VirginiaTech

Deep Learning Summer School

Beam Search for Top-B Decoding in Bi-RNNs

Qing Sun

Dhruv Batra

Deep Learning Summer School, Montreal, CA

Image captioning

[Karpathy *et al*, CVPR2015]

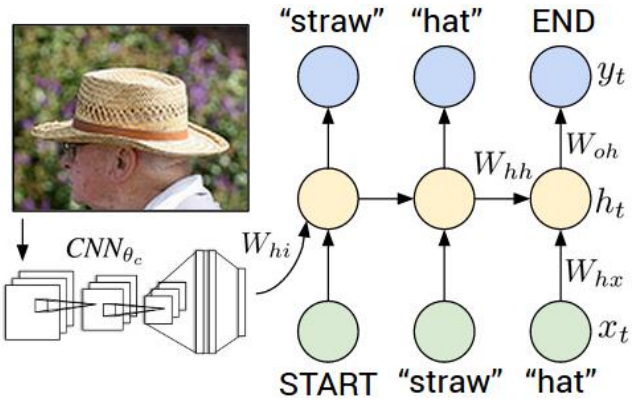
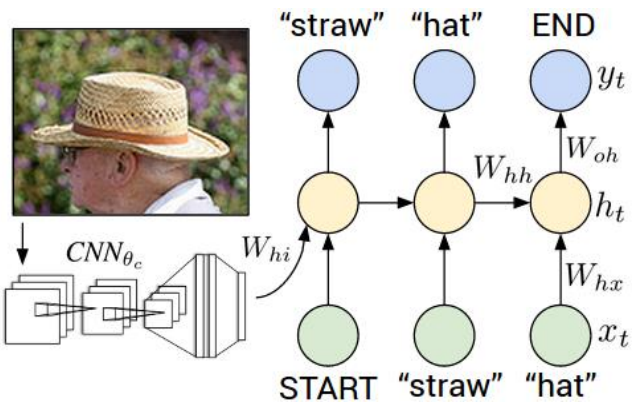


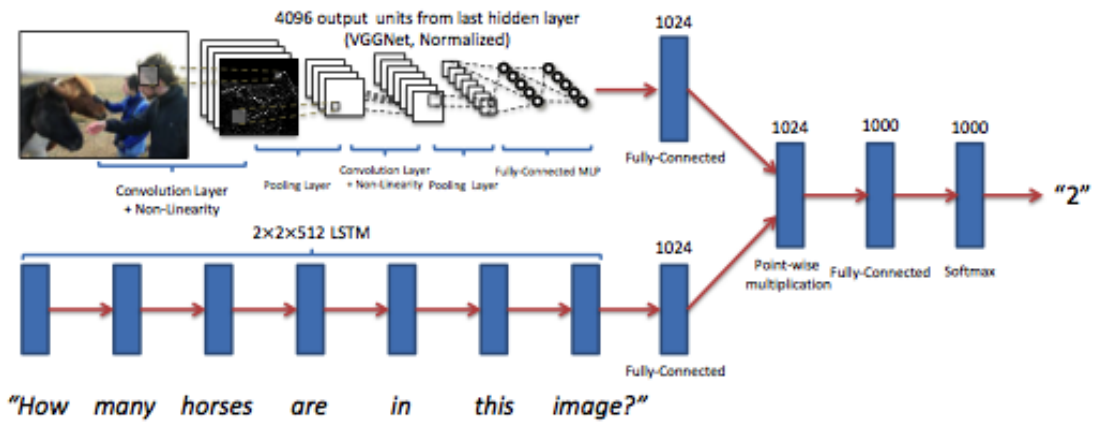
Image captioning

[Karpathy *et al*, CVPR2015]



Visual Question Answering

[Antol *et al*, ICCV 2015]



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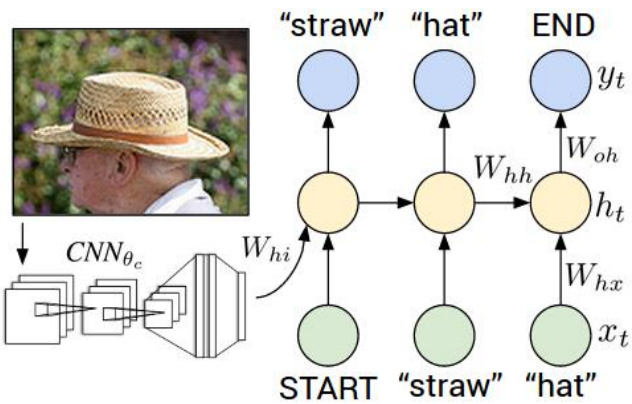

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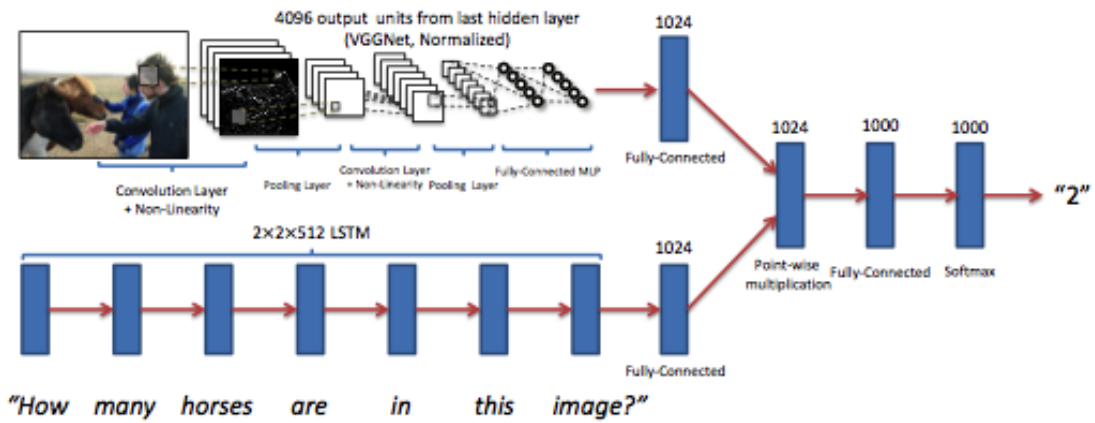
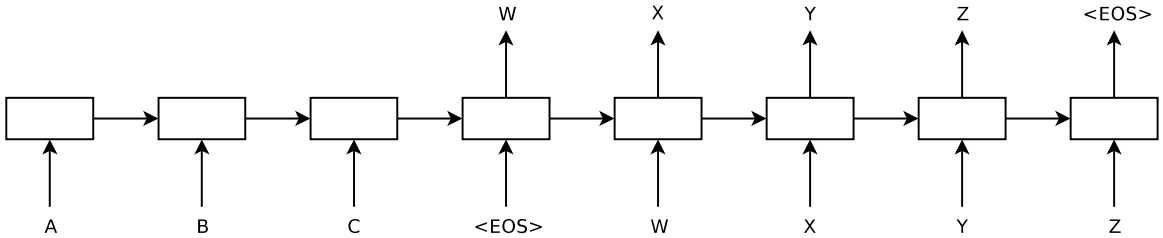


Machine Translation

[Ilya Sutskever *et al*, NIPS 2014]



Encoder vs. Decoder

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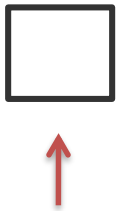
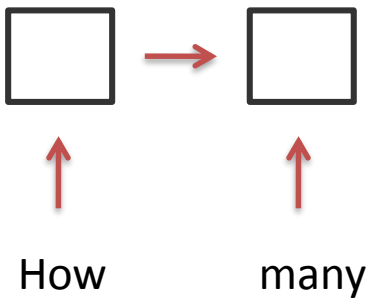


How

Encoder vs. Decoder



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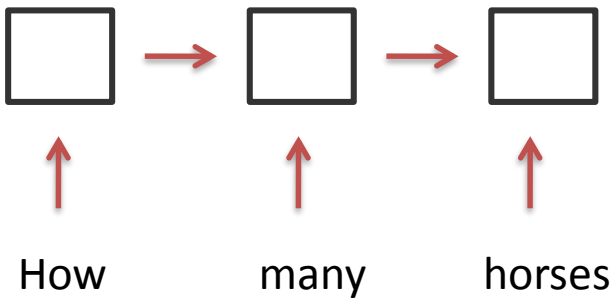

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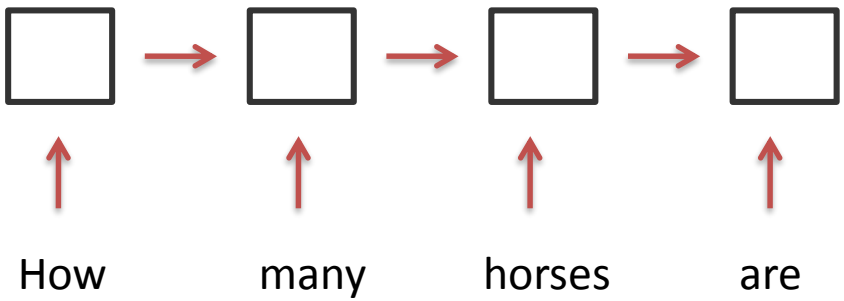

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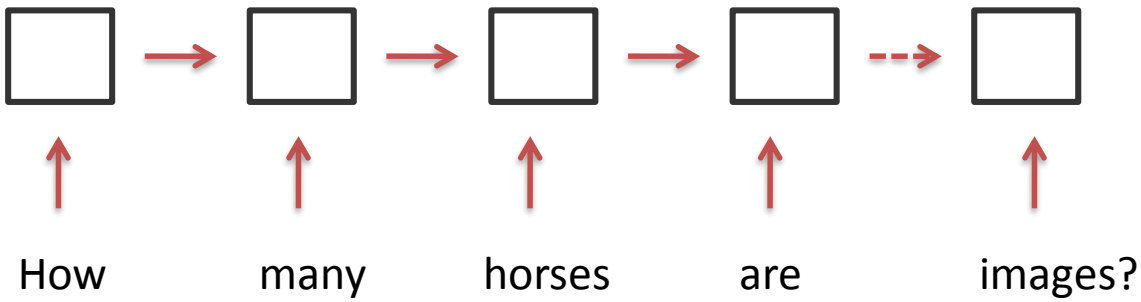

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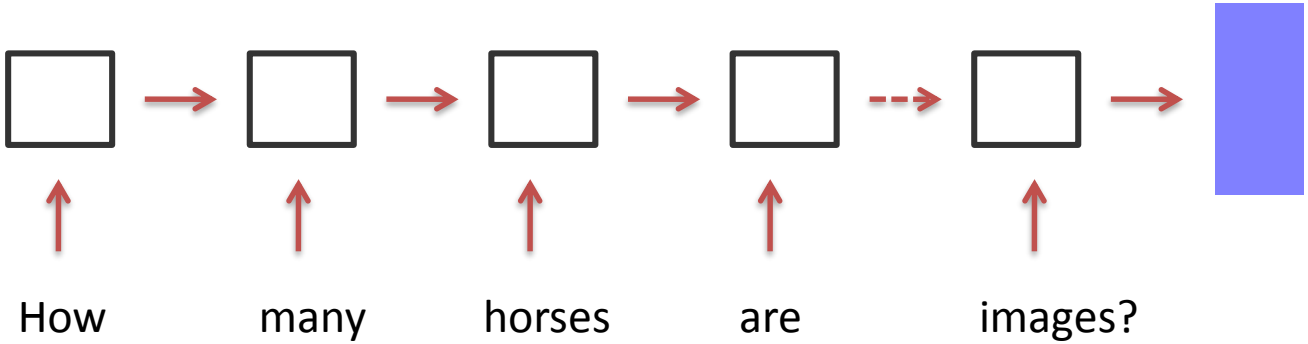

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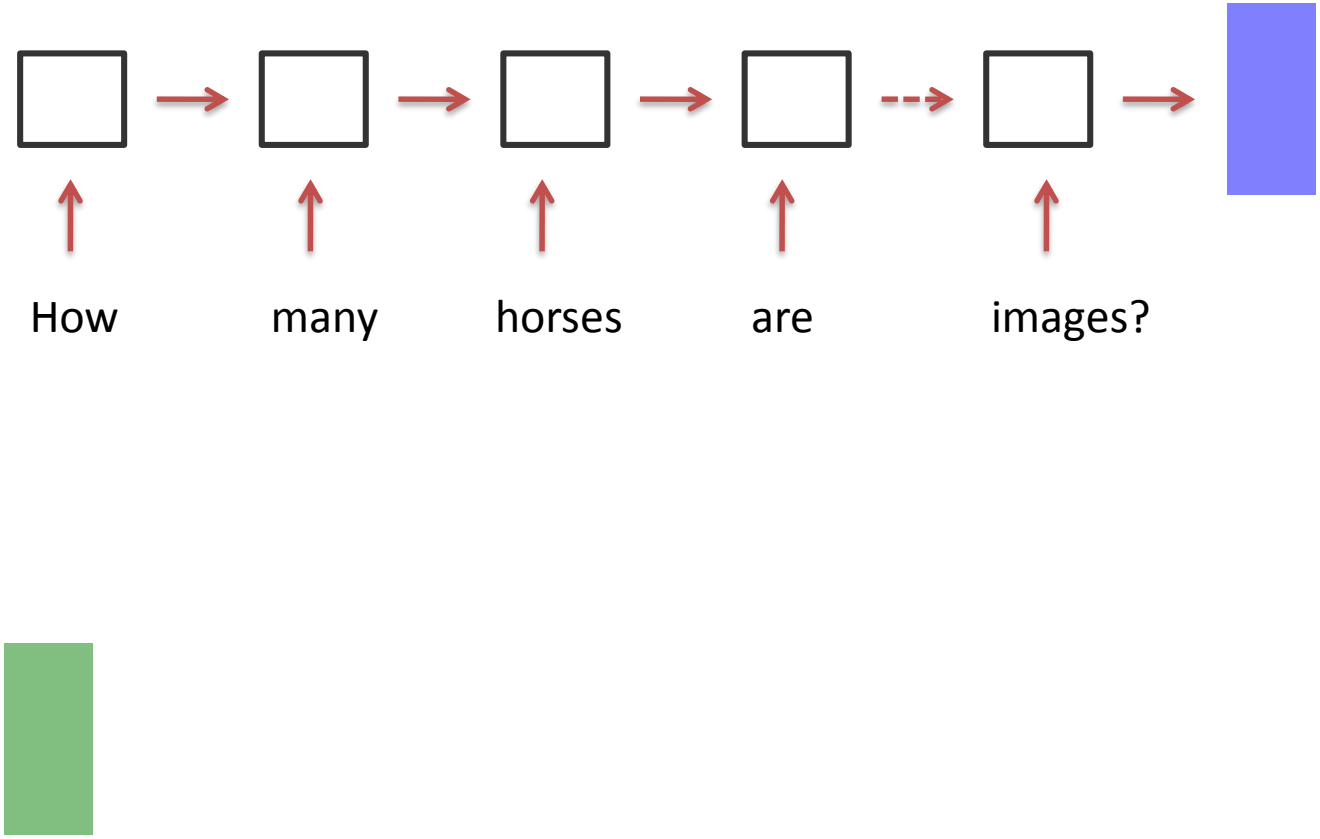

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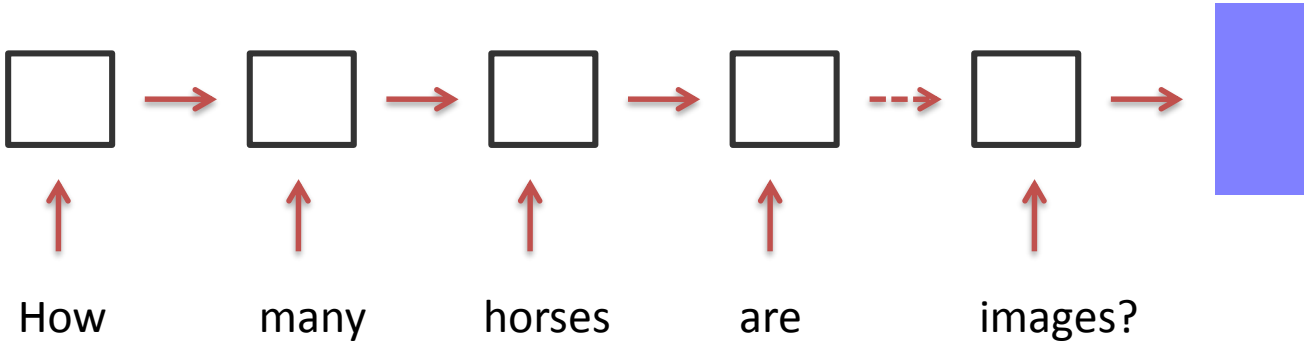

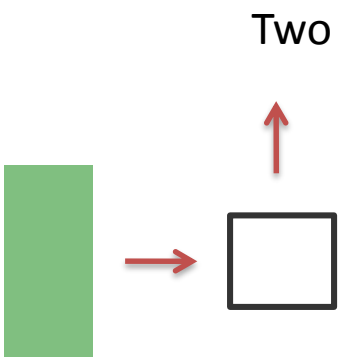

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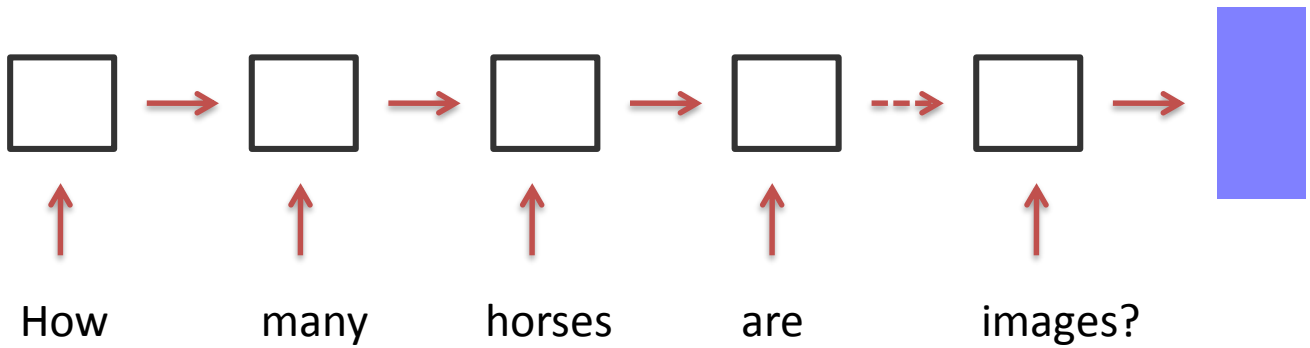

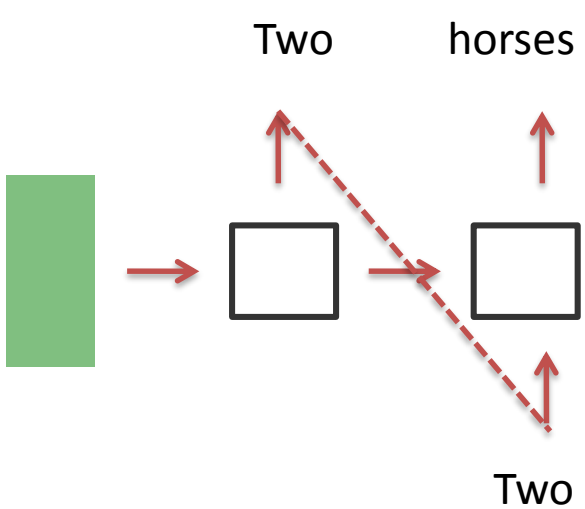

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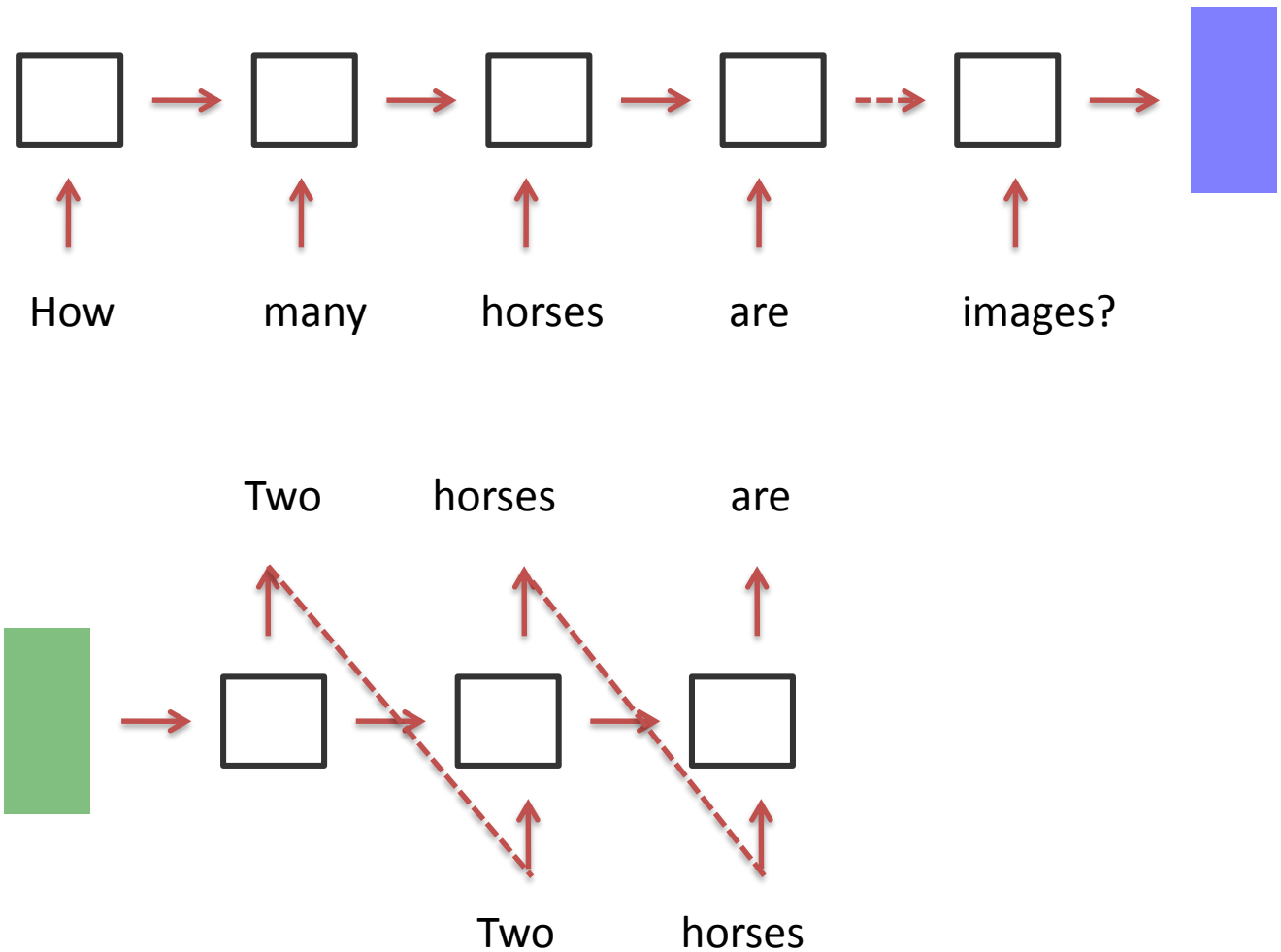

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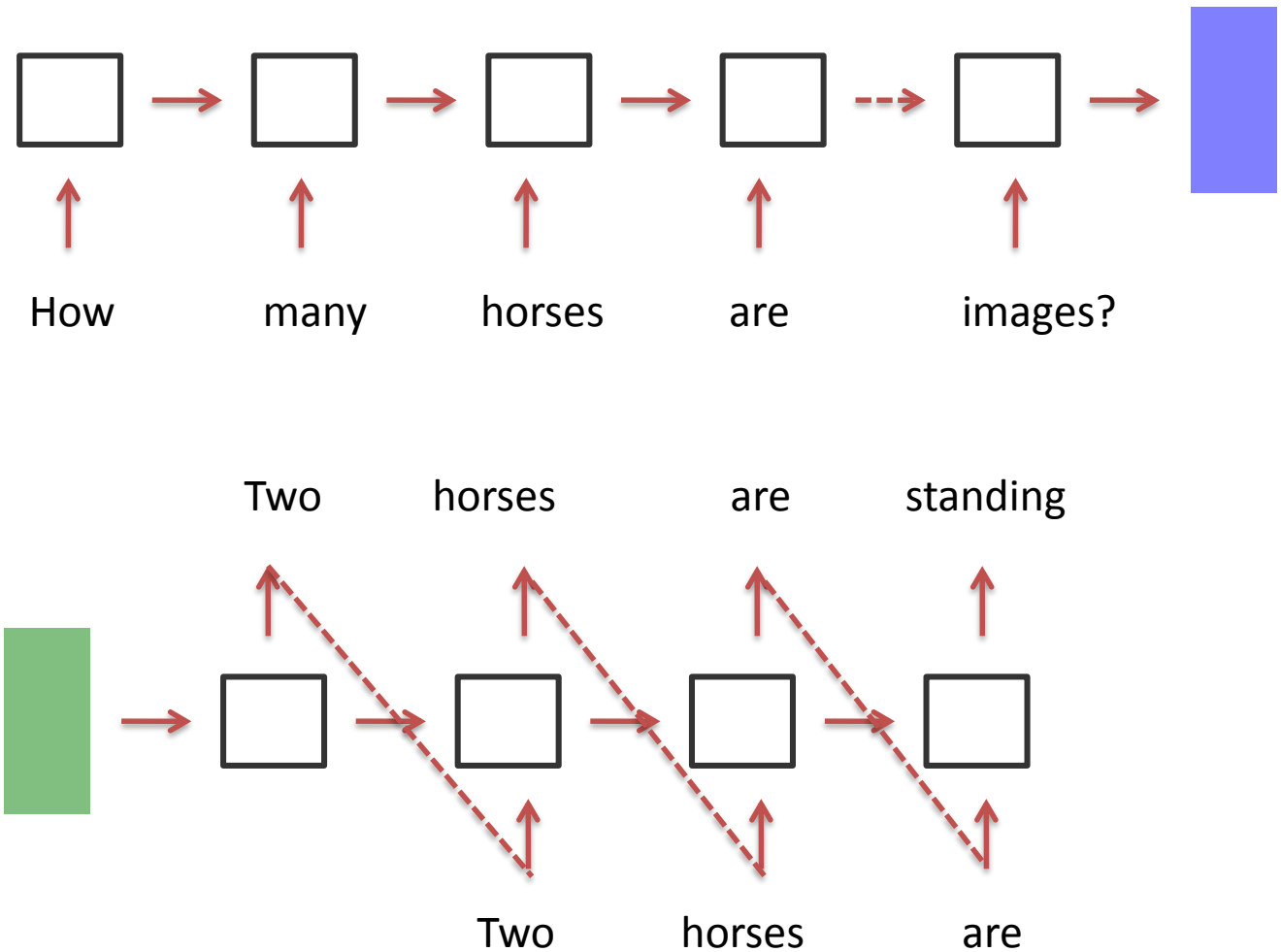

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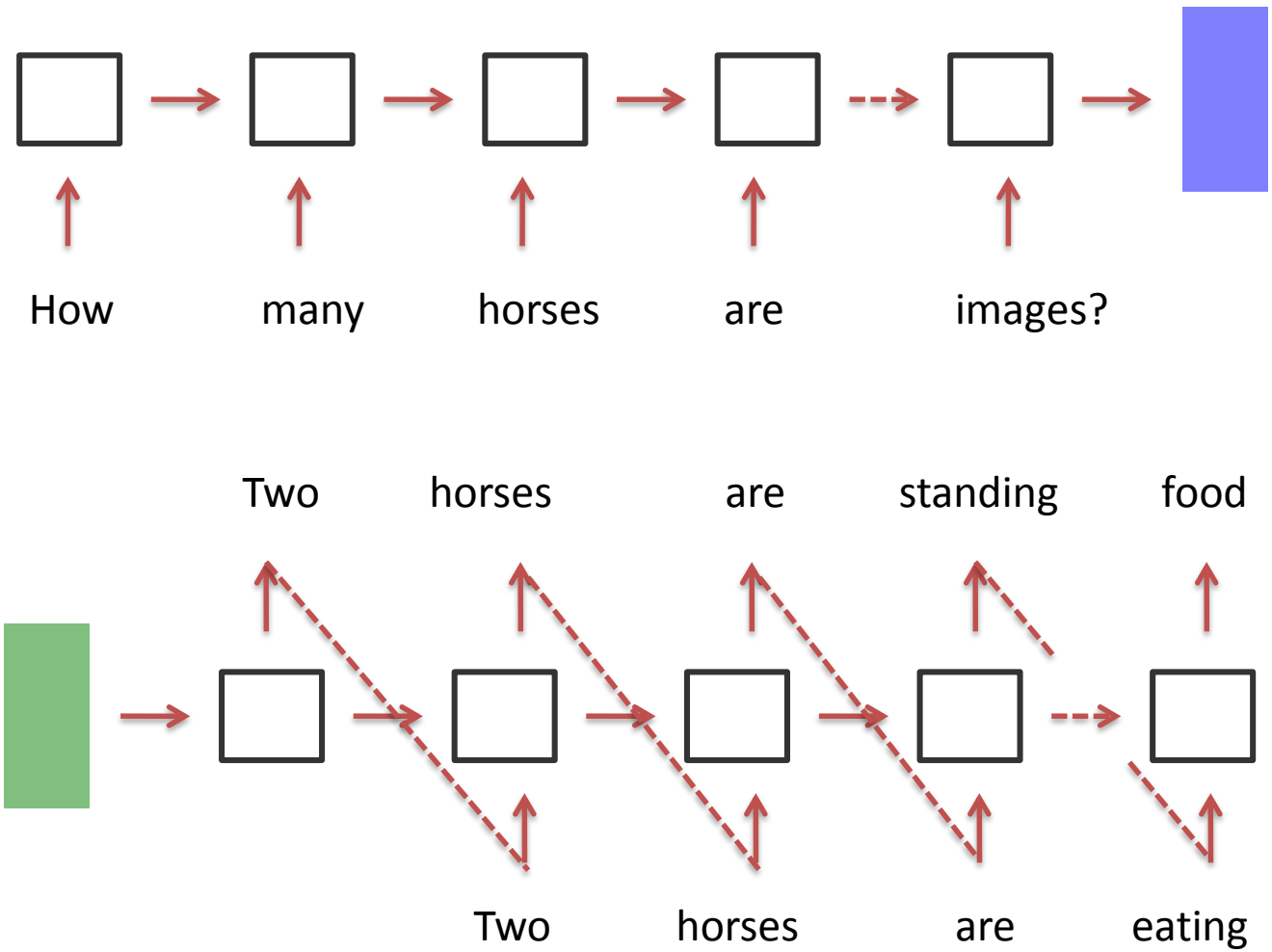
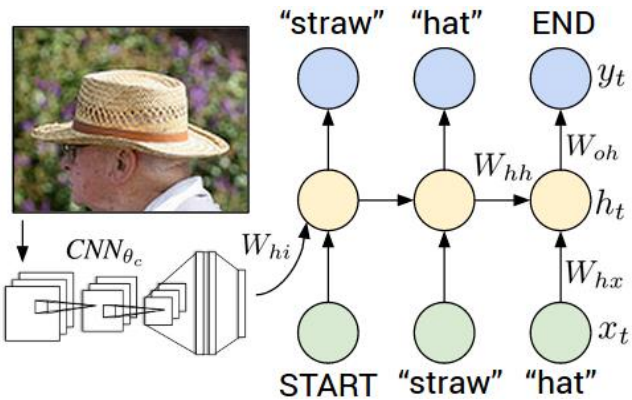


Image captioning

[Karpathy, *etal*, CVPR 2015]



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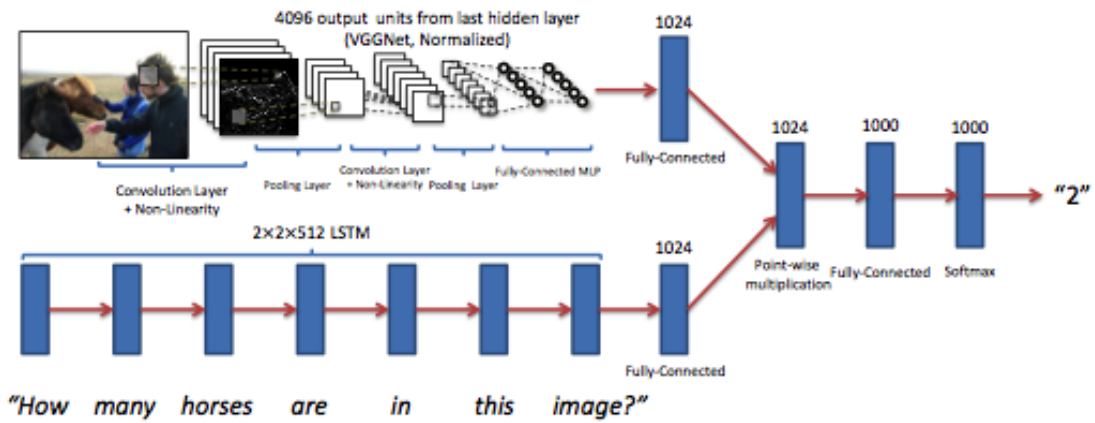

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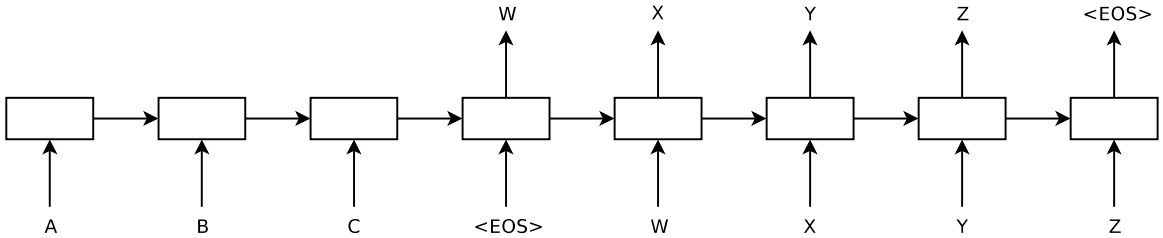

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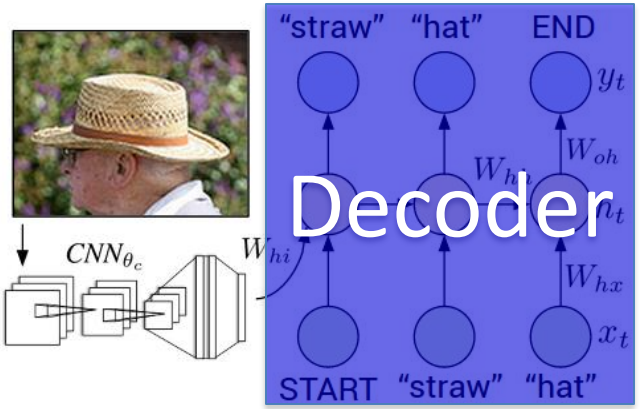

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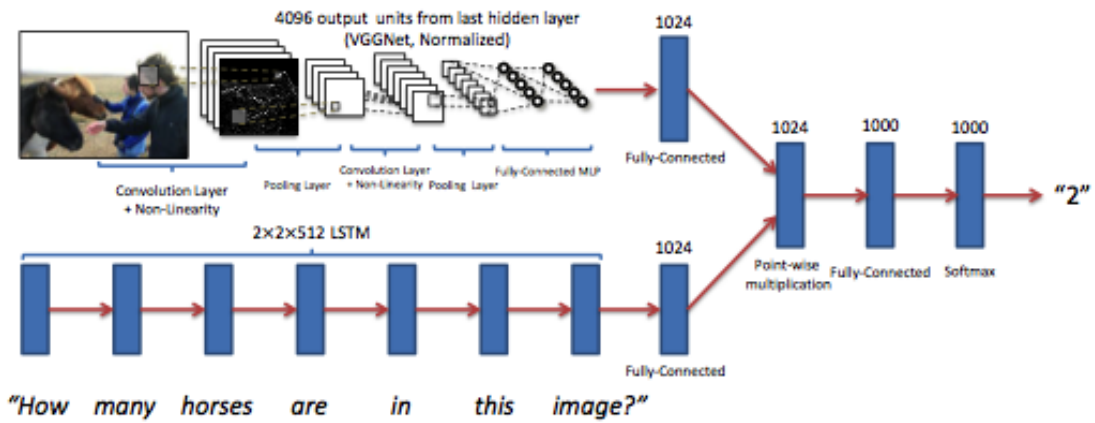

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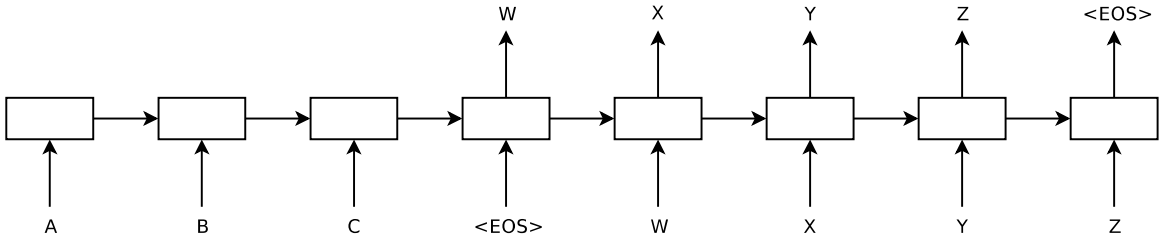

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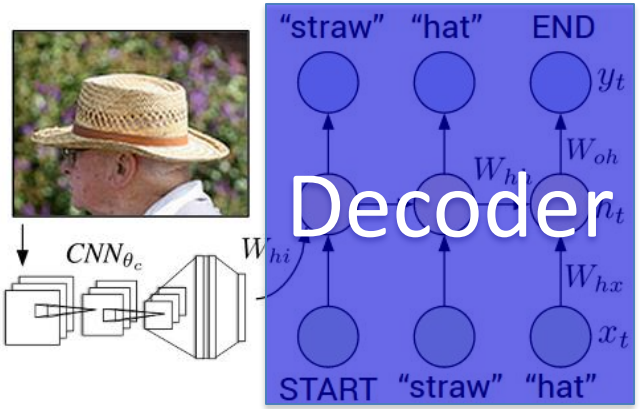

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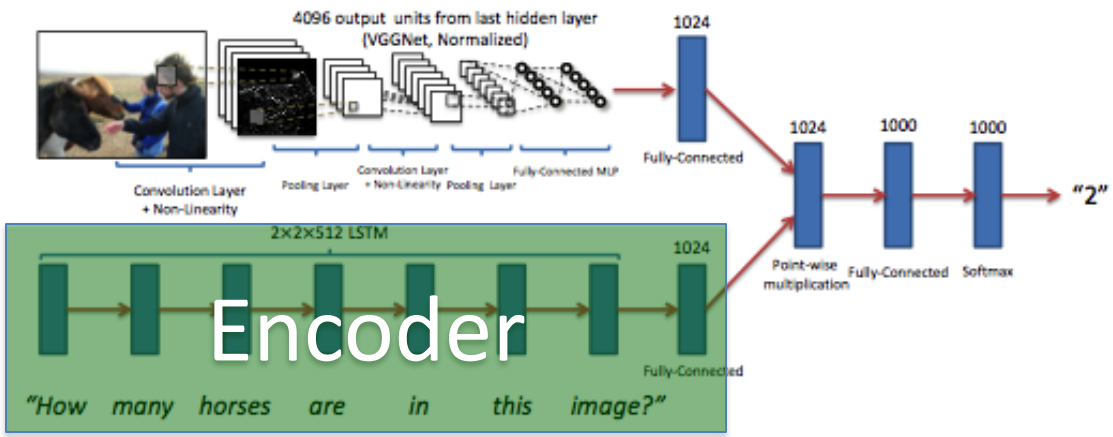

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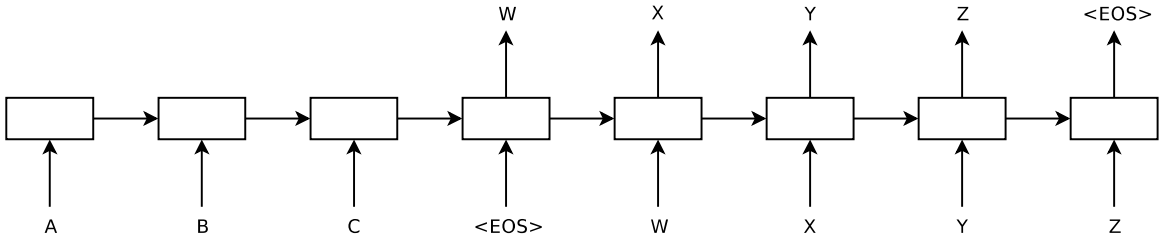

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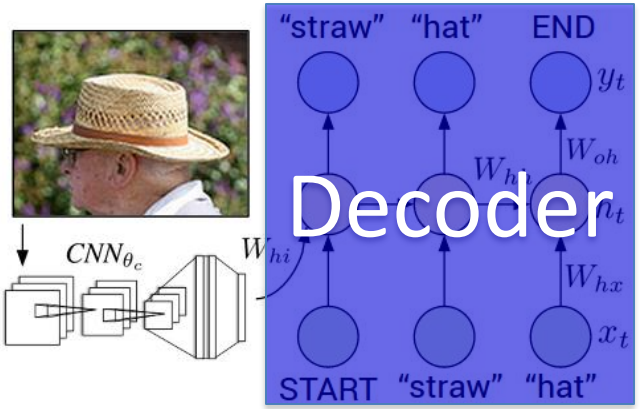

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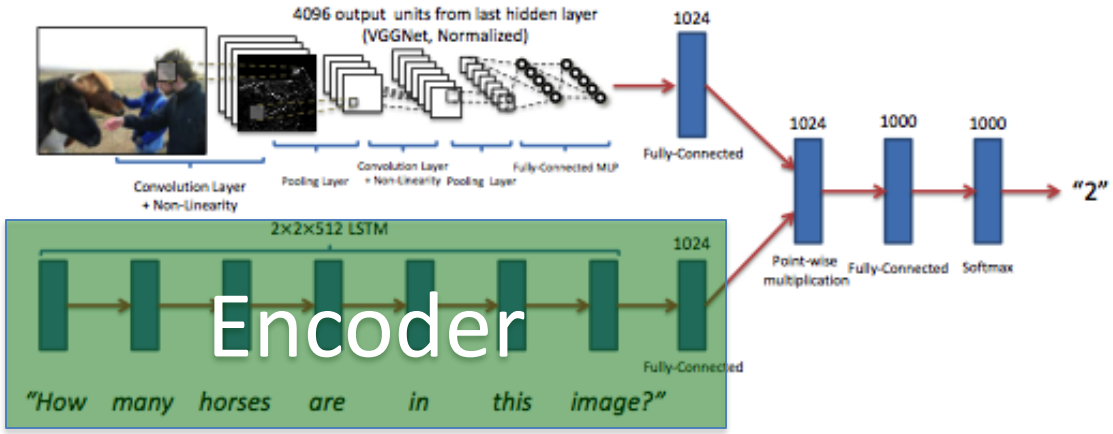

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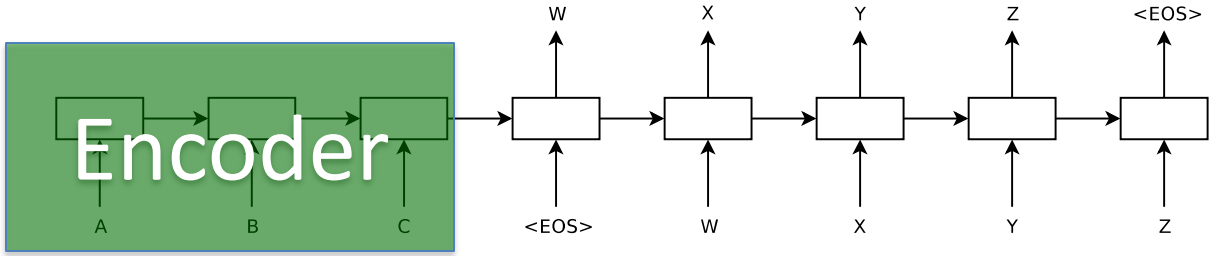

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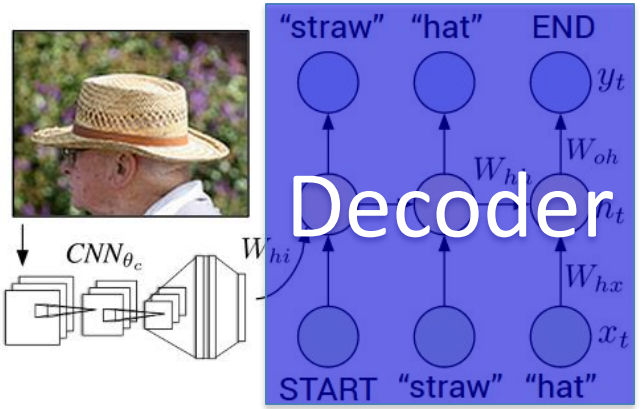

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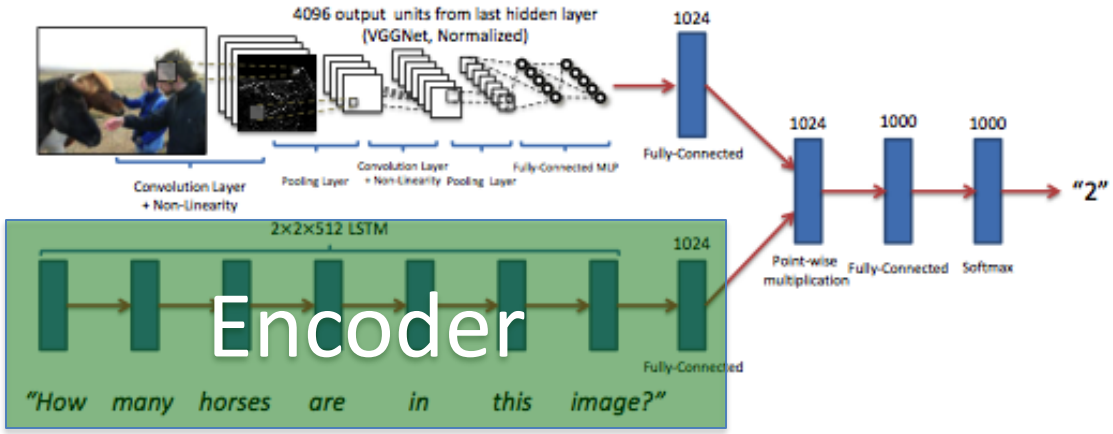

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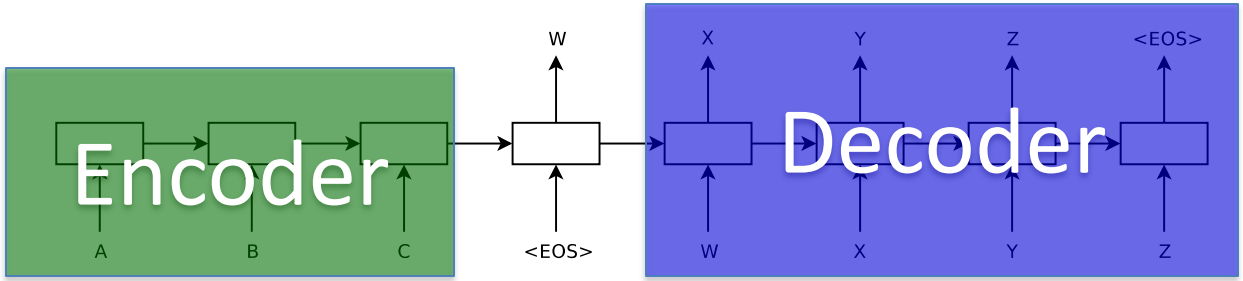

Uni-RNNs vs. Bi-RNNs

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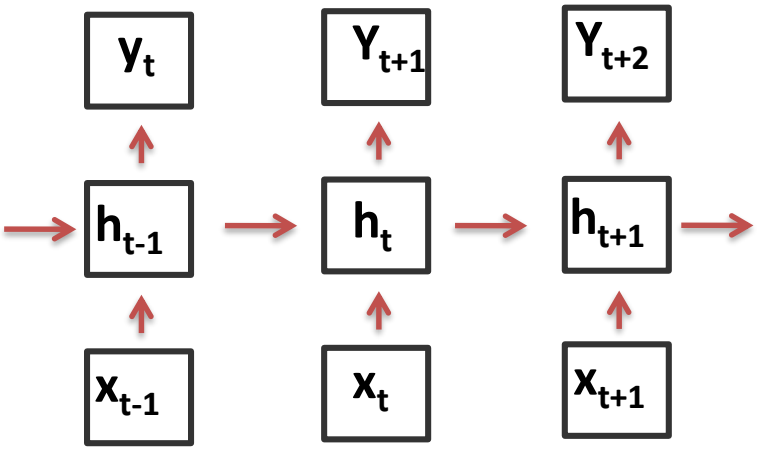
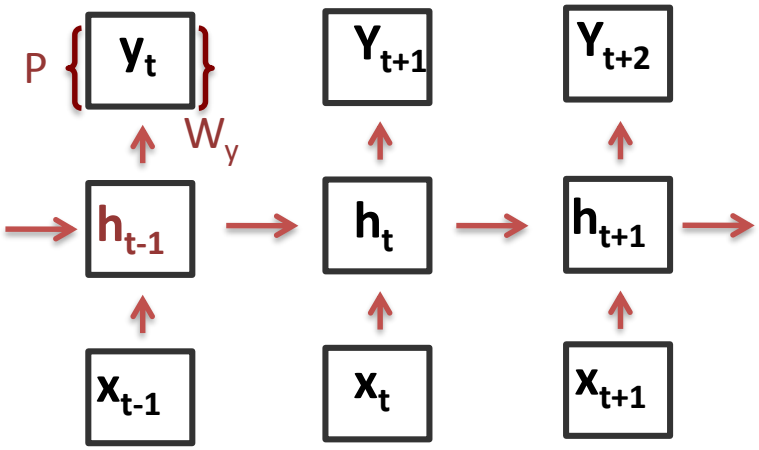


(a) Unidirectional RNNs

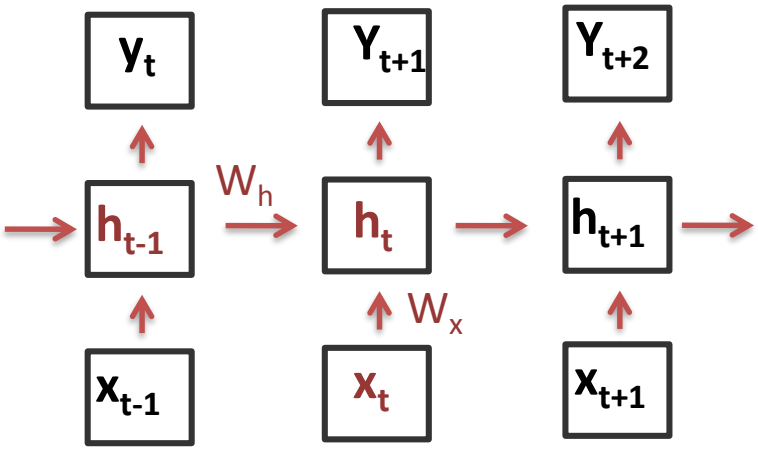
Uni-RNNs vs. Bi-RNNs



(a) Unidirectional RNNs

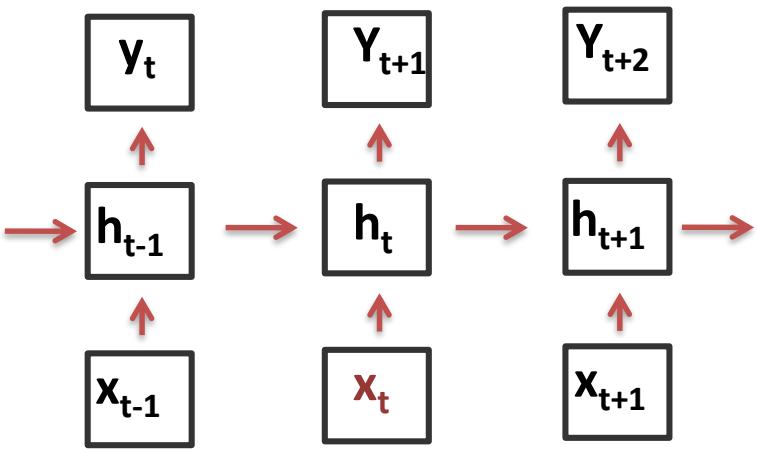
$$p(y_t|X_{[1:t-1]}) = \phi(W_y h_{t-1} + b_y)$$

Uni-RNNs vs. Bi-RNNs



(a) Unidirectional RNNs

$$h_t = \tanh(W_x x_t + W_h h_{t-1} + b_h)$$



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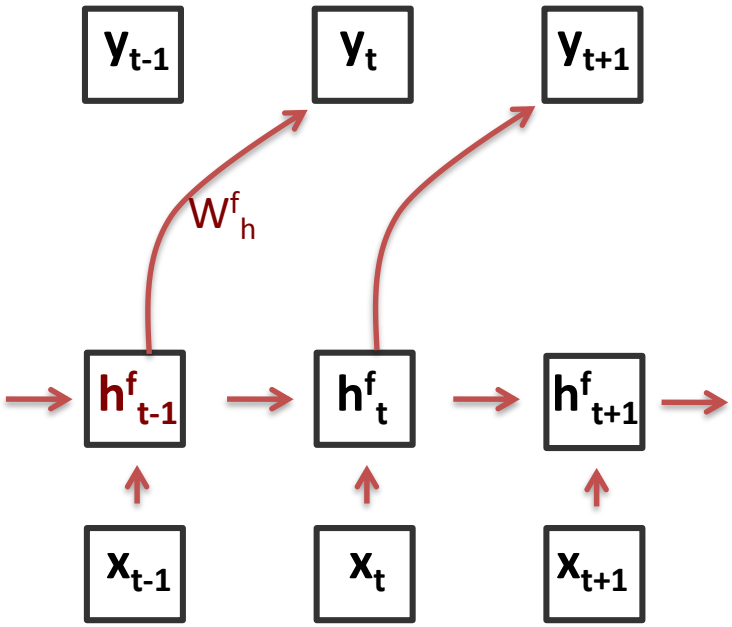
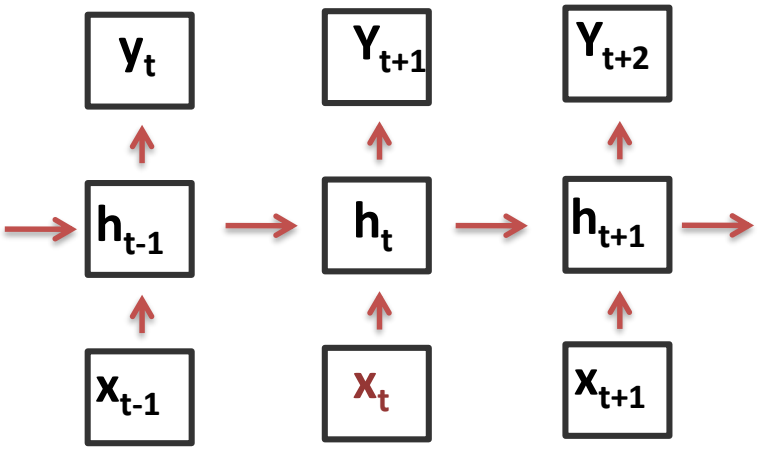


(b) Bidirectional RNNs

$$p(y_t|X_{[1:T]\setminus t}) = \phi(\ W_y^f h_{t-1}^f\ + W_y^b h_{t+1}^b + b_y\ )$$



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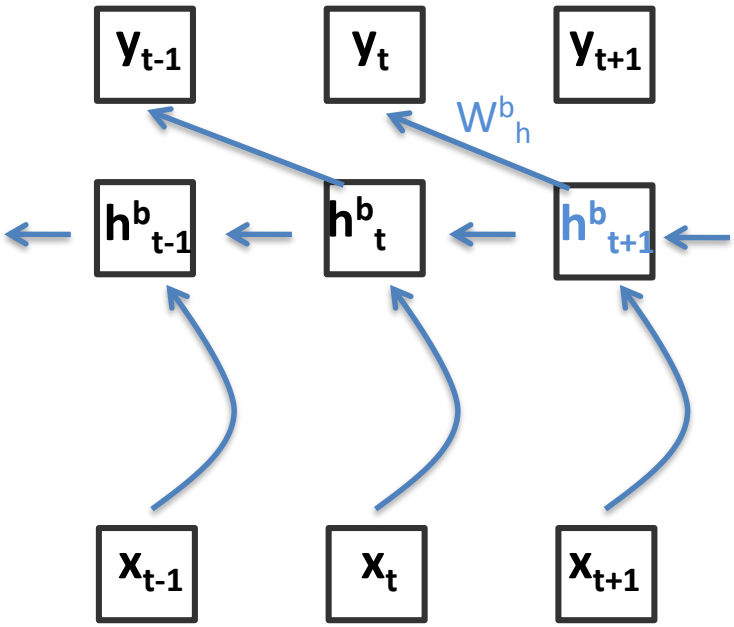

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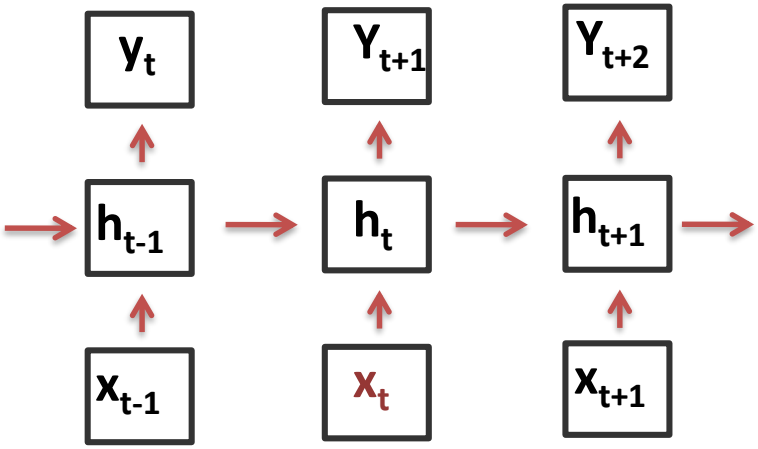

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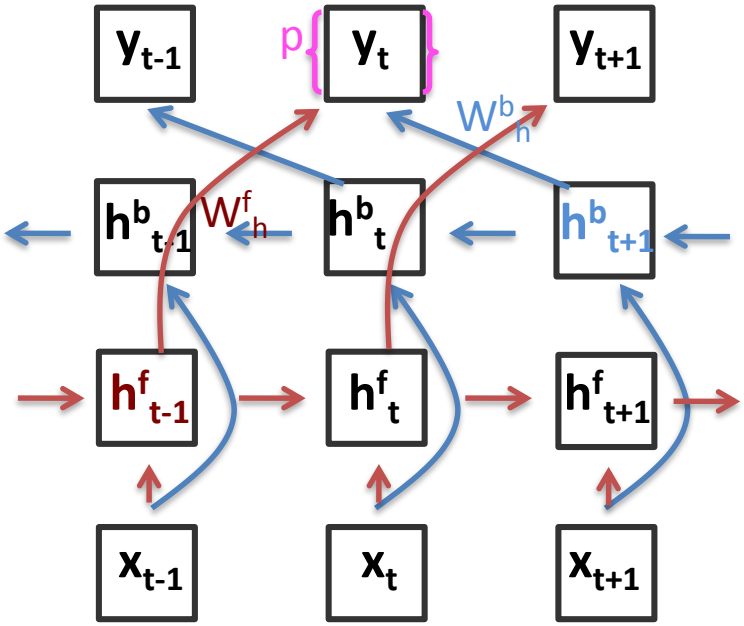

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Left-to-right Beam Search

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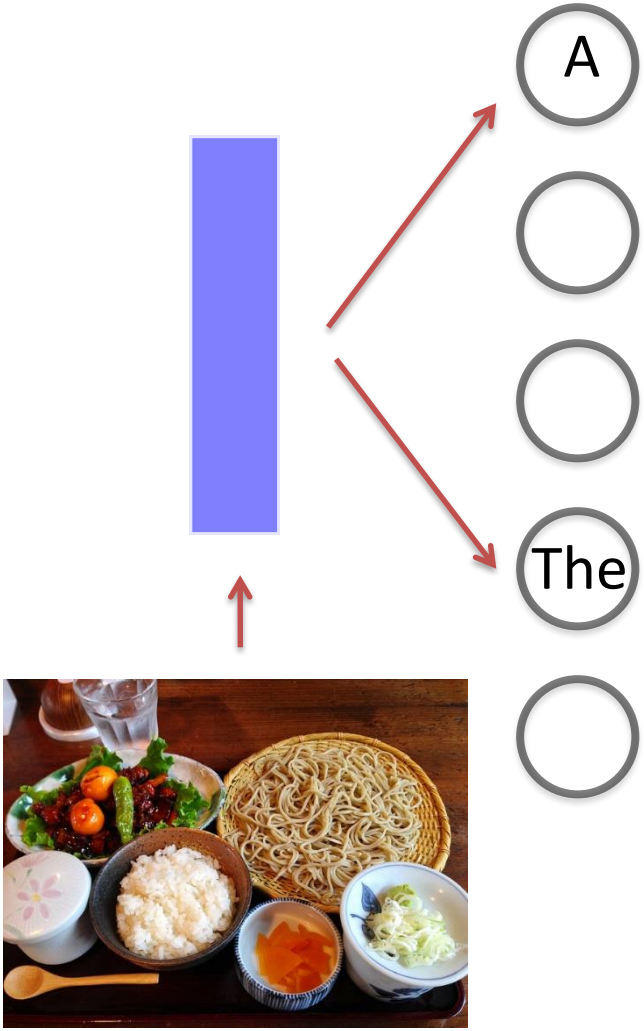

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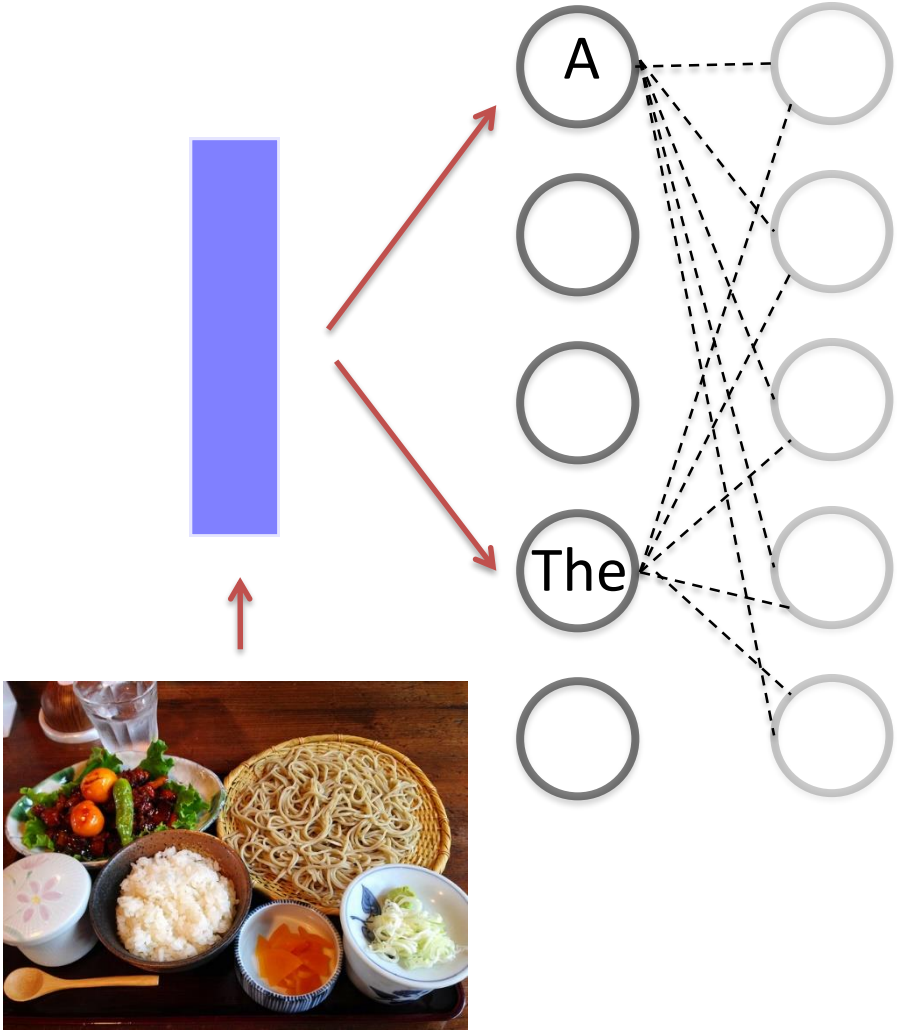

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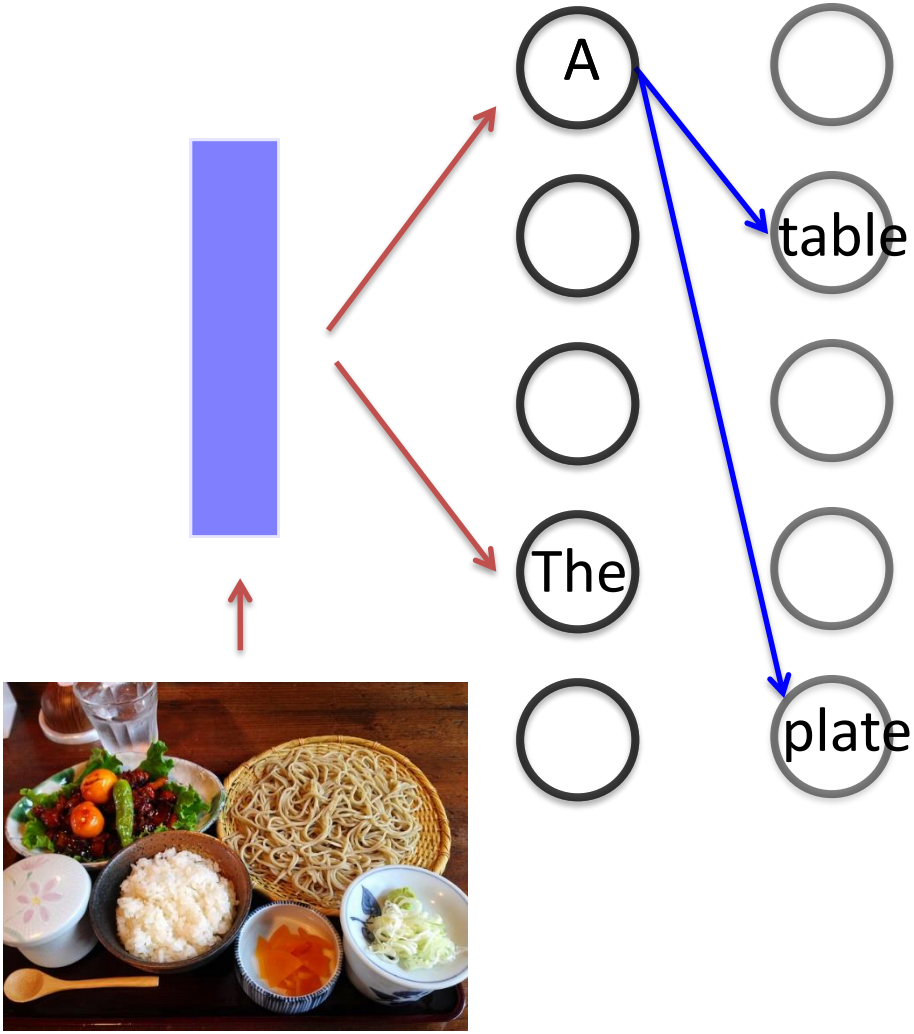

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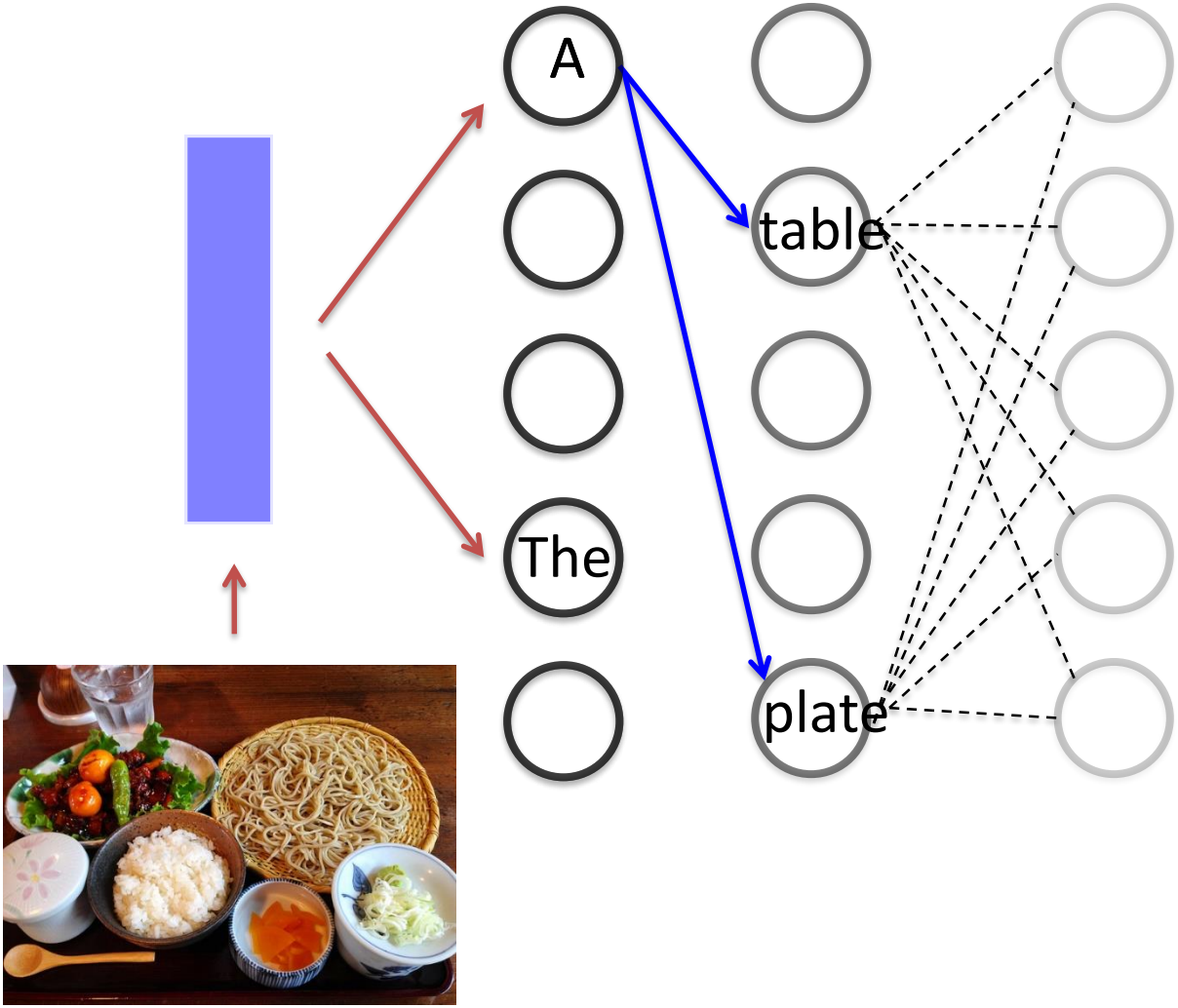

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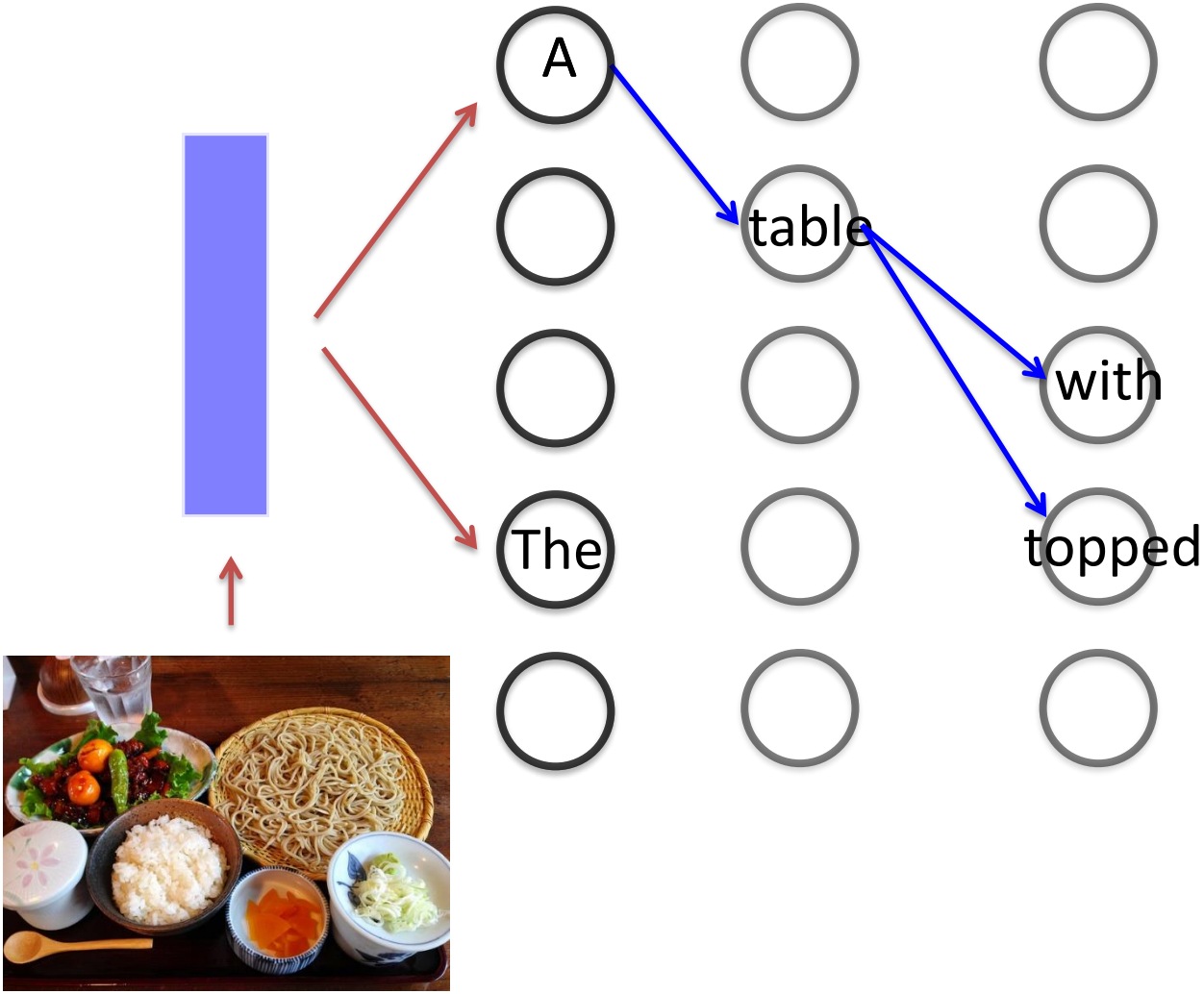

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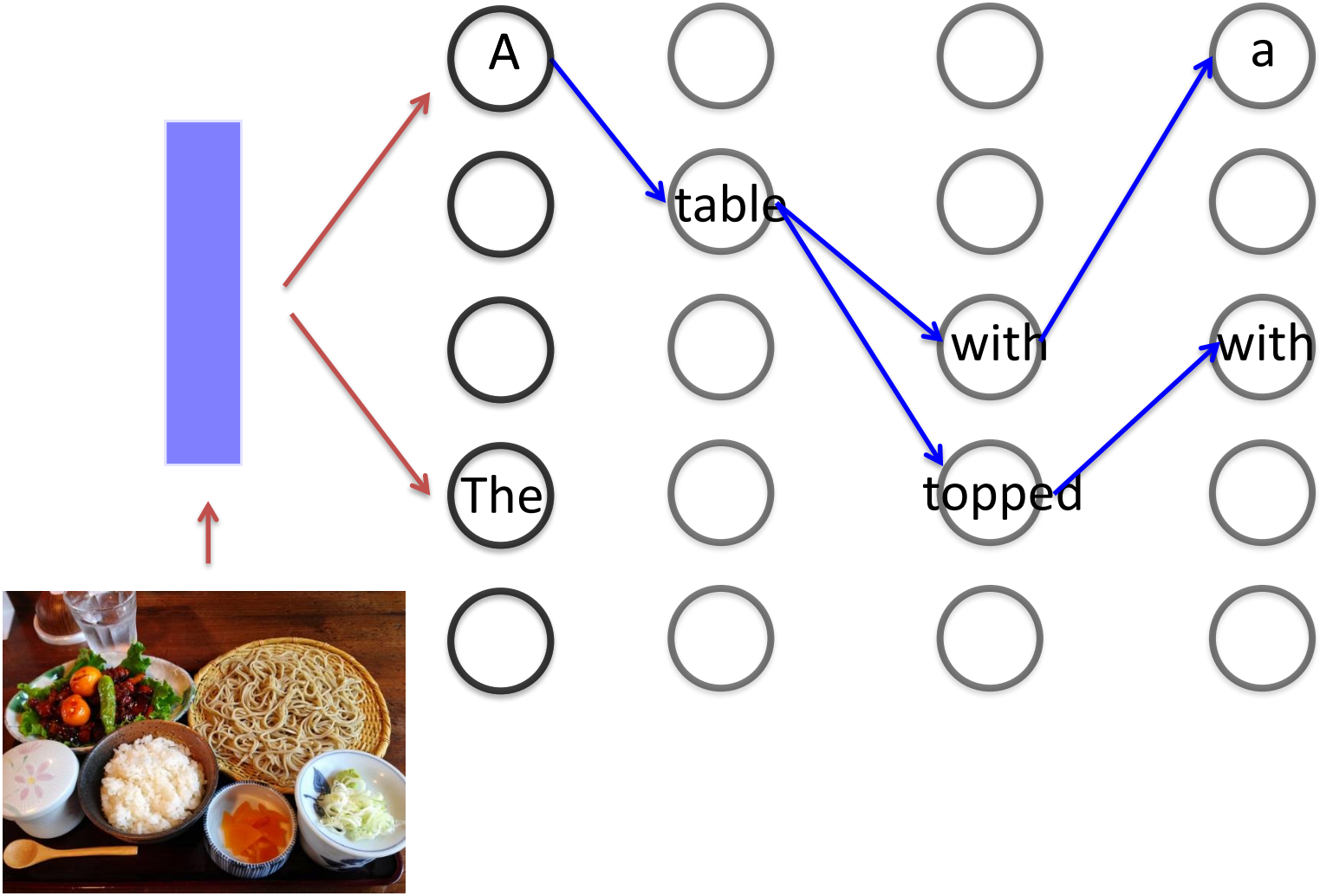

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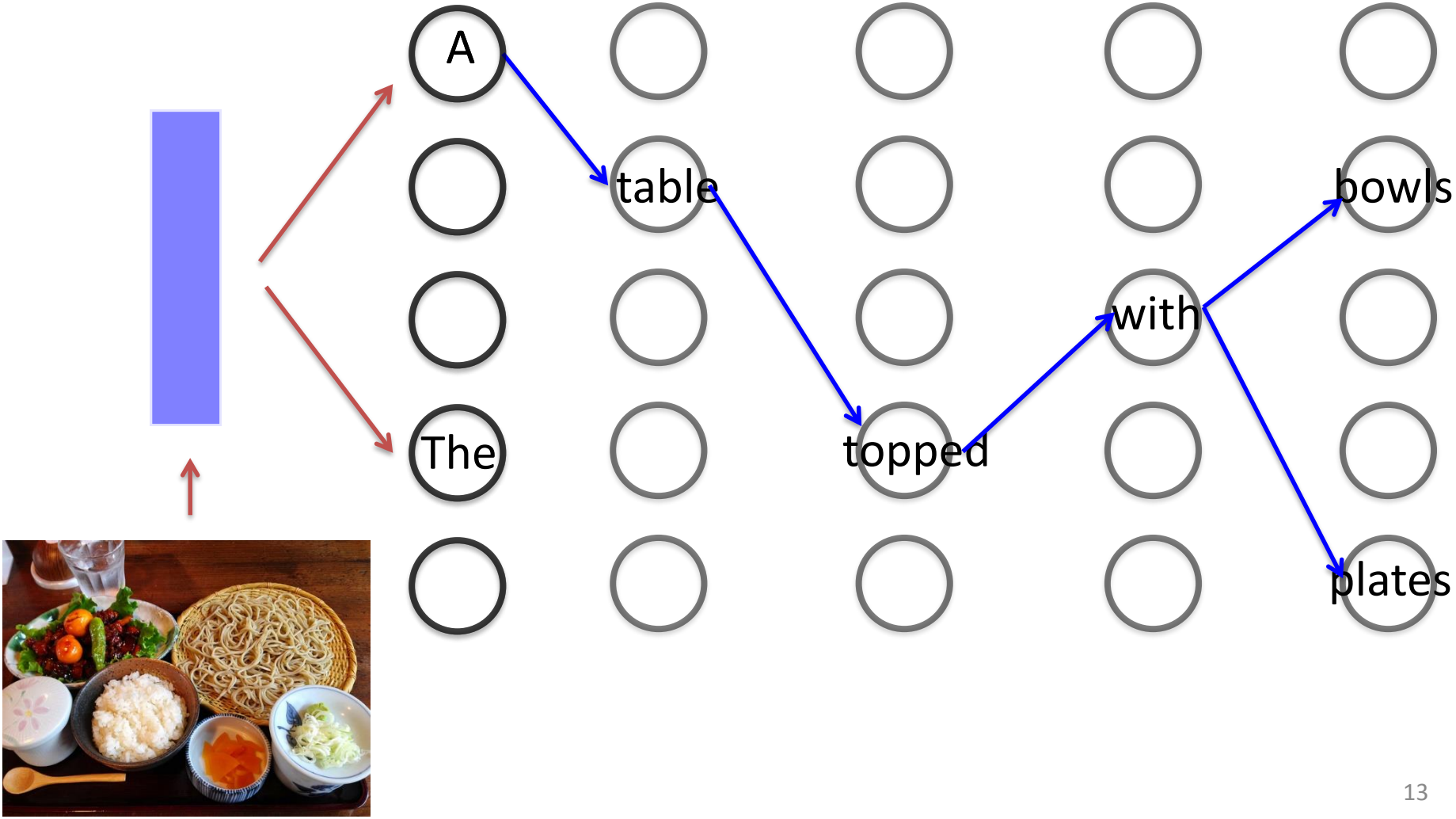

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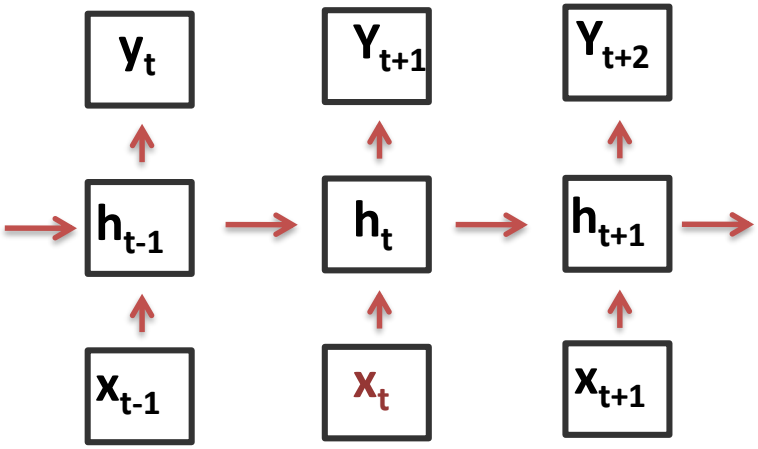
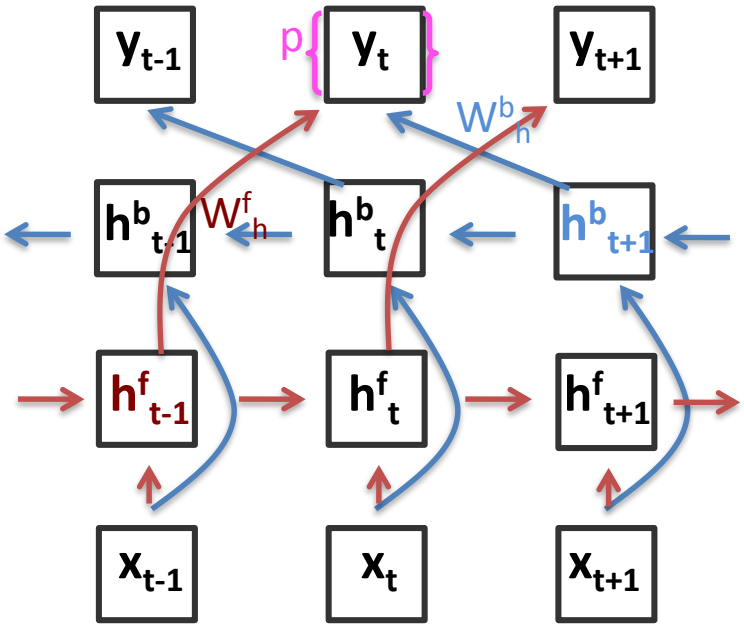


(a) Unidirectional RNNs



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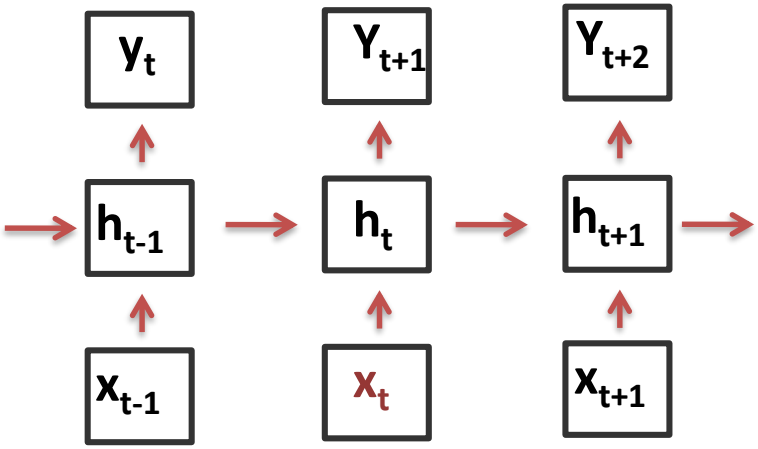

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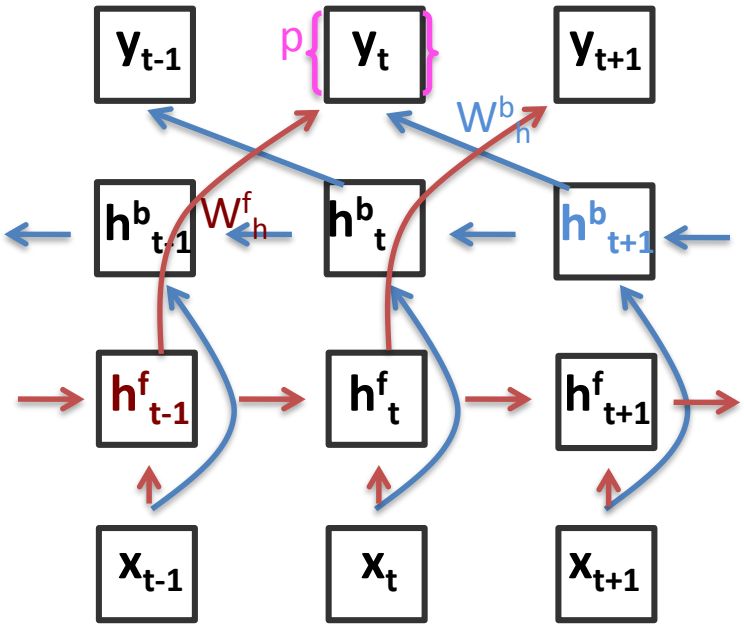


(b) Bidirectional RNNs

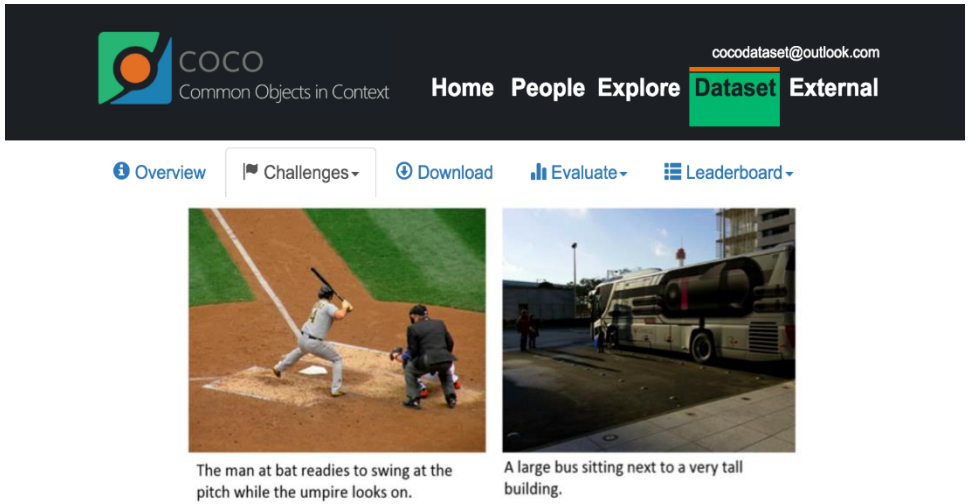
$$p(y_t|X_{[1:T]\setminus t}) = \phi(\ W_y^f h_{t-1}^f\ + W_y^b h_{t+1}^b + b_y\ )$$

Future variables

Inference in Bi-RNNs

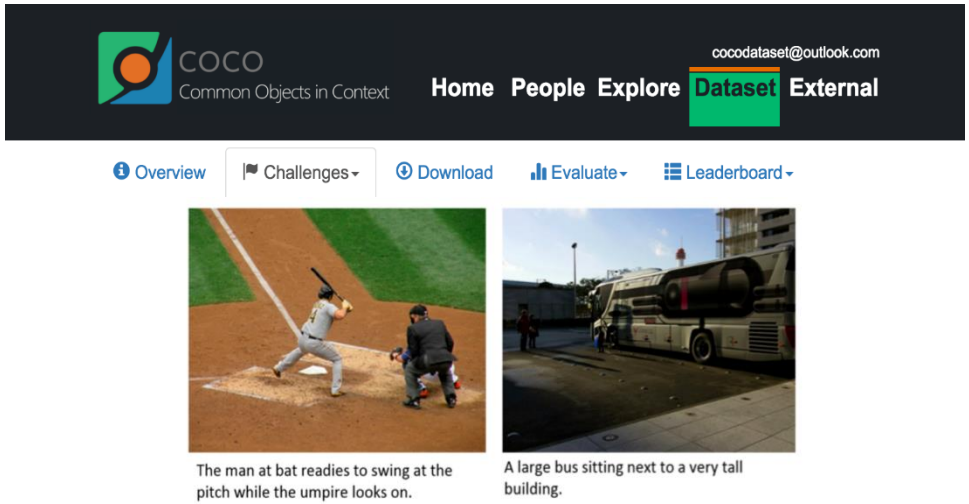
Inference in Bi-RNNs

Fill-in-the-blank Image Captioning



Inference in Bi-RNNs

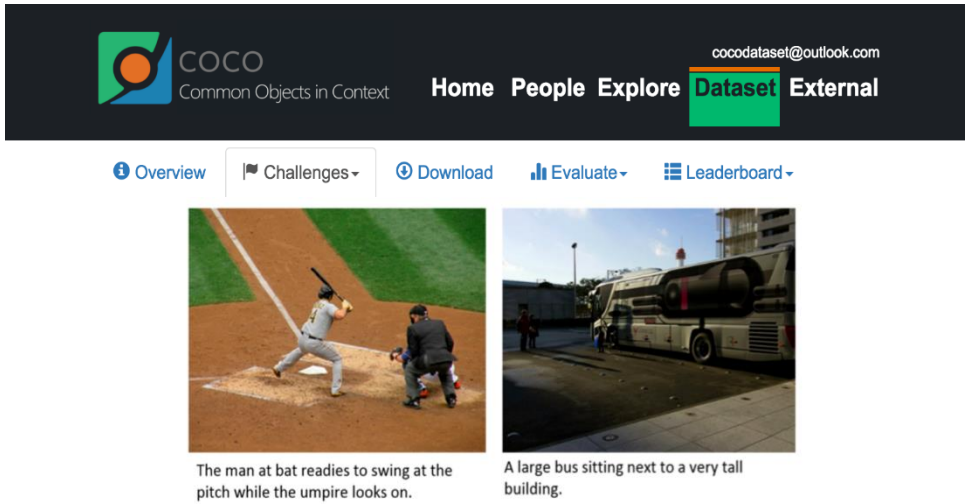
Fill-in-the-blank Image Captioning



Visual Madlibs

Inference in Bi-RNNs

Fill-in-the-blank Image Captioning

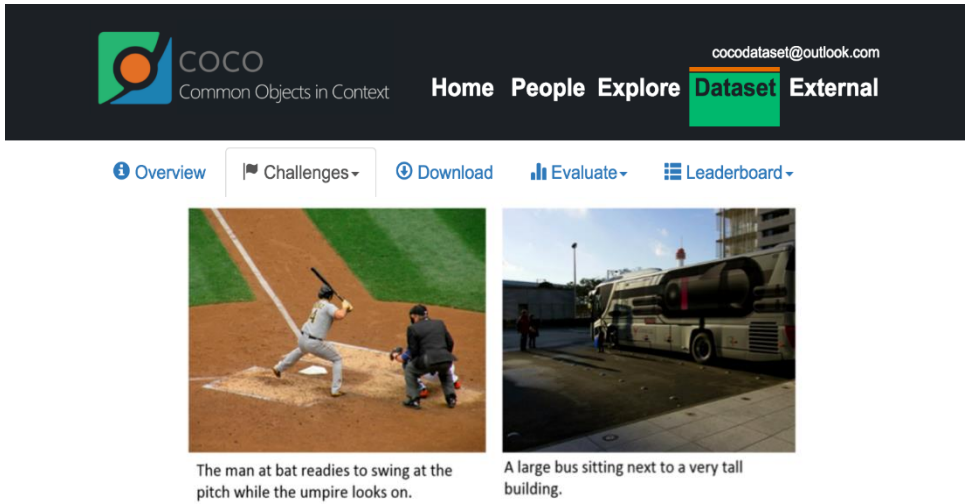


Visual Madlibs

Image Completion/Impainting

Inference in Bi-RNNs

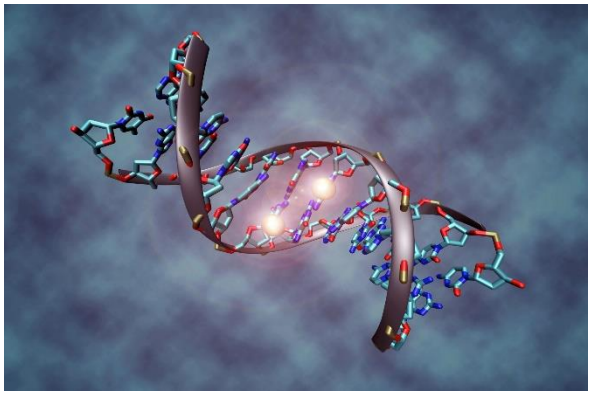
Fill-in-the-blank Image Captioning



Visual Madlibs

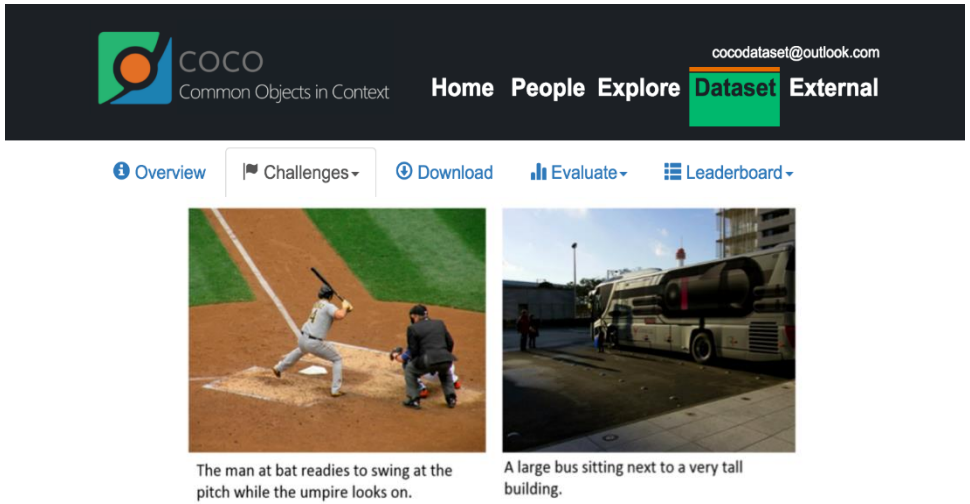
Image Completion/Impainting

Genome Sequencing



Inference in Bi-RNNs

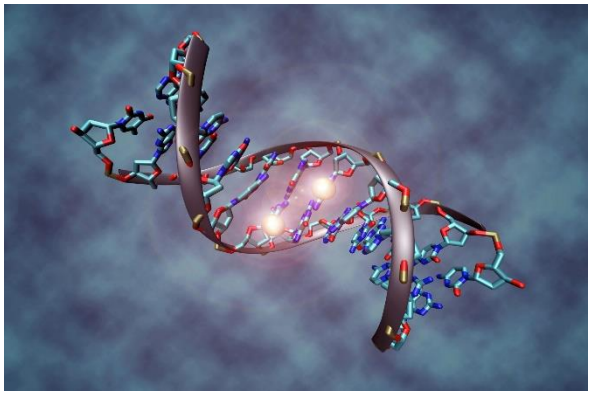
Fill-in-the-blank Image Captioning



Visual Madlibs

Image Completion/Impainting

Genome Sequencing



A girl and a dog are balancing on a wind board

A girl and a wind board

URNN-f: A girl and a dog are in the a wind board

URNN-b: A girl and sitting in the water with a wind board

BiRNN+BSCD: A girl and a dog are sitting on a wind board

A girl in a room full of books wearing a long red tie

A girl in _a long red tie

URNN-f: A girl in a dress shirt and tie standing a long red tie

URNN-b: A girl in a woman is wearing a long red tie

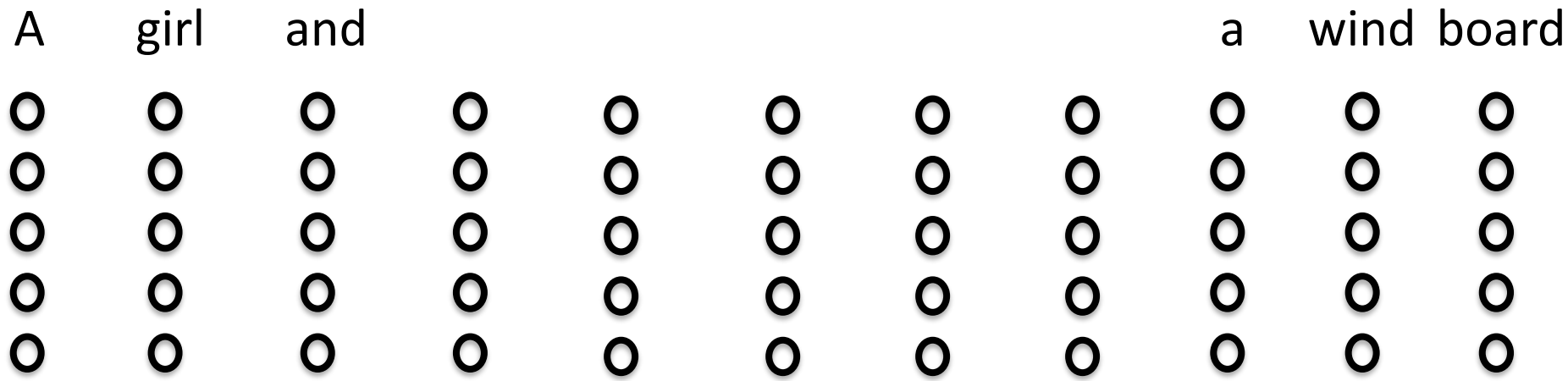
BiRNN+BSCD:A girl in a white dress shirt is holding a long red tie

Inference in Bi-RNNs

Contributions:

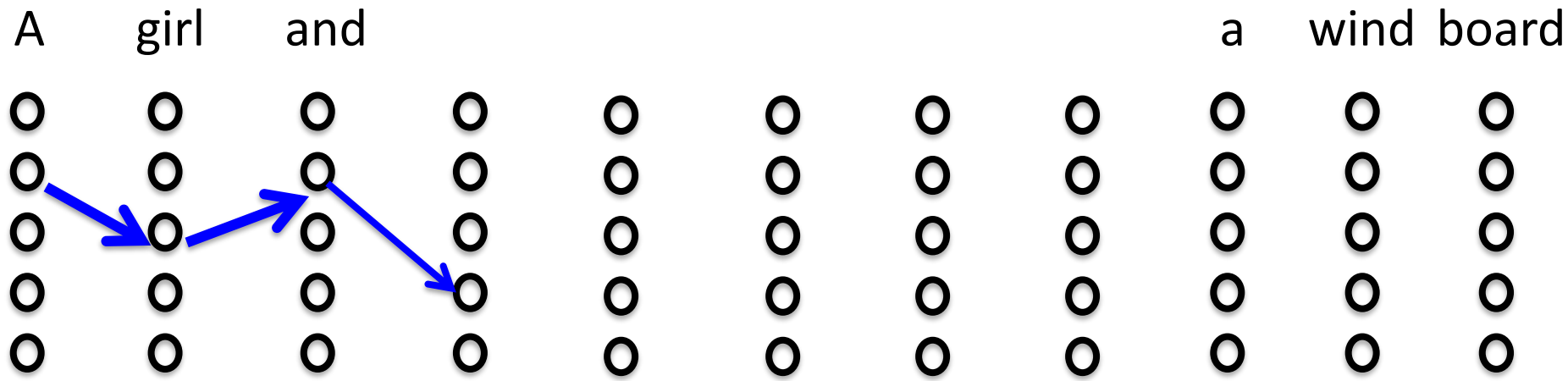
Beam-based Top-B MAP Inference algorithm for Bi-RNNs

Left-to-right BS in Uni-RNN-f



$$S^f(t) = S^f(t-1) + \log p(y_t | y_{[1:t-1]})$$

Left-to-right BS in Uni-RNN-f



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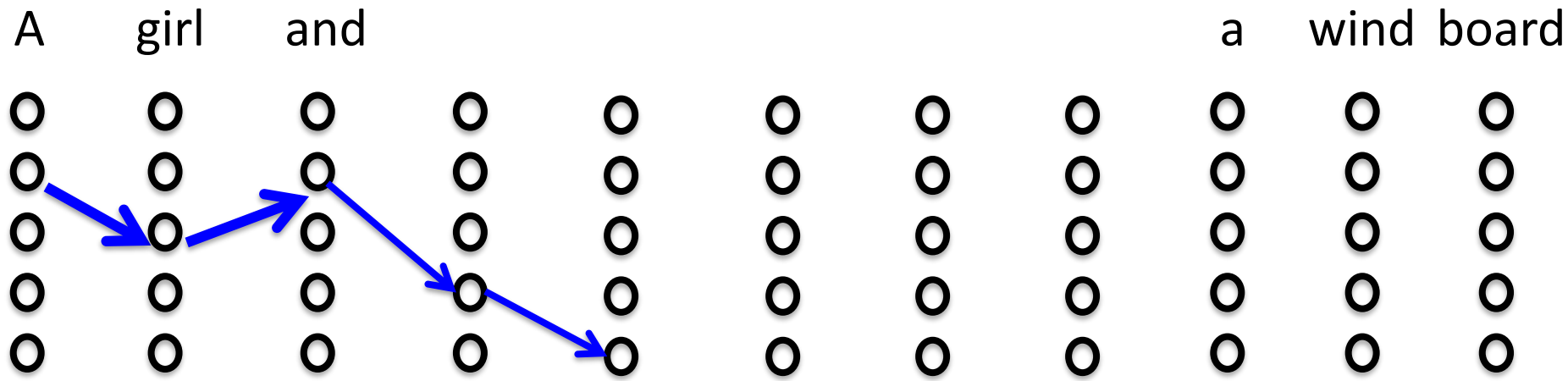

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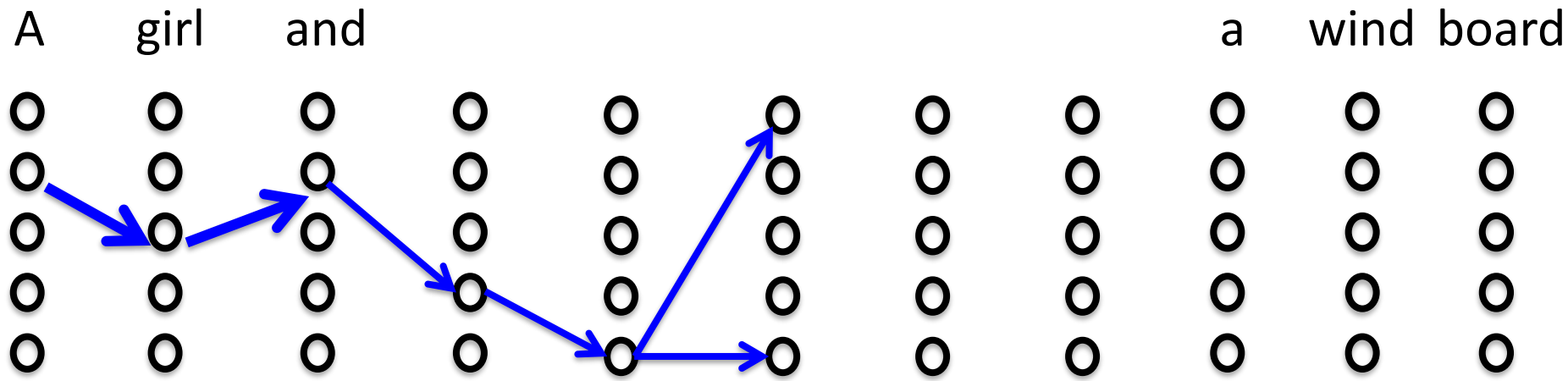
Left-to-right BS in Uni-RNN-f



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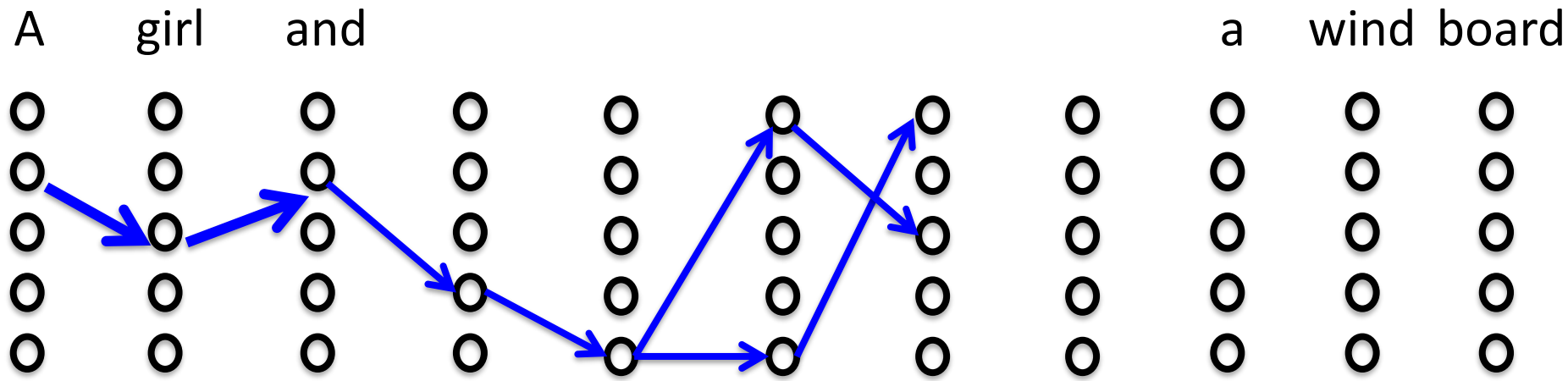

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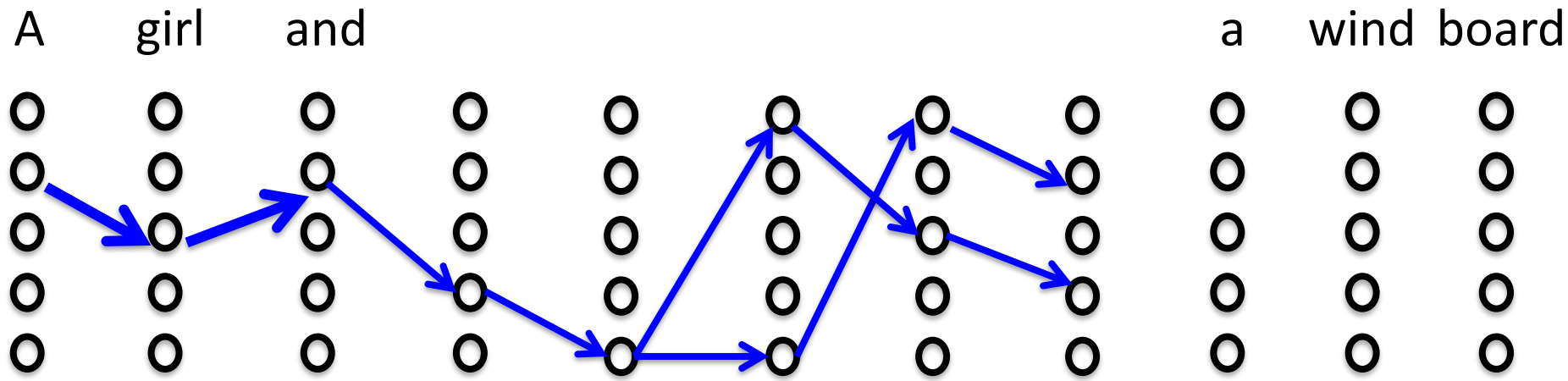
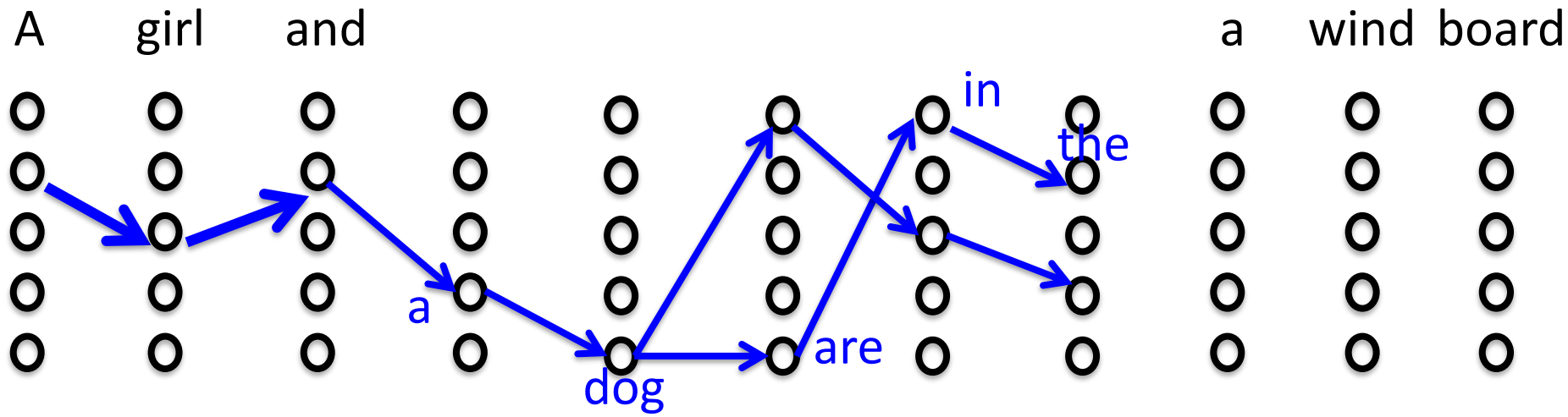
Left-to-right BS in Uni-RNN-f



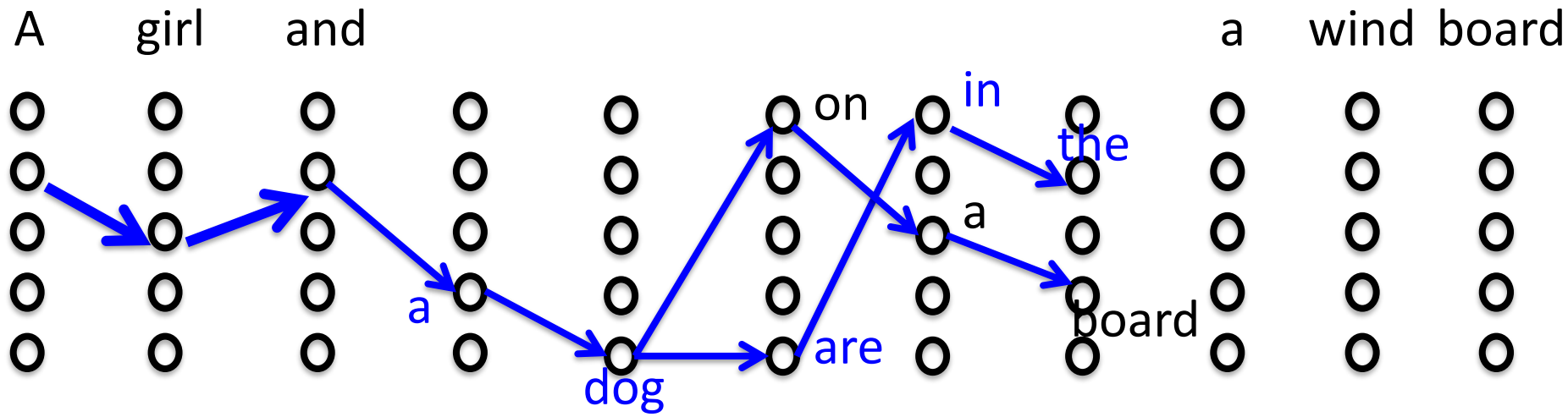
$$S^f(t) = S^f(t-1) + \log p(y_t | y_{[1:t-1]})$$

Left-to-right BS in Uni-RNN-f



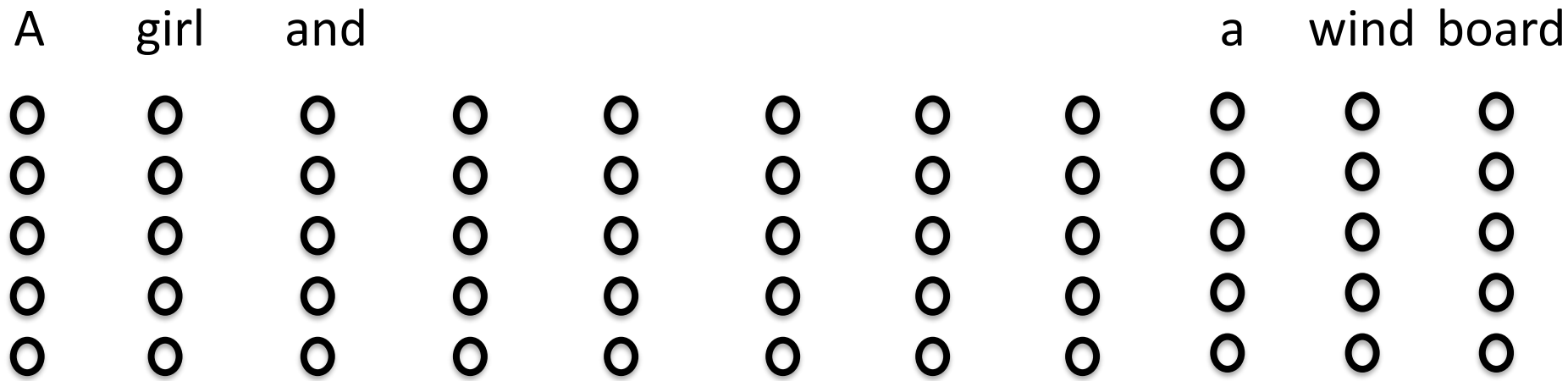
$$S^f(t) = S^f(t-1) + \log p(y_t | y_{[1:t-1]})$$

Left-to-right BS in Uni-RNN-f



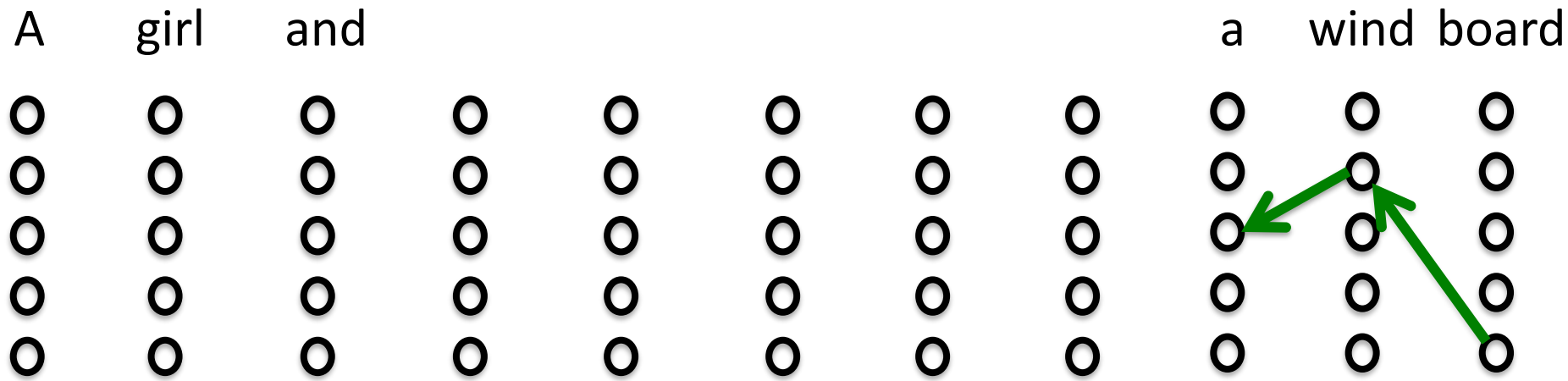
$$S^f(t) = S^f(t-1) + \log p(y_t | y_{[1:t-1]})$$

Right-to-left BS in Uni-RNN-b



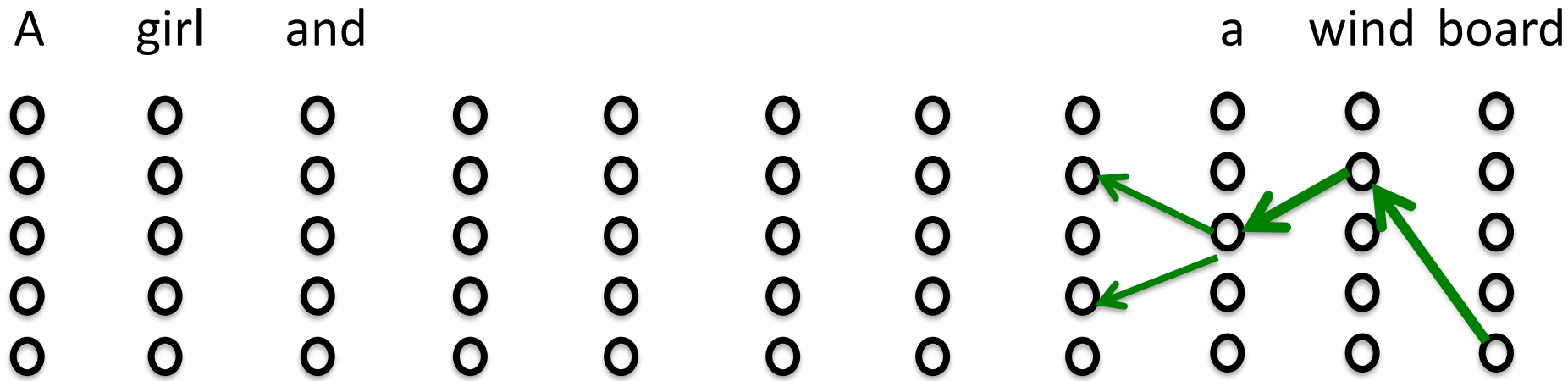
$$S^b(t) = S^b(t+1) + \log\, p(y_t | y_{[t+1:T]})$$

Right-to-left BS in Uni-RNN-b



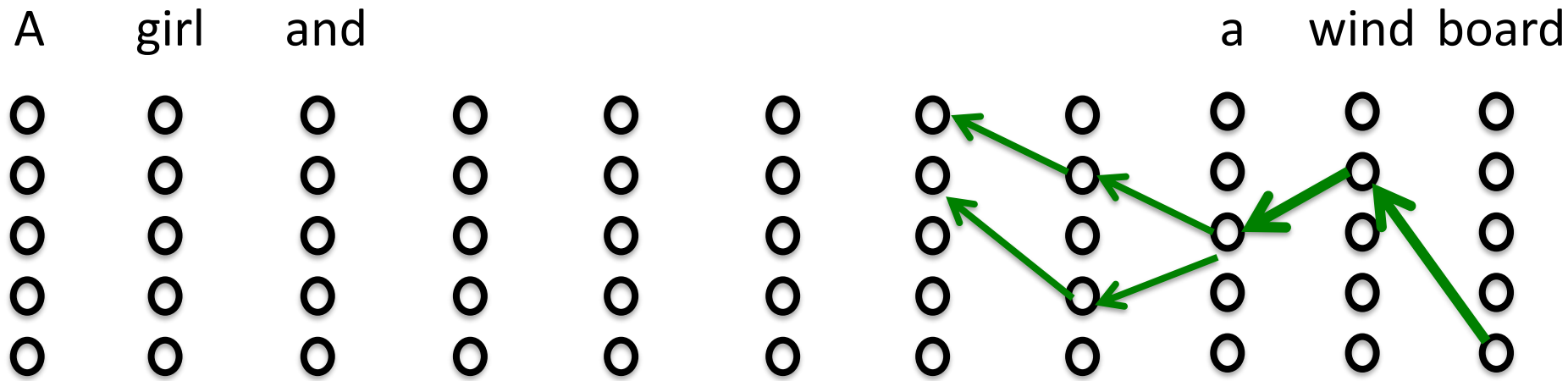
$$S^b(t) = S^b(t+1) + \log\, p(y_t | y_{[t+1:T]})$$

Right-to-left BS in Uni-RNN-b



$$S^b(t) = S^b(t+1) + \log\, p(y_t | y_{[t+1:T]})$$

Right-to-left BS in Uni-RNN-b



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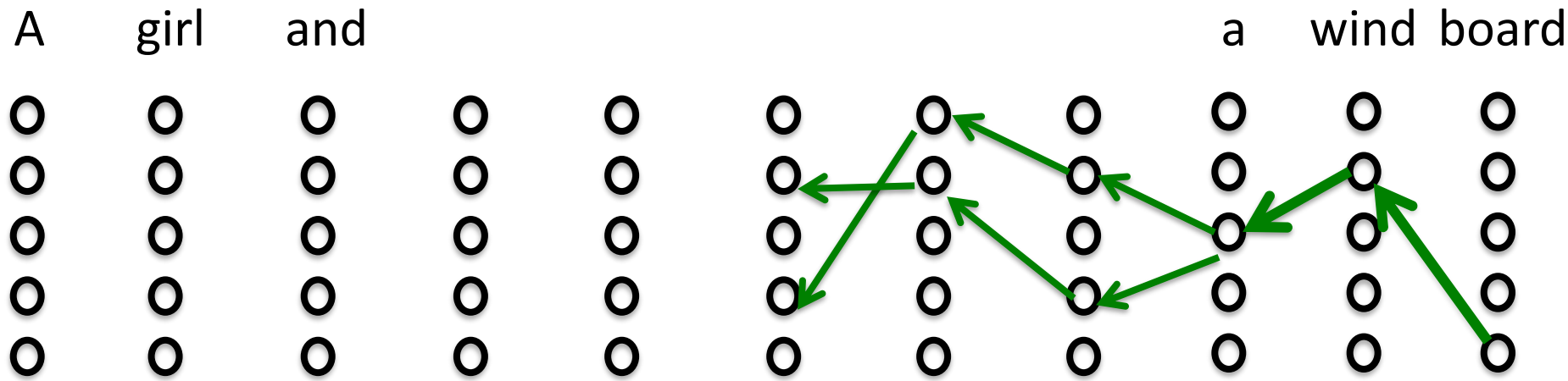
Right-to-left BS in Uni-RNN-b



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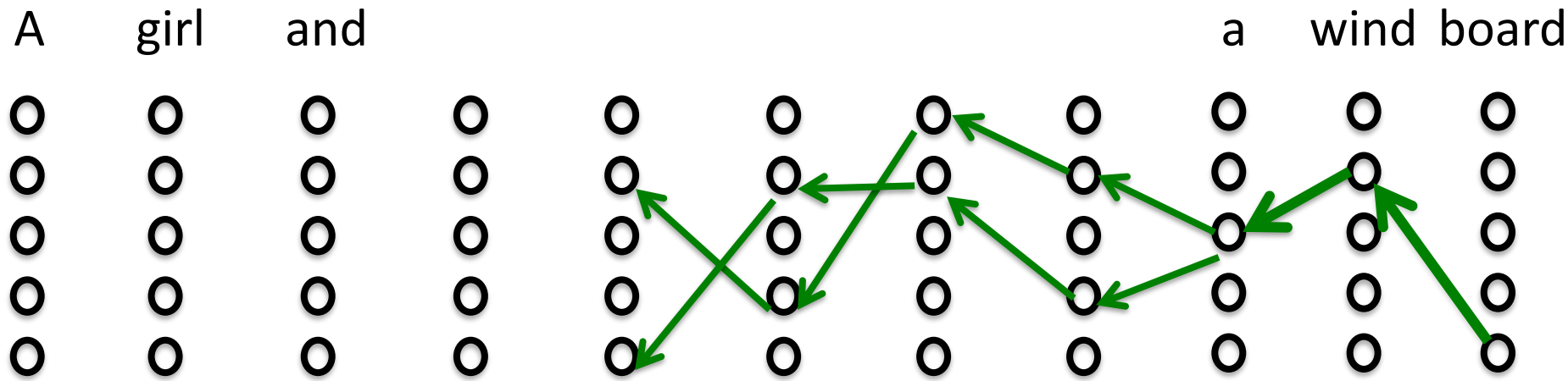
Right-to-left BS in Uni-RNN-b



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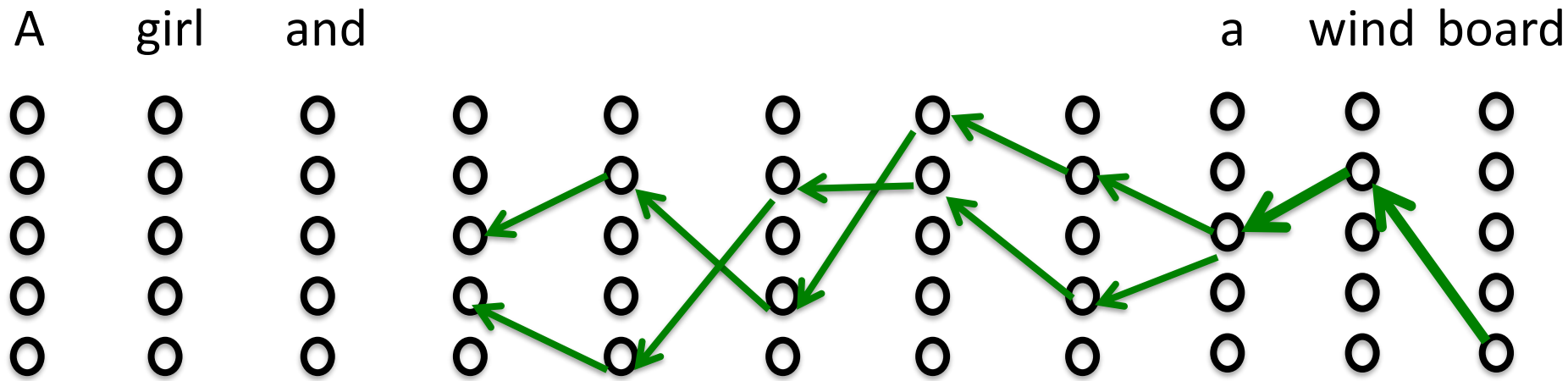
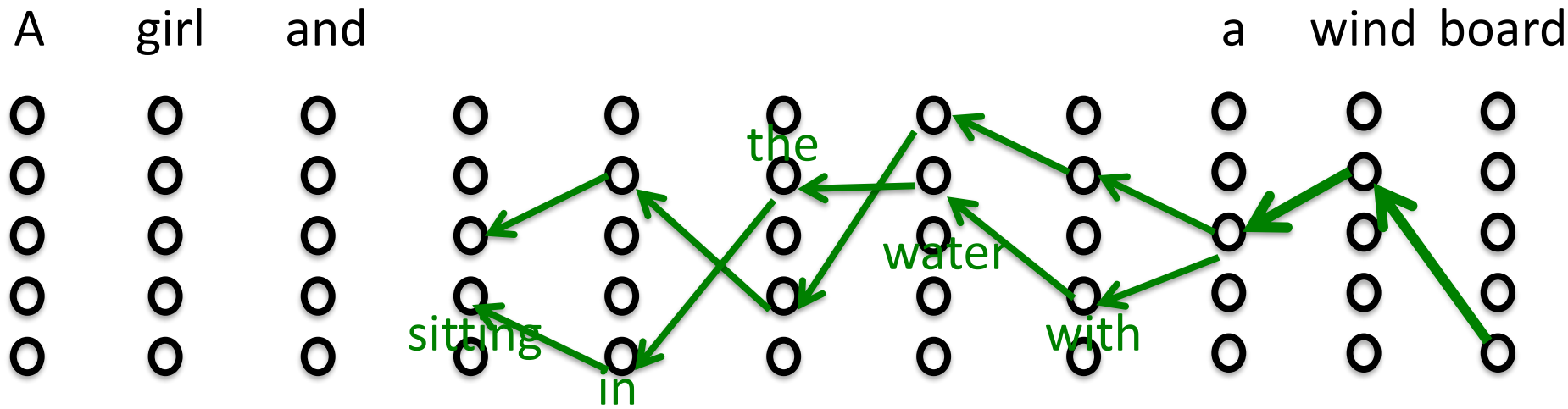
Right-to-left BS in Uni-RNN-b



$$S^b(t) = S^b(t+1) + \log\, p(y_t | y_{[t+1:T]})$$

Right-to-left BS in Uni-RNN-b



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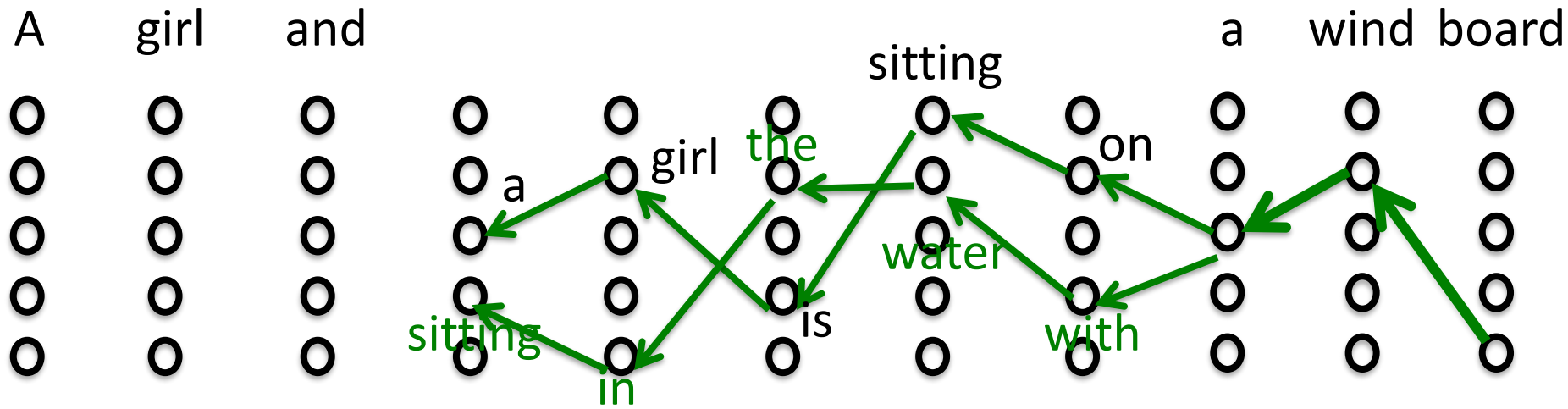
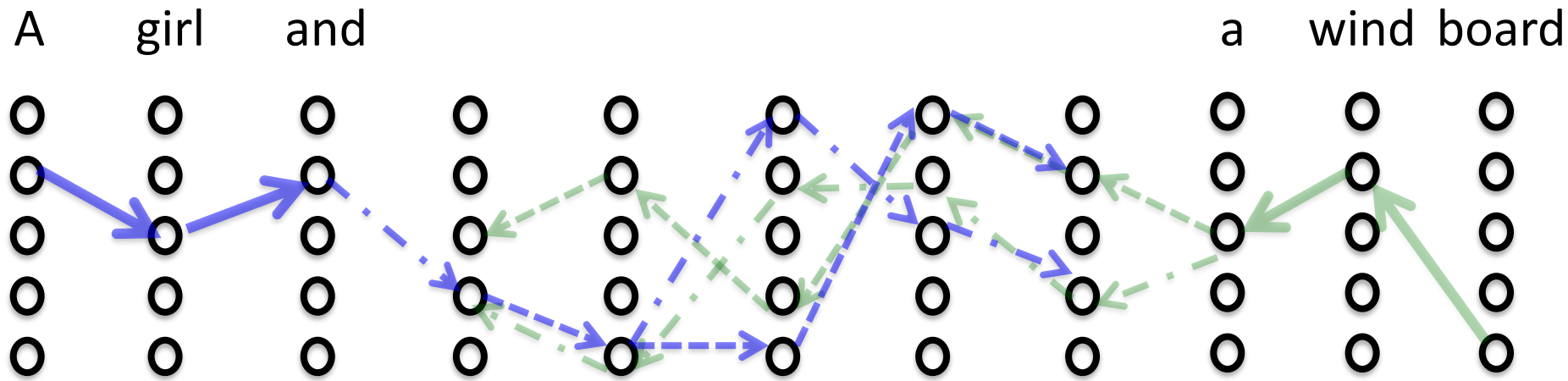
Right-to-left BS in Uni-RNN-b



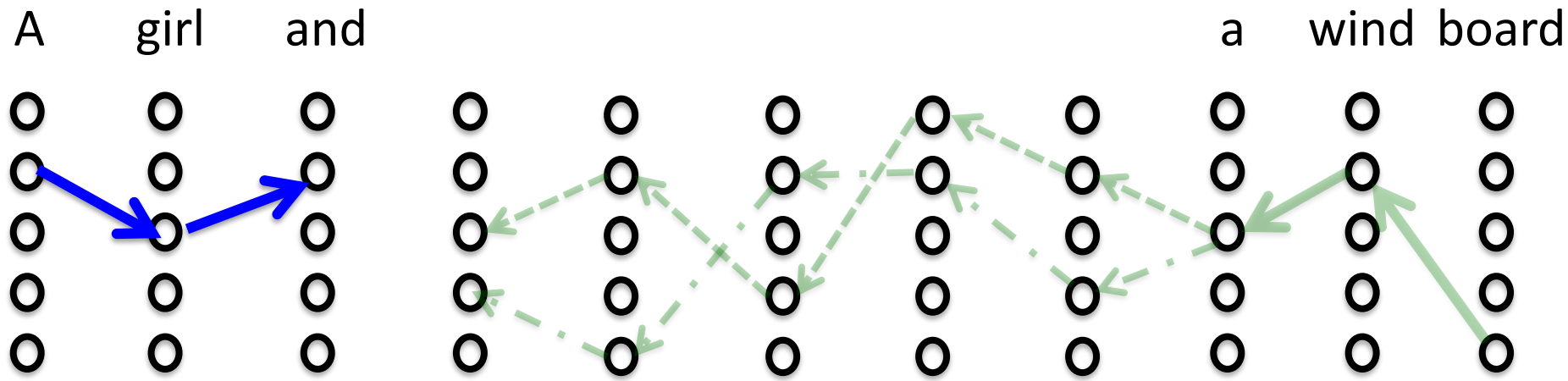
$$S^b(t) = S^b(t+1) + \log\, p(y_t | y_{[t+1:T]})$$

Beam-Search Coordinate Descent (BSCD) in Bi-RNNs

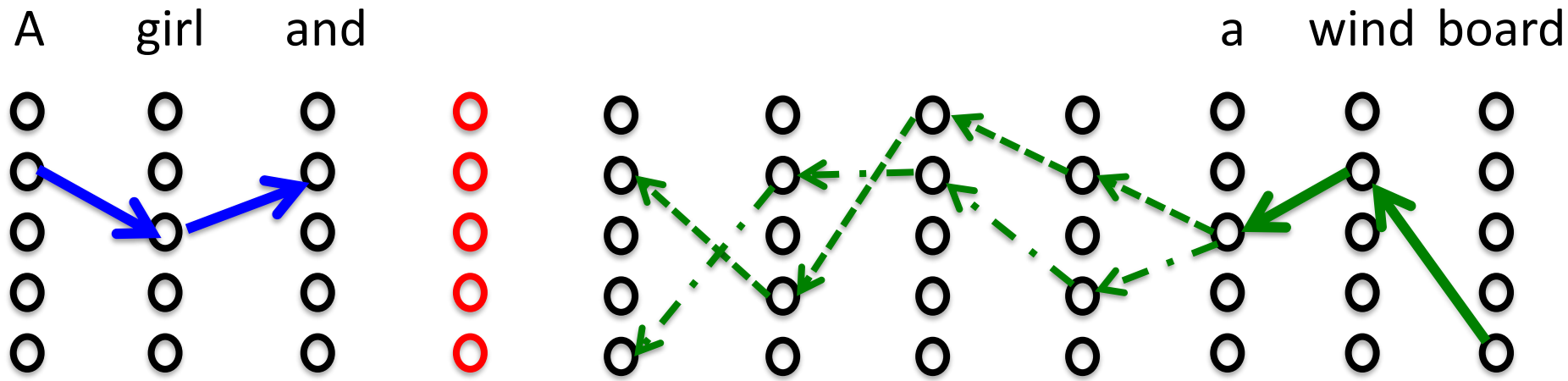


Initialize forward & backward beams using classical BS

Beam-Search Coordinate Descent (BSCD) in Bi-RNNs

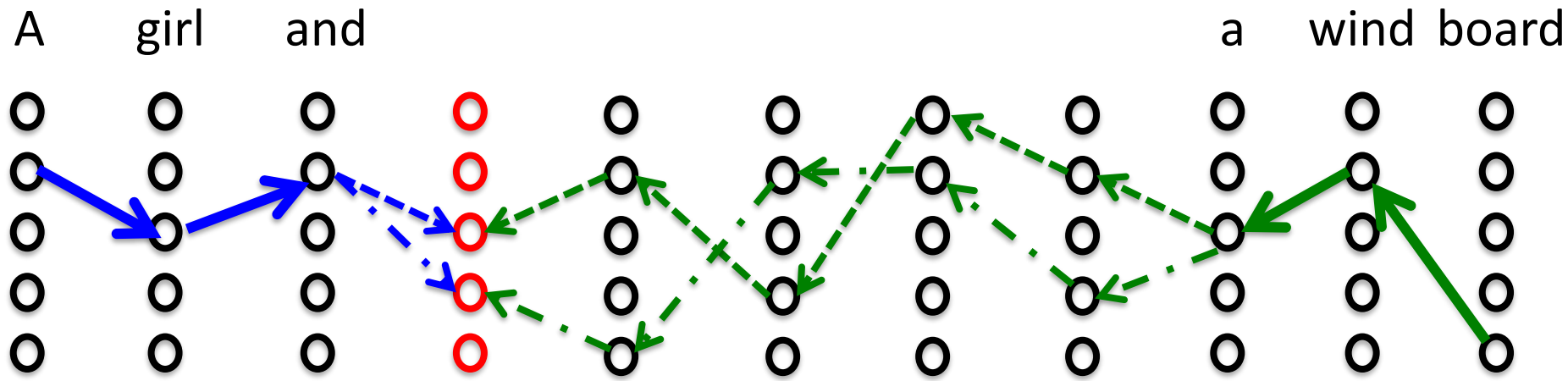


Beam-Search Coordinate Descent (BSCD) in Bi-RNNs

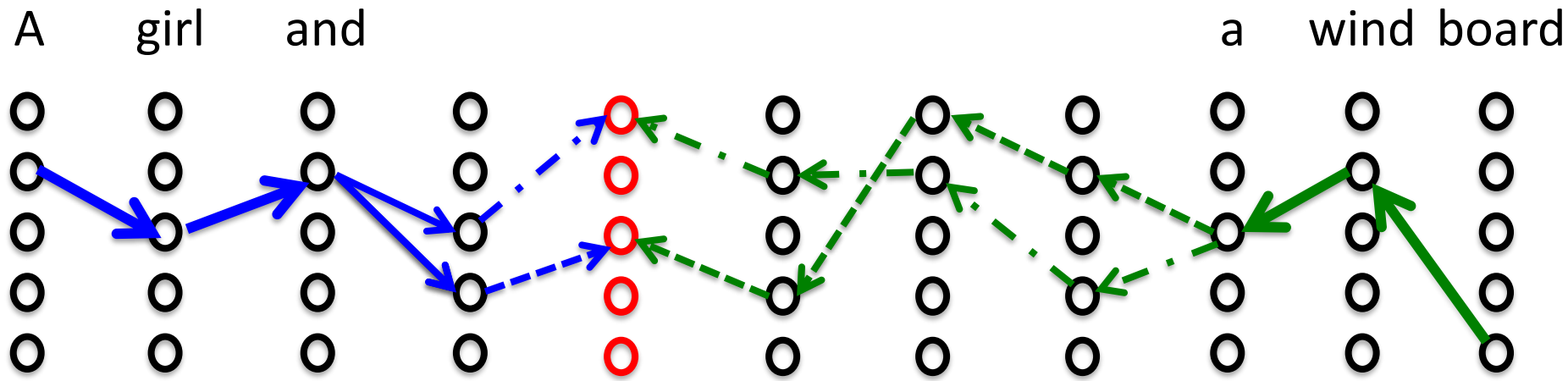


$$S(\leftarrow, \circ, \rightarrow) = S^f(t-1) + \log p(y_t | y_{t' \neq t}) + S^b(t+1)$$

Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



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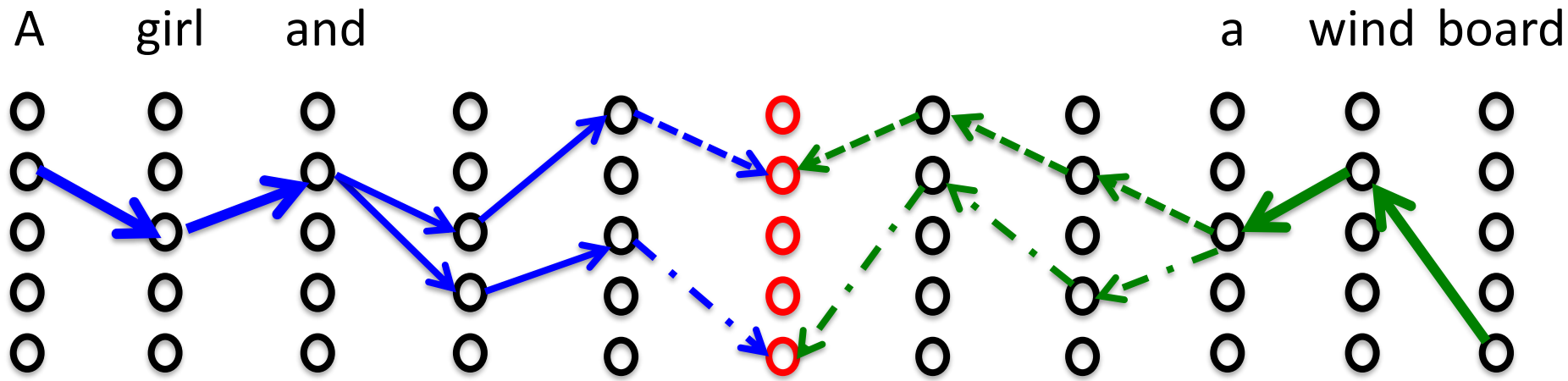
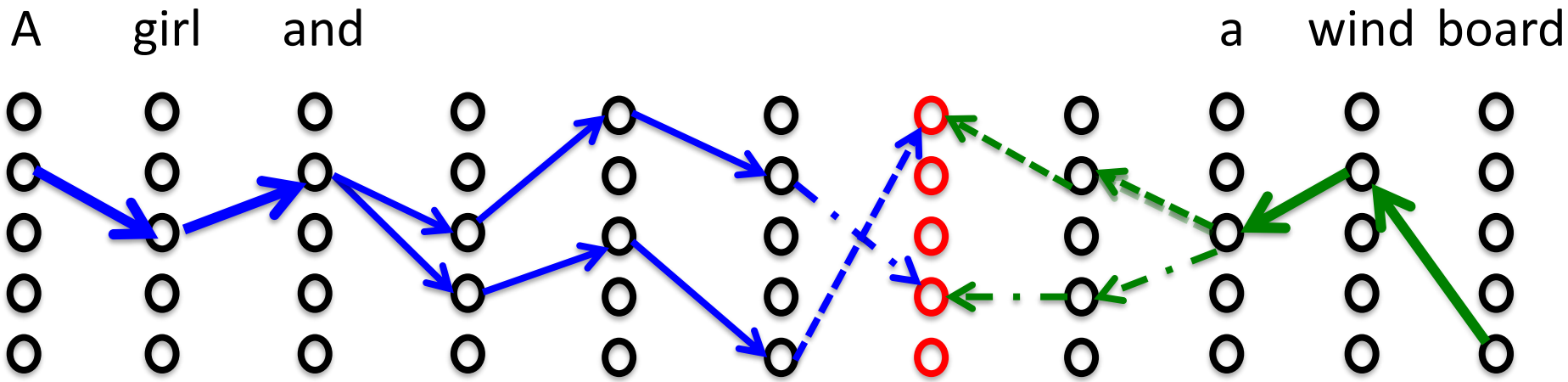
Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



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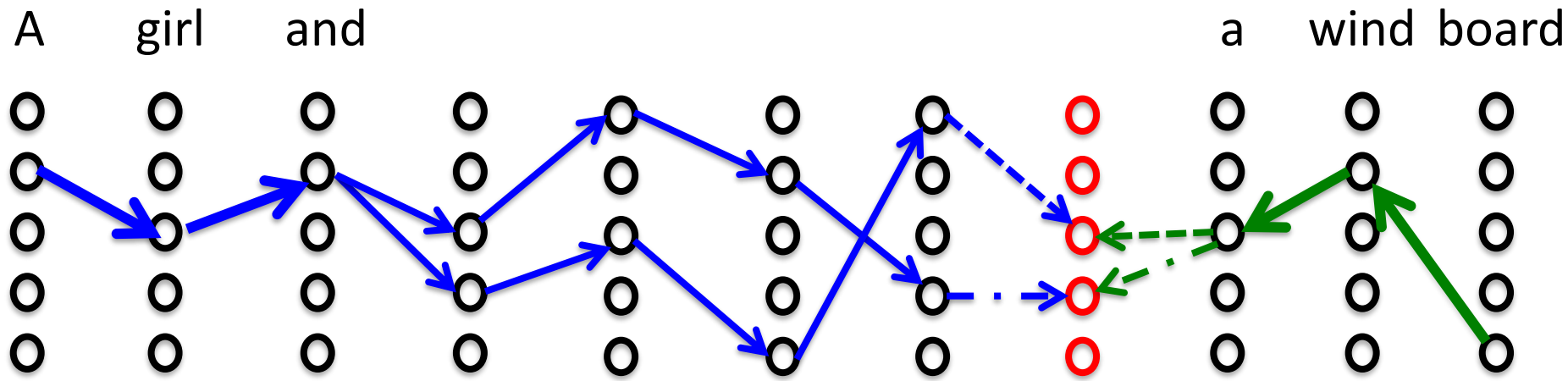
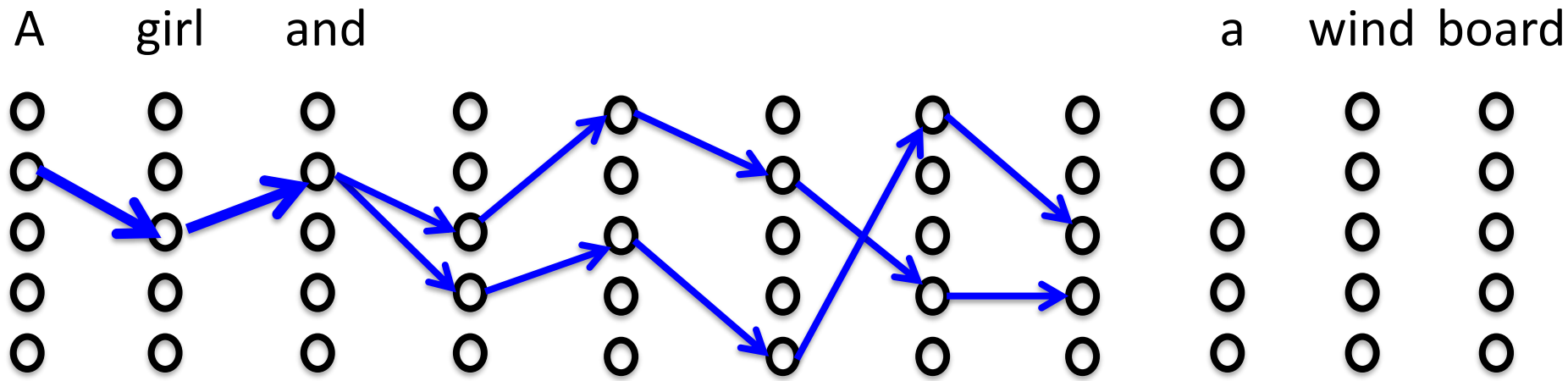
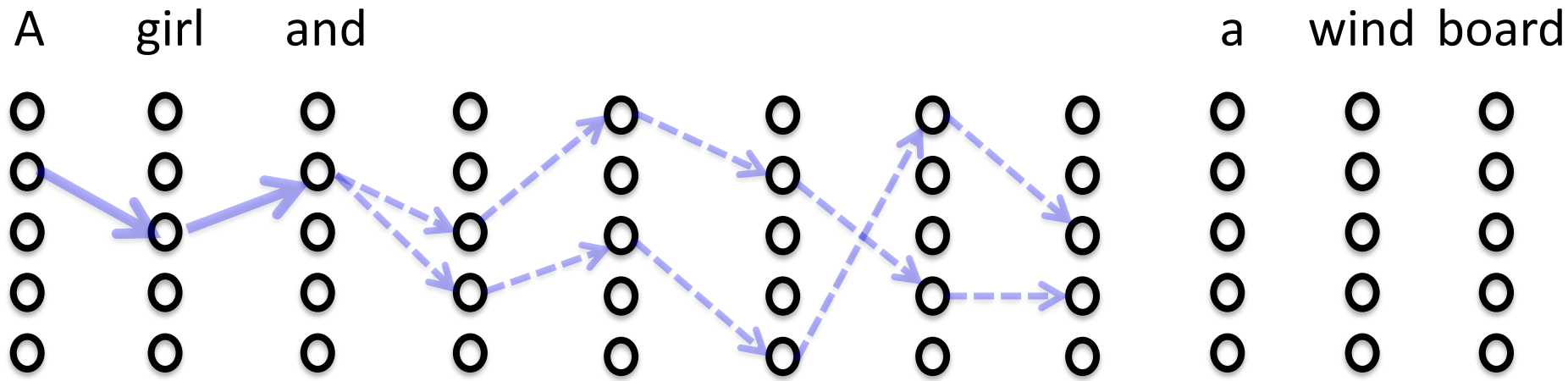


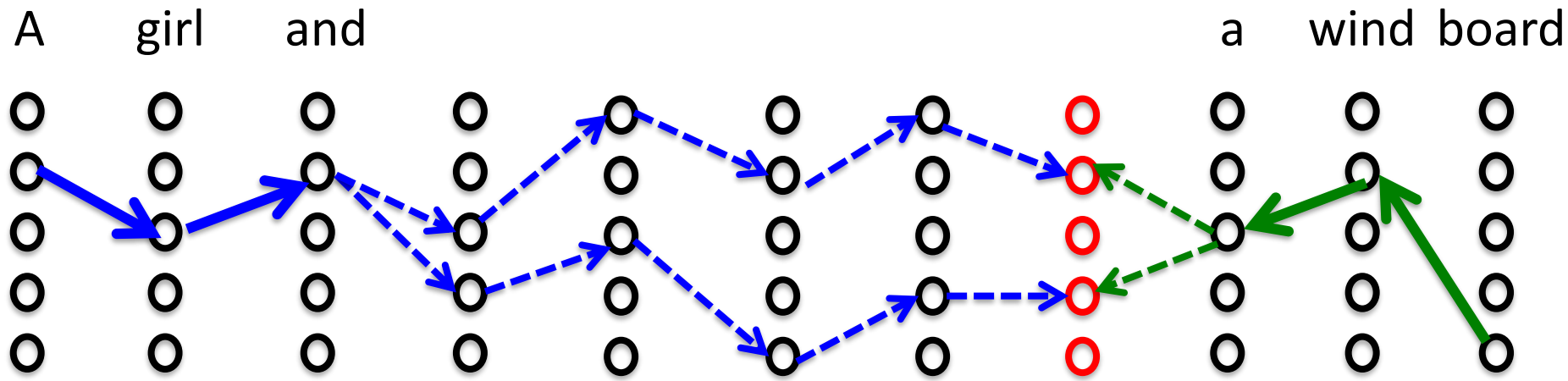
Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



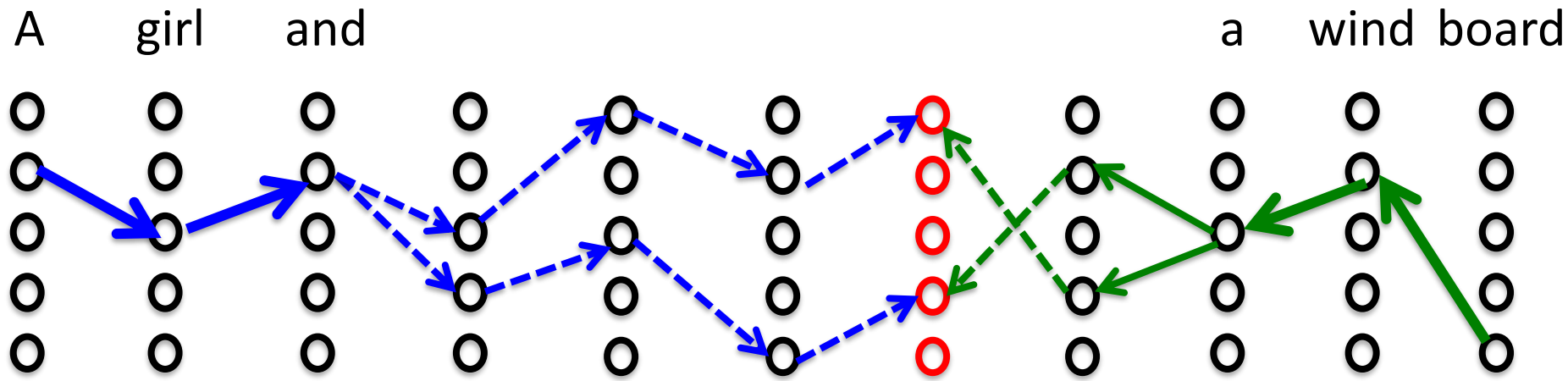
Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



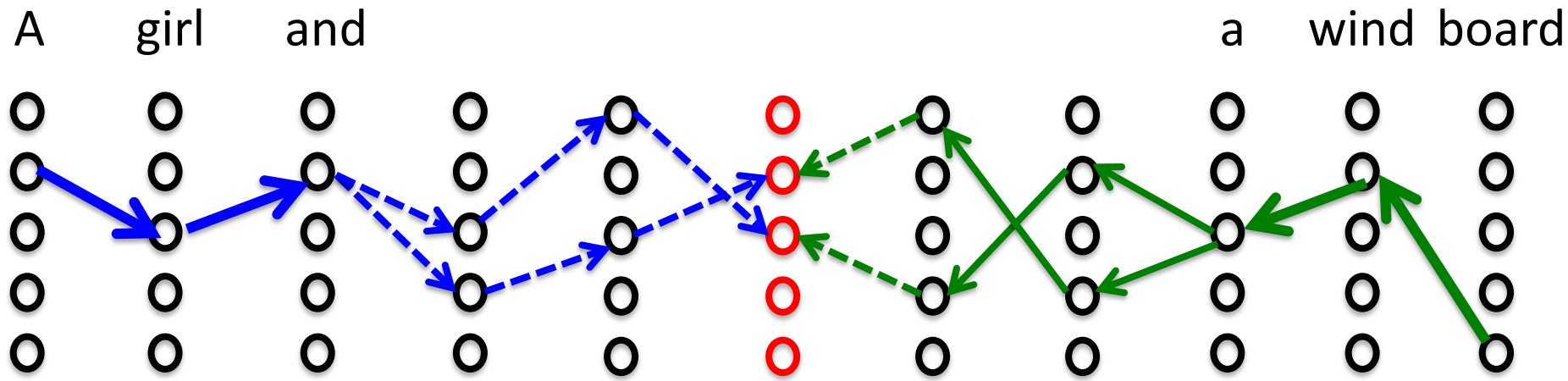
Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



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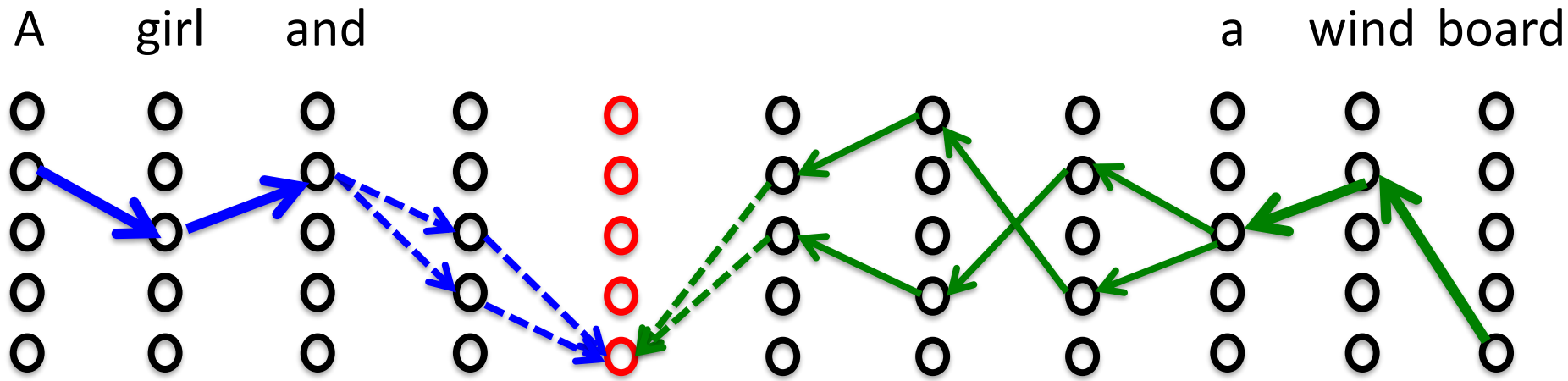

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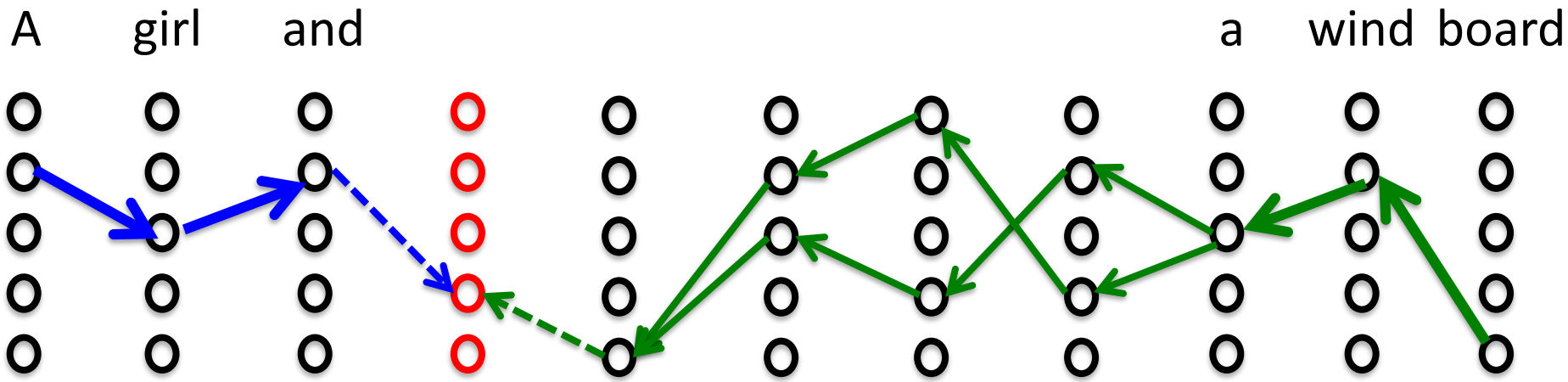
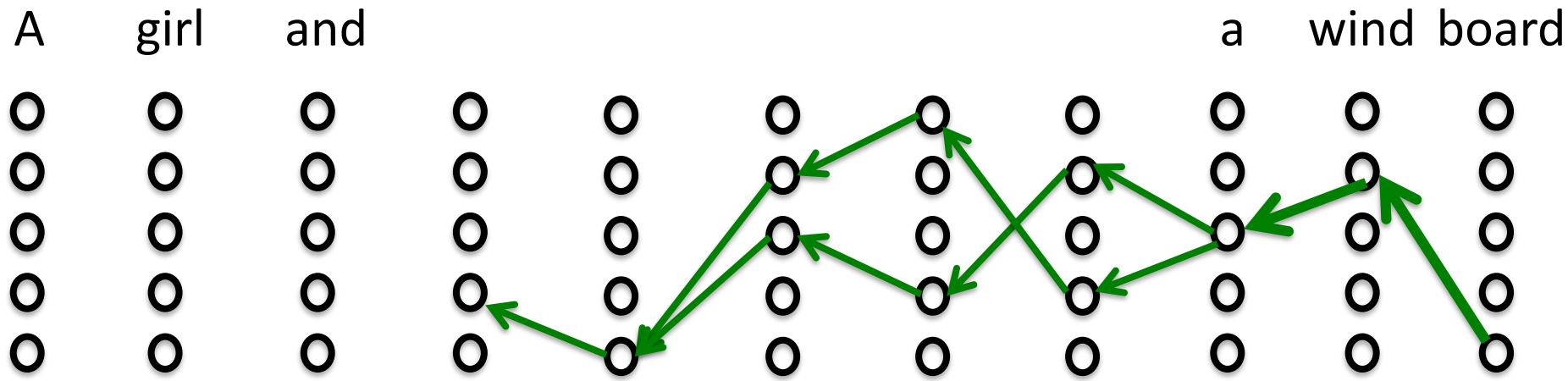
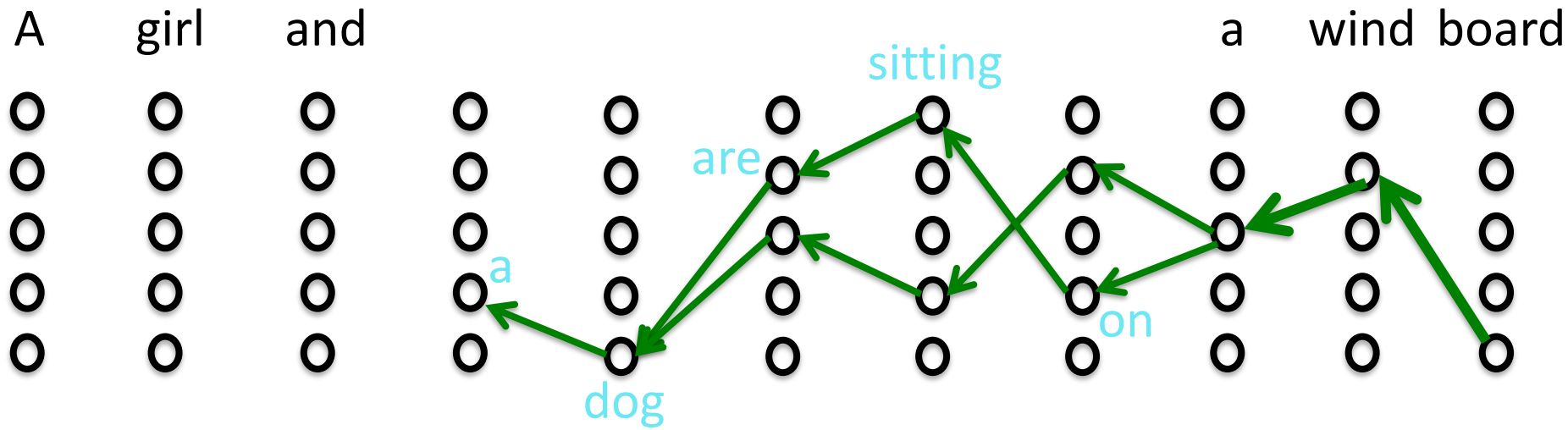


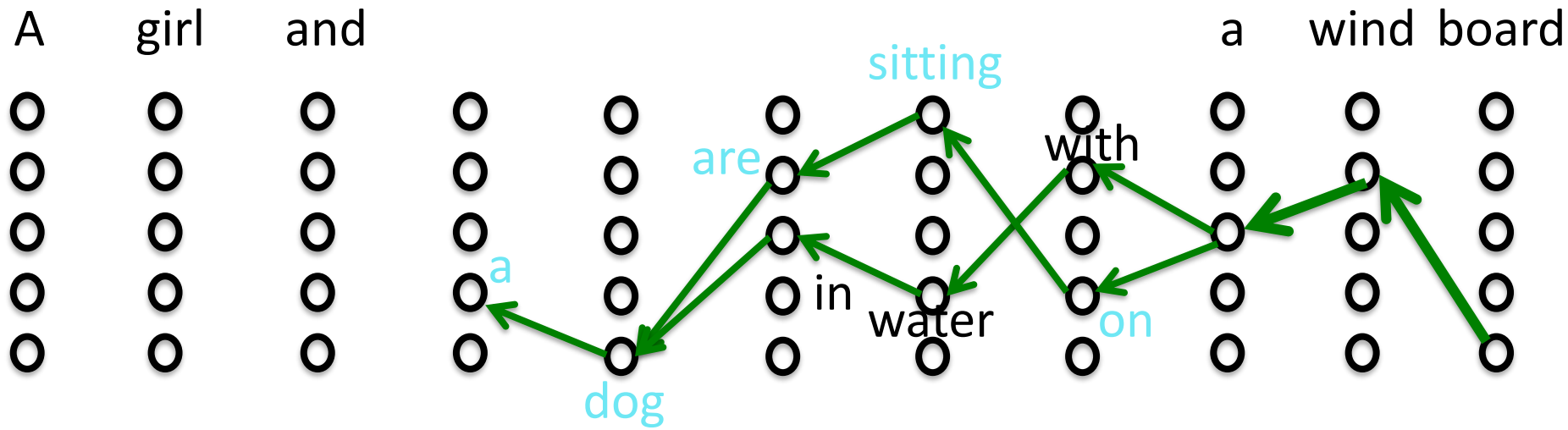
Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Beam-Search Coordinate Descent (BSCD) in Bi-RNNs



Fill-in-the-Blank in Image captioning

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO

Fill-in-the-Blank in Image captioning

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  - 123,000 images, 5 captions annotated by AMT

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

r = 0.25: A girl and a dog are balancing on a wind board

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

r = 0.50: A girl and a dog are balancing on a wind board

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

r = 0.75: A girl and a dog are balancing on a wind board

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

  r = 0.75: A girl and a dog are balancing on a wind board
- Evaluation

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

  r = 0.75: A girl and a dog are balancing on a wind board
- Evaluation
  - Full sentence BLEU, CIDEr, Meteor.

Fill-in-the-Blank in Image captioning

- Dataset: MSCOCO
  - 123,000 images, 5 captions annotated by AMT
  - Val: 5000, test: 5000, train: rest
    - consistent with Neuraltalk2
- Remove words in the middle

  r = 0.75: A girl <u>and a dog are balancing on a wind</u> board
- Evaluation
  - Full sentence BLEU, CIDEr, Meteor.
  - Bad completion "A girl and <u>sitting</u> "

    -> low n-gram match with humans

Qualitative Result

Qualitative Result

A person standing posing for a photo holding a glass of wine

Qualitative Result

URNN-f: A person standing in a room holding a cell glass of wine

Qualitative Result

URNN-b: A person standing a women is holding a glass of wine

Qualitative Result

BiRNN-BSCD: A person standing in a room while holding a glass of wine

Qualitative Result

Qualitative Result

A close up flowers and plants inside of a bowl

Qualitative Result

URNN-f: A close up of a vase with of a bowl

Qualitative Result

URNN-b: A close vase that is sitting inside of a bowl

Qualitative Result

BiRNN-BSCD: A close up of flowers sitting inside of a bowl

Qualitative Result

Qualitative Result

A white hand holding a chocolate sprinkled donut

Qualitative Result

RNN-f:A white frosted doughnut with sprinkles sprinkled donut

Qualitative Result

URNN-b: A white close up of a sprinkled donut

Qualitative Result

BiRNN-BSCD: A white hand holding a pink sprinkled donut

Qualitative Result

Qualitative Result

A woman holding a pizza in her hand in the middle of a kitchen

Qualitative Result

URNN-f: A woman holding a plate of food in a kitchen middle of a kitchen

Qualitative Result

URNN-b: A woman holding a woman preparing food in the middle of the kitchen

Qualitative Result

BiRNN-BSCD: A woman holding a plate of food sitting in the middle of a kitchen

Qualitative Result

BiRNN-BSCD: A woman holding a plate of food sitting in the middle of a kitchen

Fill-in-the-Blank in Image captioning

(Length of Ground-truth is known)

	r = 0.25	r = 0.5	r = 0.75
URNN-f	6.628	3.915	2.034

Table 1. Comparison of different approaches on MSCOCO test dataset(metric: CIDEr; r: the fraction of removed words.)

Fill-in-the-Blank in Image captioning

(Length of Ground-truth is known)

	r = 0.25	r = 0.5	r = 0.75
URNN-f	6.628	3.915	2.034
URNN-b	6.639	3.965	2.532

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URNN-f	6.628	3.915	2.034
URNN-b	6.639	3.965	2.532
URNN-fb-max	6.758	4.054	2.297

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URNN-f	6.628	3.915	2.034
URNN-b	6.639	3.965	2.532
URNN-fb-max	6.758	4.054	2.297
URNN-fb-BiRNN	6.622	3.92	2.088

Table 1. Comparison of different approaches on MSCOCO test dataset(metric: CIDEr; r: the fraction of removed words.)

Fill-in-the-Blank in Image captioning

(Length of Ground-truth is known)

	r = 0.25	r = 0.5	r = 0.75
URNN-f	6.628	3.915	2.034
URNN-b	6.639	3.965	2.532
URNN-fb-max	6.758	4.054	2.297
URNN-fb-BiRNN	6.622	3.92	2.088
BiRNN-BSCD	**7.262**	**4.413**	**2.534**
	↓ 7.4%	↓ 8.8%	↓ 7%

Table 1. Comparison of different approaches on MSCOCO test dataset(metric: CIDEr; r: the fraction of removed words.)

Visual Madlib

- 360,001 focused descriptions for 10,738 images
- Two evaluation tasks:
  - Multiple-choice question-answering
  - **Fill-in-the-blank** image description
- 12 types of fill-in-the-blanks:

Type 7: object's affordance

People could **relax on** the couches

Type 12: pair's relationship

Person B is **putting food in** the bowl

Visual Madlib

(Length of Ground-truth is known)

	Type 7		Type 12	
	Bleu-1	Bleu-2	Bleu-1	Bleu-2
nCCA(box)	0.6	0.11	0.48	0.08
URNN-f	0.315	0.140	0.275	0.158
URNN-b	0.461	0.285	0.346	0.212
URNN-fb-max	0.449	0.275	0.345	0.211
BiRNN-BSCD	**0.470**	**0.300**	**0.353**	**0.231**

Table 2. Comparison of different approaches on Madlibs test dataset

Visual Madlib

(Length of Ground-truth is known)

	Type 7		Type 12	
	Bleu-1	Bleu-2	Bleu-1	Bleu-2
nCCA(box)	0.6	0.11	0.48	0.08
URNN-f	0.315	0.140	0.275	0.158
URNN-b	0.461	0.285	0.346	0.212
URNN-fb-max	0.449	0.275	0.345	0.211
BiRNN-BSCD	**0.470**	**0.300**	**0.353**	**0.231**
		5%		8.9%

Table 2. Comparison of different approaches on Madlibs test dataset

Conclusion

- Beam-based Top-B MAP Inference algorithm for Bi-RNNs
- Any Partial-MAP estimation in sequence prediction problem

Thank You !

Q&A

Fill-in-the-Blank in Image captioning

(Length of Ground-truth is unknown)

	r = 0.25	r = 0.5	r = 0.75
URNN-fb-max	6.971	4.203	2.665
BiRNN-BSMP	**8.356**	**5.40**	**3.544**

Table 2. Comparison of different approaches on MSCOCO test dataset(metric: CIDEr; r: the fraction of removed words.)