Semi-supervised Learning for Neural Machine Translation

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Machine Translation

Automated translation using computer software

Machine Translation

- Rule-based Machine Translation 1970s
- Example-based Machine Translation 1984
- Statical Machine Translation (SMT) 1993
- **Neural Machine Translation （NMT） 2014**

Trends: learning to translate from **DATA**

Machine Translation

Parallel corpora are usually limited in

quantity & **quality** & **coverage**

Monolingual Corpora

Parallel Corpora

Monolingual Corpora Used in SMT and NMT

- N-gram language model in SMT
  Koehn et al., [2007]

- Monolingual corpora as decipherment
  Ravi and Knight [2011]

- Integrate a neural language model into NMT.
  Gulccehre et al. [2015]

- Additional pseudo parallel corpus.
  Sennrich et al. [2016]

Supervised Training

Parallel Corpus $$\mathcal{D} = \{\langle \mathbf{x}^{(n)}, \mathbf{y}^{(n)} \rangle\}_{n=1}^{N}$$

Objective $$L(\boldsymbol{\theta}) = \sum_{n=1}^{N} \log P(\mathbf{y}^{(n)} | \mathbf{x}^{(n)}; \boldsymbol{\theta})$$

Unsupervised Training

Monolingual Corpus $\mathcal{T} = \{\mathbf{y}^{(t)}\}_{t=1}^{T}$

Our Approach — Autoencoders

bushi yu shalong juxing le huitan

$\mathbf{x}$

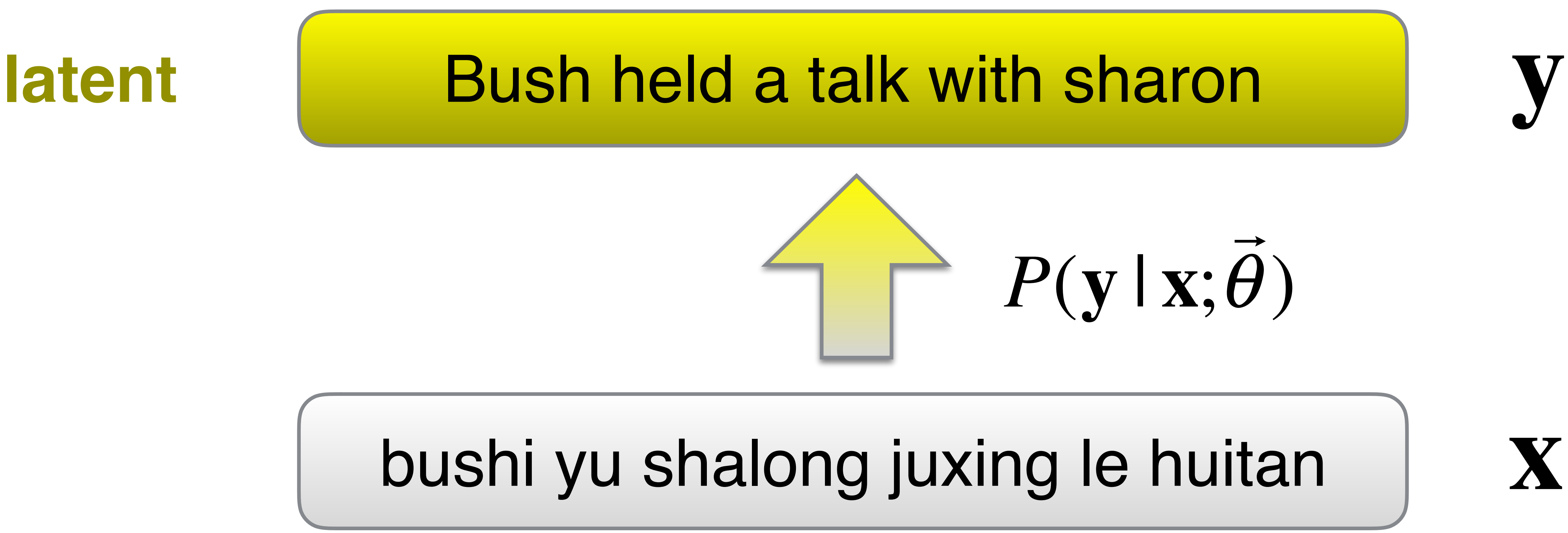
Our Approach — Autoencoders

$$P(\mathbf{y} \mid \mathbf{x}; \vec{\theta})$$

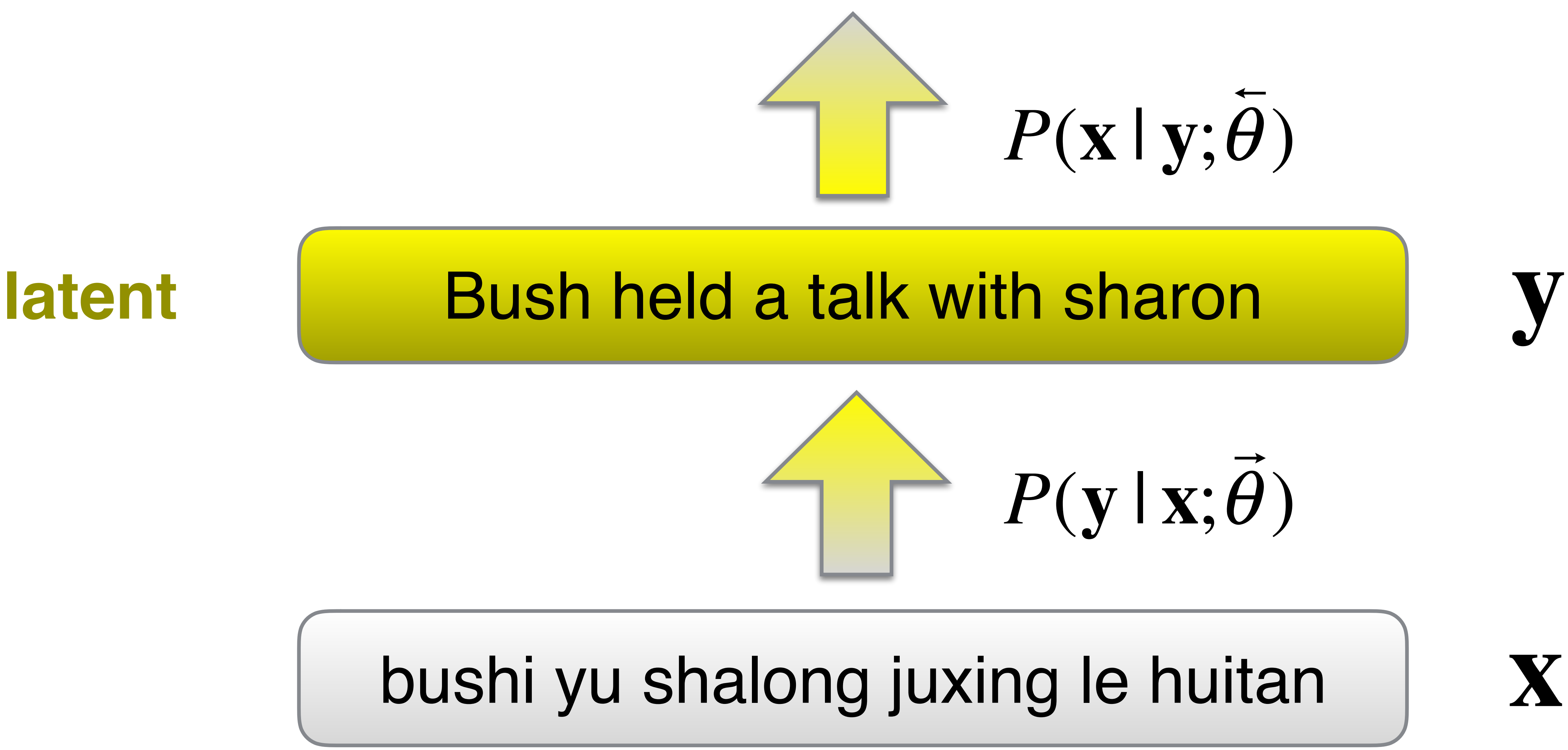
bushi yu shalong juxing le huitan

$\mathbf{x}$

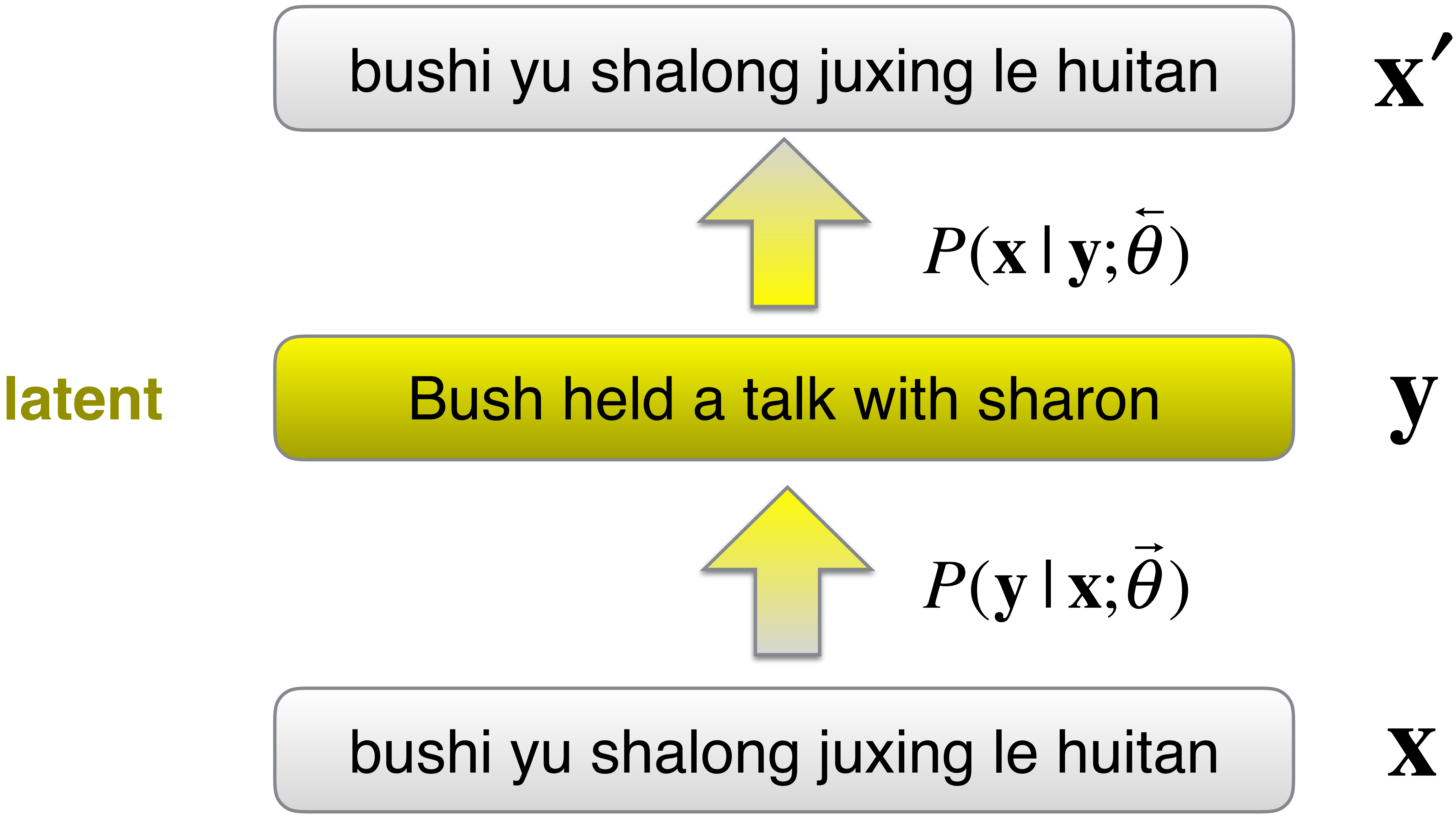
Our Approach — Autoencoders



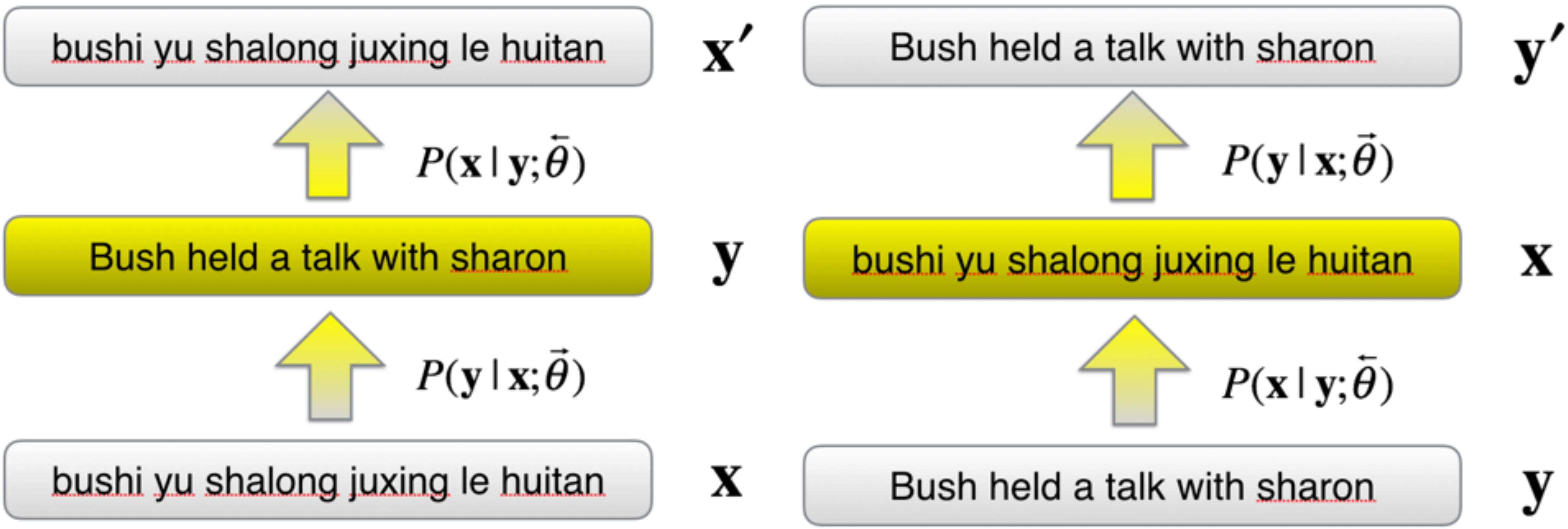
Our Approach — Autoencoders



Our Approach — Autoencoders



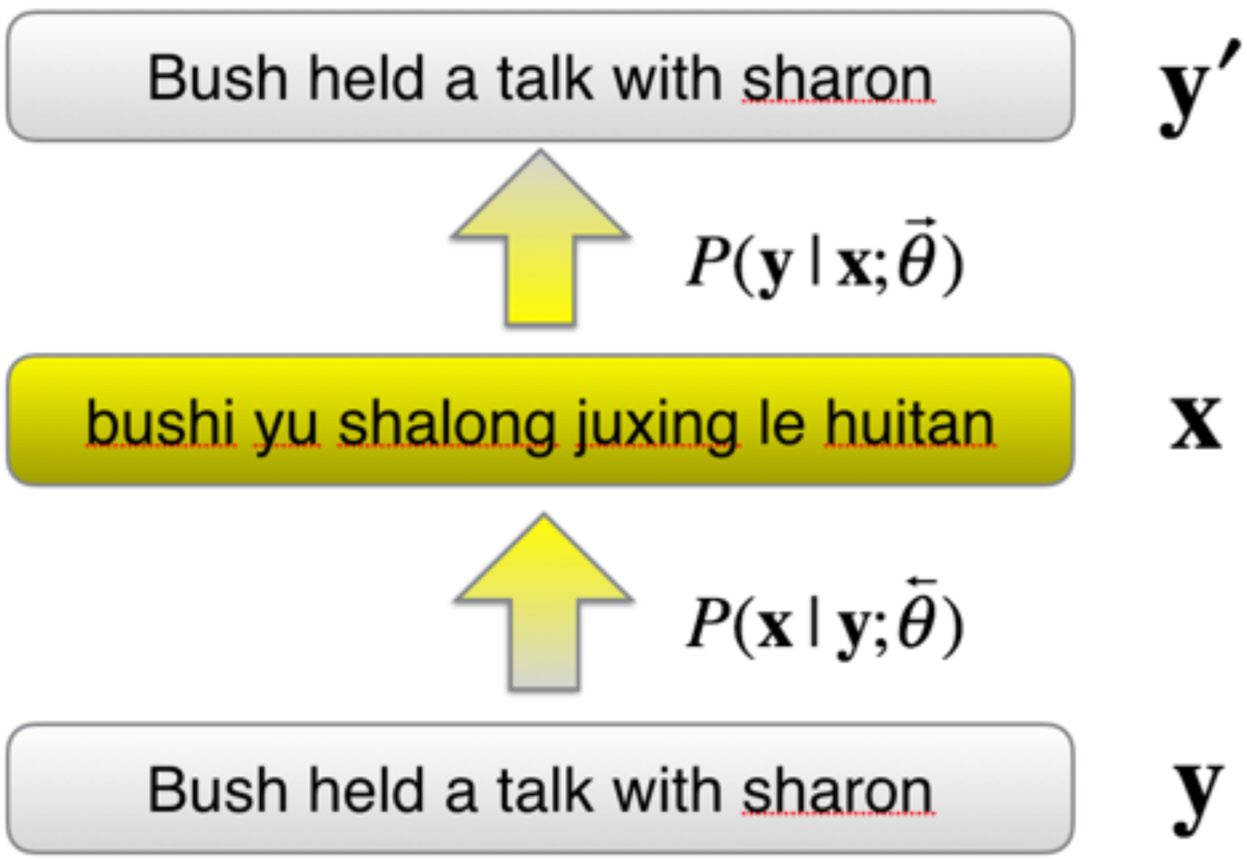
Our Approach — Autoencoders



source autoencoder **target autoencoder**

Unsupervised Training (Autoencoders)

Monolingual Corpus $\mathcal{T} = \{\mathbf{y}^{(t)}\}_{t=1}^{T}$



target autoencoder

$$
\begin{aligned}
& P(\mathbf{y}'|\mathbf{y}; \overrightarrow{\boldsymbol{\theta}}, \overleftarrow{\boldsymbol{\theta}}) \\
= & \sum_{\mathbf{x}} P(\mathbf{y}', \mathbf{x}|\mathbf{y}; \overrightarrow{\boldsymbol{\theta}}, \overleftarrow{\boldsymbol{\theta}}) \\
= & \sum_{\mathbf{x}} \underbrace{P(\mathbf{x}|\mathbf{y}; \overleftarrow{\boldsymbol{\theta}})}_{encoder} \underbrace{P(\mathbf{y}'|\mathbf{x}; \overrightarrow{\boldsymbol{\theta}})}_{decoder}
\end{aligned}
$$

Semi-supervised Training

Training Objective

$$
\begin{aligned}
& J(\overrightarrow{\boldsymbol{\theta}}, \overleftarrow{\boldsymbol{\theta}}) \\
= & \underbrace{\sum_{n=1}^{N} \log P(\mathbf{y}^{(n)}|\mathbf{x}^{(n)}; \overrightarrow{\boldsymbol{\theta}})}_{\textit{source-to-target likelihood}} + \underbrace{\sum_{n=1}^{N} \log P(\mathbf{x}^{(n)}|\mathbf{y}^{(n)}; \overleftarrow{\boldsymbol{\theta}})}_{\textit{target-to-source likelihood}} \\
& \boxed{+\lambda_1 \underbrace{\sum_{t=1}^{T} \log P(\mathbf{y}'|\mathbf{y}^{(t)}; \overrightarrow{\boldsymbol{\theta}}, \overleftarrow{\boldsymbol{\theta}})}_{\textit{target autoencoder}} + \lambda_2 \underbrace{\sum_{s=1}^{S} \log P(\mathbf{x}'|\mathbf{x}^{(s)}; \overrightarrow{\boldsymbol{\theta}}, \overleftarrow{\boldsymbol{\theta}})}_{\textit{source autoencoder}},}
\end{aligned}
$$

Translation Results

Compared with Moses (SMT) and RNNSearch (NMT)

System	Training Data			Direction	NIST06	NIST02
	CE	C	E			
MOSES	√	×	×	C → E E → C	32.48 14.27	32.69 18.28
RNNSEARCH	√	×	×	C → E E → C	30.74 15.71	35.16 20.76

Translation Results

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	CE	C	E			
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				E → C	14.27	18.28
	√	×	√	C → E	34.59	35.21
	√	√	×	E → C	20.69	25.85
RNNSearch	√	×	×	C → E	30.74	35.16
				E → C	15.71	20.76

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RNNSEARCH	√	×	×	C → E	30.74	35.16
				E → C	15.71	20.76
	√	×	√	C → E	35.61**++	38.78**++
				E → C	17.59++	23.99 ++

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				E → C	15.71	20.76
	√	×	√	C → E	35.61**++	38.78**++
				E → C	17.59++	23.99 ++
	√	√	×	C → E	35.01++	38.20**++
				E → C	21.12*++	29.52**++

Translation Results

Compared with Moses (SMT) and RNNSearch (NMT)

System	Training Data CE	C	E	Direction	NIST06	NIST02	NIST03	NIST04	NIST05
Moses	√	×	×	C → E	32.48	32.69	32.39	33.62	30.23
				E → C	14.27	18.28	15.36	13.96	14.11
	√	×	√	C → E	34.59	35.21	35.71	35.56	33.74
	√	√	×	E → C	20.69	25.85	19.76	18.77	19.74
RNNSearch	√	×	×	C → E	30.74	35.16	33.75	34.63	31.74
				E → C	15.71	20.76	16.56	16.85	15.14
	√	×	√	C → E	35.61**++	38.78**++	38.32**++	38.49**++	36.45**++
				E → C	17.59++	23.99 ++	18.95++	18.85++	17.91++
	√	√	×	C → E	35.01++	38.20**++	37.99**++	38.16**++	36.07**++
				E → C	21.12*++	29.52**++	20.49**++	21.59**++	19.97++

Translation Results

Compared with *Sennrich et al. [2015a]*

Method	Training Data CE	C	E	Direction	NIST06	NIST02	NIST03	NIST04	NIST05
Sennrich *et al.* [2015a]	√	×	√	C →E	34.10	36.95	36.80	37.99	35.33
	√	√	×	E →C	19.85	28.83	20.61	20.54	19.17
this work	√	×	√	C →E	35.61**	38.78**	38.32**	38.49*	36.45**
				E →C	17.59	23.99	18.95	18.85	17.91
	√	√	×	C →E	35.01**	38.20**	37.99**	38.16	36.07**
				E →C	21.12**	29.52**	20.49	21.59**	19.97**

Example Translation of Monolingual Corpus

Monolingual	hongsen shuo , ruguo you na jia famu gongsi dangan yishenshifa , name tamen jiang zihui qiancheng .
Reference	hongsen said, if any *logging companies* dare to defy the law, then they will *destroy their own future* .
Translation	hun sen said , if any of *those companies* dare defy the law , then they will *have their own fate* . [*iteration 0*]
	hun sen said if any *tree felling company* dared to break the law , then they would *kill themselves* . [*iteration 40K*]
	hun sen said if any *logging companies* dare to defy the law , they would *destroy the future themselves* . [*iteration 240K*]

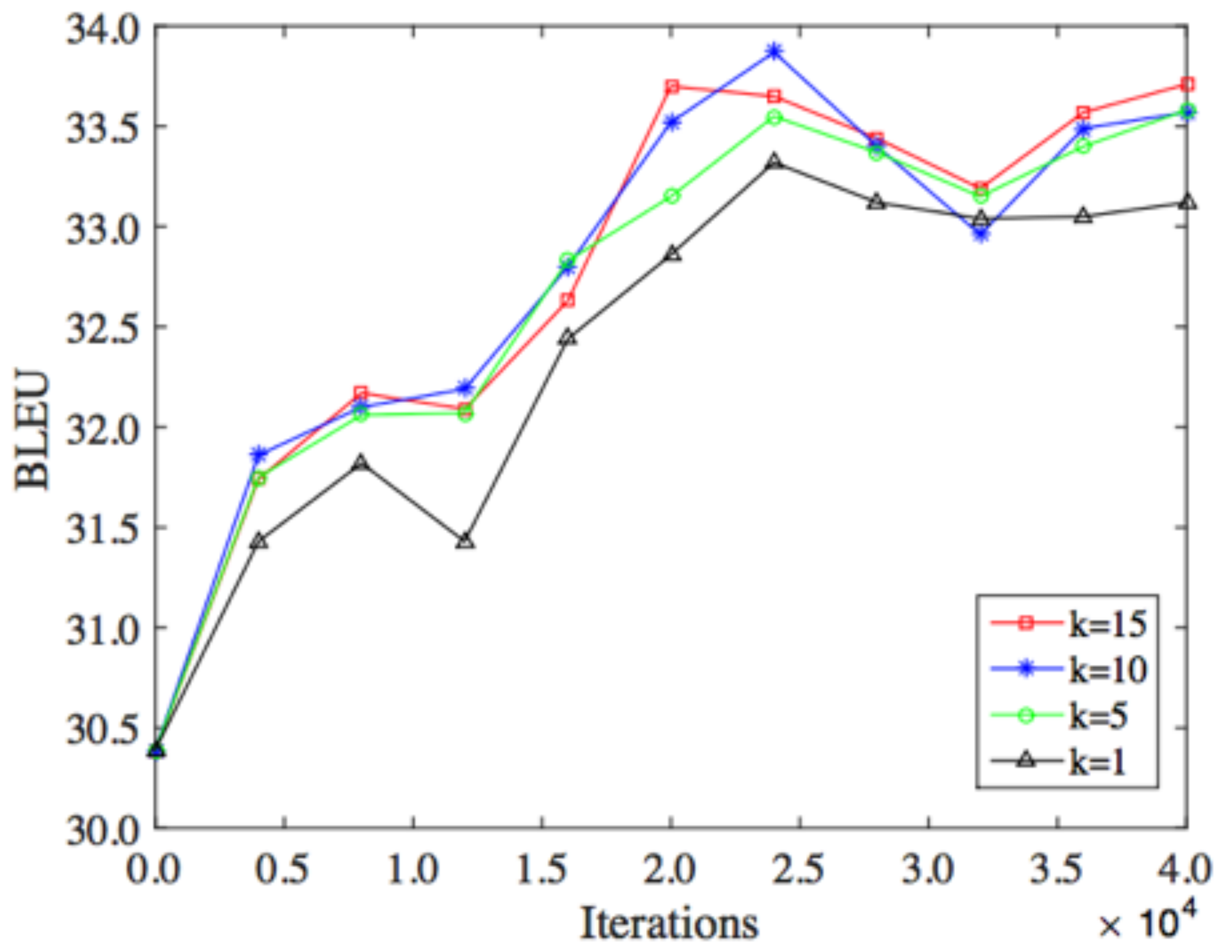
$$\mathbf{y}^* = \operatorname*{argmax}_{\mathbf{x}} \left\{ P(\mathbf{y}|\mathbf{x}; \overrightarrow{\boldsymbol{\theta}}) P(\mathbf{x}'|\mathbf{y}; \overleftarrow{\boldsymbol{\theta}}) \right\}$$

Conclusion

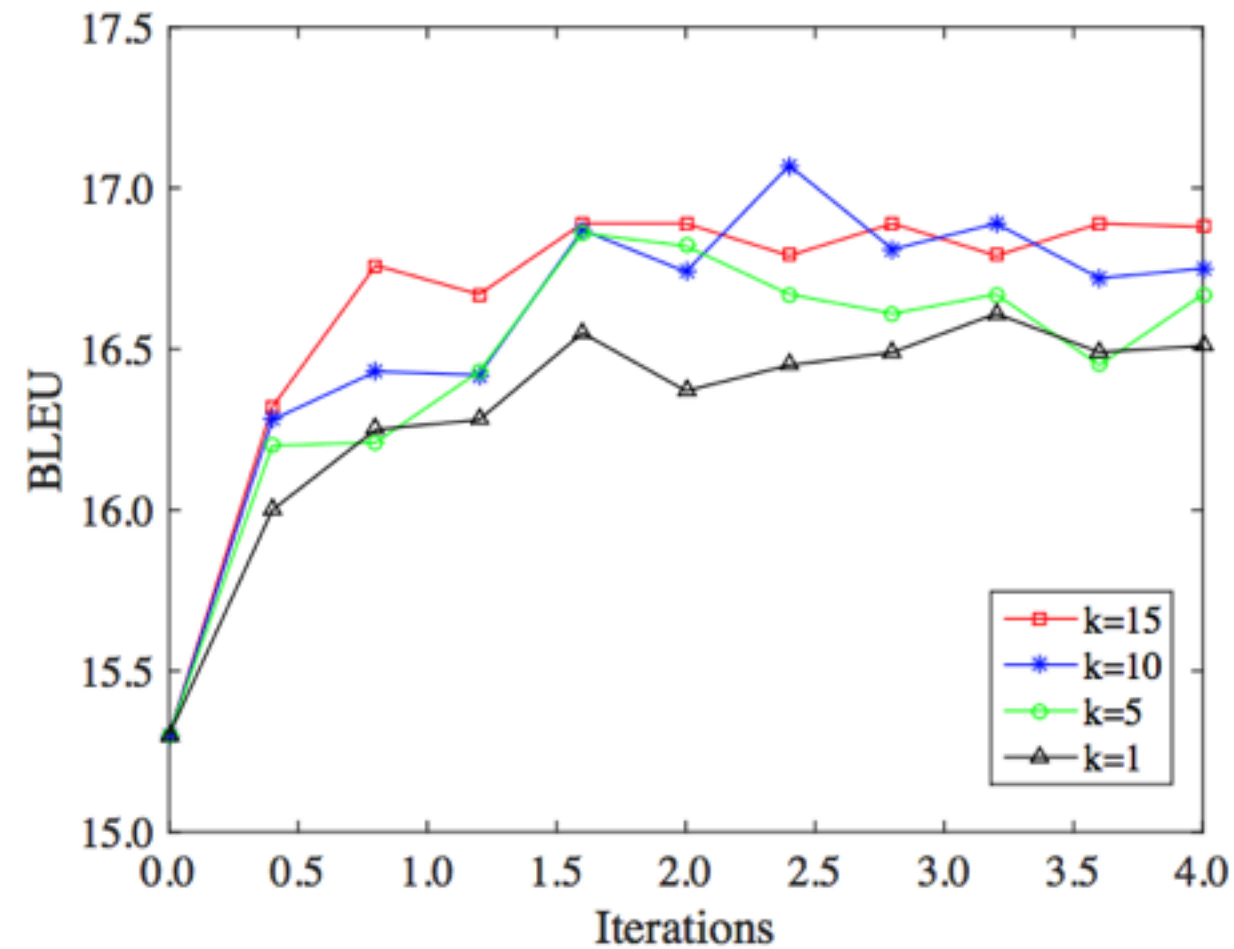
- Monolingual corpora is an important resource for neural machine translation.
- We have proposed a semi-supervised approach to training bidirectional neural machine translation models for exploiting monolingual corpora.
- As our method is sensitive to the OOVs present in monolingual corpora, we plan to integrate Jean et al. (2015)'s technique on using very large vocabulary into our approach.

Thank You !

Effect of Sample Size



ZH-EN



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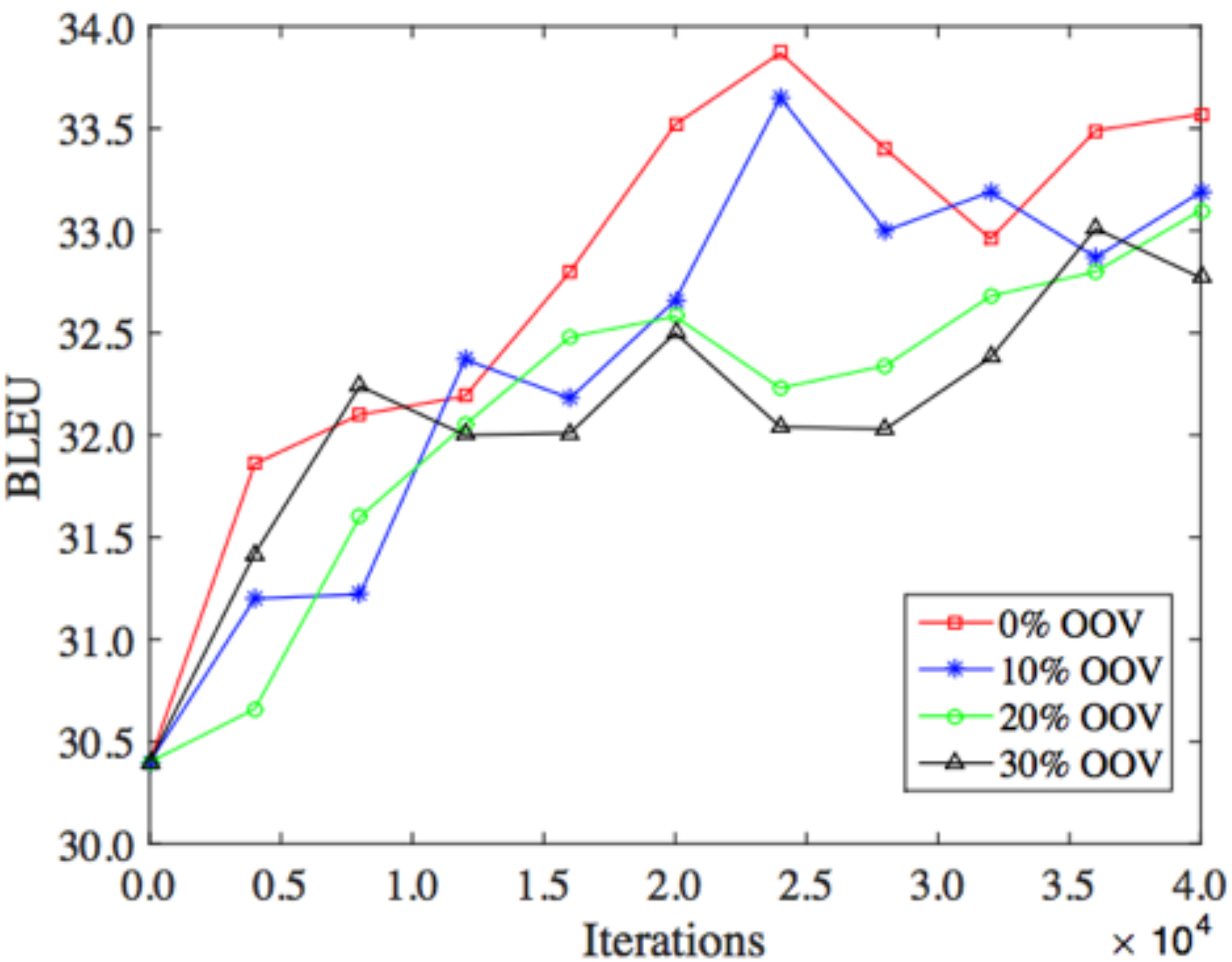
Effect of OOV ratio



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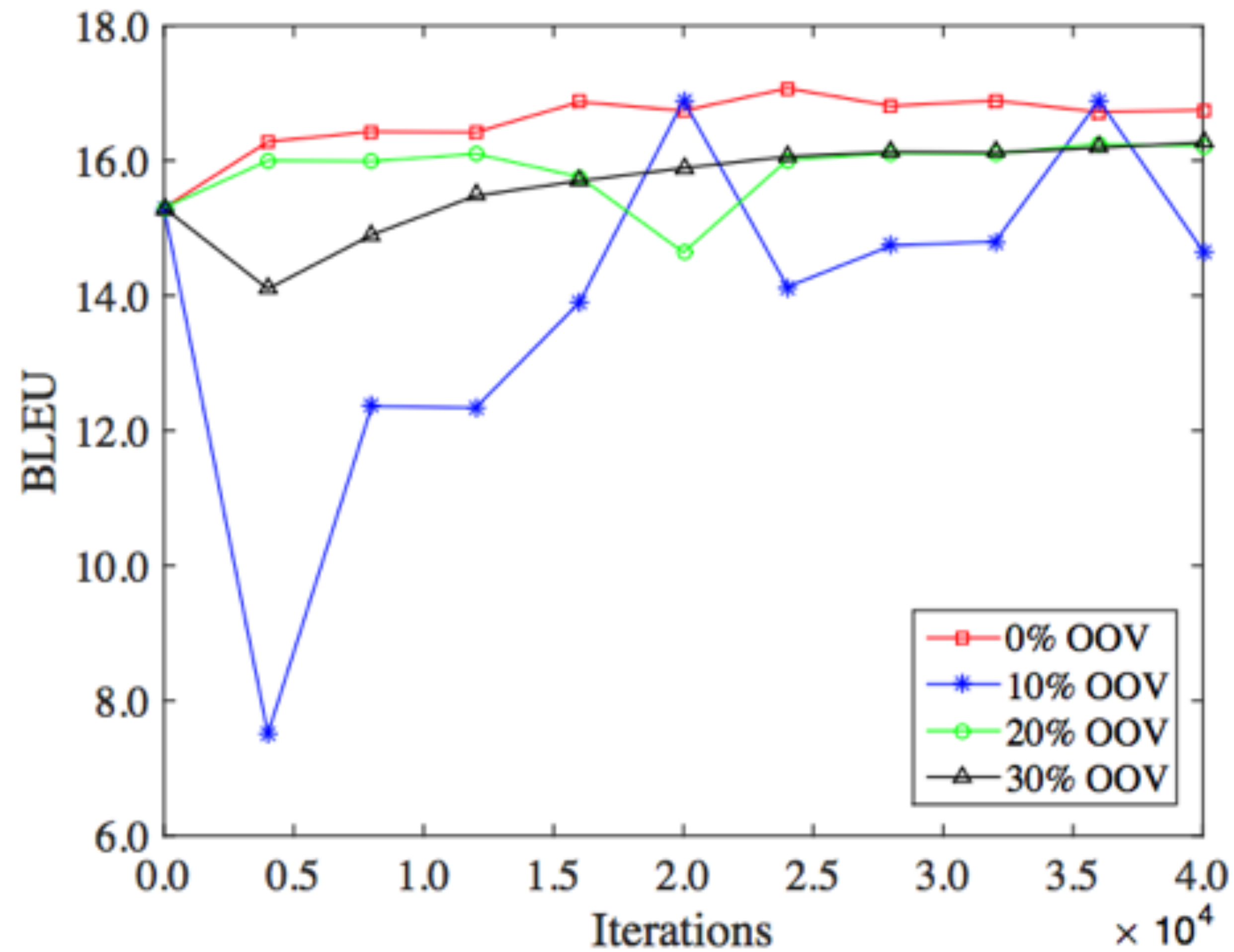

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