Incorporating Multilingual Knowledge Distillation into Machine Translation Evaluation

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Introduction

- In this paper, it is found out that multilingual knowledge distillation could implicitly achieve cross-lingual word embedding alignment, which is critically important for reference-free machine translation evaluation (where source texts are directly compared with system translations).

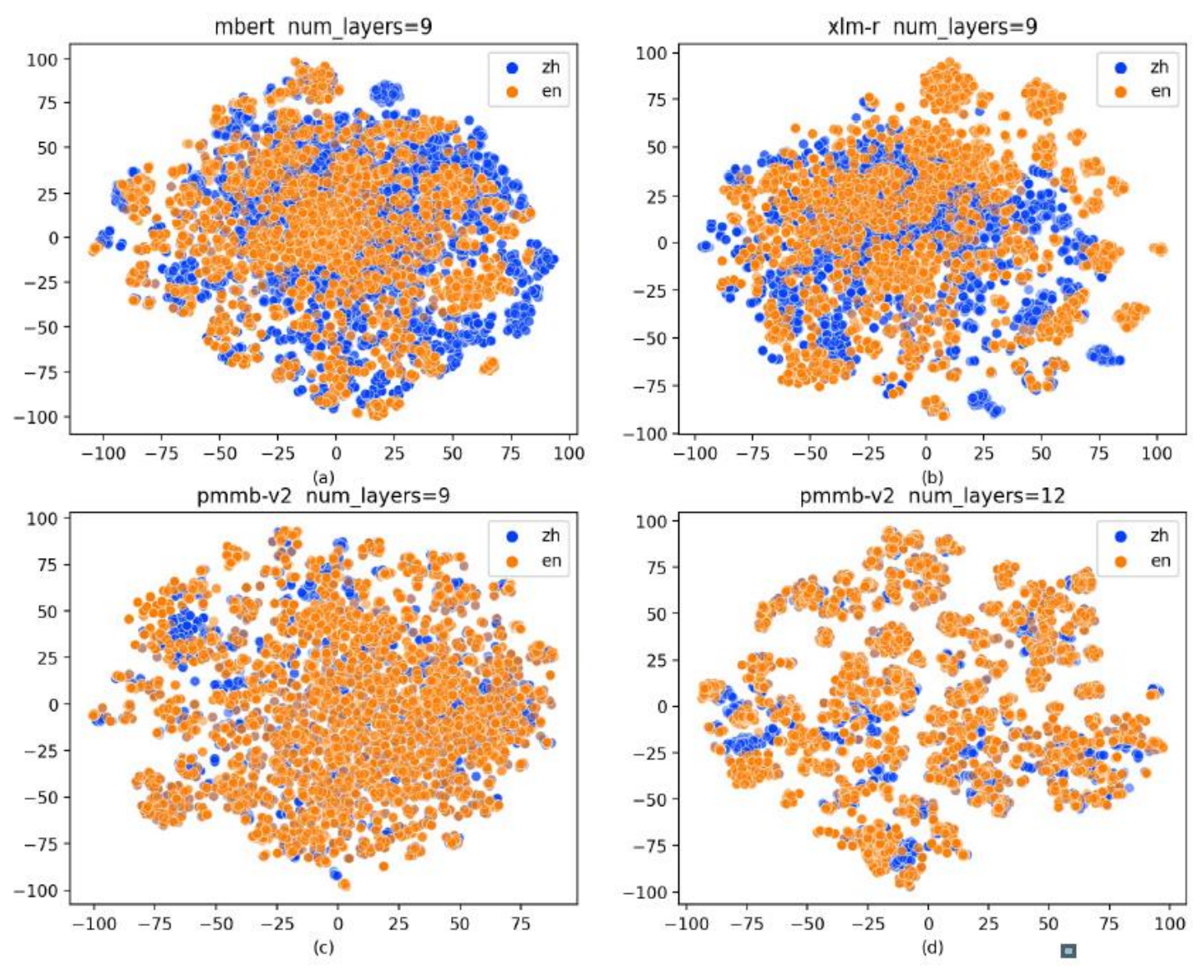


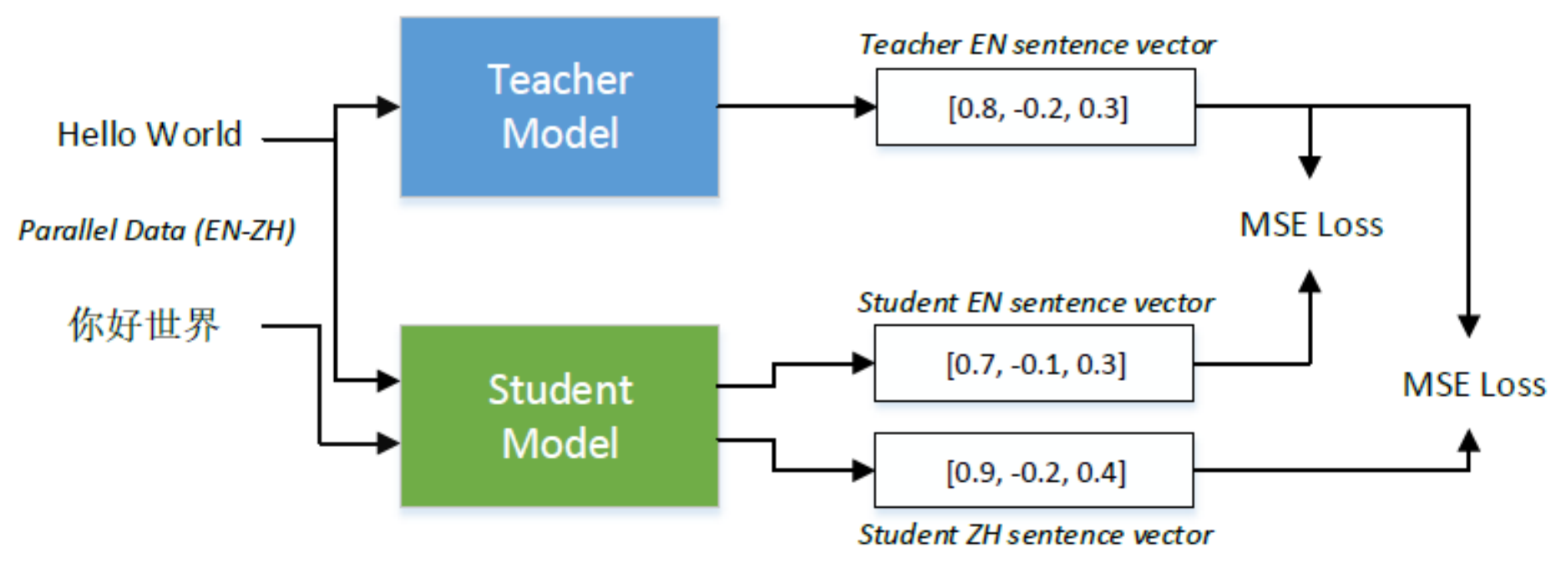
Fig. 1. First two principle components of contextual token embeddings of mBERT, XLM-R and pmmb-v2 for 100 zh-en parallel sentences in WMT19 by t-SNE (The more areas that do not cover each other, the worse the word embedding alignment effectiveness)

$$\frac{1}{m}\sum_{i=1}^{m} E_{LL}(s_i \mid \boldsymbol{s}) \approx \frac{1}{n}\sum_{j=1}^{n} E_{LL}(r_j \mid \boldsymbol{r})$$

- With the framework of BERTScore, we propose a metric BERTScore-MKD for reference-free machine translation evaluation.

Methods

1. Multilingual Knowledge Distillation



2. BERTScore-MKD

$$R = \frac{1}{|\boldsymbol{x}|}\sum_{x_i \in \boldsymbol{x}} \max_{\hat{x}_j \in \hat{\boldsymbol{x}}} E(x_i \mid \boldsymbol{x})^\top E(\hat{x}_j \mid \hat{\boldsymbol{x}}),$$

$$P = \frac{1}{|\hat{\boldsymbol{x}}|}\sum_{\hat{x}_j \in \hat{\boldsymbol{x}}} \max_{x_i \in \boldsymbol{x}} E(\hat{x}_j \mid \hat{\boldsymbol{x}})^\top E(x_i \mid \boldsymbol{x}),$$

$$F1 = 2 \cdot \frac{P \cdot R}{P + R},$$

Results

- Segment-level results

Table 1. Segment-level metric results (Pearson correlation) for the into-English language pairs of WMT17. Best results excluding sentBLEU are in bold.

Metrics	cs-en	de-en	fi-en	lv-en	ru-en	tr-en	zh-en	Avg
sentBLEU	0.435	0.432	0.571	0.404	0.484	0.538	0.512	0.481
SentSim	**0.499**	**0.523**	0.578	0.574	0.551	0.569	**0.600**	0.556
CLP-UMD	0.494	0.462	**0.647**	**0.664**	0.511	0.560	0.528	0.552
BERTScore+XML-R	0.319	0.409	0.414	0.402	0.337	0.382	0.510	0.396
BERTScore-MKD	**0.499**	0.475	0.644	0.584	**0.597**	**0.579**	0.565	**0.563**

Table 2. Segment-level metric results (Kendall's Tau correlation) for the into-English language pairs of WMT19. Best results excluding sentBLEU are in bold.

Metrics	de-en	fi-en	gu-en	kk-en	lt-en	ru-en	zh-en	Avg
sentBLEU	0.056	0.233	0.188	0.377	0.262	0.125	0.323	0.223
LASIM	-0.024	-	-	-	-	0.022	-	-
LP	-0.096	-	-	-	-	-0.035	-	-
UNI	0.022	0.202	-	-	-	0.084	-	-
UNI+	0.015	0.211	-	-	-	**0.089**	-	-
YiSi-2	0.068	0.126	-0.001	0.096	0.075	0.053	**0.253**	0.096
BERTScore+XLM-R	0.084	0.185	0.149	0.176	0.144	0.057	0.157	0.136
BERTScore-MKD	**0.093**	**0.234**	**0.171**	**0.310**	**0.211**	**0.089**	0.208	**0.188**

- System-level results

Table 3. System-level metric results (Pearson correlation) for the into-English language pairs of WMT17. Best results excluding BLEU are in bold.

Metrics	cs-en	de-en	fi-en	lv-en	ru-en	tr-en	zh-en	Avg
BLEU	0.971	0.923	0.903	0.979	0.912	0.976	0.864	0.933
CLP-UMD	**0.984**	0.904	0.861	**0.968**	0.850	0.922	0.817	0.901
BERTScore+XLM-R	0.750	0.692	0.653	0.650	0.332	0.689	0.635	0.629
BERTScore-MKD	0.953	**0.974**	**0.958**	0.871	**0.976**	**0.950**	**0.913**	**0.942**

Table 4. System-level metric results (Pearson correlation) for the into-English language pairs of WMT18. Best results excluding BLEU are in bold.

Metrics	cs-en	de-en	et-en	fi-en	ru-en	tr-en	zh-en	Avg
BLEU	0.970	0.971	0.986	0.973	0.979	0.657	0.978	0.931
CLP-UMD	**0.979**	**0.967**	**0.979**	0.947	0.942	0.673	**0.954**	0.919
BERTScore+XLM-R	-0.528	0.958	0.908	**0.957**	0.905	0.489	0.770	0.637
BERTScore-MKD	0.948	0.963	0.936	0.952	**0.978**	**0.939**	0.925	**0.949**

Table 5. System-level metric results (Pearson correlation) for the into-English language pairs of WMT19. Best results excluding BLEU are in bold.

Metrics	de-en	fi-en	gu-en	kk-en	lt-en	ru-en	zh-en	Avg
BLEU	0.849	0.982	0.834	0.946	0.961	0.879	0.899	0.907
LASIM	0.247	-	-	-	-	0.310	-	-
LP	0.474	-	-	-	-	0.488	-	-
UNI	0.846	0.930	-	-	-	0.805	-	-
UNI+	**0.850**	0.924	-	-	-	0.808	-	-
YiSi-2	0.796	0.642	**0.566**	0.324	0.442	0.339	0.940	0.578
CLP-UMD	0.625	0.890	-0.060	**0.993**	0.851	**0.928**	**0.968**	0.742
BERTScore+XLM-R	0.785	0.866	-0.007	0.117	0.657	-0.372	0.728	0.396
BERTScore-MKD	0.823	**0.956**	0.420	0.828	**0.946**	0.747	0.924	**0.806**

Discussion

- Effects of Embedding Layers

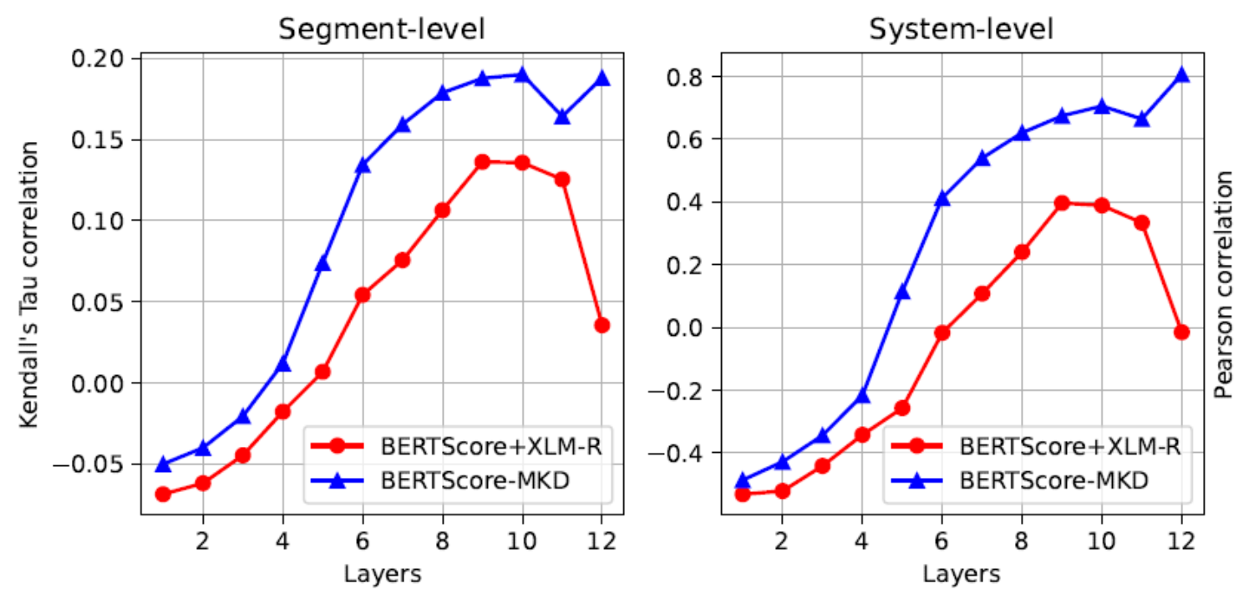


Fig. 3. Mean measure values of BERTScore-MKD and BERTScore+XLM-R with different layers of word embeddings for segment-level and system-level reference-free MT evaluations on the into-English language pairs of WMT19

Supplementary

- As Reference-based Metric

Table 6. System-level reference-based metric results (Pearson correlation) for the into-English language pairs of WMT19. Best results are in bold.

Metrics	de-en	fi-en	gu-en	kk-en	lt-en	ru-en	zh-en	Avg
BLEU	0.849	0.982	0.834	0.946	0.961	0.879	0.899	0.907
BERTScore+XLM-R	0.932	0.981	**0.919**	**0.998**	**0.992**	0.912	0.962	0.957
BERTScore-MKD^{9th}	0.931	**0.994**	0.897	0.970	0.991	0.971	0.964	**0.960**
BERTScore-MKD^{last}	**0.934**	0.990	0.801	0.943	0.981	**0.974**	**0.968**	0.941

Table 7. System-level reference-based metric results (Pearson correlation) for the from-English language pairs of WMT19. Best results are in bold.

Metrics	en-cs	en-de	en-fi	en-gu	en-kk	en-lt	en-ru	en-zh	Avg
BLEU	0.897	0.921	0.969	0.737	0.852	**0.989**	0.986	0.901	0.907
BERTScore+XLM-R	**0.979**	**0.990**	**0.980**	**0.922**	**0.983**	0.978	0.985	**0.929**	**0.968**
BERTScore-MKD^{9th}	0.966	0.986	0.956	0.899	0.980	0.938	**0.991**	0.871	0.948
BERTScore-MKD^{last}	0.942	0.982	0.928	0.889	0.972	0.876	0.985	0.814	0.924

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