A Transition-Based Directed Acyclic Graph Parser for Universal Conceptual Cognitive Annotation

Daniel Hershcovich, Omri Abend and Ari Rappoport

האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM

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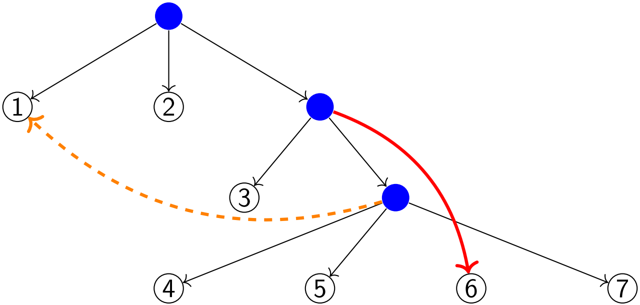
TUPA — Transition-based UCCA Parser

The first parser to support the combination of

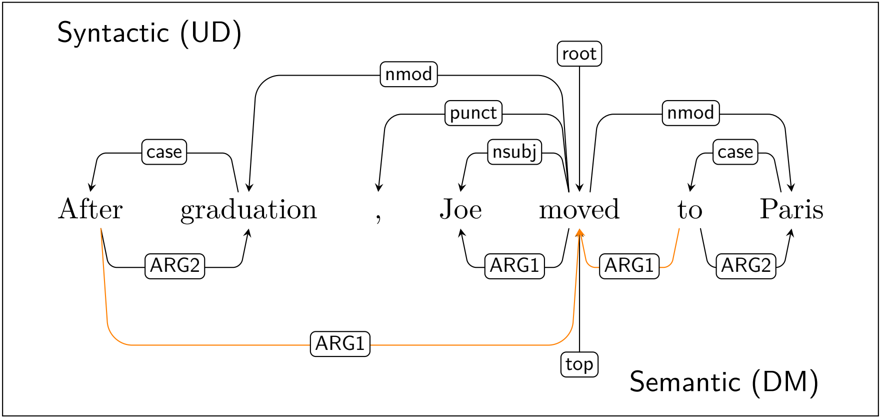
1. Non-terminal nodes
2. Reentrancy
3. Discontinuity

— needed for many semantic schemes (e.g. AMR, UCCA).



Linguistic Structure Annotation Schemes

- Syntactic dependencies (Nivre, 2005)
- Semantic dependencies (Oepen et al., 2016)



Bilexical dependencies.

Linguistic Structure Annotation Schemes

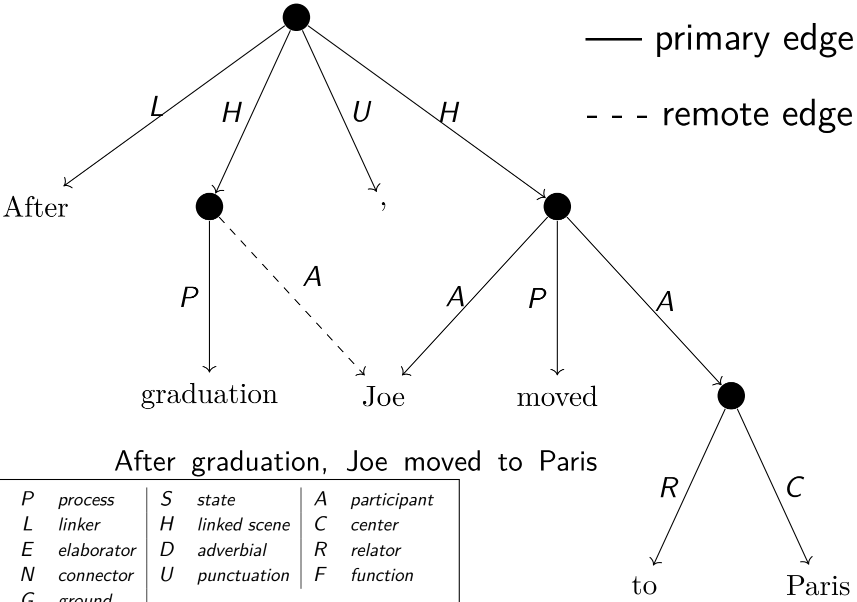
- Syntactic dependencies (Nivre, 2005)
- Semantic dependencies (Oepen et al., 2016)
- AMR (Banarescu et al., 2013)
- UCCA (Abend and Rappoport, 2013)
- Other semantic representation schemes[1]

$$\boxed{\ldots\text{showered}} = \boxed{\ldots\text{took a shower}}$$

$$\boxed{\ldots\text{'s war against crime}} = \boxed{\ldots\text{fights crime}}$$

[1] See recent survey (Abend and Rappoport, 2017)

Universal Conceptual Cognitive Annotation (UCCA)

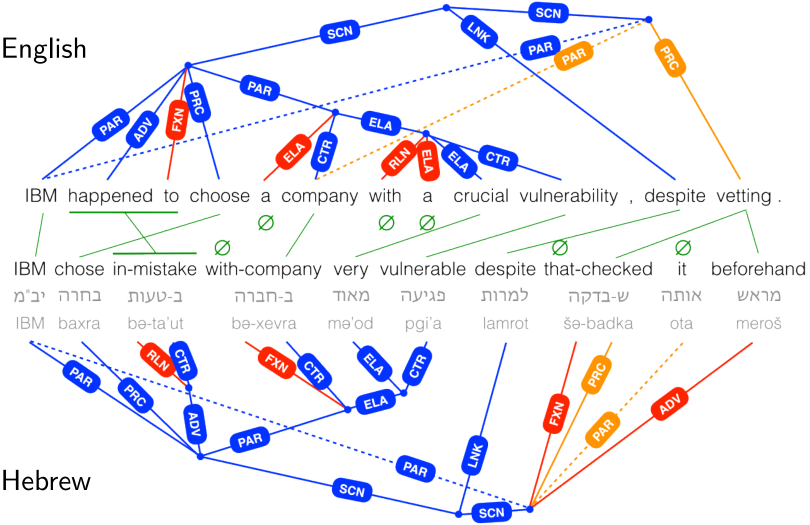


After graduation, Joe moved to Paris

P	*process*	*S*	*state*	*A*	*participant*
L	*linker*	*H*	*linked scene*	*C*	*center*
E	*elaborator*	*D*	*adverbial*	*R*	*relator*
N	*connector*	*U*	*punctuation*	*F*	*function*
G	*ground*				

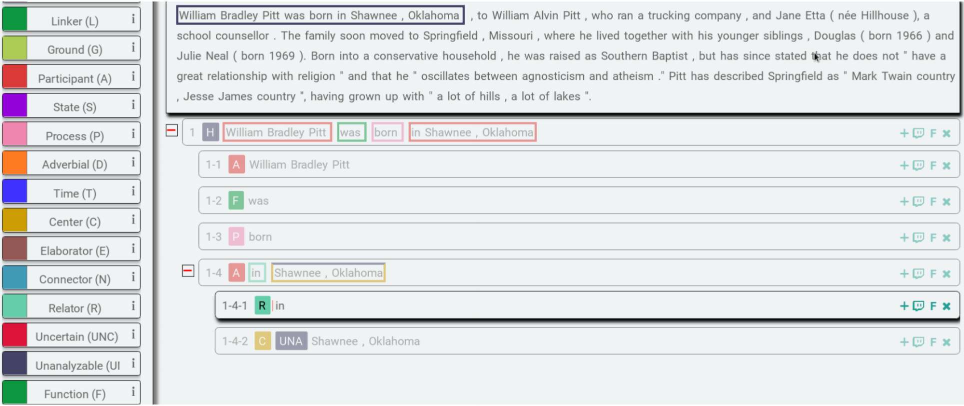
The UCCA Semantic Representation Scheme

Cross-linguistically applicable (Abend and Rappoport, 2013).
Stable in translation (Sulem et al., 2015).



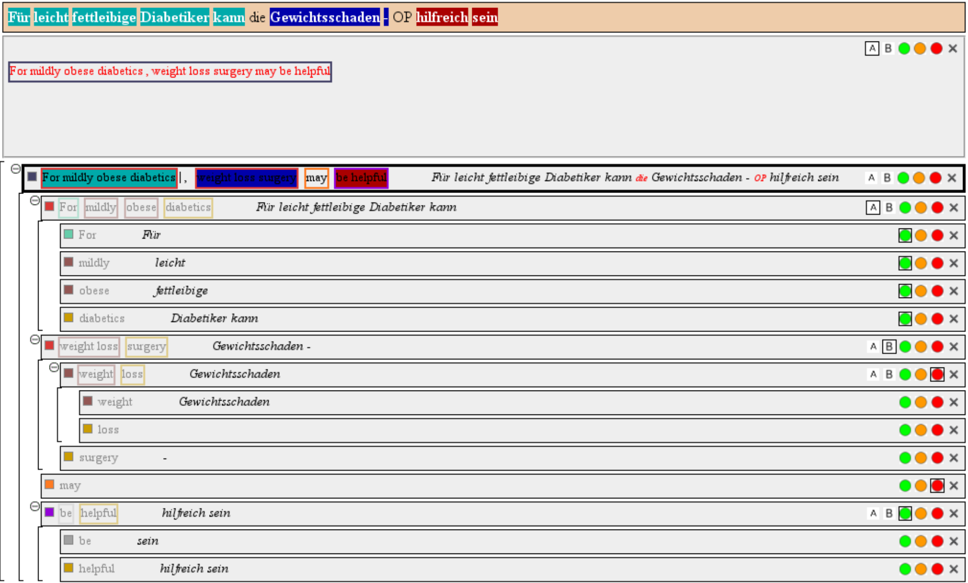
UCCAApp

Rapid and intuitive annotation interface (Abend et al., 2017).
Usable by non-experts. `http://ucca-demo.cs.huji.ac.il`



HUME

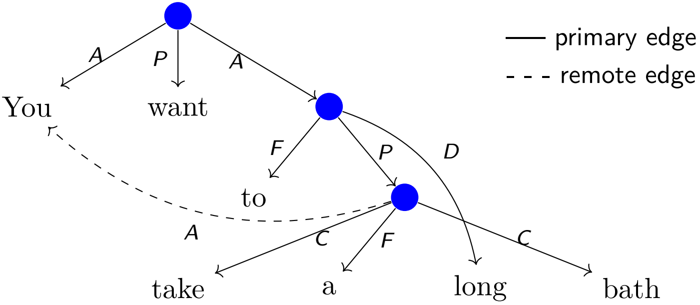
UCCA facilitates semantics-based human evaluation of machine translation (Birch et al., 2016). `http://ucca.cs.huji.ac.il/mteval`



Graph Structure

UCCA generates a directed acyclic graph (DAG), where the text tokens are terminals. Structural properties:

1. Non-terminal nodes — hierarchy of entities and events

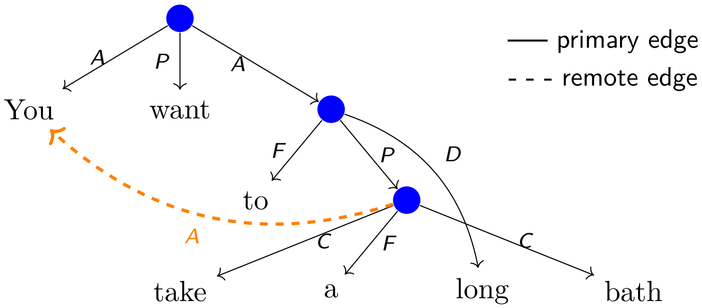


You want to take a long bath

Graph Structure

UCCA generates a directed acyclic graph (DAG), where the text tokens are terminals. Structural properties:

1. Non-terminal nodes — hierarchy of entities and events
2. Reentrancy — allow argument sharing

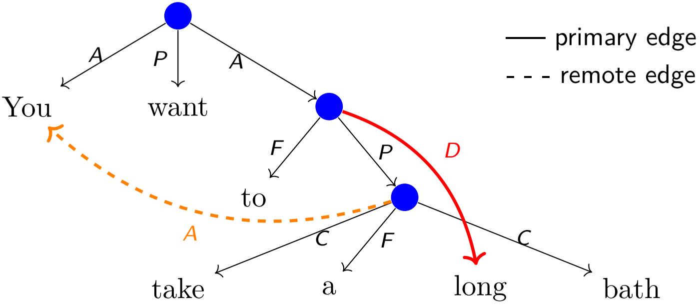


You want to take a long bath

Graph Structure

UCCA generates a directed acyclic graph (DAG), where the text tokens are terminals. Structural properties:

1. Non-terminal nodes — hierarchy of entities and events
2. Reentrancy — allow argument sharing
3. Discontinuity – conceptual units are split



You want to take a long bath

Transition-Based Parsing

First used for dependency parsing (Nivre, 2004).
Parse text $w_1 \dots w_n$ to graph $G = (V, E, \ell)$ incrementally.

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Parse text $w_1 \ldots w_n$ to graph $G = (V, E, \ell)$ incrementally.

Initial state:

stack

●

buffer

You	want	to	take	a	long	bath

Transition-Based Parsing

First used for dependency parsing (Nivre, 2004).
Parse text $w_1 \ldots w_n$ to graph $G = (V, E, \ell)$ incrementally.

Initial state:

stack | | buffer

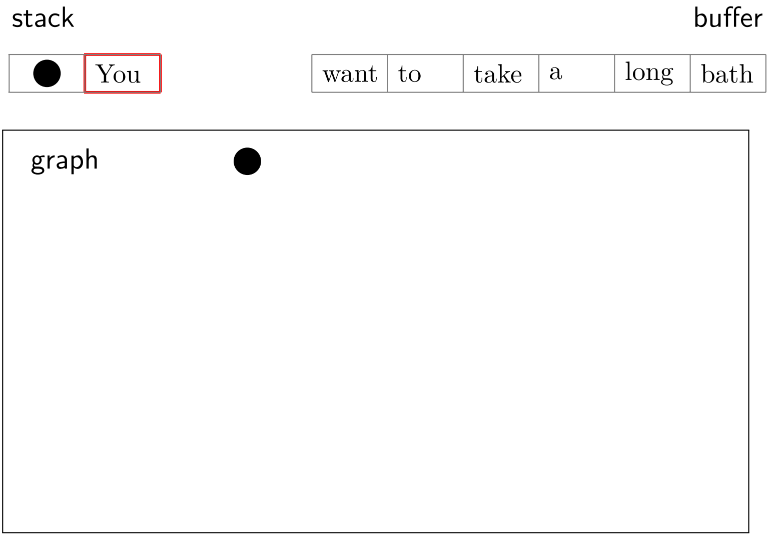
stack							
●	You	want	to	take	a	long	bath

TUPA transitions:
$\{$Shift, Reduce, Node$_X$, Left-Edge$_X$, Right-Edge$_X$, Left-Remote$_X$, Right-Remote$_X$, Swap, Finish$\}$

Support non-terminal nodes, reentrancy and discontinuity.

Transition-Based UCCA Parsing

⇒ SHIFT



Transition-Based UCCA Parsing

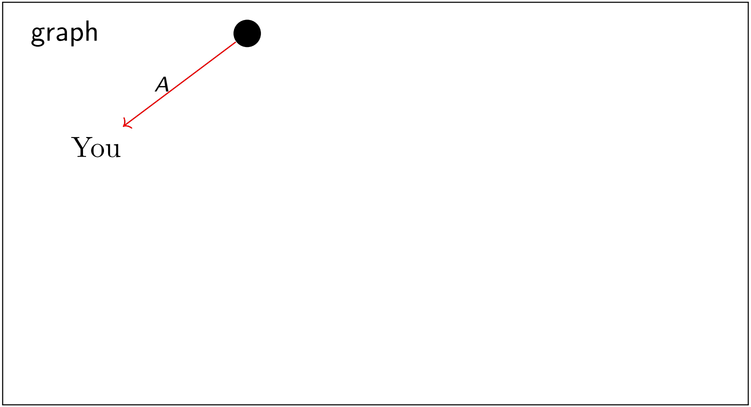
$\Rightarrow$ RIGHT-EDGE$_A$

stack

●	You

buffer

want	to	take	a	long	bath



Transition-Based UCCA Parsing

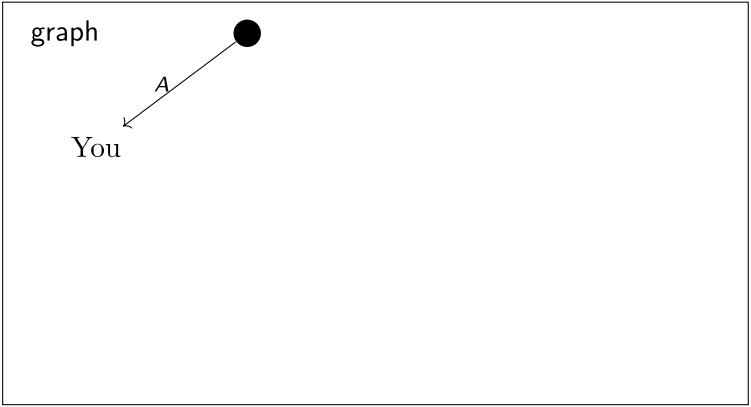
$\Rightarrow$ Shift

stack

●	You	want

buffer

to	take	a	long	bath



Transition-Based UCCA Parsing

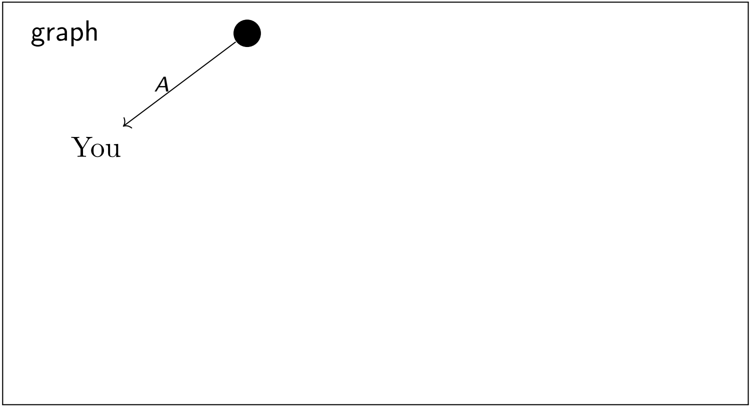
$\Rightarrow$ SWAP

stack

●	want

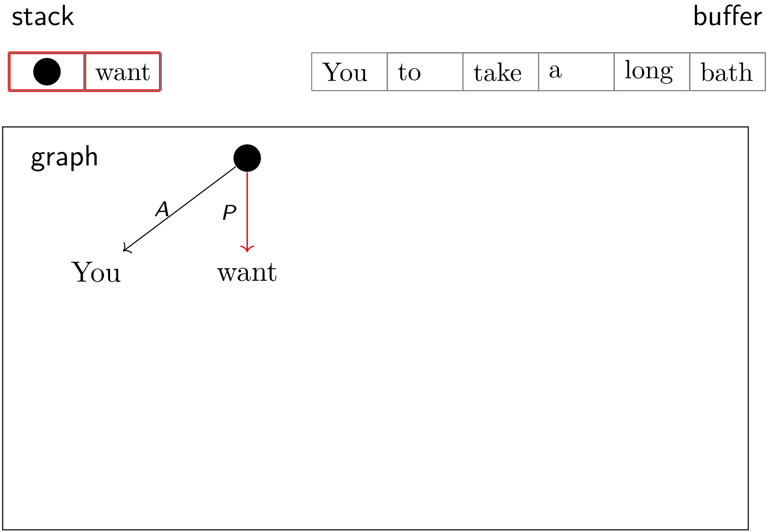
buffer

You	to	take	a	long	bath



Transition-Based UCCA Parsing

⇒ Right-Edge$_P$



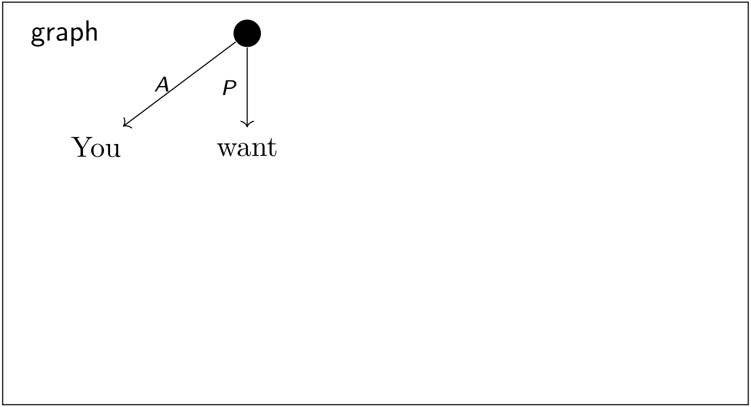
Transition-Based UCCA Parsing

⇒ REDUCE

stack

buffer

to	take	a	long	bath



Transition-Based UCCA Parsing

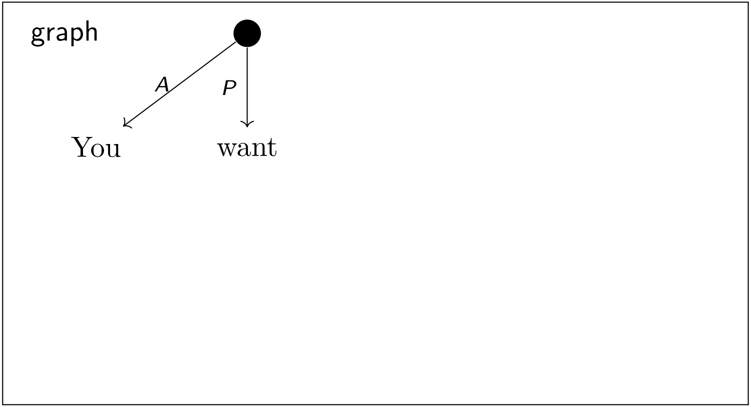
⇒ SHIFT

stack

●	You

buffer

to	take	a	long	bath



Transition-Based UCCA Parsing

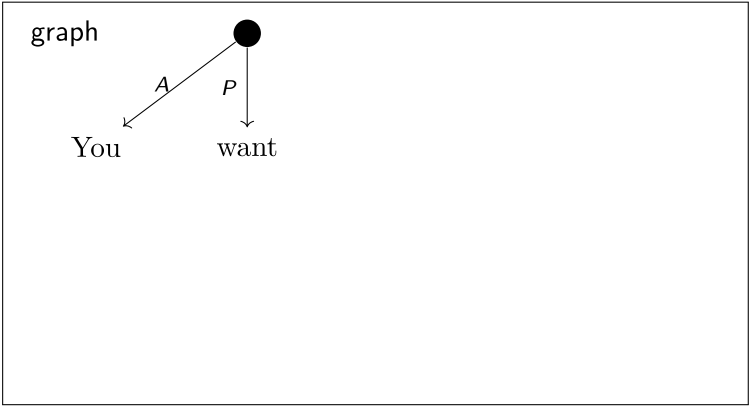
$\Rightarrow$ Shift

stack

●	You	to

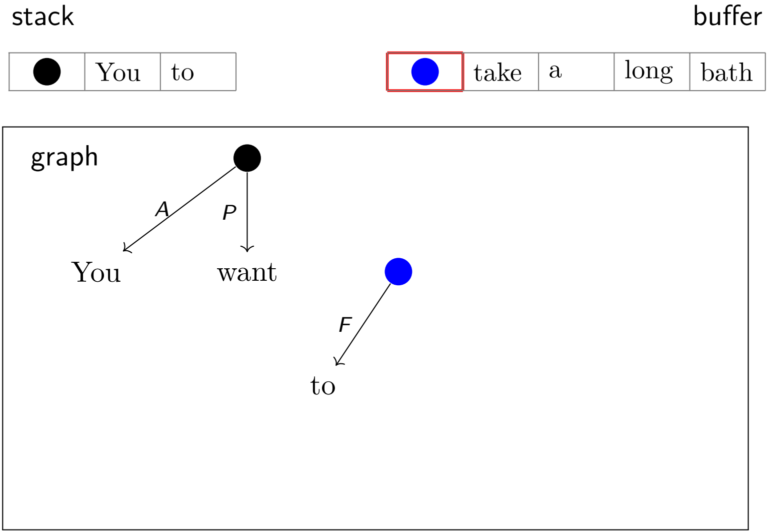
buffer

take	a	long	bath



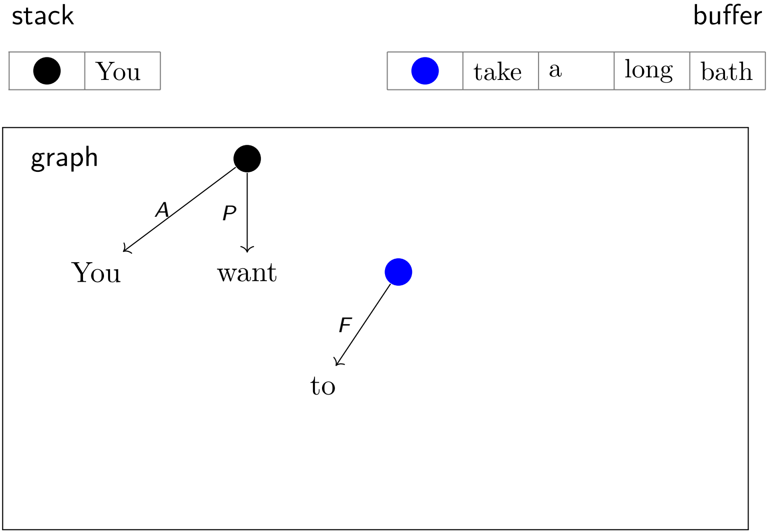
Transition-Based UCCA Parsing

$\Rightarrow$ $\textsc{Node}_{\mathrm{F}}$



Transition-Based UCCA Parsing

⇒ REDUCE



Transition-Based UCCA Parsing

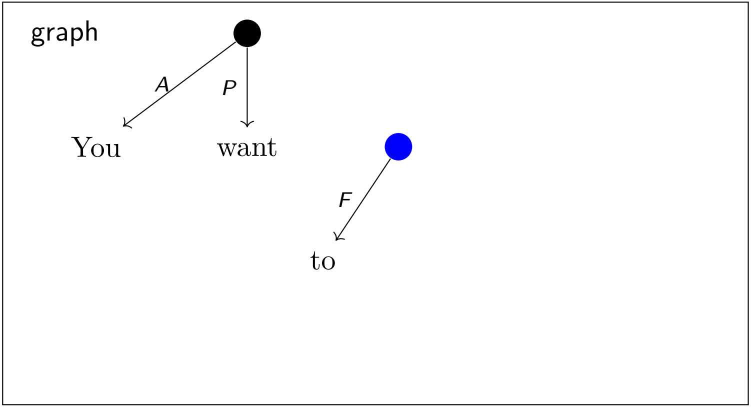
⇒ Shift

stack

●	You	●

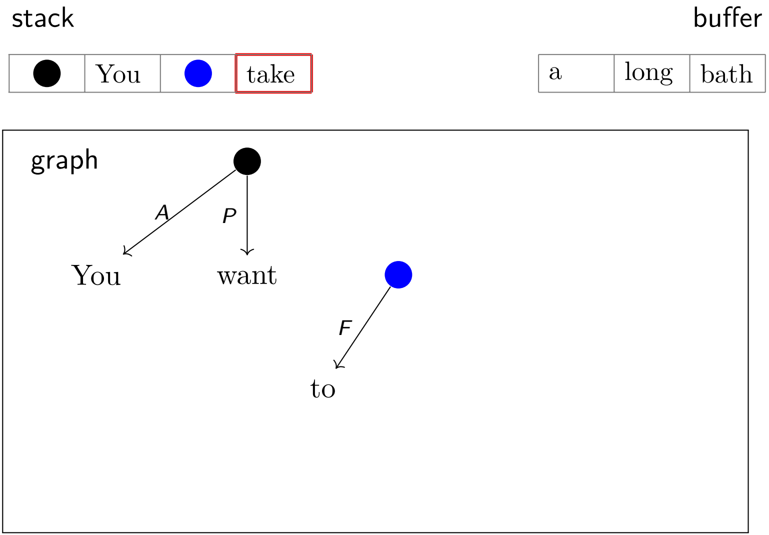
buffer

take	a	long	bath



Transition-Based UCCA Parsing

⇒ Shift



Transition-Based UCCA Parsing

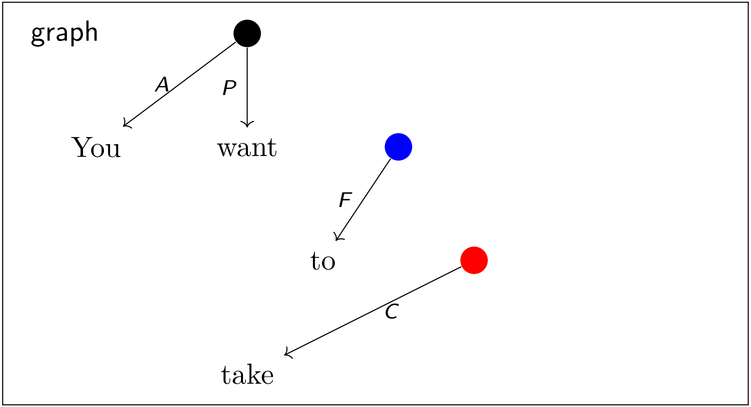
$\Rightarrow$ $\textsc{Node}_{\textsc{C}}$

stack

●	You	●	take

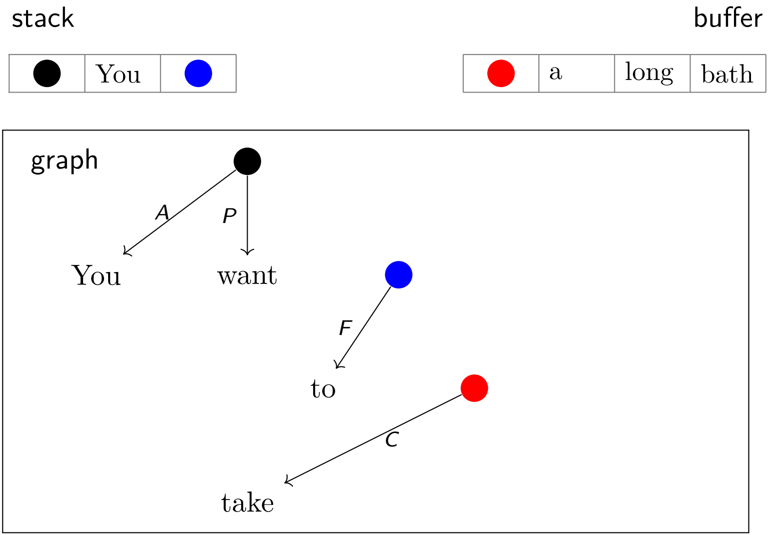
buffer

●	a	long	bath



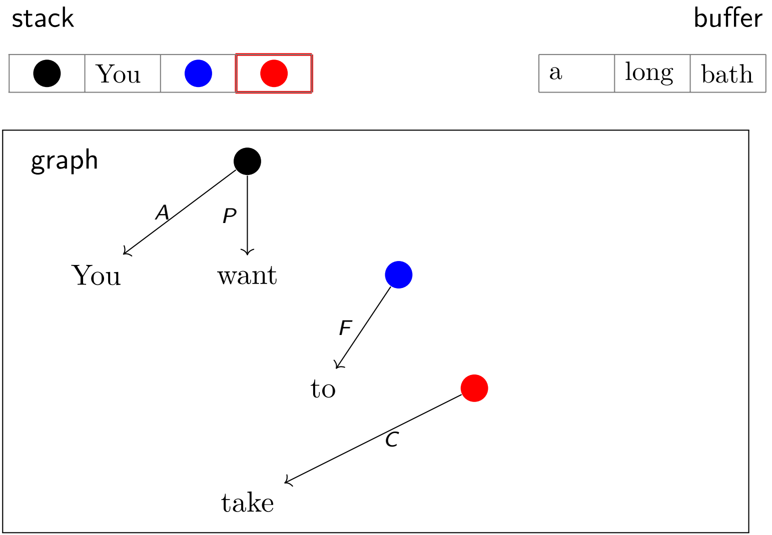
Transition-Based UCCA Parsing

⇒ REDUCE



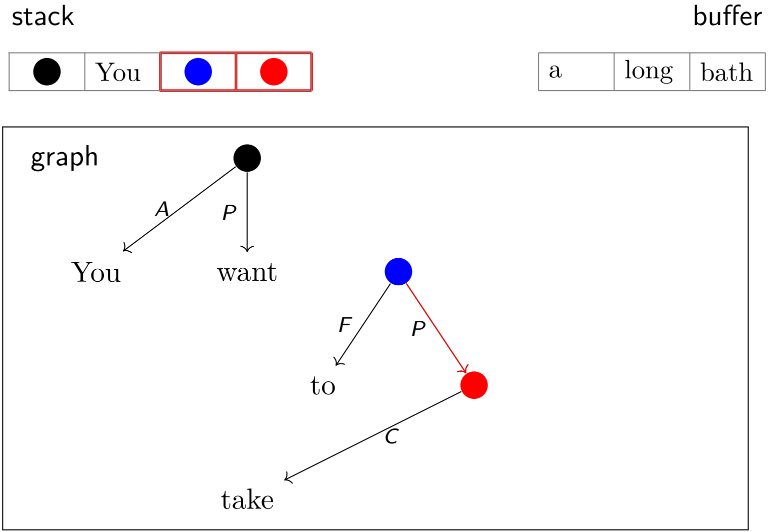
Transition-Based UCCA Parsing

⇒ SHIFT



Transition-Based UCCA Parsing

⇒ RIGHT-EDGE$_P$



Transition-Based UCCA Parsing

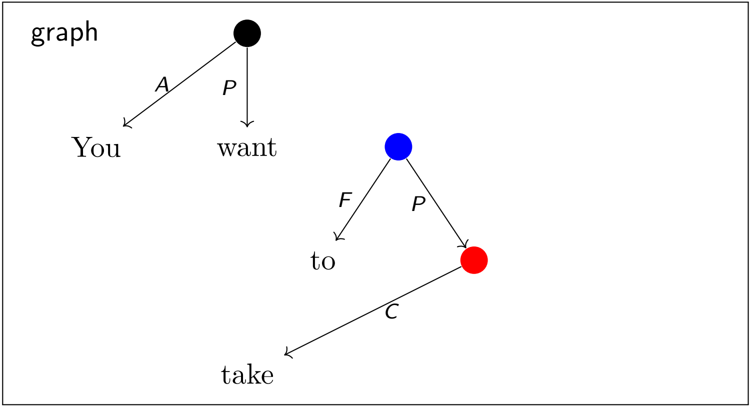
⇒ SHIFT

stack

●	You	●	●	a

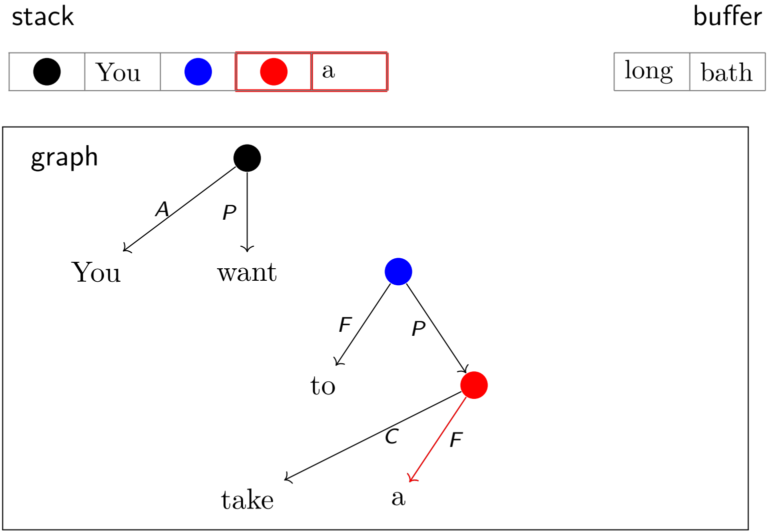
buffer

long	bath



Transition-Based UCCA Parsing

$\Rightarrow$ RIGHT-EDGE$_{F}$



Transition-Based UCCA Parsing

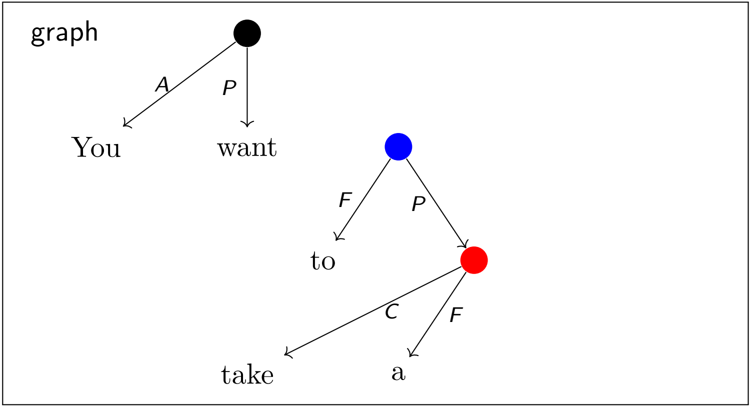
⇒ Reduce

stack

●	You	●	●

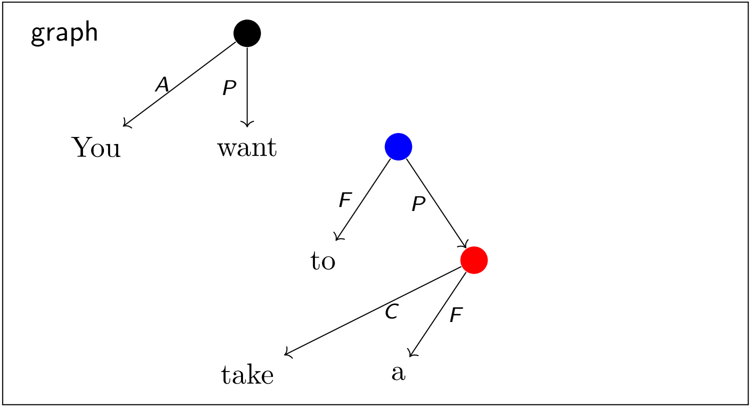
buffer

long	bath



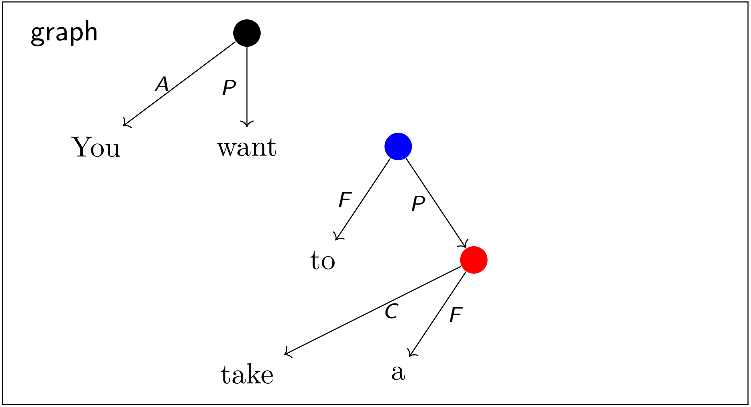
Transition-Based UCCA Parsing

$\Rightarrow$ SHIFT



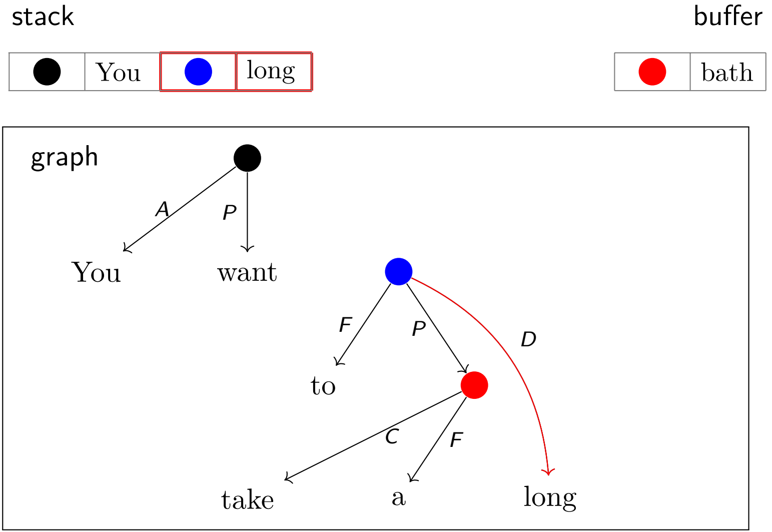
Transition-Based UCCA Parsing

⇒ Swap



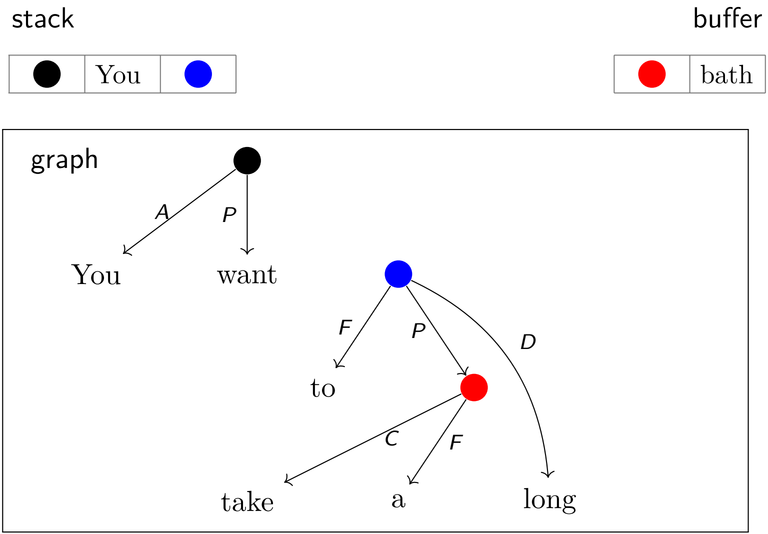
Transition-Based UCCA Parsing

⇒ RIGHT-EDGE$_D$



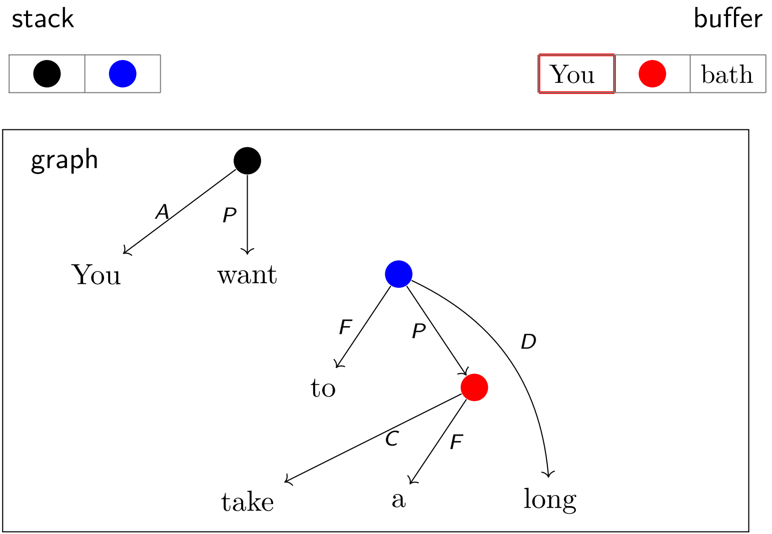
Transition-Based UCCA Parsing

$\Rightarrow$ Reduce



Transition-Based UCCA Parsing

⇒ Swap

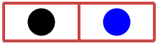


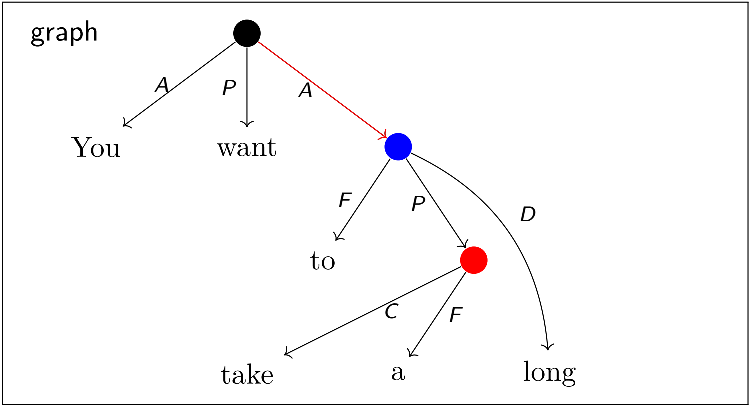
Transition-Based UCCA Parsing

$\Rightarrow$ RIGHT-EDGE$_A$

stack

buffer





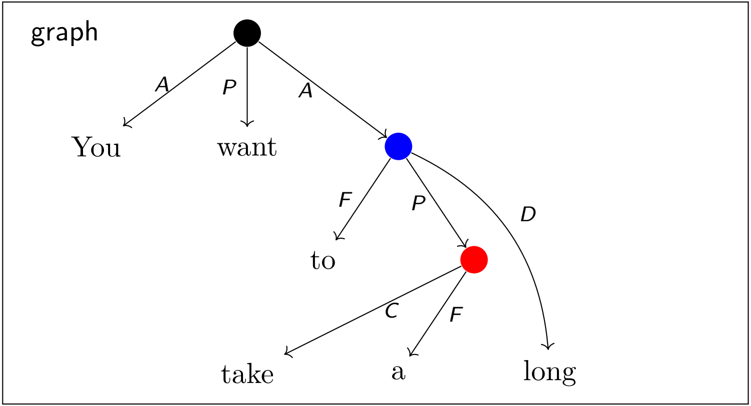
Transition-Based UCCA Parsing

⇒ REDUCE

stack

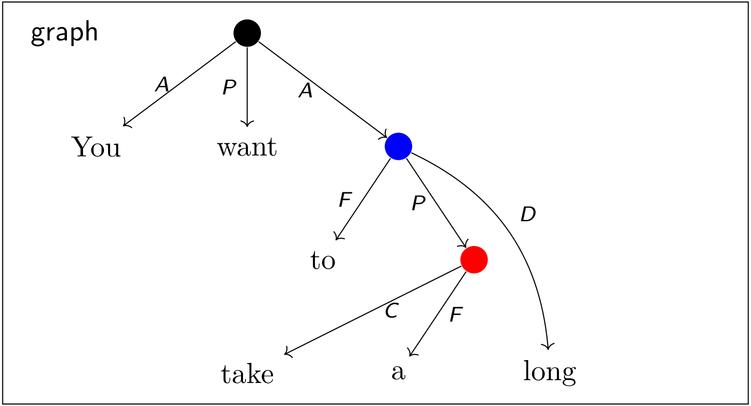
buffer

You	●	bath



Transition-Based UCCA Parsing

⇒ REDUCE



Transition-Based UCCA Parsing

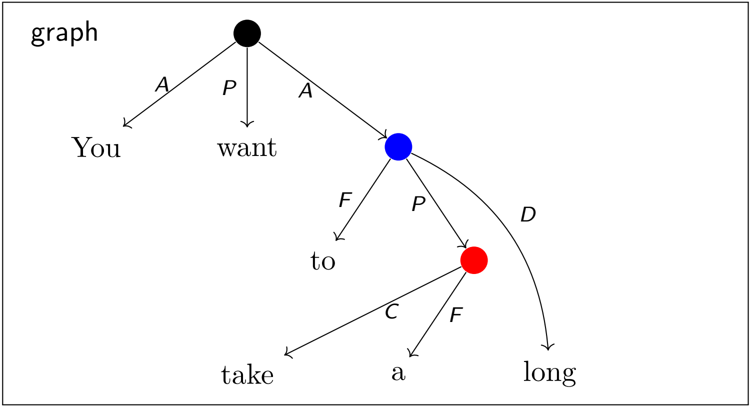
⇒ SHIFT

stack

You

buffer

bath



Transition-Based UCCA Parsing

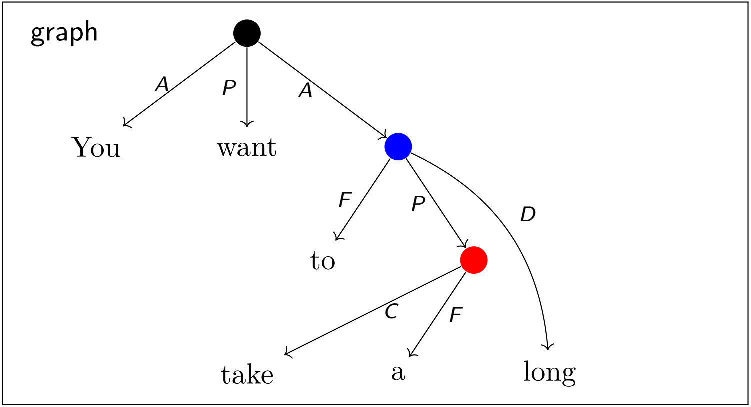
⇒ SHIFT

stack

You	

buffer

bath



Transition-Based UCCA Parsing

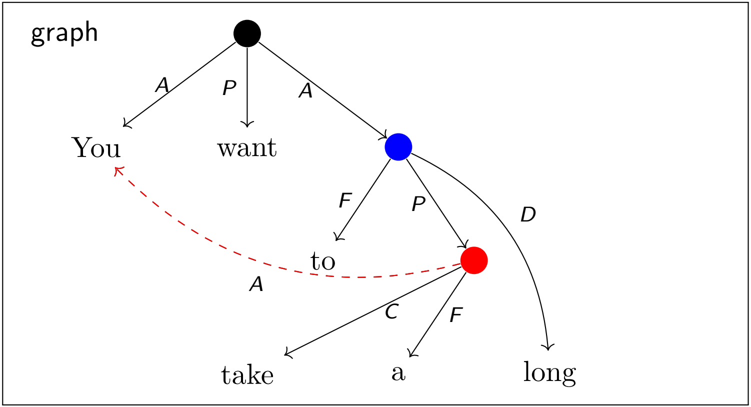
⇒ $\textsc{Left-Remote}_A$

stack

You	●

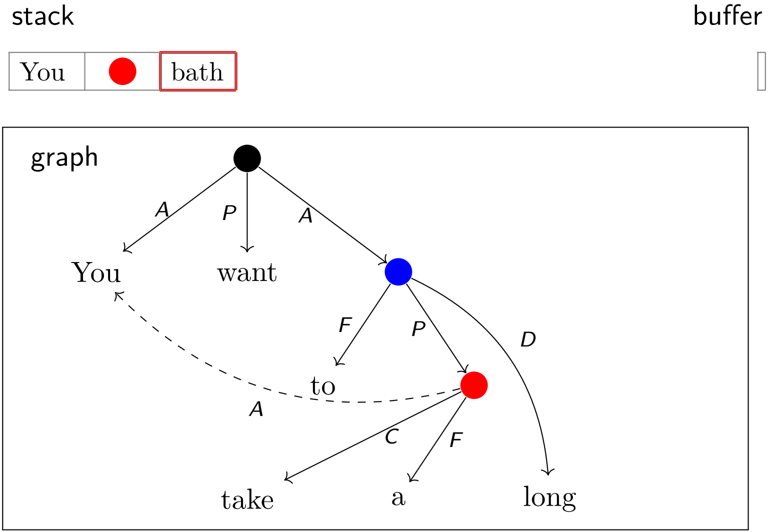
buffer

bath



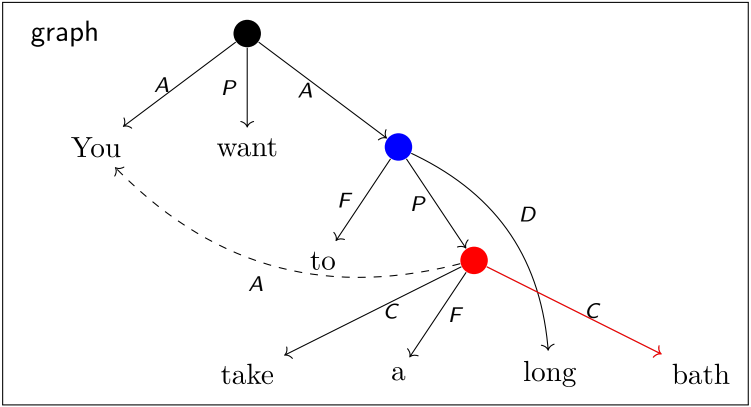
Transition-Based UCCA Parsing

⇒ Shift



Transition-Based UCCA Parsing

$\Rightarrow$ RIGHT-EDGE$_C$

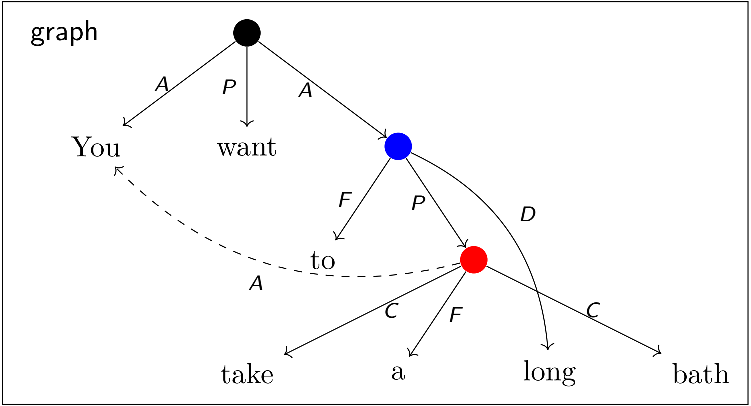


Transition-Based UCCA Parsing

⇒ FINISH

stack

buffer

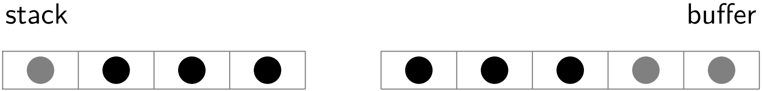


TUPA Model

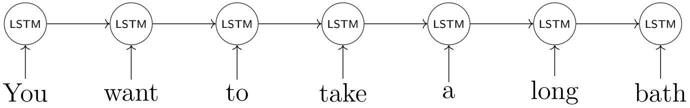
Greedy parsing, experimenting with three classifiers:

Sparse	Perceptron with sparse features.
MLP	Embeddings + feedforward NN classifier.
BiLSTM	Embeddings + deep bidirectional LSTM + MLP (Kiperwasser and Goldberg, 2016).

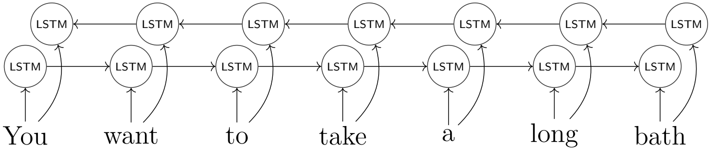
Features: words, POS, syntactic dependencies, existing edge labels from the stack and buffer + parents, children, grandchildren; ordinal features (height, number of parents and children)



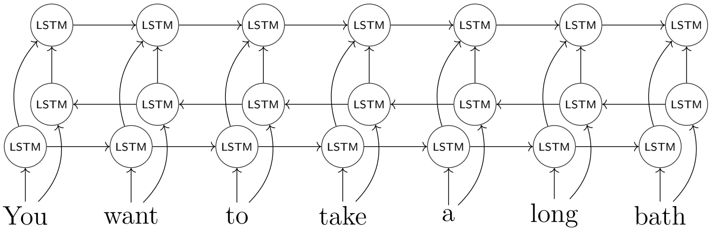
BiLSTM


LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
You
want
to
take
a
long
bath

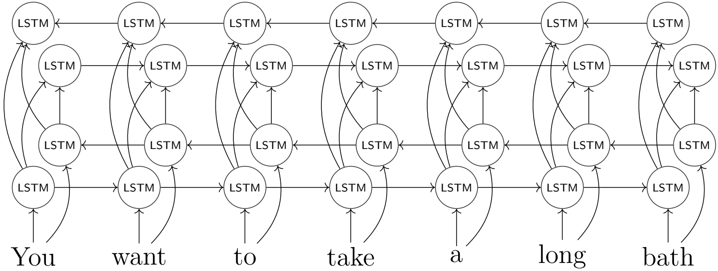
BiLSTM

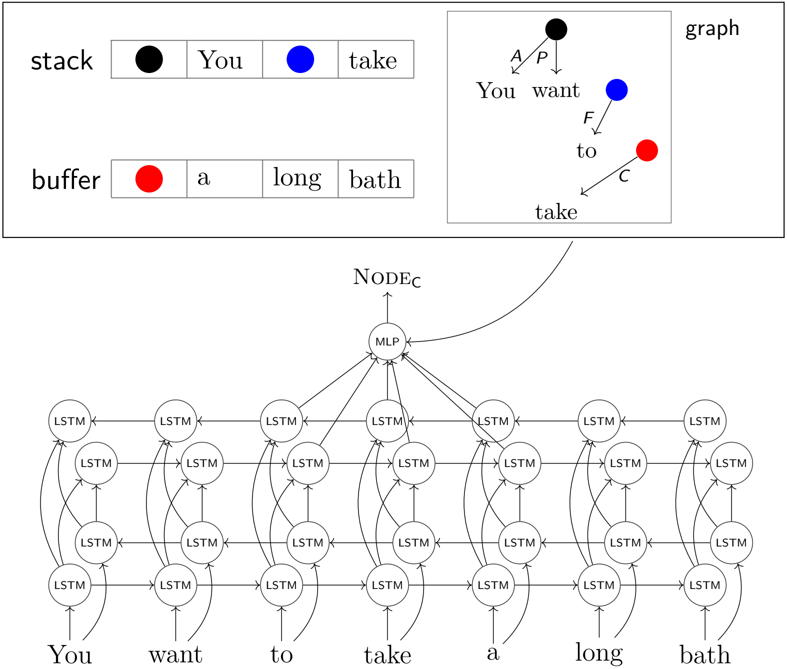


BiLSTM



BiLSTM

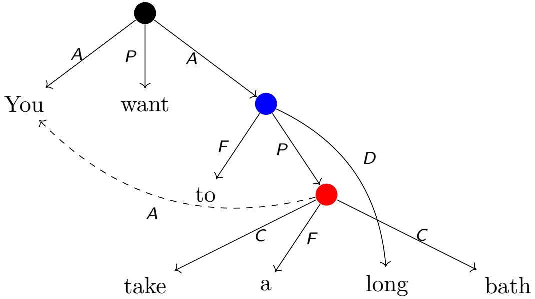




stack
You
take
buffer
a
long
bath
graph
A
P
You
want
F
to
C
take
NODE_C
MLP
LSTM
You
want
to
take
a
long
bath

Training

An *oracle* provides the transition sequence given the correct graph:

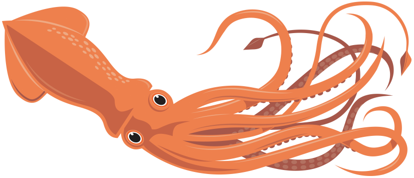


$\Downarrow$

Shift, Right-Edge$_{\text{A}}$, Shift, Swap, Right-Edge$_{\text{P}}$, Reduce, Shift, Shift, Node$_{\text{F}}$, Reduce, Shift, Shift, Node$_{\text{C}}$, Reduce, Shift, Right-Edge$_{\text{P}}$, Shift, Right-Edge$_{\text{F}}$, Reduce, Shift, Swap, Right-Edge$_{\text{D}}$, Reduce, Swap, Right-Edge$_{\text{A}}$, Reduce, Reduce, Shift, Shift, Left-Remote$_{\text{A}}$, Shift, Right-Edge$_{\text{C}}$, Finish

Experimental Setup

- UCCA Wikipedia corpus ($\overset{\text{train}}{4268} + \overset{\text{dev}}{454} + \overset{\text{test}}{503}$ sentences).
- Out-of-domain: English part of English-French parallel corpus, *Twenty Thousand Leagues Under the Sea* (506 sentences).



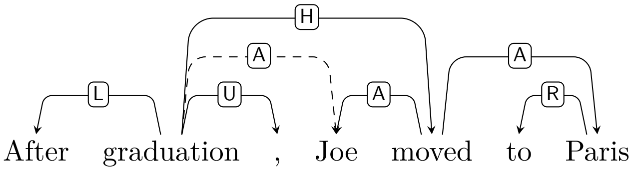
Baselines

Bilexical DAG parsers (allow reentrancy):

- DAGParser (Ribeyre et al., 2014): transition-based.
- TurboParser (Almeida and Martins, 2015): graph-based.

Tree parsers (all transition-based):

- MaltParser (Nivre et al., 2007): bilexical tree parser.
- LSTM Parser (Dyer et al., 2015): bilexical tree parser, NN.
- UPARSE (Maier, 2015): allows non-terminals, discontinuity.



Bilexical DAG approximation (for tree, delete remote edges).

Results

$\text{TUPA}_{\text{BiLSTM}}$ obtains the highest F-scores in all metrics:

	Primary			Remote		
	LP	**LR**	**LF**	**LP**	**LR**	**LF**
$\text{TUPA}_{\text{Sparse}}$	64.5	63.7	64.1	19.8	13.4	16
TUPA_{MLP}	65.2	64.6	64.9	23.7	13.2	16.9
$\text{TUPA}_{\text{BiLSTM}}$	74.4	72.7	**73.5**	47.4	51.6	**49.4**
Bilexical DAG			(91)			(58.3)
DAGParser	61.8	55.8	58.6	9.5	0.5	1
TurboParser	57.7	46	51.2	77.8	1.8	3.7
Bilexical tree			(91)			–
MaltParser	62.8	57.7	60.2	–	–	–
LSTM Parser	73.2	66.9	69.9	–	–	–
Tree			(100)			–
UPARSE	60.9	61.2	61.1	–	–	–

Results on the Wiki test set.

Results

Comparable out-of-domain test set:

	Primary			Remote		
	LP	**LR**	**LF**	**LP**	**LR**	**LF**
$\text{TUPA}_{\text{Sparse}}$	59.6	59.9	59.8	22.2	7.7	11.5
TUPA_{MLP}	62.3	62.6	62.5	20.9	6.3	9.7
$\text{TUPA}_{\text{BiLSTM}}$	68.7	68.5	**68.6**	38.6	18.8	**25.3**
Bilexical DAG			(91.3)			(43.4)
DAGParser	56.4	50.6	53.4	–	0	0
TurboParser	50.3	37.7	43.1	100	0.4	0.8
Bilexical tree			(91.3)			–
MaltParser	57.8	53	55.3	–	–	–
LSTM Parser	66.1	61.1	63.5	–	–	–
Tree			(100)			–
UPARSE	52.7	52.8	52.8	–	–	–

Results on the 20K Leagues out-of-domain set.

Conclusion

- UCCA's semantic distinctions require a graph structure including non-terminals, reentrancy and discontinuity.
- TUPA is an accurate transition-based UCCA parser, and the first to support any DAG over the text's tokens.
- Outperforms strong conversion-based baselines.

Code: `https://github.com/danielhers/tupa`
Demo: `http://bit.ly/tupademo`
Corpora: `http://www.cs.huji.ac.il/~oabend/ucca.html`

Conclusion

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Future Work:

- More languages (German corpus construction is underway).
- Parsing other schemes, such as AMR.
- Text simplification, MT evaluation and other applications.

Code: `https://github.com/danielhers/tupa`
Demo: `http://bit.ly/tupademo`
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Thank you

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UCCA Corpora

	Wiki			20K
	Train	Dev	Test	Leagues
# passages	300	34	33	154
# sentences	4268	454	503	506
# nodes	298,993	33,704	35,718	29,315
% terminal	42.96	43.54	42.87	42.09
% non-term.	58.33	57.60	58.35	60.01
% **discont.**	**0.54**	**0.53**	**0.44**	**0.81**
% **reentrant**	**2.38**	**1.88**	**2.15**	**2.03**
# edges	287,914	32,460	34,336	27,749
% primary	98.25	98.75	98.74	97.73
% remote	1.75	1.25	1.26	2.27
Average per non-terminal node				
# children	1.67	1.68	1.66	1.61

Corpus statistics.

Evaluation

Mutual edges between predicted graph $G_p = (V_p, E_p, \ell_p)$ and gold graph $G_g = (V_g, E_g, \ell_g)$, both over terminals $W = \{w_1, \ldots, w_n\}$:

$$M(G_p, G_g) = \left\{(e_1, e_2) \in E_p \times E_g \;\middle|\; y(e_1) = y(e_2) \wedge \ell_p(e_1) = \ell_g(e_2)\right\}$$

The yield $y(e) \subseteq W$ of an edge $e = (u, v)$ in either graph is the set of terminals in W that are descendants of v. ℓ is the edge label.

Labeled precision, recall and F-score are then defined as:

$$\mathrm{LP} = \frac{|M(G_p, G_g)|}{|E_p|}, \quad \mathrm{LR} = \frac{|M(G_p, G_g)|}{|E_g|},$$

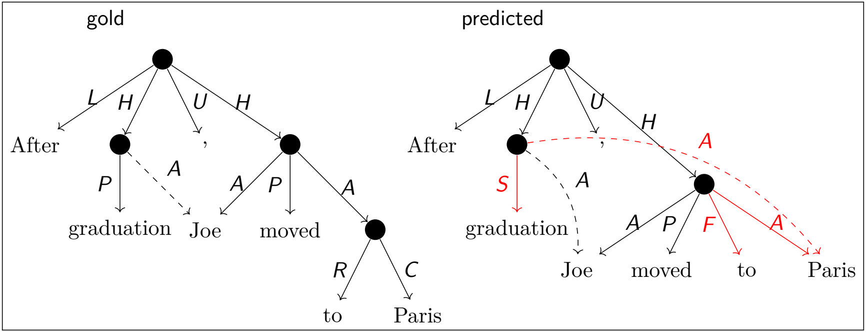
$$\mathrm{LF} = \frac{2 \cdot \mathrm{LP} \cdot \mathrm{LR}}{\mathrm{LP} + \mathrm{LR}}.$$

Two variants: one for primary edges, and another for remote edges.

Evaluation

Comparing graphs over the same sequence of tokens,

- Match edges by their terminal yield and label.
- Calculate labeled precision, recall and F1 scores.
- Separate primary and remote edges.



Primary:

LP	LR	LF
$\frac{6}{9} = 67\%$	$\frac{6}{10} = 60\%$	64%

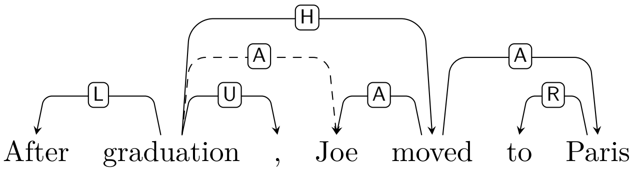
Remote:

LP	LR	LF
$\frac{1}{2} = 50\%$	$\frac{1}{1} = 100\%$	67%

Bilexical Graph Approximation

No existing UCCA parsers ⇒ compare to bilexical parsers:

1. Convert UCCA to bilexical dependencies.
2. Train bilexical parsers and apply to test sentences.
3. Reconstruct UCCA graphs and compare with gold standard.



Bilexical DAG approximation (for tree, delete remote edges).