NLP 南京大学
自然语言处理实验室
Natural Language Processing Group

Neural Machine Translation with Word Predictions

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Outline

- Background
- Motivation
- Approach
- Experiment
- Conclusion

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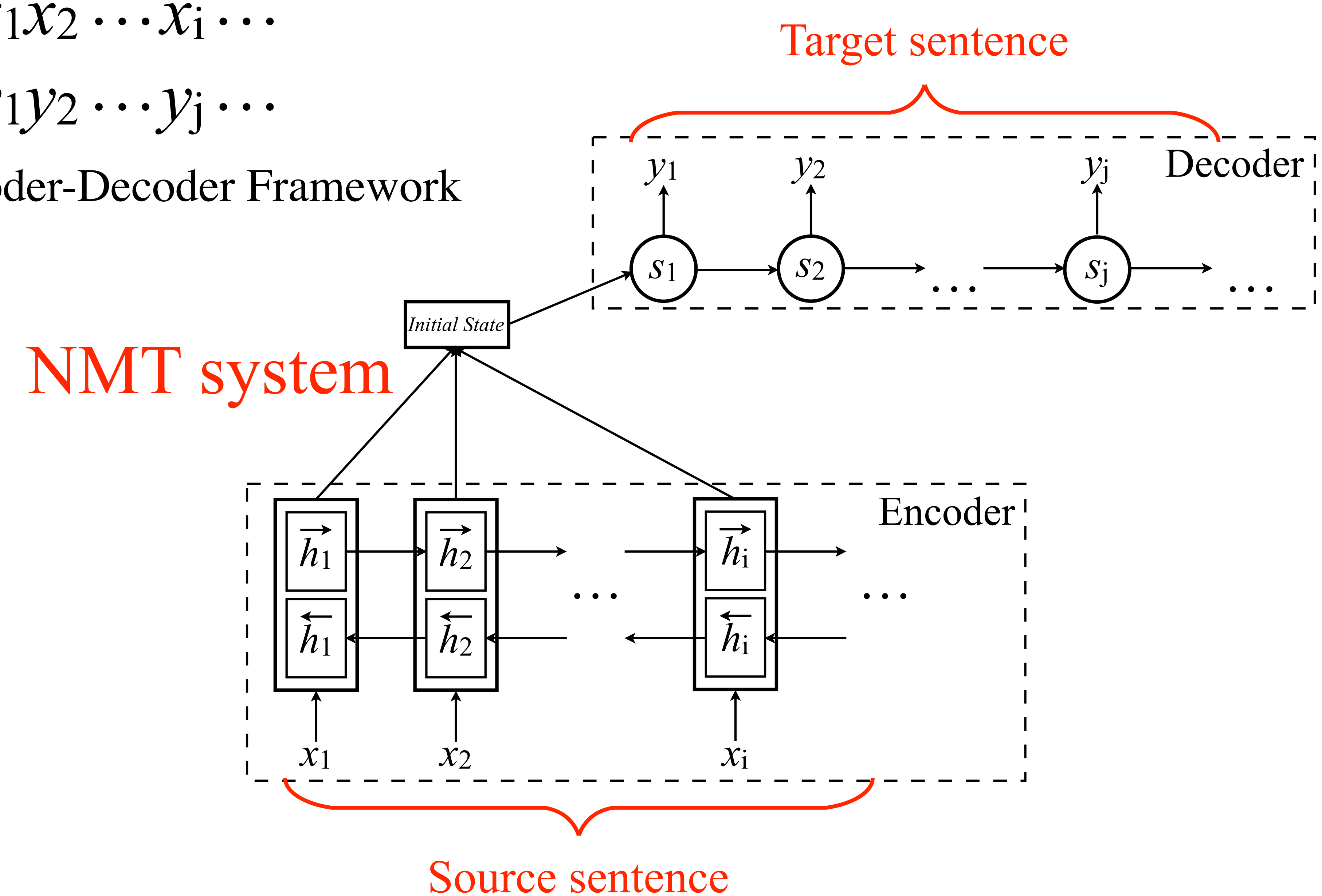
Neural Machine Translation

- Source sentence: $x_1 x_2 \cdots x_i \cdots$
- Target sentence: $y_1 y_2 \cdots y_j \cdots$
- NMT system: Encoder-Decoder Framework



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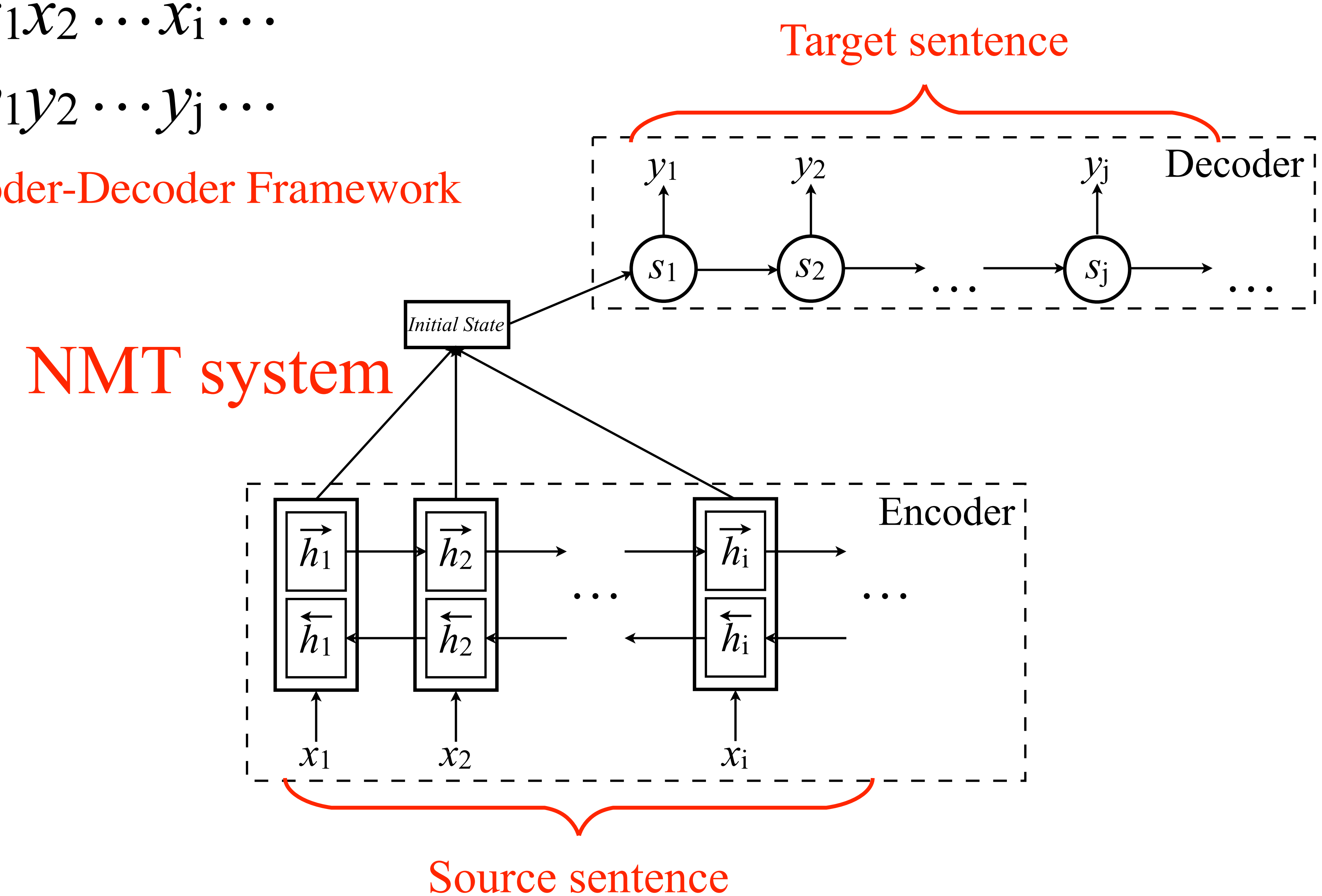
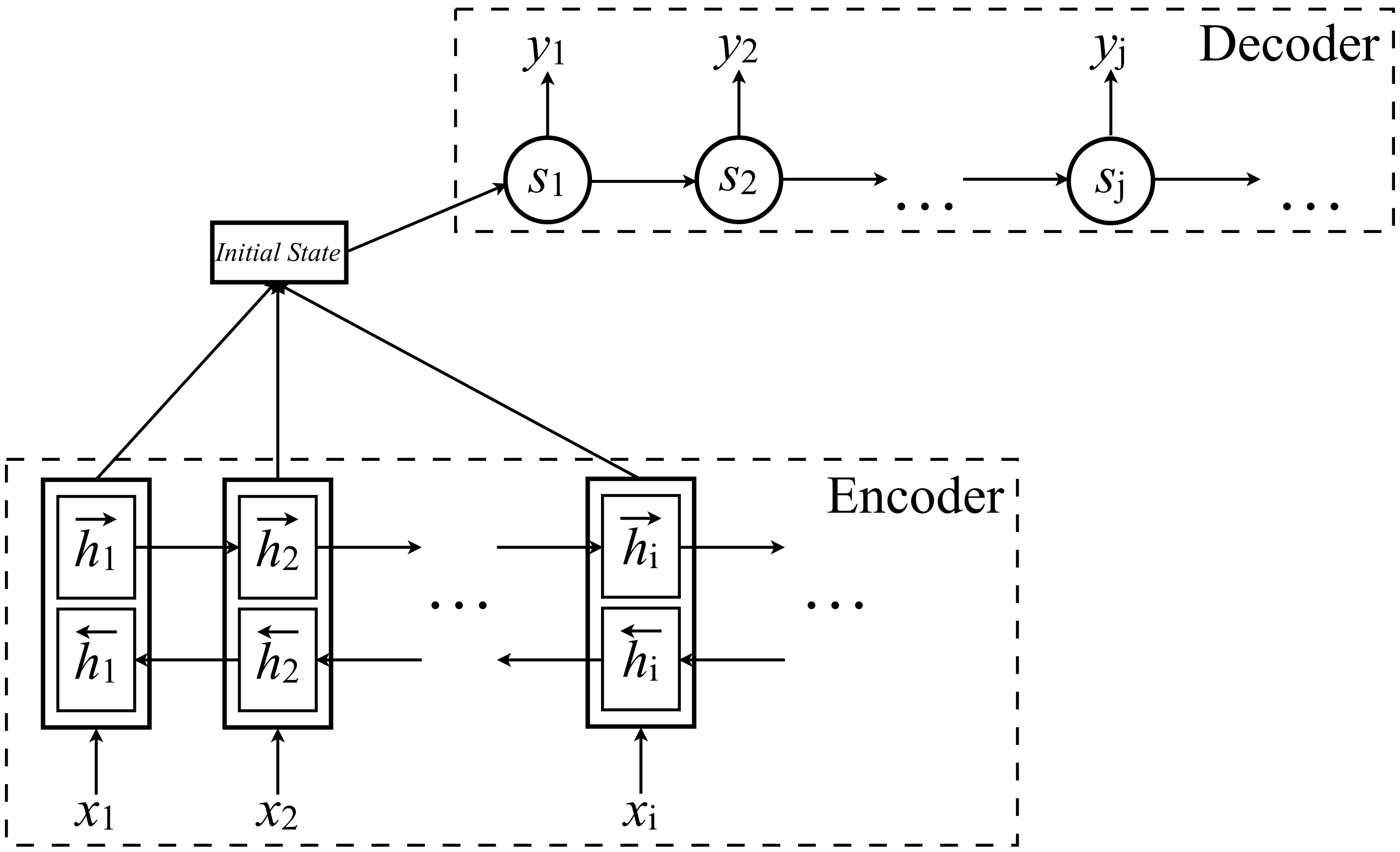


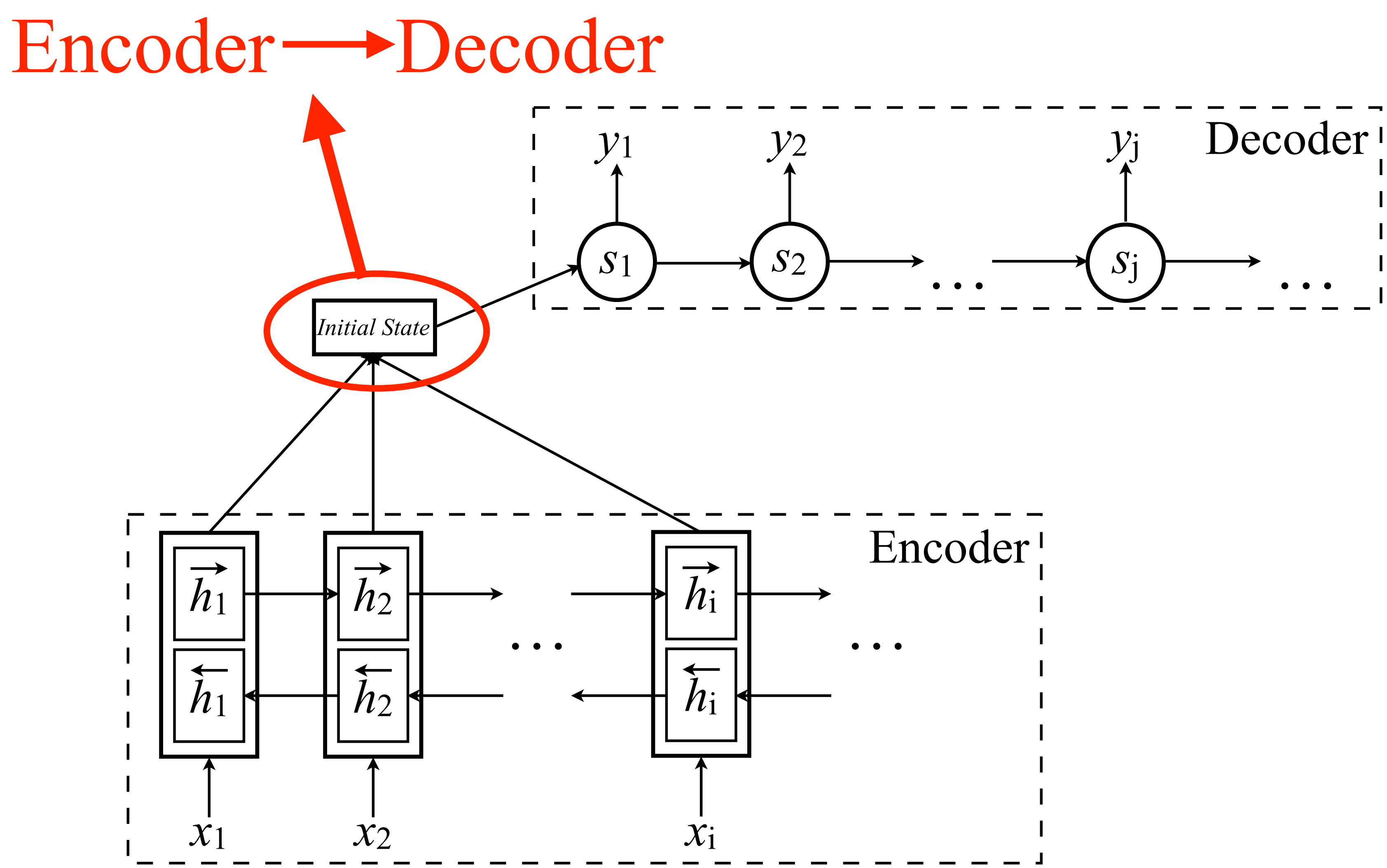
Encoder-Decoder Framework

- Encoder: encode all information of source sentence and generate the Initial State
- Decoder: decode target sentence start from Initial State



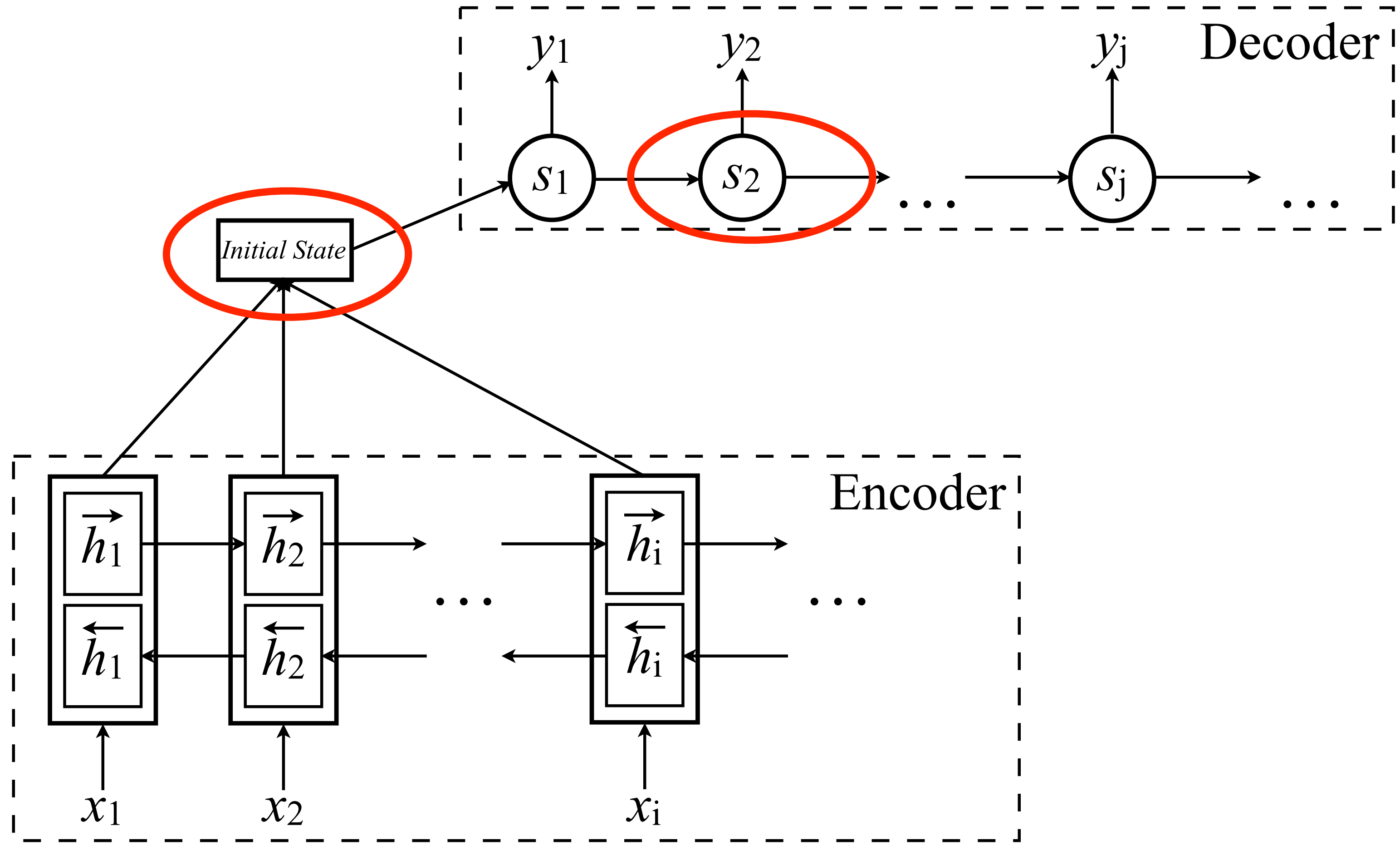
Encoder-Decoder Framework

- Encoder and Decoder are connected by Initial State



Encoder-Decoder Framework

- Initial State has all target information
- Hidden States of Decoder have target information which have not been generated



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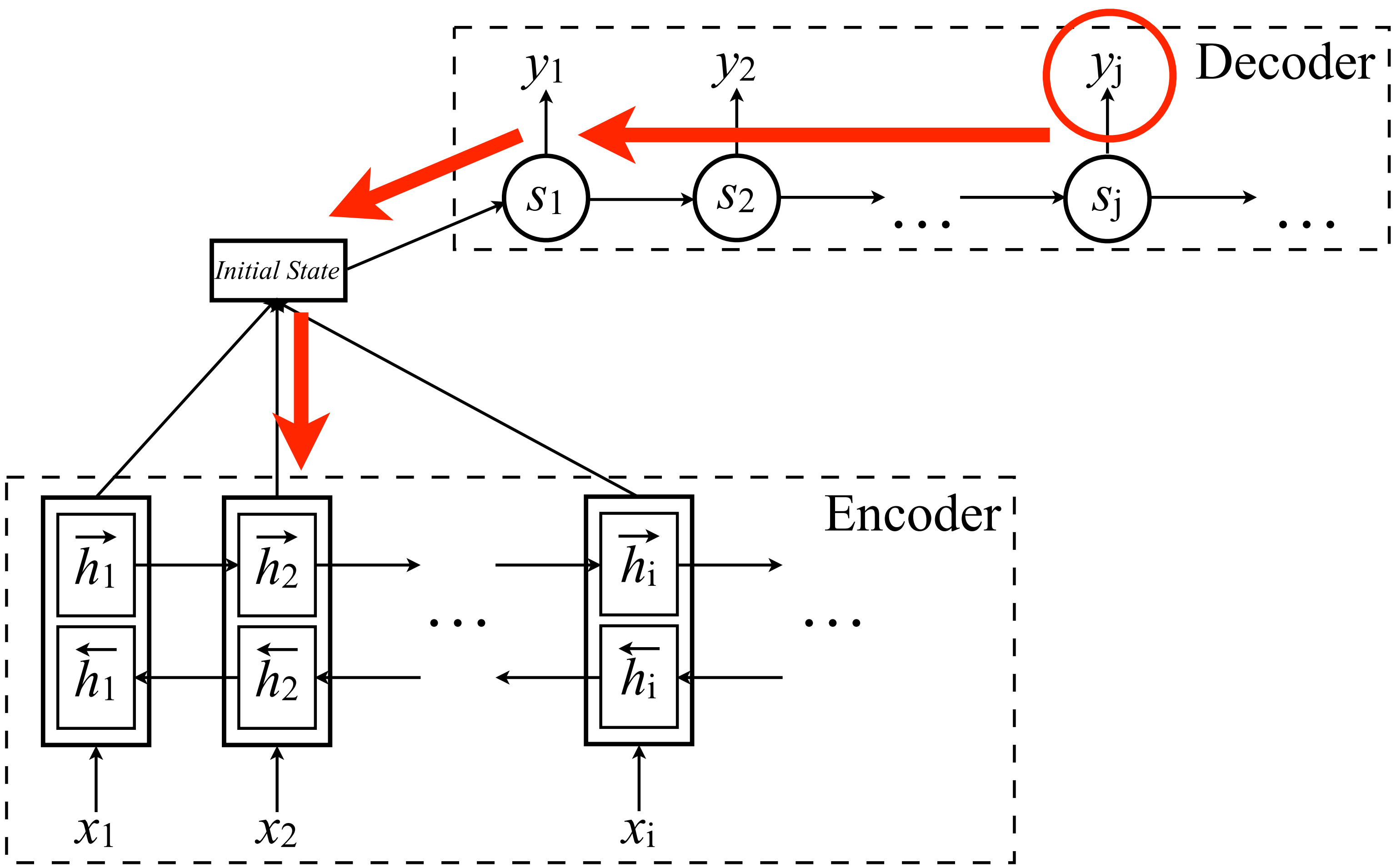
Shortage

- Initial State does not have a direct control
- Hidden States of Decoder are just supervised by current word



Motivation

- The initial state and hidden state plays an important role of translation, but it does not have a good control in the currently research
- Propagating translation errors through the end-to-end recurrent structures is not enough of control the hidden states

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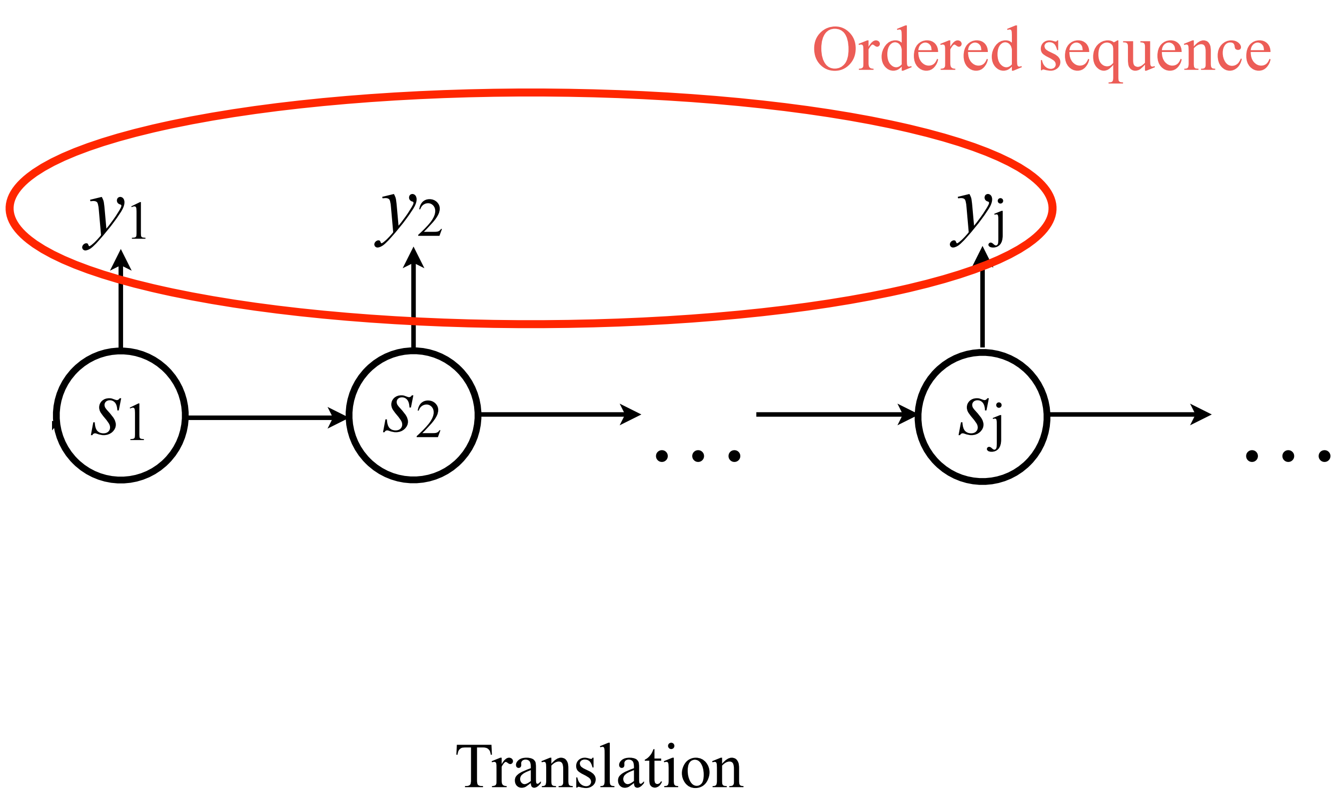
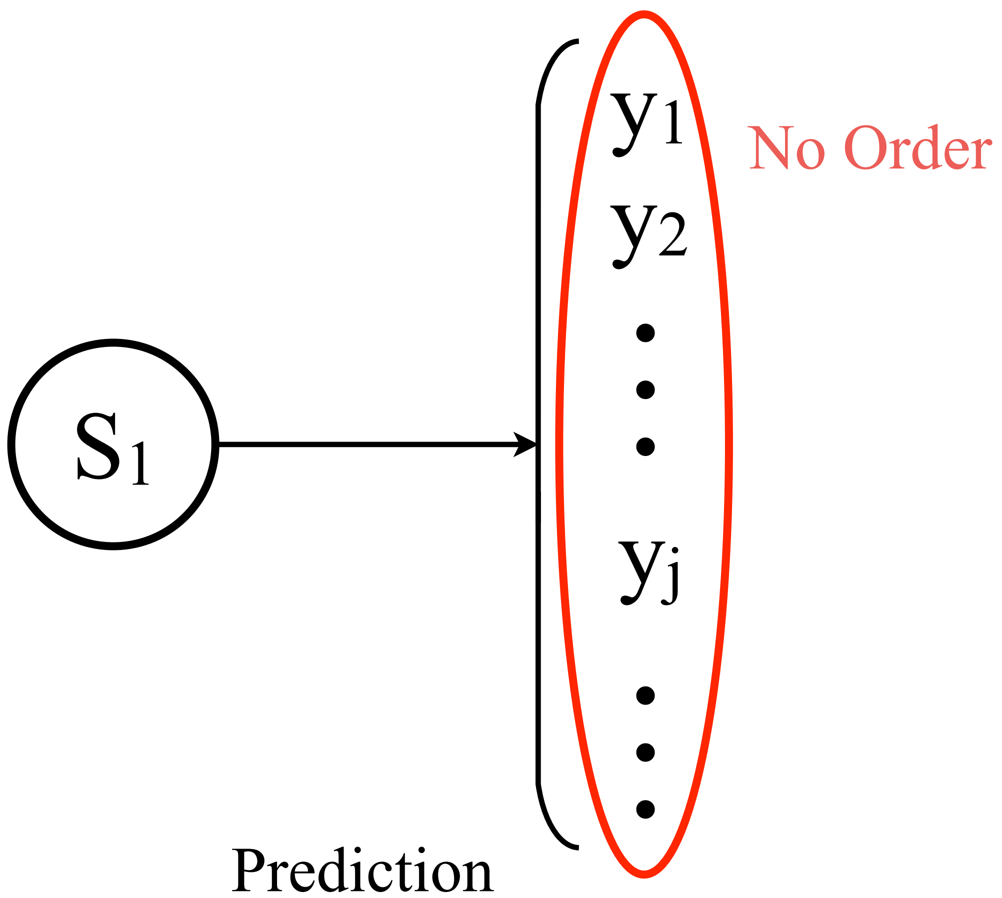
Word Prediction

- Translation task to generate an ordered sequence
- The goal of word prediction is to generate several words which is no order





Word Prediction

- Words in the target sentence could be viewed as a natural annotation
- Initial State and Hidden States should contain information about words in target sentence

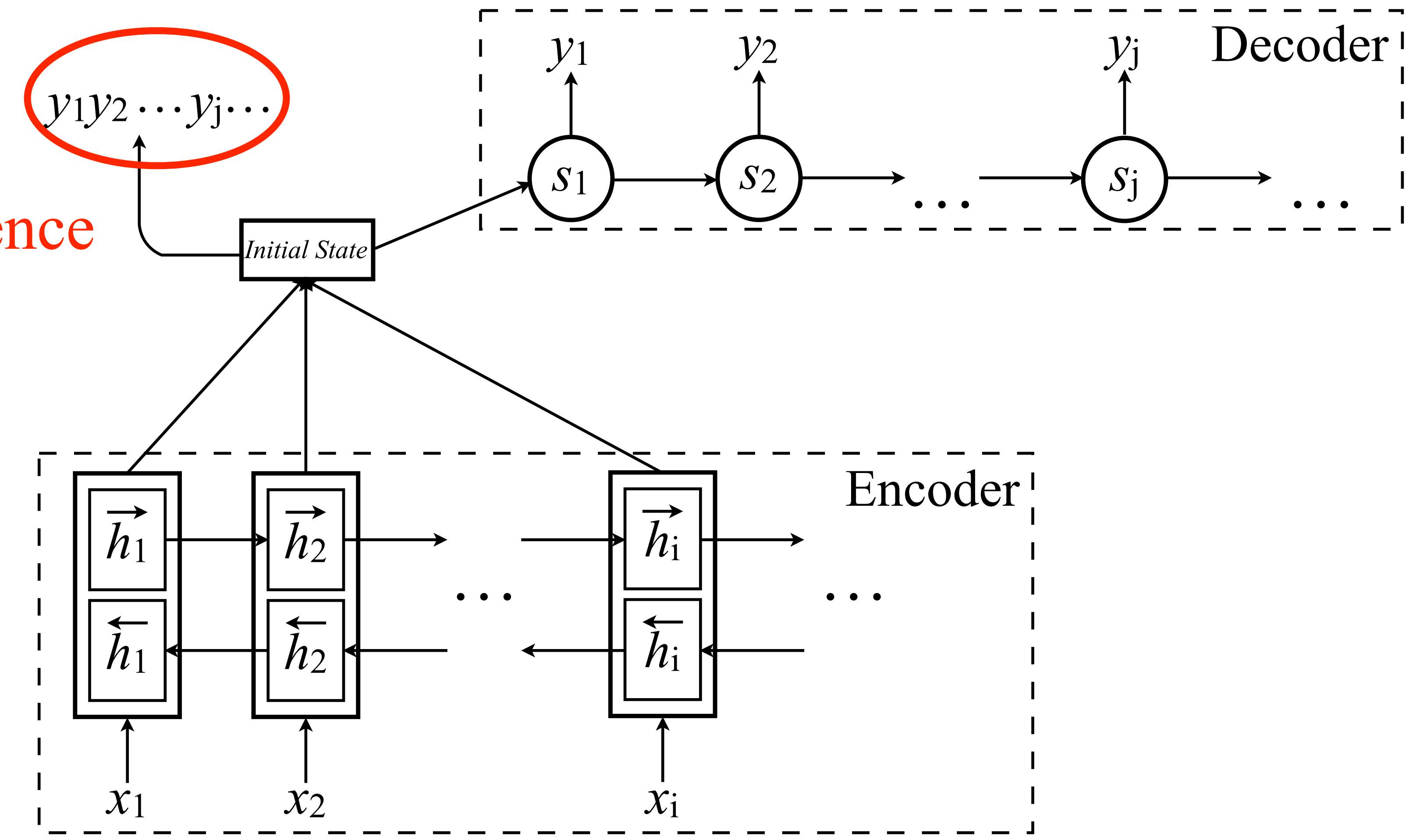
Word Prediction

- For the Initial State (WP_E)
- For Decoder's Hidden States (WP_D)

WP for the Initial State

- Initial State is responsible for the translation of whole target sentence, it should contain information of each word in the target sentence

Predict all words in target sentence



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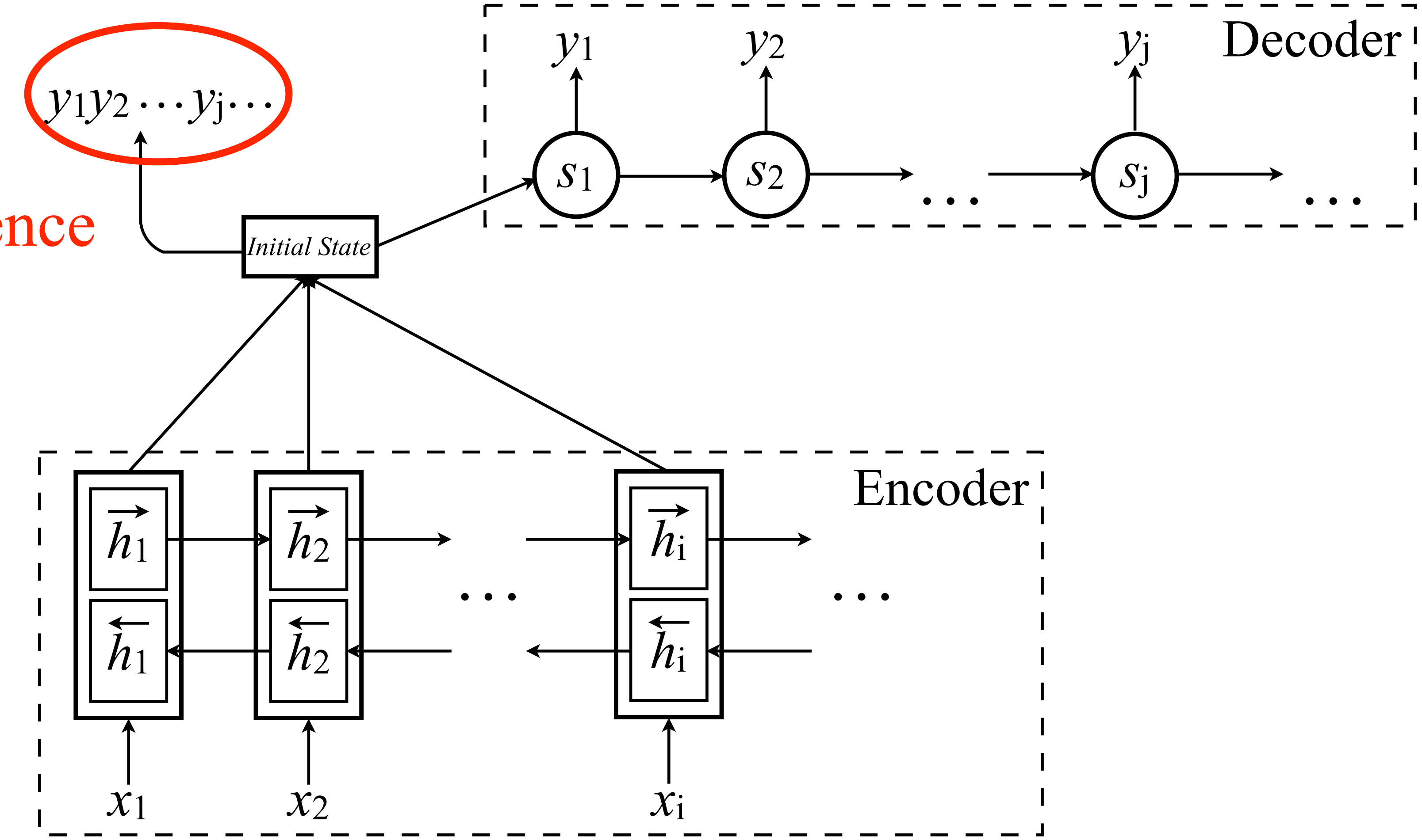
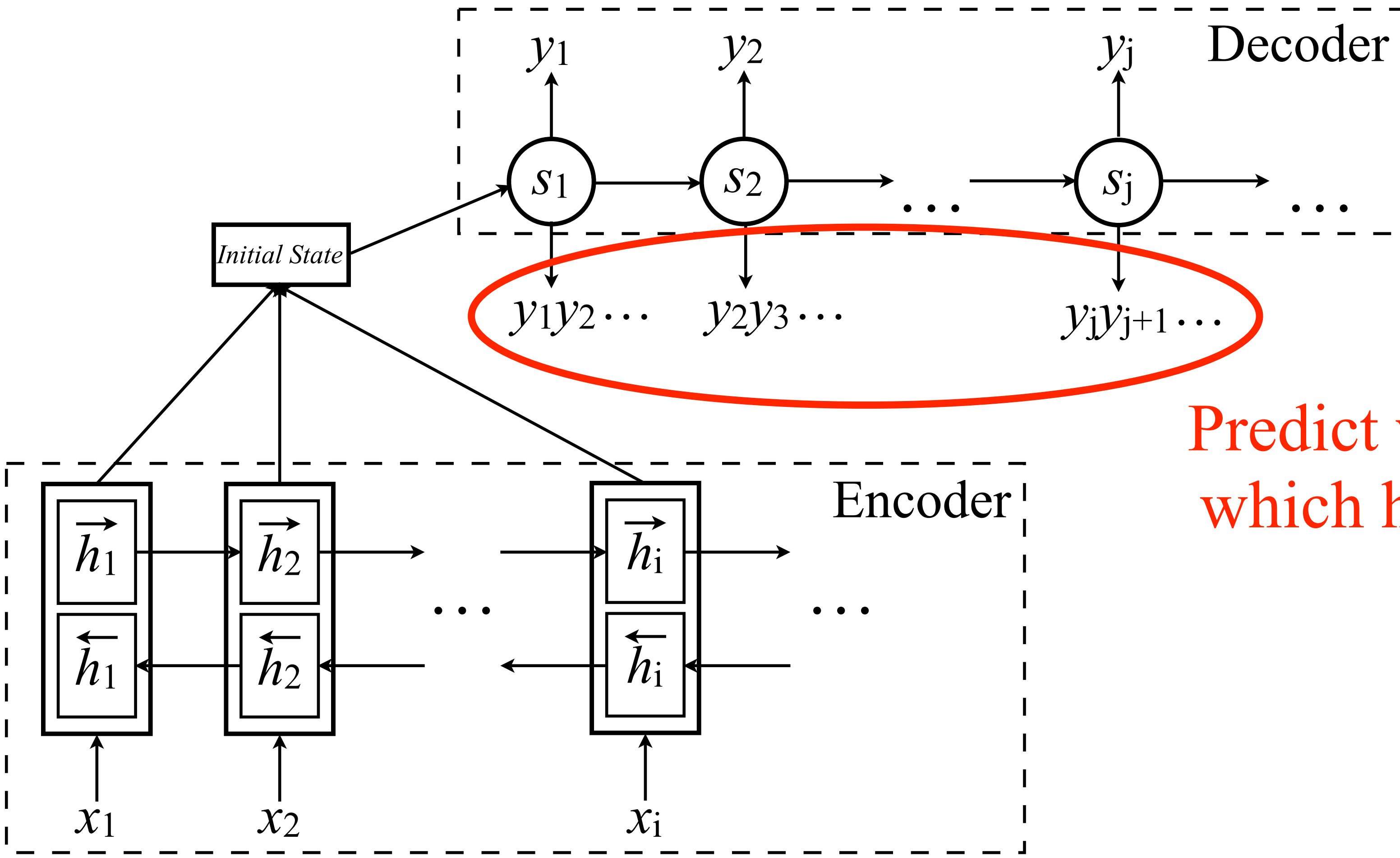
Predict all words in target sentence

$$P_{\mathrm{WP_E}}(\mathbf{y}|\mathbf{x}) = \prod_{j=1}^{|\mathbf{y}|} P_{\mathrm{WP_E}}(y_j|\mathbf{x})$$



WP for Decoder's Hidden States

- The hidden states of Decoder are responsible for the translation of target words, and they should contain information of each word which have not been translated



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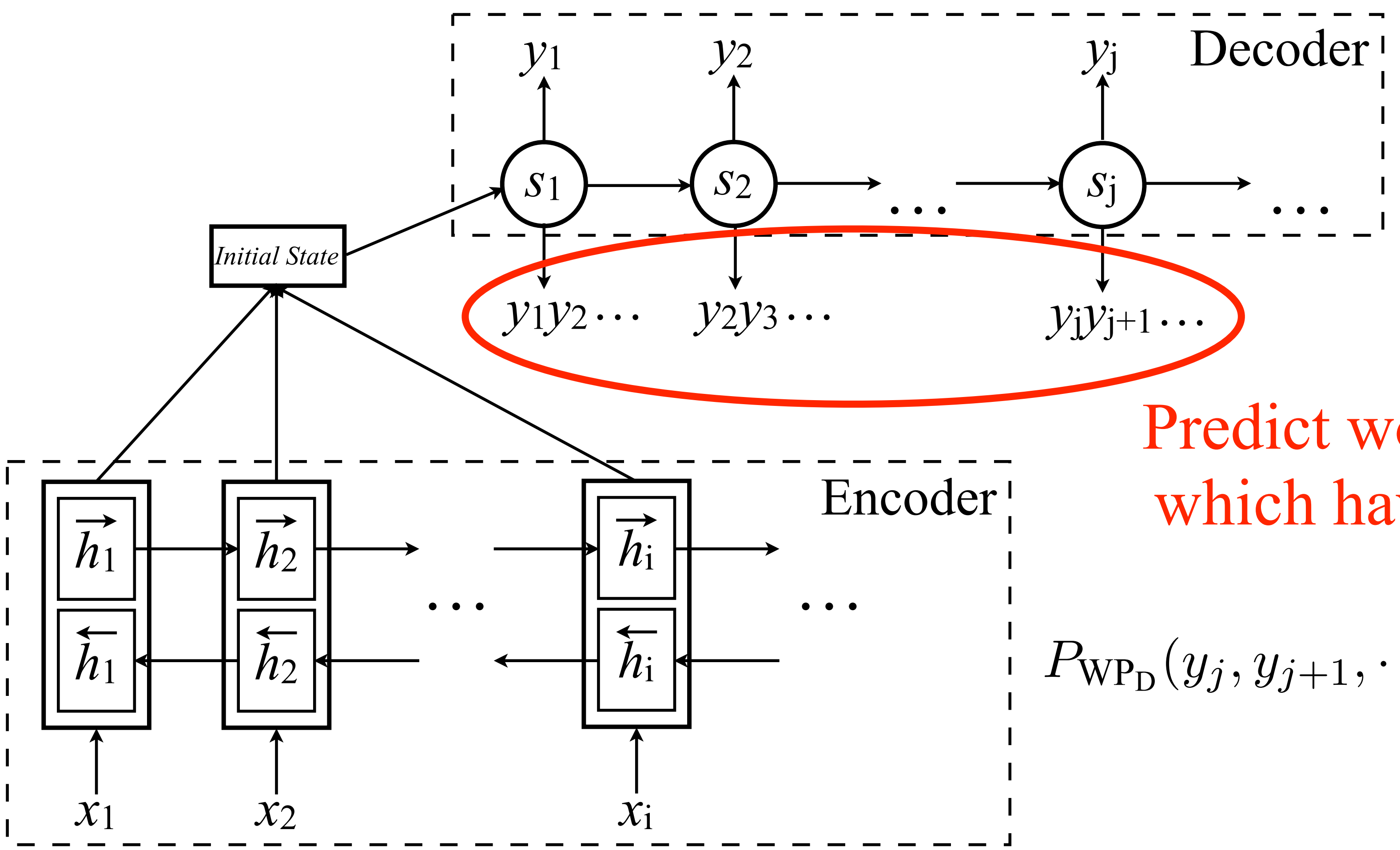


Predict words in target sentence which have not been translated

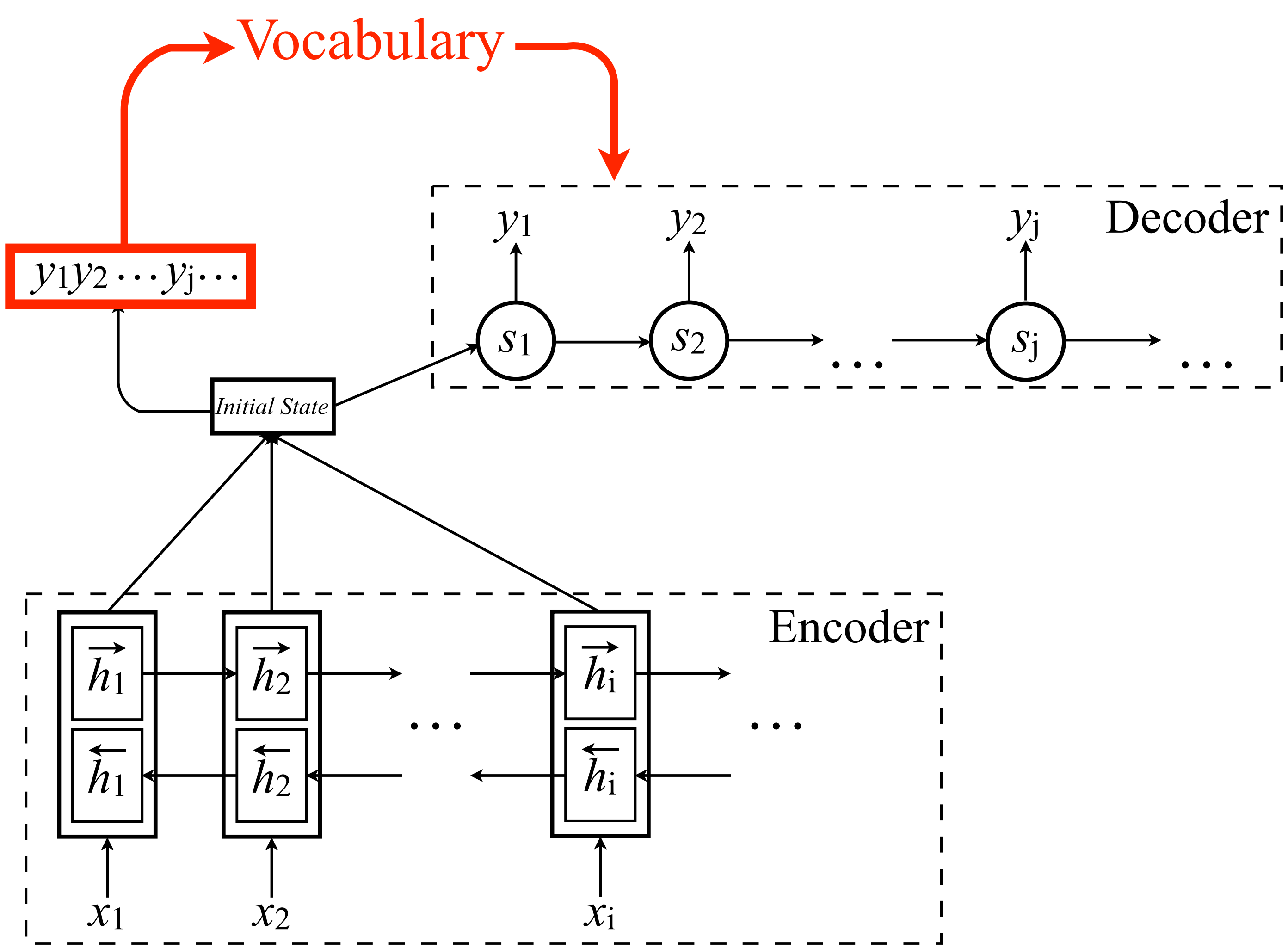
$$P_{\mathrm{WP_D}}(y_j, y_{j+1}, \cdots, y_{|\mathbf{y}|} | y_{<j}, \mathbf{x}) = \prod_{k=j}^{|\mathbf{y}|} P_{\mathrm{WP_D}}(y_k | y_{<j}, \mathbf{x})$$

Make use of word predictor

- Using large vocabulary will reduce decoding efficiency
- Exact small vocabulary will produce better translation effects
- In the testing stage, word prediction mechanism can predict a small vocabulary to decode

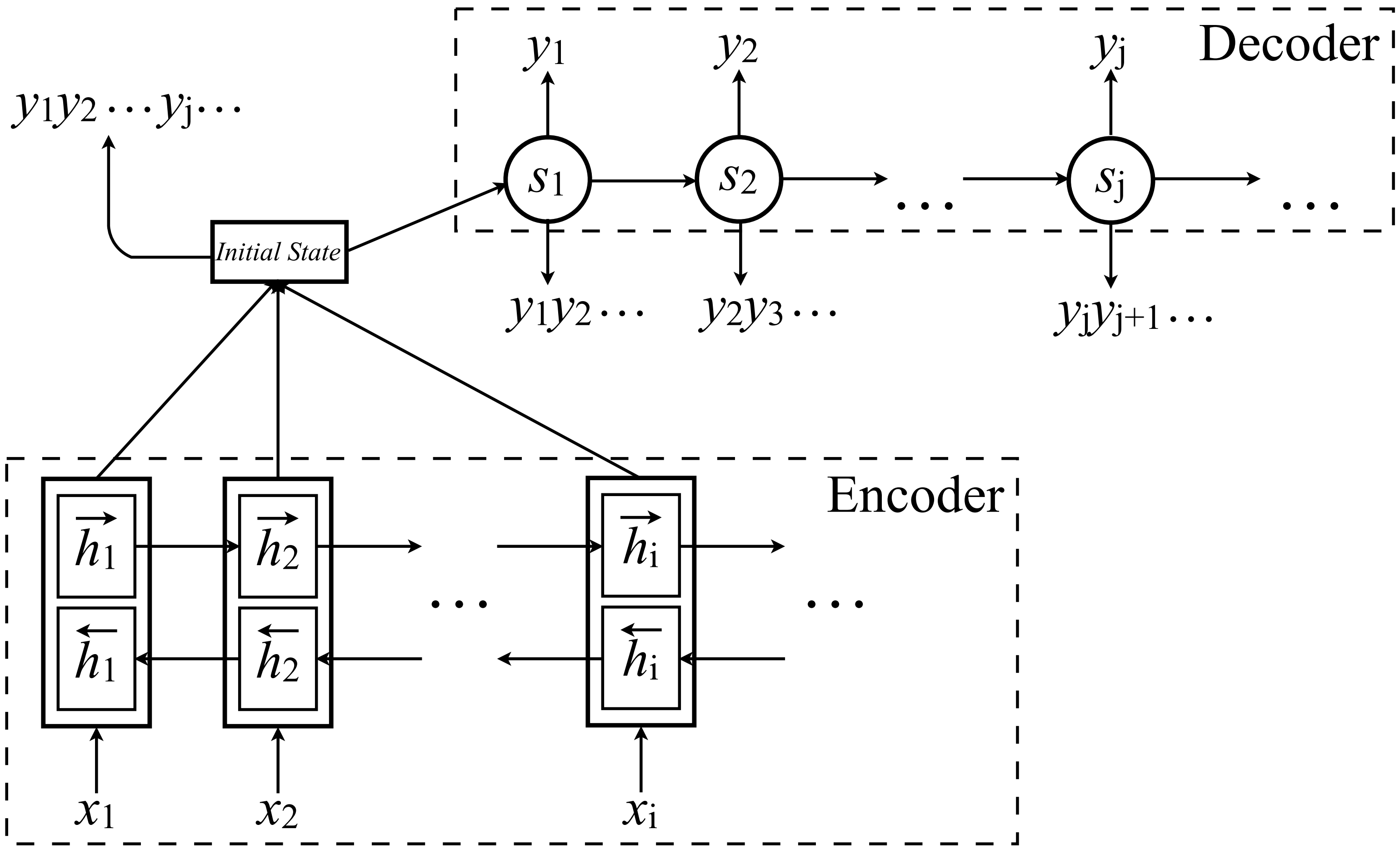
Make use of word predictor

- Predicting top-k words as new vocabulary
- Using the new vocabulary to decode



WP_E+WP_D (WP_{ED})

- Training stage
  - WP_E mechanism
  - WP_D mechanism
- Testing stage
  - WP_E as word predictor



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Data and Setting

- Chinese-English (CH-EN)
  - 8M LDC data set as training set
  - MT02 as validation set
  - MT03, MT04 and MT05 as test sets
  - Both validation set and test sets have 4 references
- German-English (DE-EN)
  - WMT14 as training set
  - Newstest 2012 as validation set
  - Newstest 2013 as test set
  - Both validation set and test set have 1 reference

Data and Setting

- The source and target vocabularies are limited to the most frequent 30K words
- The out-of-vocabulary words mapped to a special token *UNK*.
- Using *EOS* as the end-of-sentence symbol
- Sentences were encoded using byte-pair encoding (BPE) on DE-EN experiments

Translation quality

- Using WP_{ED} technique improves the baseline by **4.53** BLEU on the CH-EN experiment and **1.3** BLEU on the DE-EN experiment

Models	MT02(dev)	MT03	MT04	MT05	Test Ave.	IMP
baseNMT	34.04	34.92	36.08	33.88	34.96	–
WP_E	39.36	37.17	39.11	36.20	37.49	**+2.53**
WP_D	40.28	38.45	40.99	37.90	39.11	**+4.15**
WP_{ED}	40.25	39.50	40.91	38.05	39.49	$\boxed{\textbf{+4.53}}$

Chinese-English

Models	NST13(dev)	NST14	IMP
baseNMT	23.56	20.68	–
WP_E	24.44	21.09	**+0.41**
WP_D	25.31	21.54	**+0.86**
WP_{ED}	25.97	21.98	**+1.3**

German-English

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Compare with other techniques

- Along with ensemble method, the improvement could be up to **5.79** BLEU on the CH-EN and **1.79** BLEU on the DE-EN

Models	Test	IMP
baseNMT	34.86	–
$\mathrm{WP}_{\mathrm{ED}}$	39.49	+4.53
baseNMT-dropout	37.02	+2.06
$\mathrm{WP}_{\mathrm{ED}}$-dropout	39.25	+4.29
baseNMT-ensemble(4)	37.71	+2.75
$\mathrm{WP}_{\mathrm{ED}}$-ensemble(4)	40.75	+5.79

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German-English

Precision and Recall

- The initial state in WP_E contains more specific information about target words

top-n	baseNMT		WP_E	
	Prec.	Recall	Prec.	Recall
top-10	45%	17%	73%	30%
top-20	33%	21%	63%	43%
top-50	21%	30%	41%	55%
top-100	14%	39%	28%	68%
top-1k	2%	67%	4%	89%
top-5k	0.7%	84%	0.9%	95%
top-10k	0.4%	90%	0.5%	97%

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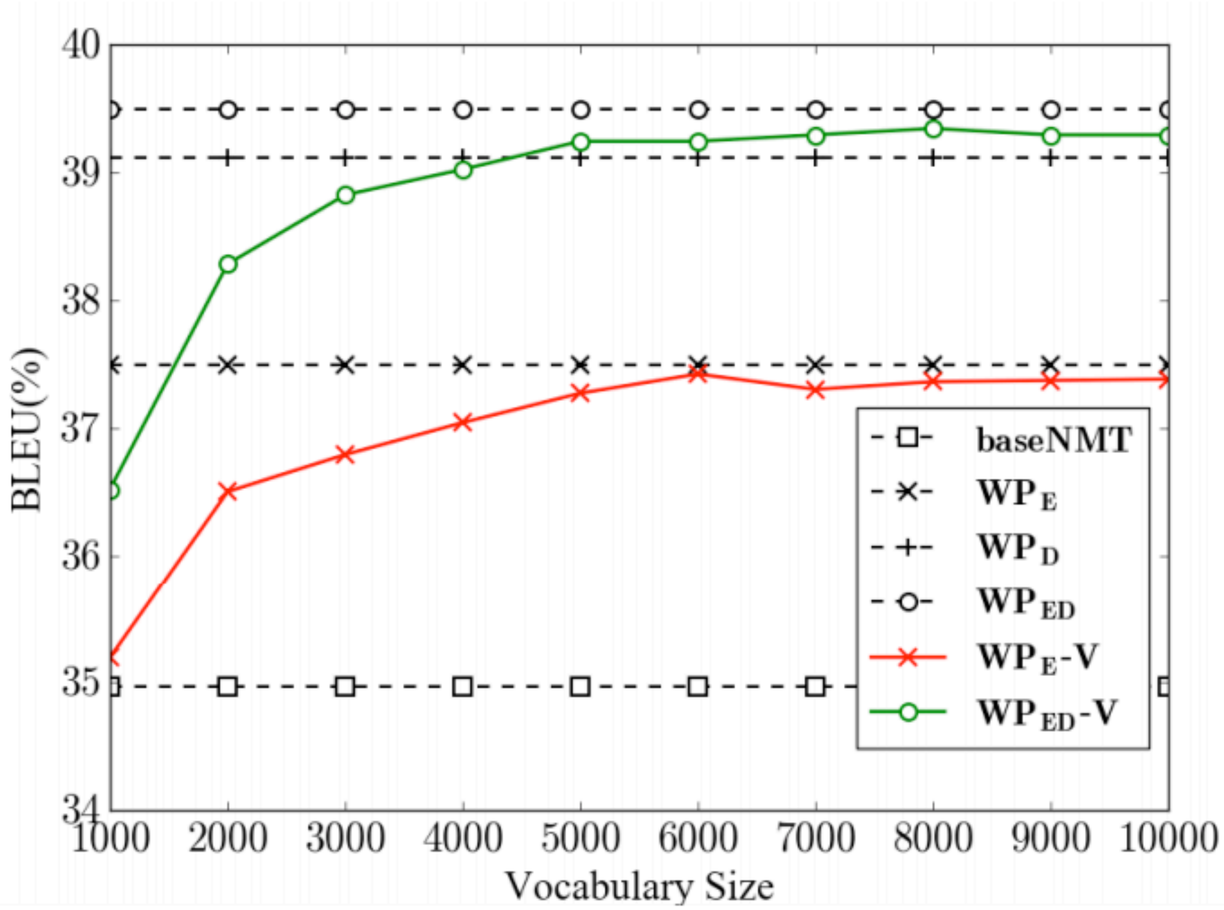
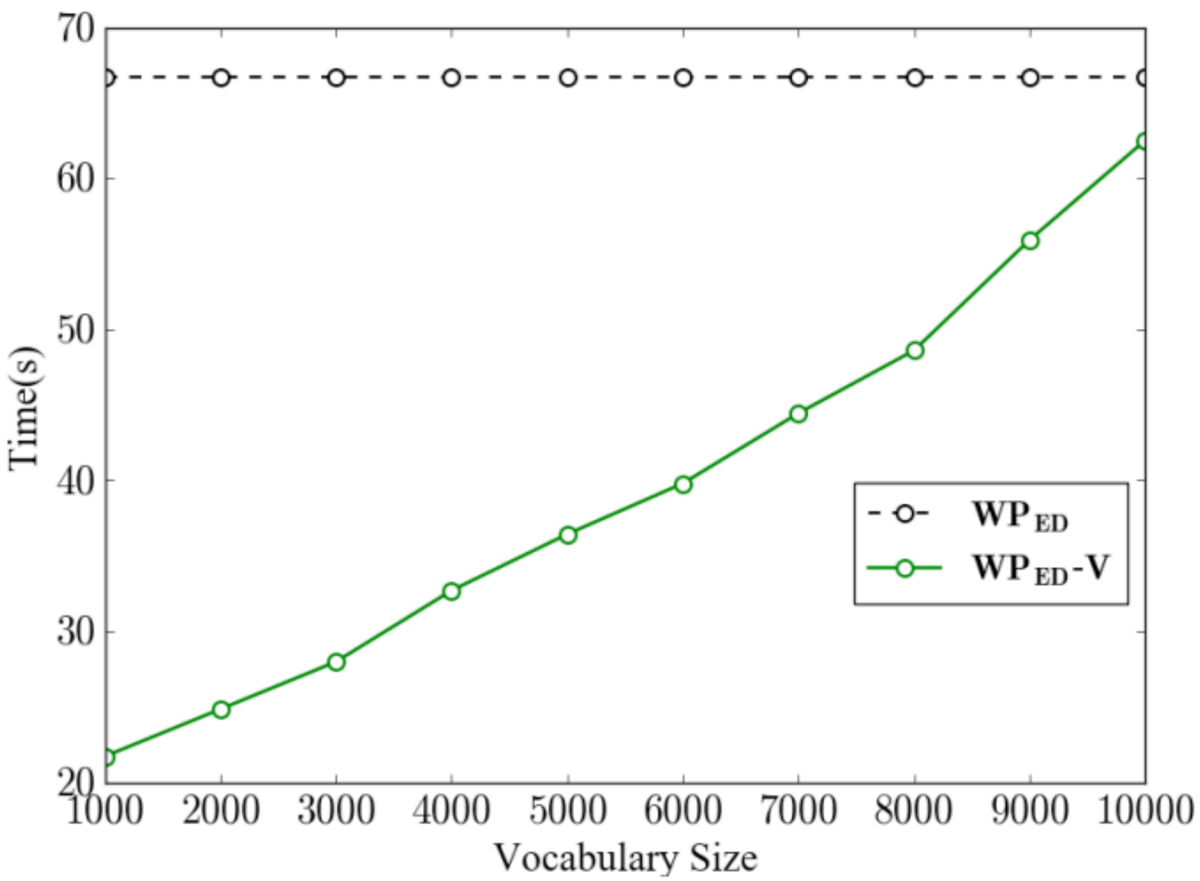
top-5k	0.7%	84%	0.9%	95%
top-10k	0.4%	90%	0.5%	97%

Decoding Efficiency

- With a 6k predicted vocabulary, the cost is about 60% of a full-vocabulary; the performance is comparable fixed-vocabulary system



BLEU scores with different vocabulary sizes for each sentence.



Decoding time with different vocabulary sizes for each sentence.

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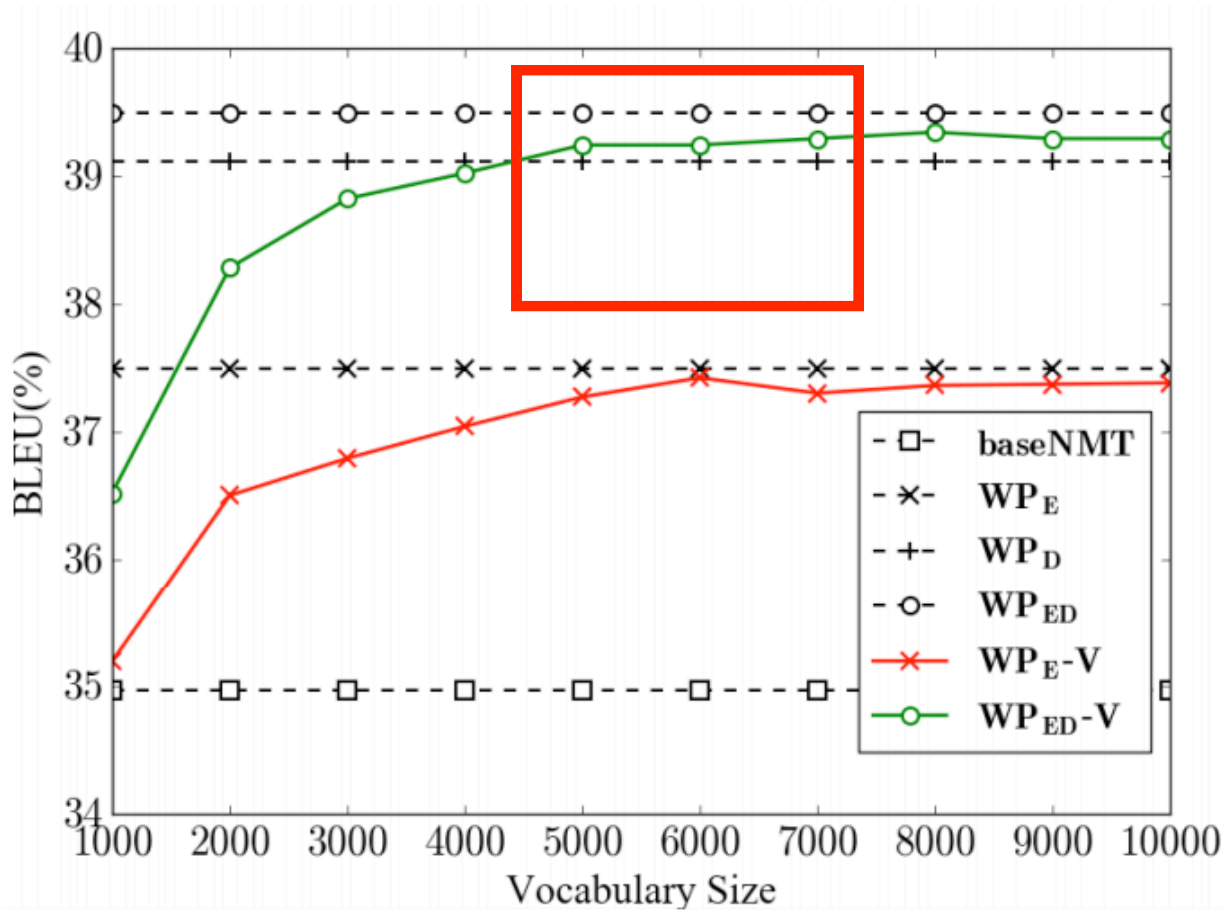

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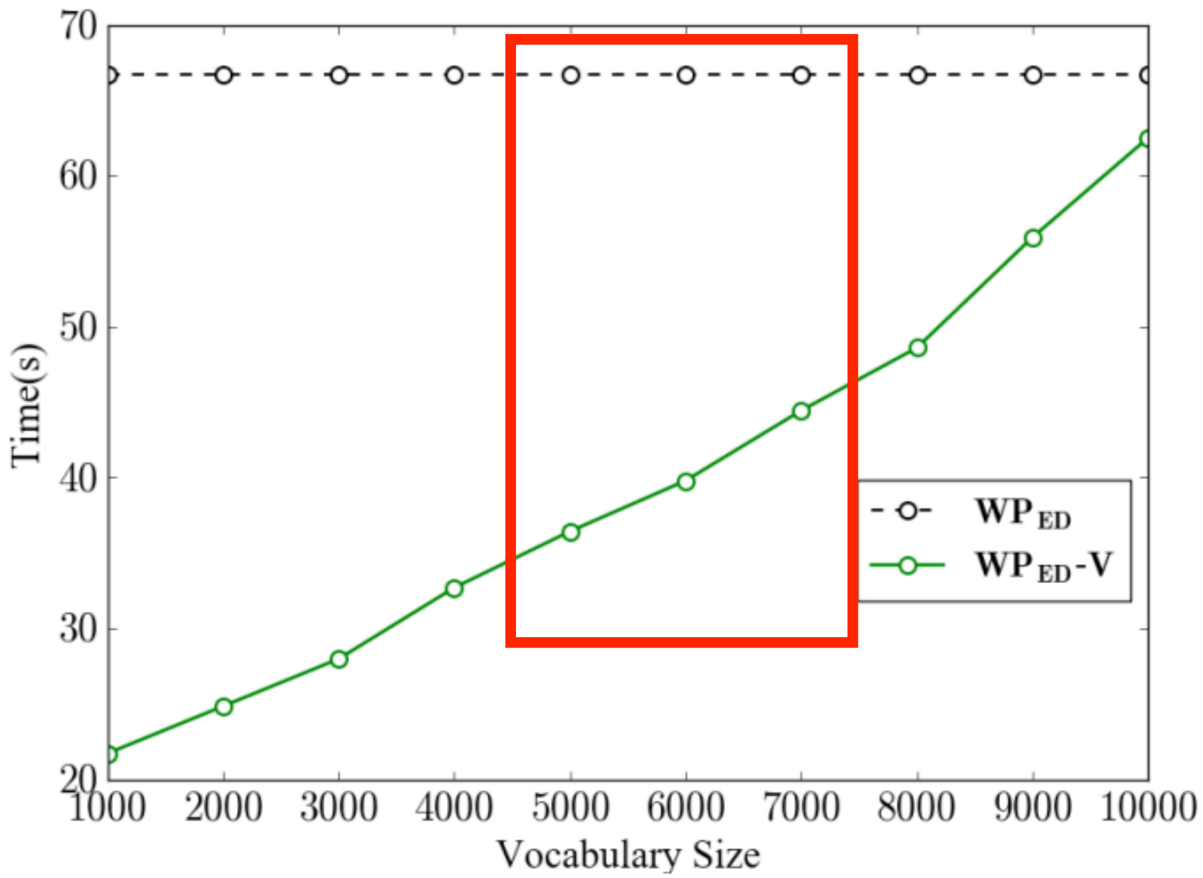

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Translation Example

- WP_{ED} carries the exact information during translation, most of errors no longer exist

source	时代华纳公司的网络公司美国线上说, 它预期二○○二年的广告与商业销售将由二○○一年的二十七亿美元减少到十五亿美元。
reference	america online , the internet arm of time warner conglomerate , said it expects advertising and commerce revenue to decline from us $ 2.7 billion in 2001 to us $ 1.5 in 2002 .
baseNMT	in the *us line* , *the internet company 's internet company said on the internet* that it expected that the business sales in 2002 would fall from $ UNK billion to $ UNK billion in 2001 .
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Conclusion

- The backpropagation provides no direct control of the information carried by the hidden states.

- Word prediction mechanism can enhance the initial state and hidden states of decoder as well.

Thanks