you can either:
  - *Shift*: Move a word from the buffer to the stack
  - *Left*: The top of the stack is the child of the buffer's next word

## Components

---

- Process a sentence word by word from a **buffer**
- You can temporarily place store words on a **stack**
- As you process you can either:
  - *Shift*: Move a word from the buffer to the stack
  - *Left*: The top of the stack is the child of the buffer's next word
  - *Right*: The buffer's next word is the child of the top of the stack



## Initial and Final Conditions

---

- Initially the stack has `ROOT`, the buffer has the sentence's words, and there are no edges
- At the end, the buffer must be empty

## Action: Left

---

- Add an edge  $(w_j, w_i)$
- $w_i$  is the top of the stack
- $w_j$  is the first word of the buffer
- Pop the stack

## Action: Left

---

- Add an edge  $(w_j, w_i)$
- $w_i$  is the top of the stack
- $w_j$  is the first word of the buffer
- Pop the stack
- Stack and buffer must be non-empty;  $w_i$  cannot be the root

## Action: Right

---

- Add an edge  $(w_i, w_j)$
- $w_i$  is the top of the stack
- $w_j$  is the first word in the buffer
- Pop the stack
- Replace  $w_j$  by  $w_i$  at the head of buffer

## Action: Right

---

- Add an edge  $(w_i, w_j)$
- $w_i$  is the top of the stack
- $w_j$  is the first word in the buffer
- Pop the stack
- Replace  $w_j$  by  $w_i$  at the head of buffer
- Stack and buffer must be non-empty

## Shift

---

- Removes  $w_i$  from the buffer
- Places it on the stack

## Shift

---

- Removes  $w_i$  from the buffer
- Places it on the stack
- Buffer must be non-empty

## Shift Reduce Example

---

Stack

[ROOT     ]

Buffer

[economic, news, had, little, effect,  
on, financial, markets, .]

ROOT   Economic   news   had   little   effect   on   financial   markets   .

Next transition: 1. Shift



## Shift Reduce Example

---

Stack

[ROOT , **economic** ]

Buffer

[news, had, little, effect, on,  
financial, markets, .]

ROOT   Economic   news   had   little   effect   on   financial   markets   .

Next transition: 2. Left

## Shift Reduce Example

---

Stack

[ROOT      ]

Buffer

[news, had, little, effect, on,  
financial, markets, .]

ROOT   Economic ← news   had   little   effect   on   financial   markets   .

Next transition:   3. Shift

## Shift Reduce Example

---

Stack

[ROOT , news ]

Buffer

[had, little, effect, on, financial,  
markets, .]

ROOT   Economic ← news   had   little   effect   on   financial   markets   .

Next transition:   4. Left

## Shift Reduce Example

---

Stack

[ROOT     ]

Buffer

[had, little, effect, on, financial,  
markets, .]

ROOT   Economic ← news ← had   little   effect   on   financial   markets   .

Next transition:     5. Shift

## Shift Reduce Example

---

Stack

[ROOT , **had** ]

Buffer

[little, effect, on, financial,  
markets, .]

ROOT   Economic ← news ← had   little   effect   on   financial   markets   .

Next transition:      6. Shift

## Shift Reduce Example

---

Stack

[ROOT , had , little ]

Buffer

[effect, on, financial, markets, .]

ROOT   Economic ← news ← had   little   effect   on   financial   markets   .

Next transition:        7. Left

## Shift Reduce Example

---

Stack

[ROOT , had ]

Buffer

[effect, on, financial, markets, .]

ROOT   Economic ← news ← had   little ← effect   on   financial   markets   .

Next transition:            8. Shift

## Shift Reduce Example

---

Stack

[ROOT , had , effect ]

Buffer

[on, financial, markets, .]

ROOT   Economic ← news ← had   little ← effect   on   financial   markets   .

Next transition:

9. Shift



## Shift Reduce Example

---

Stack

[ROOT , had , effect , **on** ]

Buffer

[financial, markets, .]

ROOT   Economic ← news ← had   little ← effect   on   financial   markets   .

Next transition:                      10. Shift

## Shift Reduce Example

---

Stack

[ROOT , had , effect , on ,  
financial ]

Buffer

[markets, .]

ROOT   Economic ← news ← had   little ← effect   on   financial   markets   .

Next transition:

11. Left

## Shift Reduce Example

---

Stack

[ROOT , had , effect , on ]

Buffer

[markets, .]

ROOT   Economic ← news ← had   little ← effect   on   financial ← markets   .

Next transition:

12. Right

## Shift Reduce Example

---

Stack

[ROOT , had , effect ]

Buffer

[on, .]

ROOT   Economic ← news ← had   little ← effect   on   financial ← markets   .



Next transition:

13. Right

## Shift Reduce Example

---

Stack

[ROOT , had ]

Buffer

[effect, .]

ROOT Economic ← news ← had little ← effect → on financial ← markets .

Next transition:

14. Right

## Shift Reduce Example

---

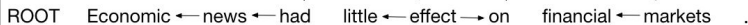
Stack

[ROOT     ]

Buffer

[had, .]

ROOT   Economic ← news ← had   little ← effect → on   financial ← markets   .



Next transition:

15. Shift

## Shift Reduce Example

---

Stack

[ROOT , had]

Buffer

[.]

ROOT Economic ← news ← had little ← effect → on financial ← markets .

```
graph TD
    ROOT[ROOT] --- Economic[Economic]
    ROOT --- news[news]
    news --- had[had]
    news --- little[little]
    little --- effect[effect]
    little --- on[on]
    effect --- financial[financial]
    effect --- markets[markets]
    markets --- period[.]
```

Next transition:

16. Right

## Shift Reduce Example

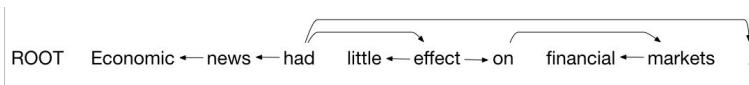
---

Stack

[ROOT     ]

Buffer

[had]



Next transition:

17. Right



## Shift Reduce Example

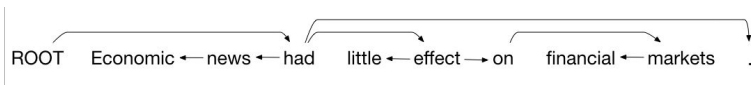
---

Stack

[   ]

Buffer

[ROOT]



Next transition:

18. Shift

## Shift Reduce Example

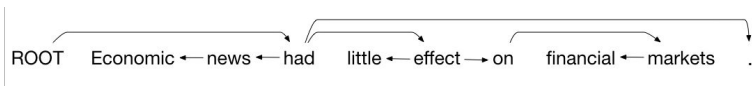
---

Stack

[ROOT     ]

Buffer

[]



Next transition:

## Transition Sequence Algorithm

---

- Start with `ROOT` on stack, buffer with whole sentence
- If there's nothing on the stack, you must *shift*
- If the top of the stack is the child of the top of the buffer, then make a *left* edge
- If the top of the buffer is is a child of the top of the stack and the top of the buffer has no children that have yet to be added to the tree, then make a *right*

## Transition Sequence Algorithm

---

- Start with `ROOT` on stack, buffer with whole sentence
- If there's nothing on the stack, you must *shift*
- If the top of the stack is the child of the top of the buffer, then make a *left* edge
- If the top of the buffer is is a child of the top of the stack and the top of the buffer has no children that have yet to be added to the tree, then make a *right*
- Part of Homework 6

## How to apply to data

---

- Create oracle for all sentences
- Create three-way classifier for each possible actions
- Features
  - The top of the stack
  - Top two words on buffer
  - The parts of speech of the words

# Complexity

---

## Complexity

---

- A word can only enter the stack once
- So complexity is  $O(2N)$

## Comparison

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- Shift-reduce parsers are faster
- Shift-reduce parsers do better at local (deeper) connections
- Arc-factored models do better at long-distance dependencies (e.g., verbs)



## In Class

---

- Transition Sequence to Parse
- Parse to Transition Sequence

Stack

[ROOT     ]

Buffer

[I, am, the, very, model, of, a,  
modern, major, general]

Edges

Next move: 1. Shift

Stack

[ROOT , | ]

Buffer

[am, the, very, model, of, a,  
modern, major, general]

Edges

Next move: 2. Left

Stack

[ROOT      ]

Buffer

[am, the, very, model, of, a,  
modern, major, general]

Edges

, I ← am

Next move: 3. Shift

Stack

[ROOT , am ]

Buffer

[the, very, model, of, a, modern,  
major, general]

Edges

, I ← am

Next move: 4. Shift

Stack

[ROOT , am , the ]

Buffer

[very, model, of, a, modern, major,  
general]

Edges

, I  $\leftarrow$  am

Next move: 5. Shift

Stack

[ROOT , am , the , **very** ]

Buffer

[model, of, a, modern, major,  
general]

Edges

, I ← am

Next move: 6. Left

Stack

[ROOT , am , the ]

Buffer

[model, of, a, modern, major,  
general]

Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

Next move: 7. Left



## Stack

[ROOT , am ]

## Buffer

[model, of, a, modern, major,  
general]

## Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

Next move: 8. Shift

Stack

[ROOT , am , model ]

Buffer

[of, a, modern, major, general]

Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

Next move: 9. Shift

## Stack

[ROOT , am , model , of ]

## Buffer

[a, modern, major, general]

## Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

Next move: 10. Shift

Stack

[ROOT , am , model , of , a ]

Buffer

[modern, major, general]

Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

Next move: 11. Shift

## Stack

[ROOT , am , model , of , a ,  
**modern** ]

## Buffer

[major, general]

## Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model

Next move: 12. Shift

## Stack

[ROOT , am , model , of , a ,  
modern , **major**]

## Buffer

[general]

## Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model

Next move: 13. Left

## Stack

[ROOT , am , model , of , a ,  
modern ]

## Buffer

[general]

## Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model  
, major  $\leftarrow$  general

Next move: 14. Left

Stack

[ROOT , am , model , of , a ]

Buffer

[general]

Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

, major  $\leftarrow$  general

, modern  $\leftarrow$  general

Next move: 15. Left



## Stack

[ROOT , am , model , of ]

## Buffer

[general]

## Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

, major  $\leftarrow$  general

, modern  $\leftarrow$  general

, a  $\leftarrow$  general

Next move: 16. Right

## Stack

[ROOT , am , model ]

## Buffer

[of, ]

## Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

, major  $\leftarrow$  general

, modern  $\leftarrow$  general

, a  $\leftarrow$  general

, of  $\rightarrow$  general

Next move: 17. Right

Stack

[ROOT , am ]

Buffer

[model, ]

Edges

, I  $\leftarrow$  am

, very  $\leftarrow$  model

, the  $\leftarrow$  model

, major  $\leftarrow$  general

, modern  $\leftarrow$  general

, a  $\leftarrow$  general

, of  $\rightarrow$  general

, model  $\rightarrow$  of

Next move: 18. Right

Stack

[ROOT       ]

Buffer

[am]

Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model  
, major  $\leftarrow$  general  
, modern  $\leftarrow$  general  
, a  $\leftarrow$  general  
, of  $\rightarrow$  general  
, model  $\rightarrow$  of  
, **am  $\rightarrow$  model**

Next move: 19. Right

Stack

[     ]

Buffer

[ROOT]

Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model  
, major  $\leftarrow$  general  
, modern  $\leftarrow$  general  
, a  $\leftarrow$  general  
, of  $\rightarrow$  general  
, model  $\rightarrow$  of  
, am  $\rightarrow$  model  
, ROOT  $\rightarrow$  am

Next move: 20. Shift

Stack

[ROOT      ]

Buffer

[]

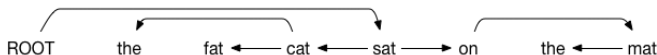
Edges

, I  $\leftarrow$  am  
, very  $\leftarrow$  model  
, the  $\leftarrow$  model  
, major  $\leftarrow$  general  
, modern  $\leftarrow$  general  
, a  $\leftarrow$  general  
, of  $\rightarrow$  general  
, model  $\rightarrow$  of  
, am  $\rightarrow$  model  
, ROOT  $\rightarrow$  am

## Transition Sequence Algorithm

---

- Start with ROOT on stack, buffer with whole sentence
- If there's nothing on the stack, you must *shift*
- If the top of the stack is the child of the top of the buffer, then make a *left* edge
- If the top of the buffer is is a child of the top of the stack and the top of the buffer has no children that have yet to be added to the tree, then make a *right*



## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
|--------|------------|-----------|-----------|----------|

---

S



## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| S      |            |           |           |          |
| S      |            |           |           |          |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
|        | 3          | cat       | 2         | fat      |
|        | 3          | cat       | 1         | the      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| S      |            |           |           |          |
| S      |            |           |           |          |
| I      | 3          | cat       | 2         | fat      |
| I      | 3          | cat       | 1         | the      |
| S      |            |           |           |          |
| I      | 4          | sat       | 3         | cat      |
| S      |            |           |           |          |
| S      |            |           |           |          |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
|        | 3          | cat       | 2         | fat      |
|        | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
|        | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |



## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
|        | 3          | cat       | 2         | fat      |
|        | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
|        | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |
|        | 7          | mat       | 6         | the      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 7          | mat       | 6         | the      |
| r      | 5          | on        | 7         | mat      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 7          | mat       | 6         | the      |
| r      | 5          | on        | 7         | mat      |
| r      | 4          | sat       | 5         | on       |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 7          | mat       | 6         | the      |
| r      | 5          | on        | 7         | mat      |
| r      | 4          | sat       | 5         | on       |
| r      | 0          | None      | 4         | sat      |

## Parse to Transition Sequence

---

| Action | Head Index | Head Word | Dep Index | Dep Word |
|--------|------------|-----------|-----------|----------|
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 3          | cat       | 2         | fat      |
| l      | 3          | cat       | 1         | the      |
| s      |            |           |           |          |
| l      | 4          | sat       | 3         | cat      |
| s      |            |           |           |          |
| s      |            |           |           |          |
| s      |            |           |           |          |
| l      | 7          | mat       | 6         | the      |
| r      | 5          | on        | 7         | mat      |
| r      | 4          | sat       | 5         | on       |
| r      | 0          | None      | 4         | sat      |
| s      |            |           |           |          |