Greedy, Joint Syntactic-Semantic Parsing with Stack LSTMs

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Joint syntactic-semantic parsing

YM-style Syntactic dependency parsing + PropBank-style semantic role labeling

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all are expected to reopen soon

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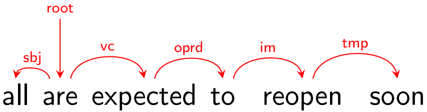

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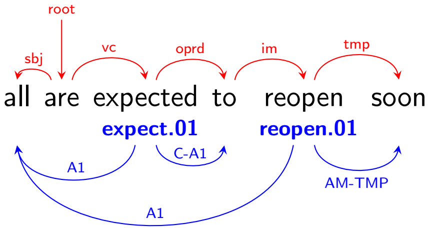

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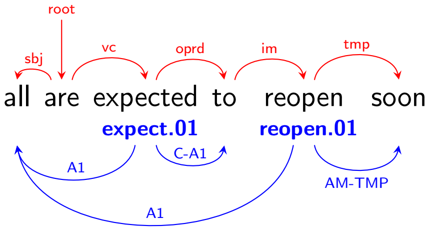

- Correspondence between syntactic and semantic dependencies [Levin and Hovav, 1996]

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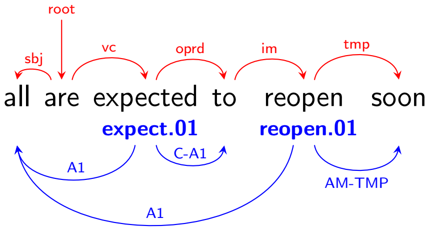

- Correspondence between syntactic and semantic dependencies [Levin and Hovav, 1996]
- Language understanding: QA, relation extraction, text categorization

A little more about PropBank SRL

[Palmer et al., 2005]

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Pipelines

- Have access to complete syntactic information

Incremental, joint approach

- No such access

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- Our approach : incremental, joint parsing of syntax and semantics

Pipelines

- Have access to complete syntactic information
- Slow feature extraction step

Incremental, joint approach

- No such access
- Fast

Outline

Incremental algorithm

- Parse structure → sequence of transitions

Incremental algorithm

- Parse structure $\rightarrow$ sequence of transitions
- Transition : **shift** and **reduce** actions

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  - Data structure contents (*parser state*)
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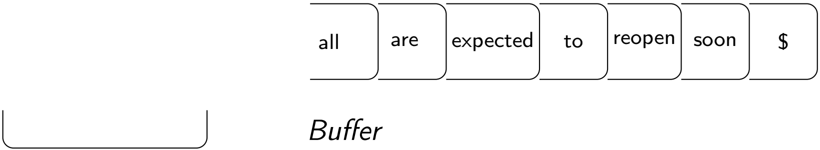
Modified arc-eager algorithm [Nivre, 2008, Henderson et al., 2008, Henderson et al., 2013, Gesmundo et al., 2009, Titov et al., 2009]

Transitions for syntax

Transitions for syntax

- S-Shift
-
-
-

all are expected to reopen soon



Buffer

Stack

Transitions for syntax

- S-Shift ✓
-
-
-

all are expected to reopen soon

are	expected	to	reopen	soon	$

Buffer

all

Stack

Transitions for syntax

- S-Shift
- S-Left
-
-

all are expected to reopen soon

are	expected	to	reopen	soon	$

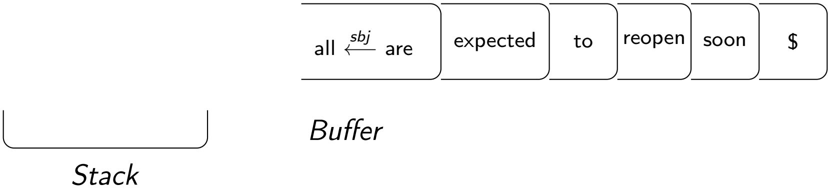
Buffer

all

Stack

Transitions for syntax

- S-Shift
- S-Left ✓
-
-



Transitions for syntax

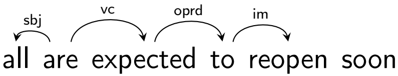
- S-Shift
- S-Left ✓
-
-

[are] | expected | to | reopen | soon | $

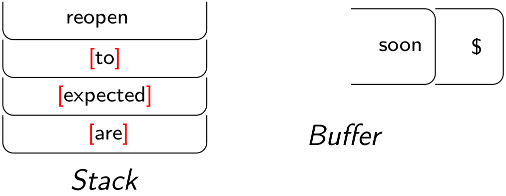
Stack

Buffer

Transitions for syntax



- S-Shift
- S-Left
- S-Right
-



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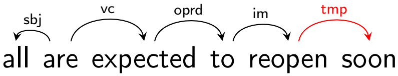
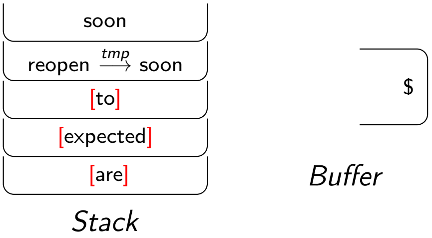


- S-Shift
- S-Left
- S-Right ✓
-



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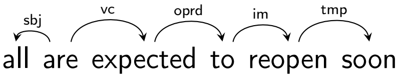
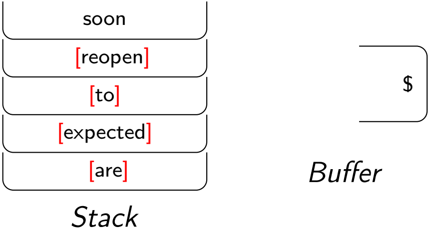
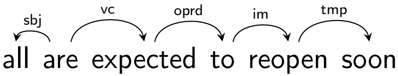




- S-Shift
- S-Left
- S-Right
- S-Reduce

Transitions for syntax



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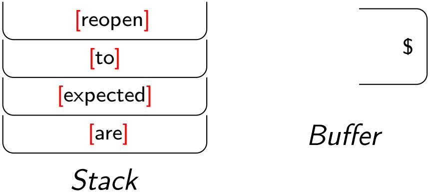
- S-Left
- S-Right
- S-Reduce ✓



More transitions for semantics

- M-Shift
- M-Left
- M-Right
- M-Reduce

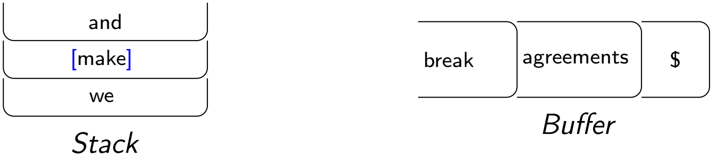
More transitions for semantics

- M-Pred
-
-

we make and break agreements

make.03

A0



More transitions for semantics

- M-Pred ✓
-
-

we make and break agreements

make.03 **break.01**

A0

and

[make]

we

Stack

break **break.01** | agreements | $

Buffer

we make and break agreements

make.03 **break.01**

A0

- M-Pred
- M-Swap
-

More transitions for semantics

we make and break agreements

make.03 **break.01**

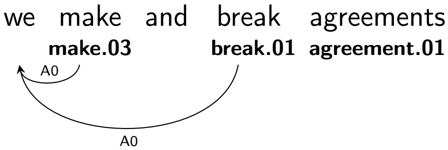
A0

- M-Pred
- M-Swap ✓
-

Stack
we
[make]

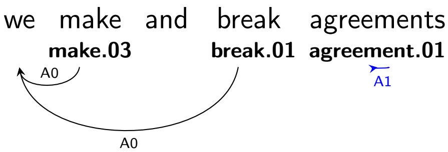
Buffer		
[break]	agreements	$

More transitions for semantics



- M-Pred
- M-Swap
- M-Self

More transitions for semantics



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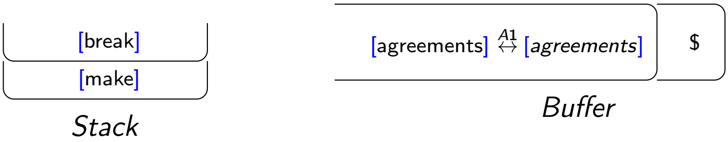
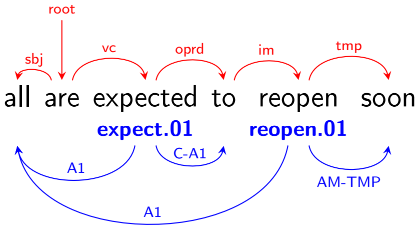
- M-Swap
- M-Self ✓

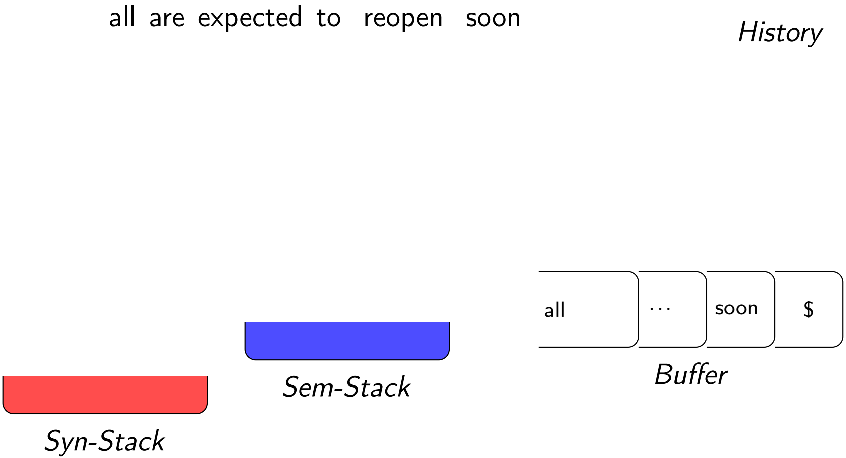


Synchronizing syntax and semantics



- Two stacks: *Syn-Stack* and *Sem-Stack*
- Share the *Buffer*
- Syntactic transitions followed by semantic transitions for a given *Buffer* state [Henderson et al., 2008]

An example transition sequence



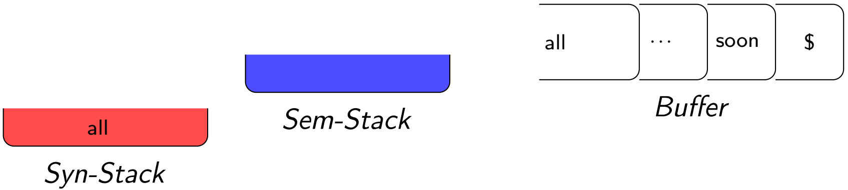
[x] denotes parse substructure headed by x

An example transition sequence

all are expected to reopen soon

History

S-Shift



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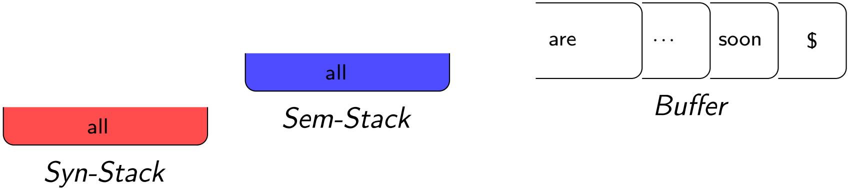
History

S-Shift
M-Shift



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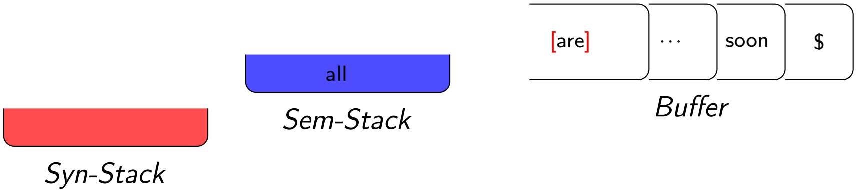
An example transition sequence

sbj

all are expected to reopen soon

History

S-Shift
M-Shift
S-Left(sbj)



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An example transition sequence

sbj

all are expected to reopen soon

History

S-Shift
M-Shift
S-Left(sbj)
S-Shift

[are] | ··· | soon | $

Buffer

all

Sem-Stack

[are]

Syn-Stack

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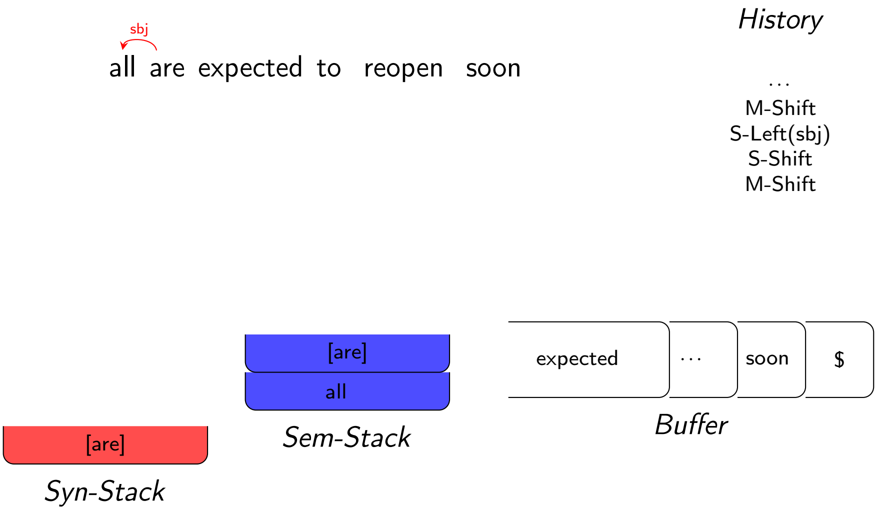
An example transition sequence



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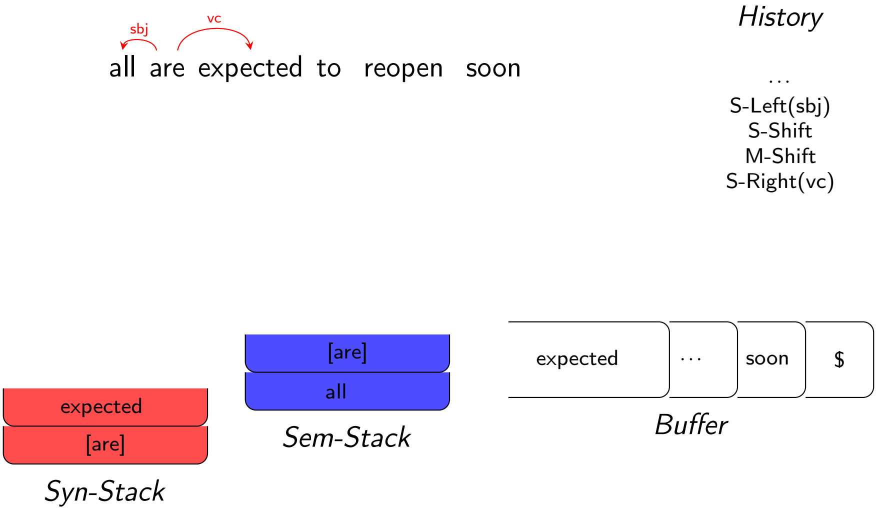

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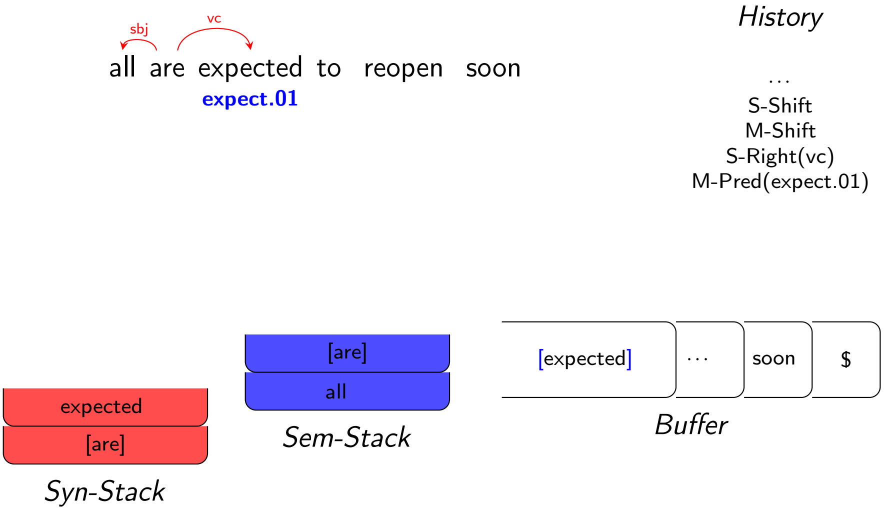

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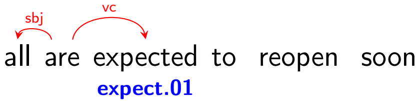
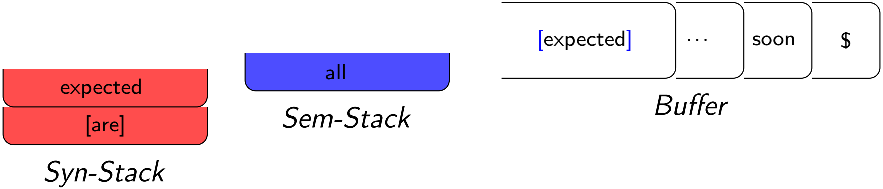


History

...
M-Shift
S-Right(vc)
M-Pred(expect.01)
M-Reduce



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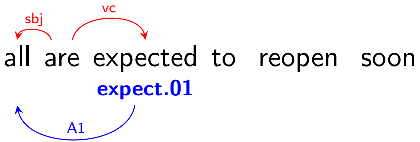
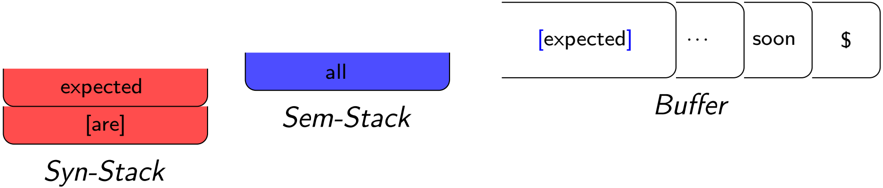


History

...
S-Right(vc)
M-Pred(expect.01)
M-Reduce
M-Left(A1)



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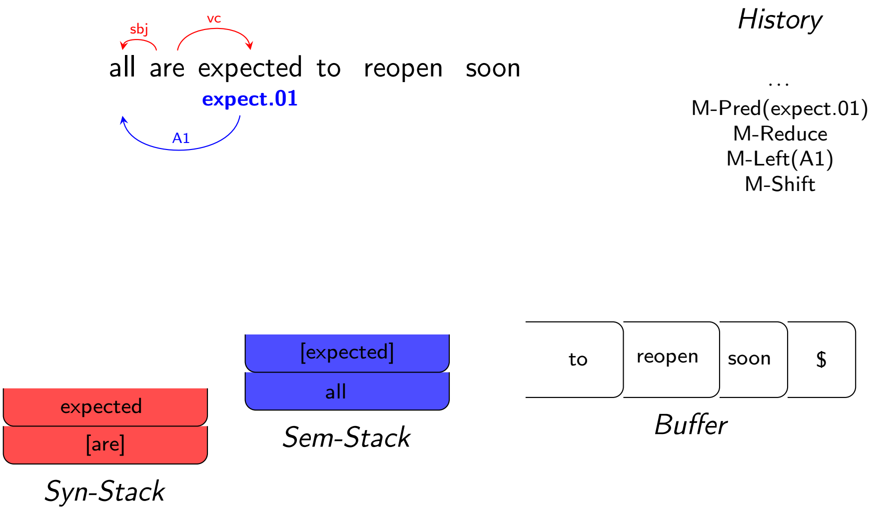

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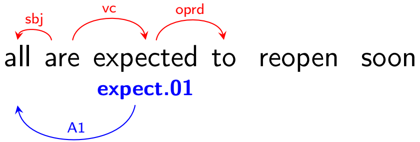
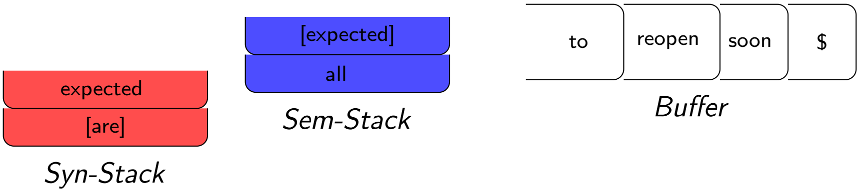


History

...
M-Reduce
M-Left(A1)
M-Shift



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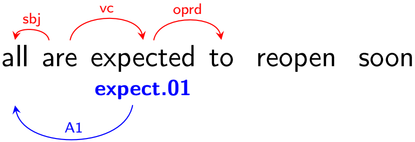
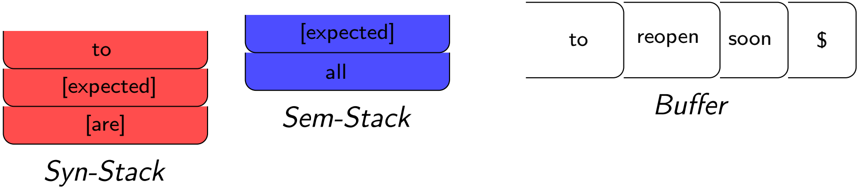


History

...
M-Left(A1)
M-Shift
S-Right(oprd)



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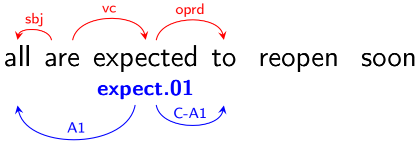
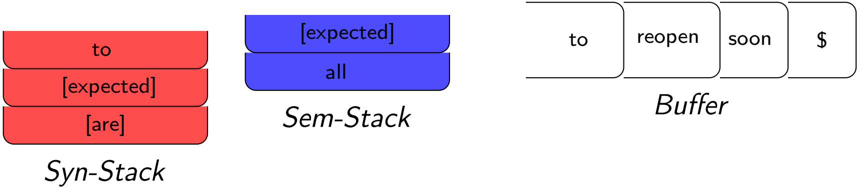


History

...
M-Shift
S-Right(oprd)
M-Right(C-A1)



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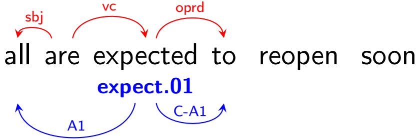
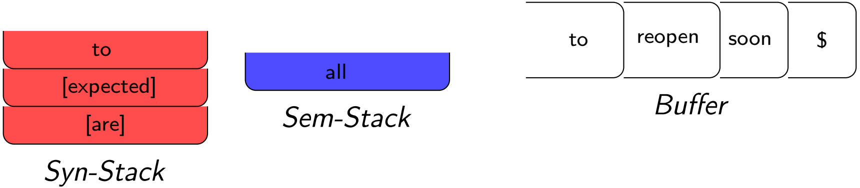


History

...
S-Right(oprd)
M-Right(C-A1)
M-Reduce



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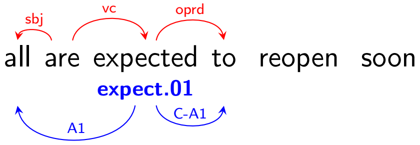
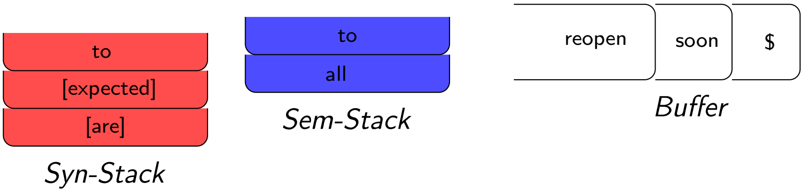


History

...
M-Right(C-A1)
M-Reduce
M-Shift



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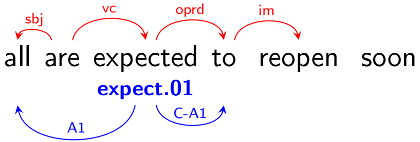
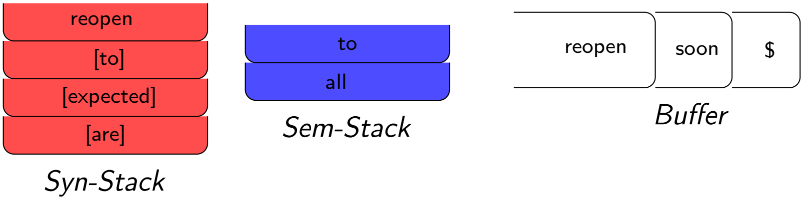


History

...
M-Reduce
M-Shift
S-Right(im)



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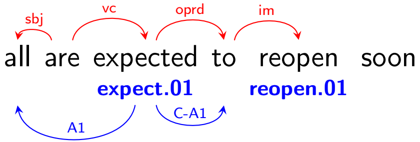
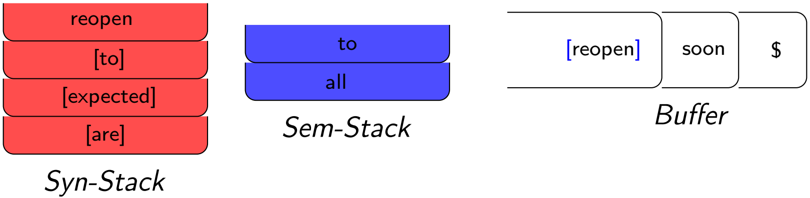


History

...
M-Shift
S-Right(im)
M-Pred(reopen.01)



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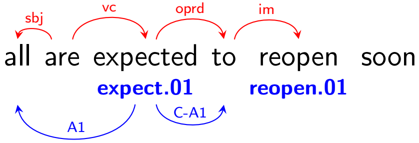

History

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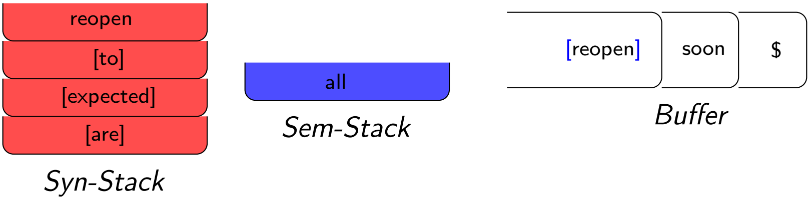
M-Pred(reopen.01)
M-Reduce



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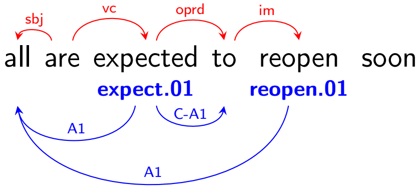
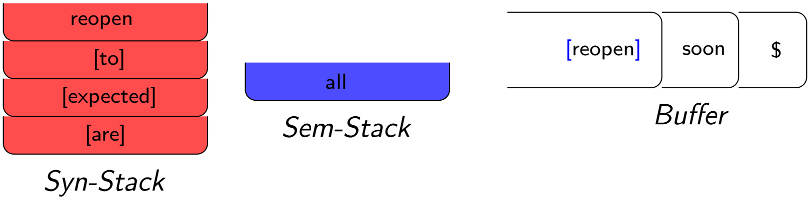


History

...
M-Pred(reopen.01)
M-Reduce
M-Left(A1)



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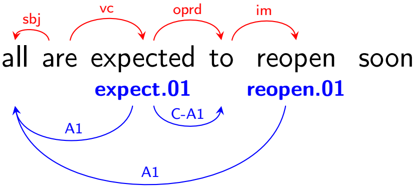
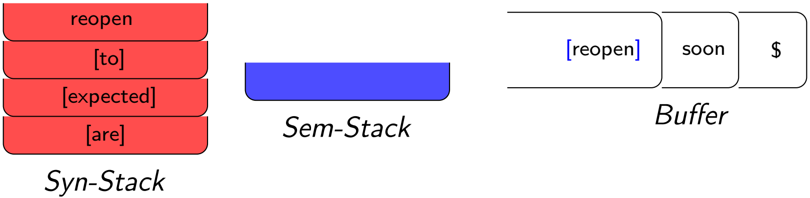


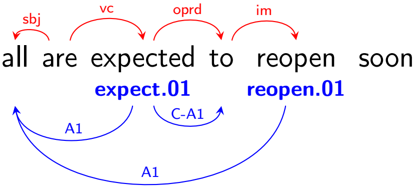
History

...
M-Reduce
M-Left(A1)
M-Reduce



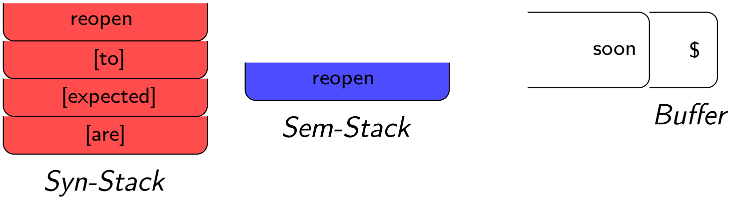
[x] denotes parse substructure headed by x

An example transition sequence



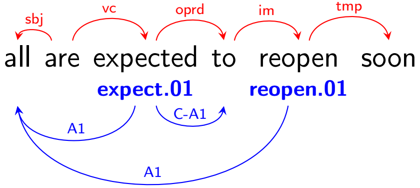
History

...
M-Left(A1)
M-Reduce
M-Shift



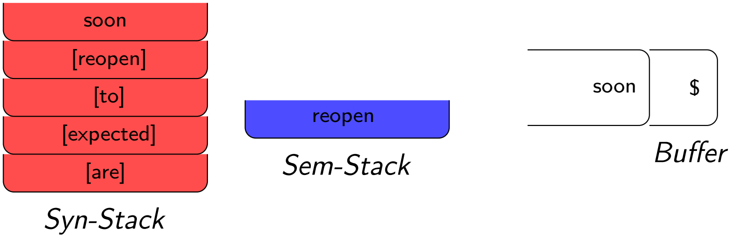
[x] denotes parse substructure headed by x

An example transition sequence



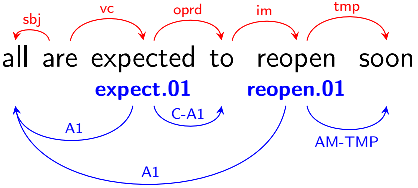
History

...
M-Reduce
M-Shift
S-Right(tmp)



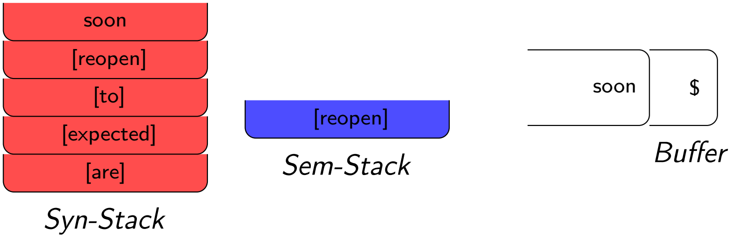
[x] denotes parse substructure headed by x

An example transition sequence



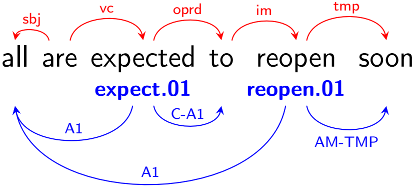
History

...
M-Shift
S-Right(tmp)
M-Right(AM-TMP)



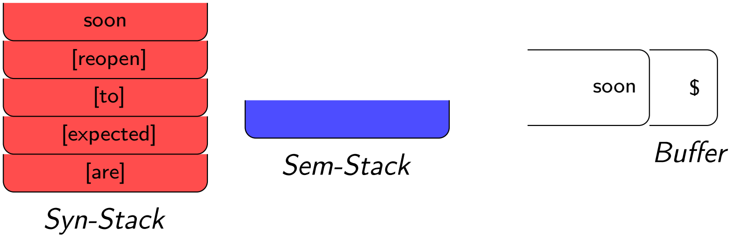
[x] denotes parse substructure headed by x

An example transition sequence



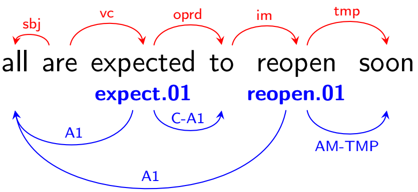
History

...
S-Right(tmp)
M-Right(AM-TMP)
M-Reduce



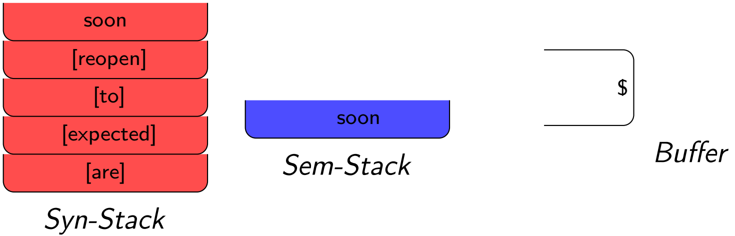
[x] denotes parse substructure headed by x

An example transition sequence



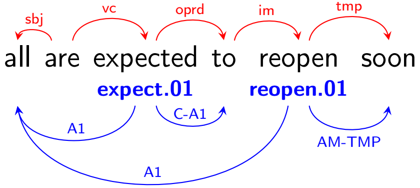
History

...
M-Right(AM-TMP)
M-Reduce
M-Shift



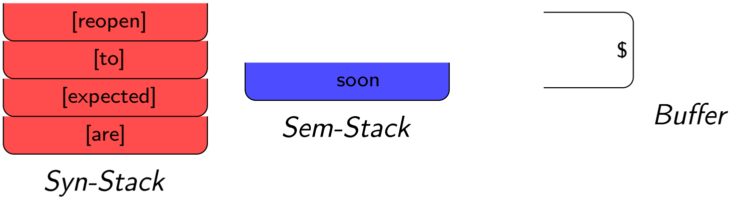
[x] denotes parse substructure headed by x

An example transition sequence



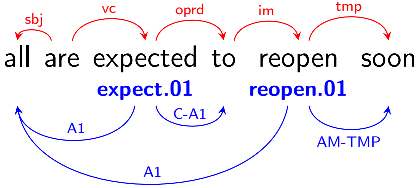
History

…
M-Reduce
M-Shift
S-Reduce



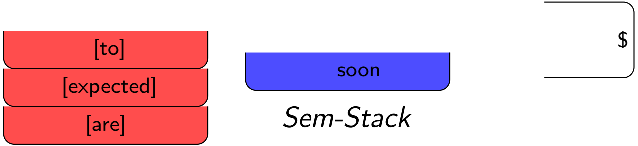
[x] denotes parse substructure headed by x

An example transition sequence



History

...
M-Shift
S-Reduce
S-Reduce



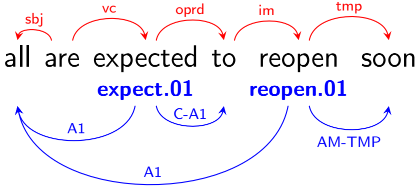
Syn-Stack

Sem-Stack

Buffer

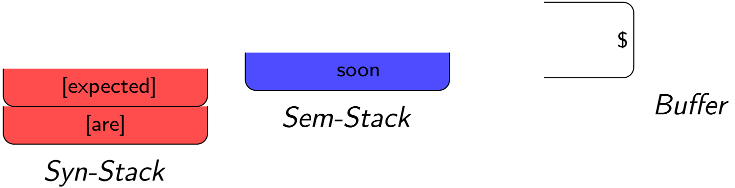
[x] denotes parse substructure headed by x

An example transition sequence



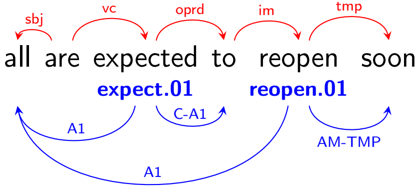
History

...
S-Reduce
S-Reduce
S-Reduce



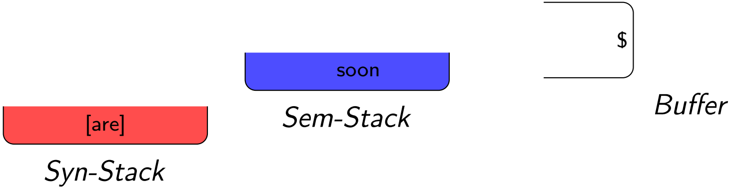
[x] denotes parse substructure headed by x

An example transition sequence



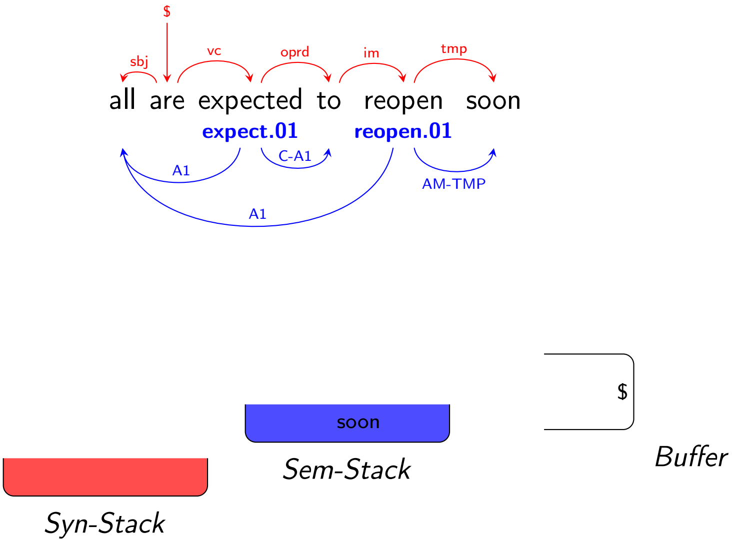
History

...
S-Reduce
S-Reduce
S-Reduce



[x] denotes parse substructure headed by x

An example transition sequence

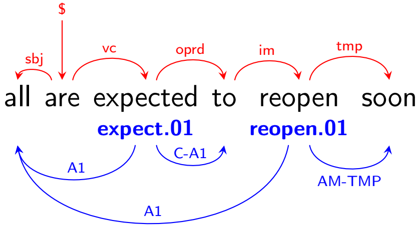


History

...
S-Reduce
S-Reduce
S-Left($)

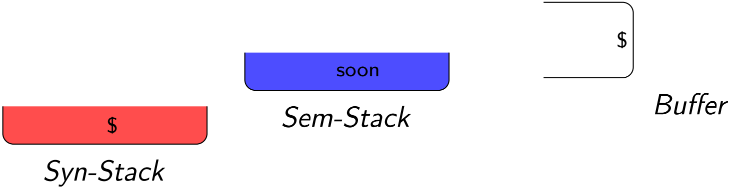
[x] denotes parse substructure headed by x

An example transition sequence



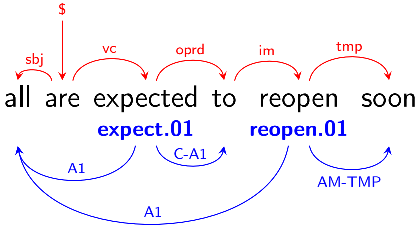
History

...
S-Reduce
S-Left($)
S-Shift



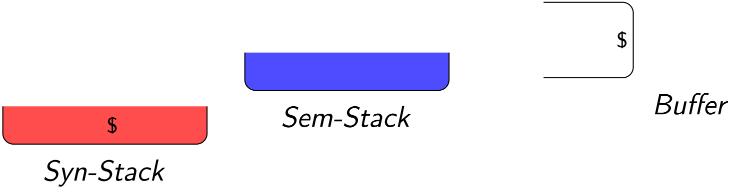
[x] denotes parse substructure headed by x

An example transition sequence



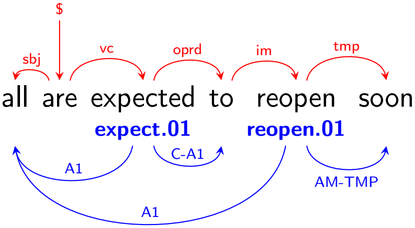
History

...
S-Left($)
S-Shift
M-Reduce



[x] denotes parse substructure headed by x

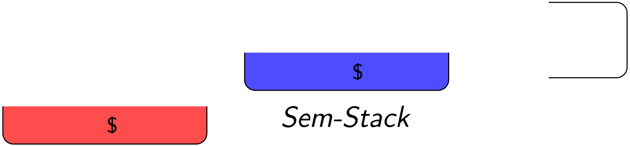
An example transition sequence



History

...
S-Left($)
S-Shift
M-Reduce
M-Shift

Linear algorithm



Sem-Stack

Buffer

Syn-Stack

[x] denotes parse substructure headed by x

Outline

Introduction

Incremental Algorithm

Stack LSTM Model

CoNLL 2008-09 Shared Task Results

Stack LSTM Model

- LSTMs: Recurrent neural networks with special memory cell [Hochreiter and Schmidhuber, 1997, Graves, 2013] to learn fixed-size representations for variable-length sequences

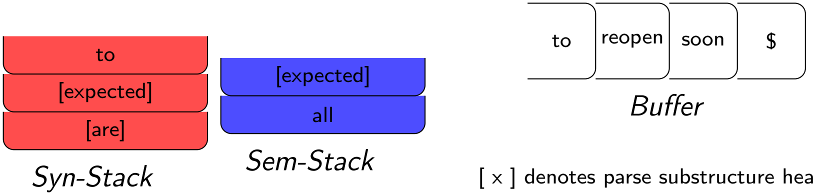
Stack LSTM Model

- LSTMs: Recurrent neural networks with special memory cell [Hochreiter and Schmidhuber, 1997, Graves, 2013] to learn fixed-size representations for variable-length sequences
- **Stack LSTMs**: LSTMs equipped with stack operations [Dyer et al., 2015]
  - summary $\rightarrow$ return a fixed-size continuous representation
  - push $\rightarrow$ add to the sequence
  - pop $\rightarrow$ remove from the sequence

Stack LSTM for Joint Parsing

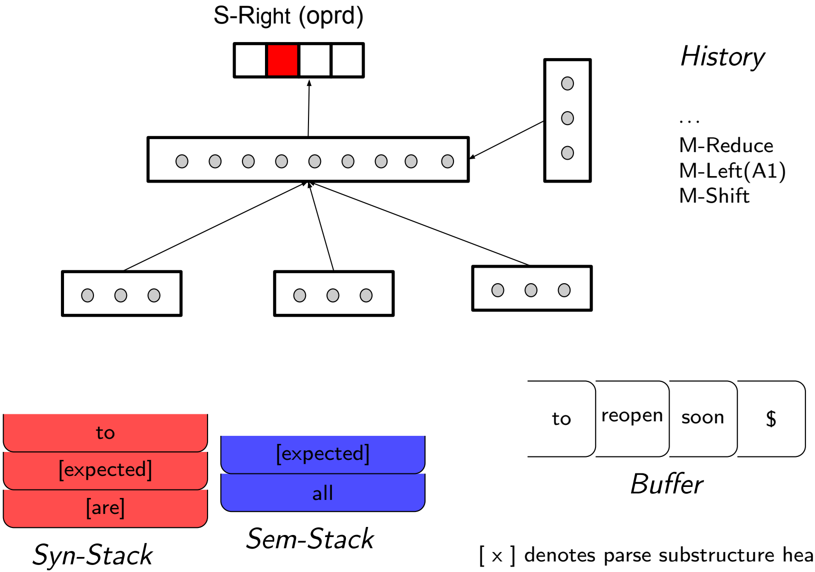
History

...
M-Reduce
M-Left(A1)
M-Shift



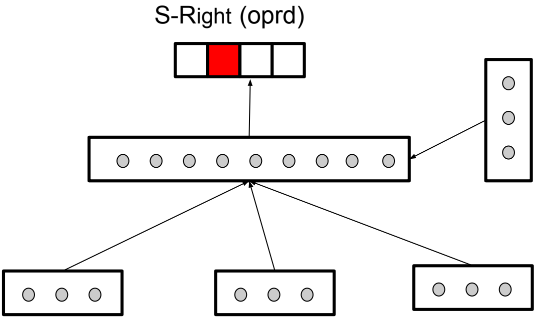
[x] denotes parse substructure headed by x

Stack LSTM for Joint Parsing



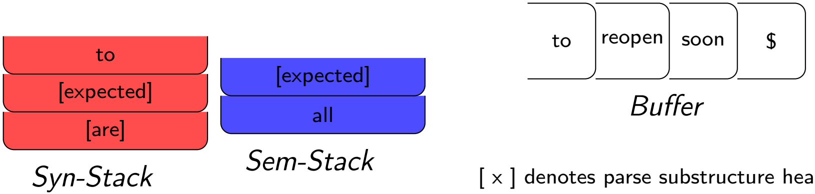
[x] denotes parse substructure headed by x

Stack LSTM for Joint Parsing



History

. . .
M-Reduce
M-Left(A1)
M-Shift



[x] denotes parse substructure headed by x

Outline

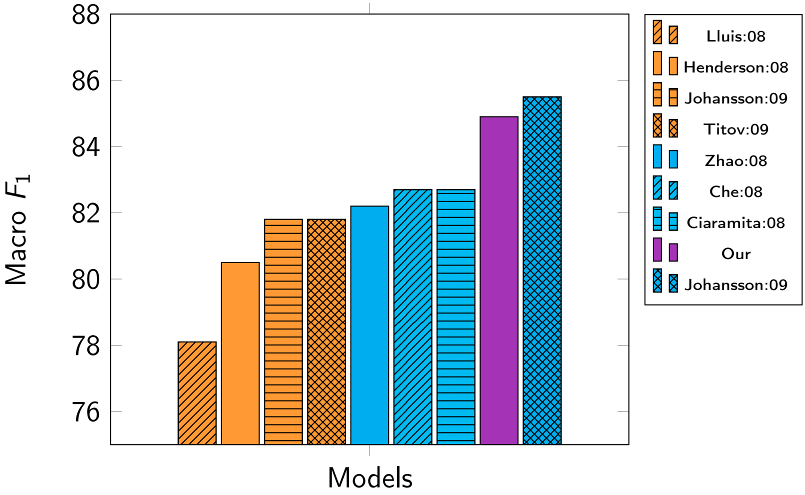
CoNLL Shared Tasks

- 2008: English only
- 2009: Multilingual
- Evaluation metrics:
  - Syntax: Labeled Accuracy Score (LAS)
  - SRL: Semantic F_1
  - Rank systems: Macro F_1

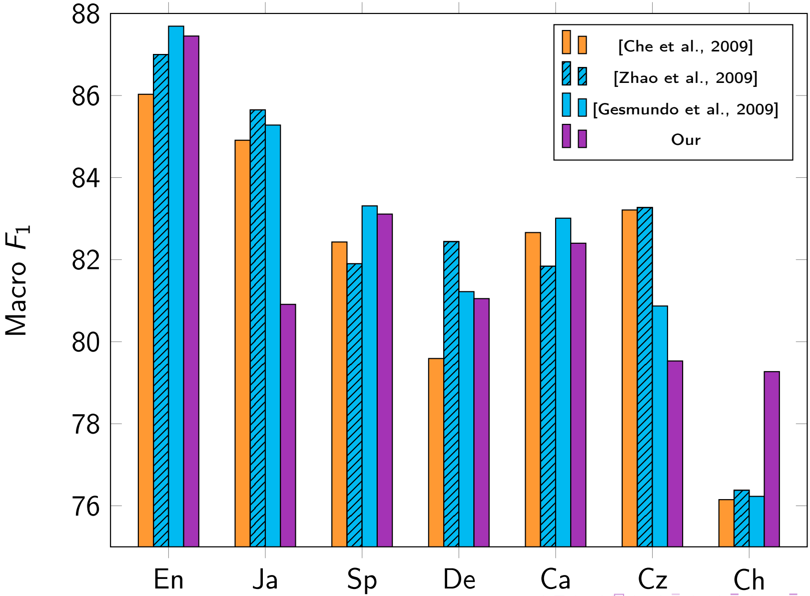
Experimental Setup

- POS tags were used, but no other provided features
- No manually-designed features
- Dataset-specific hyperparameter tuning

CoNLL 2008 (English only) Shared Task



CoNLL 2009 (Multilingual) Shared Task



Conclusion

Take-aways!

- Incremental algorithm (linear) + model using stack LSTMs
- Avoid the effort involved in manual feature engineering
- Light-weight alternative to expensive pipelined systems

Code available at
`https://github.com/clab/joint-lstm-parser`

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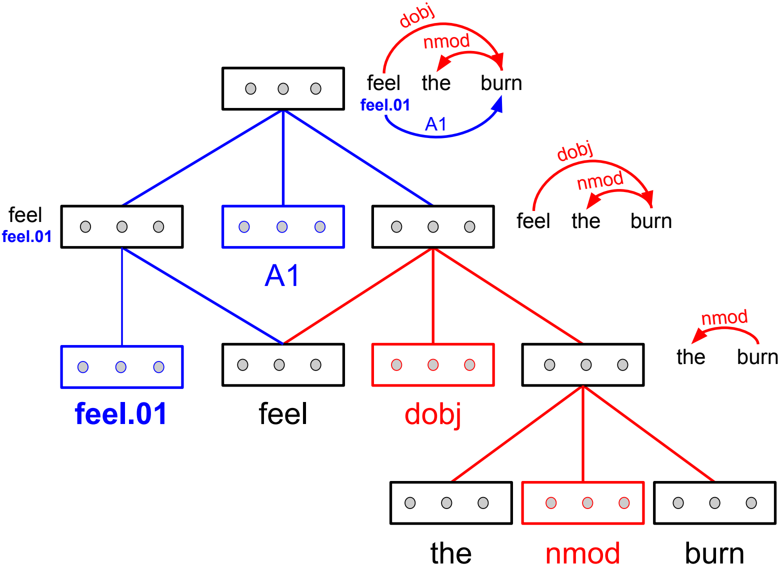
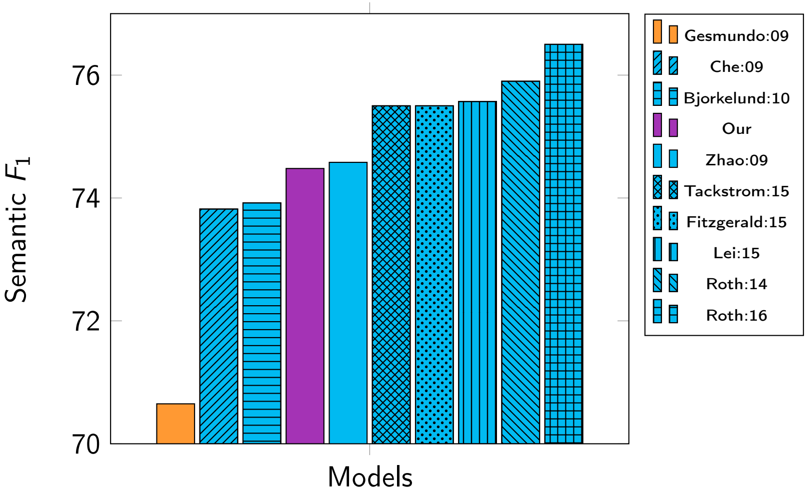
Extras

Syntactic-semantic composition

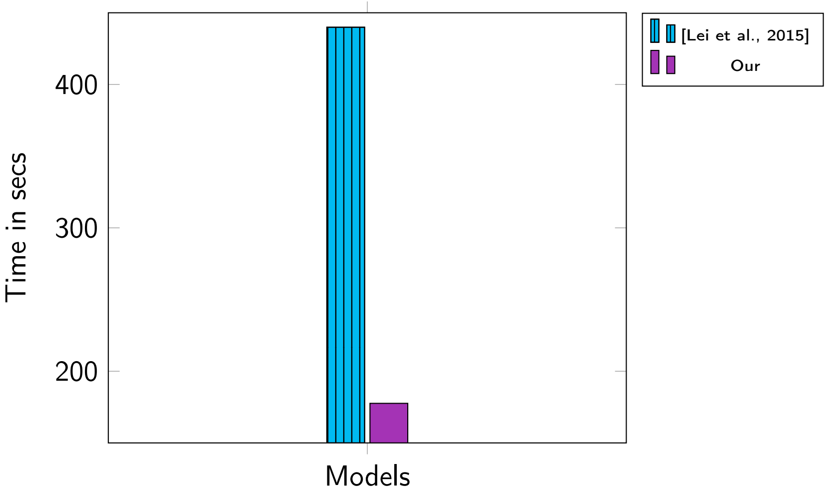


SRL performance on out-of-domain (Brown) data

CoNLL 2009 Shared Task



Time to decode the CoNLL 2009 English dataset



Experiments were run end to end on a single CPU