Improving Named Entity Recognition by External Context Retrieving and Cooperative Learning

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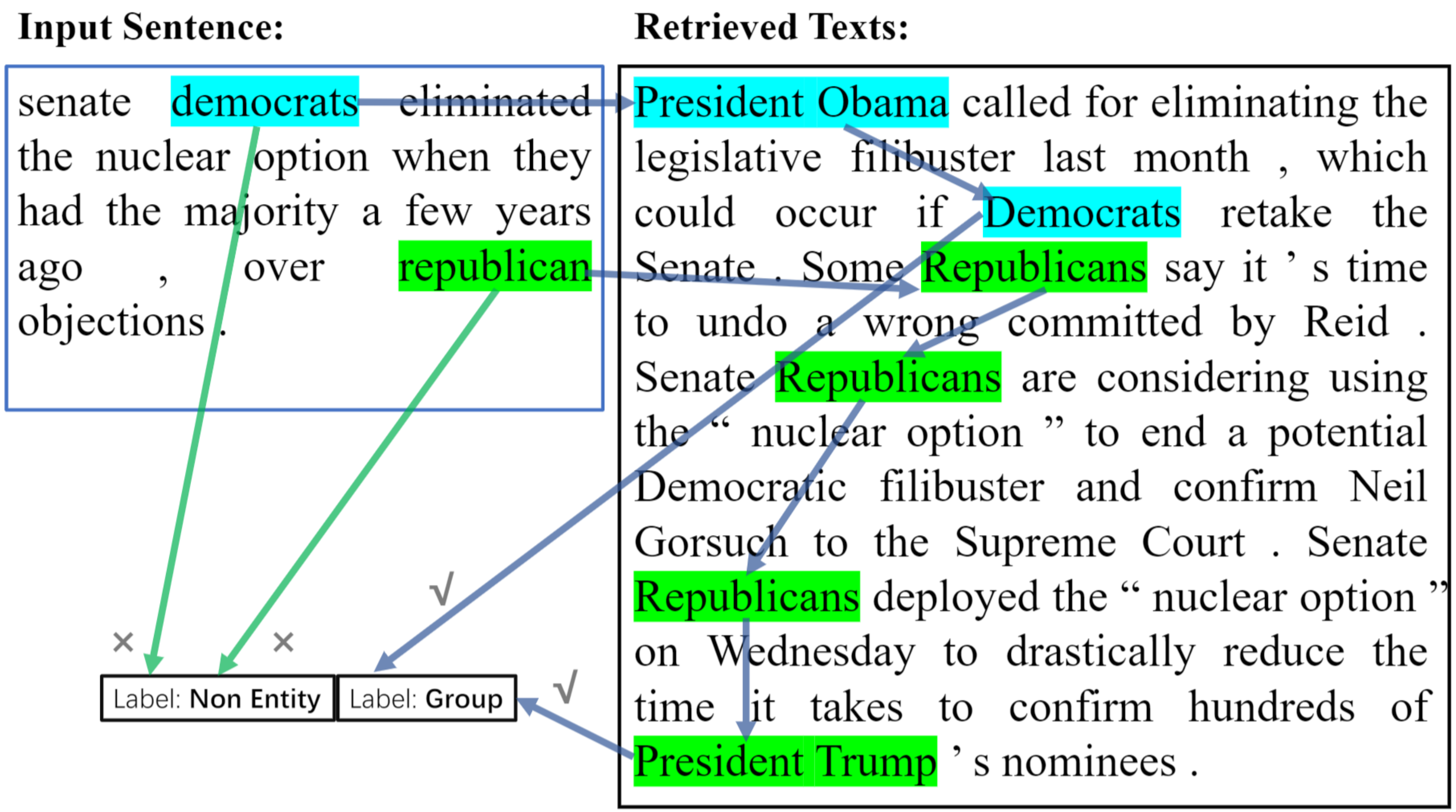
DAMO
ALIBABA DAMO ACADEMY

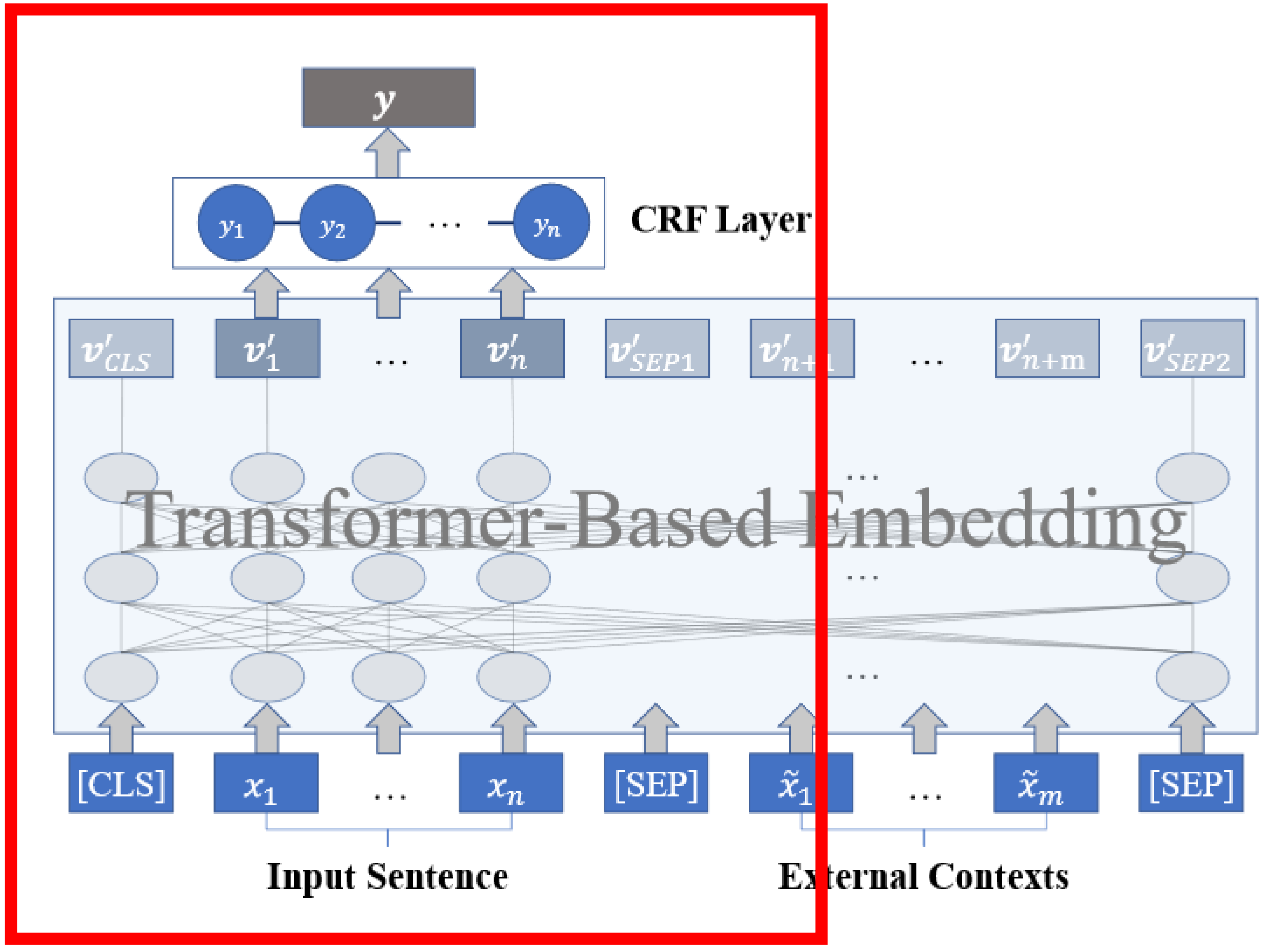
Motivation

- Previous studies
  - Including document-level contexts of the target sentence in the input of contextual embeddings methods can boost the accuracy of NER models
- Problem
  - There are a lot of application scenarios in which document-level contexts are unavailable
- Idea
  - Knowledge from search engines helps human annotators of NER
  - It should benefit machines too!

Motivating Example

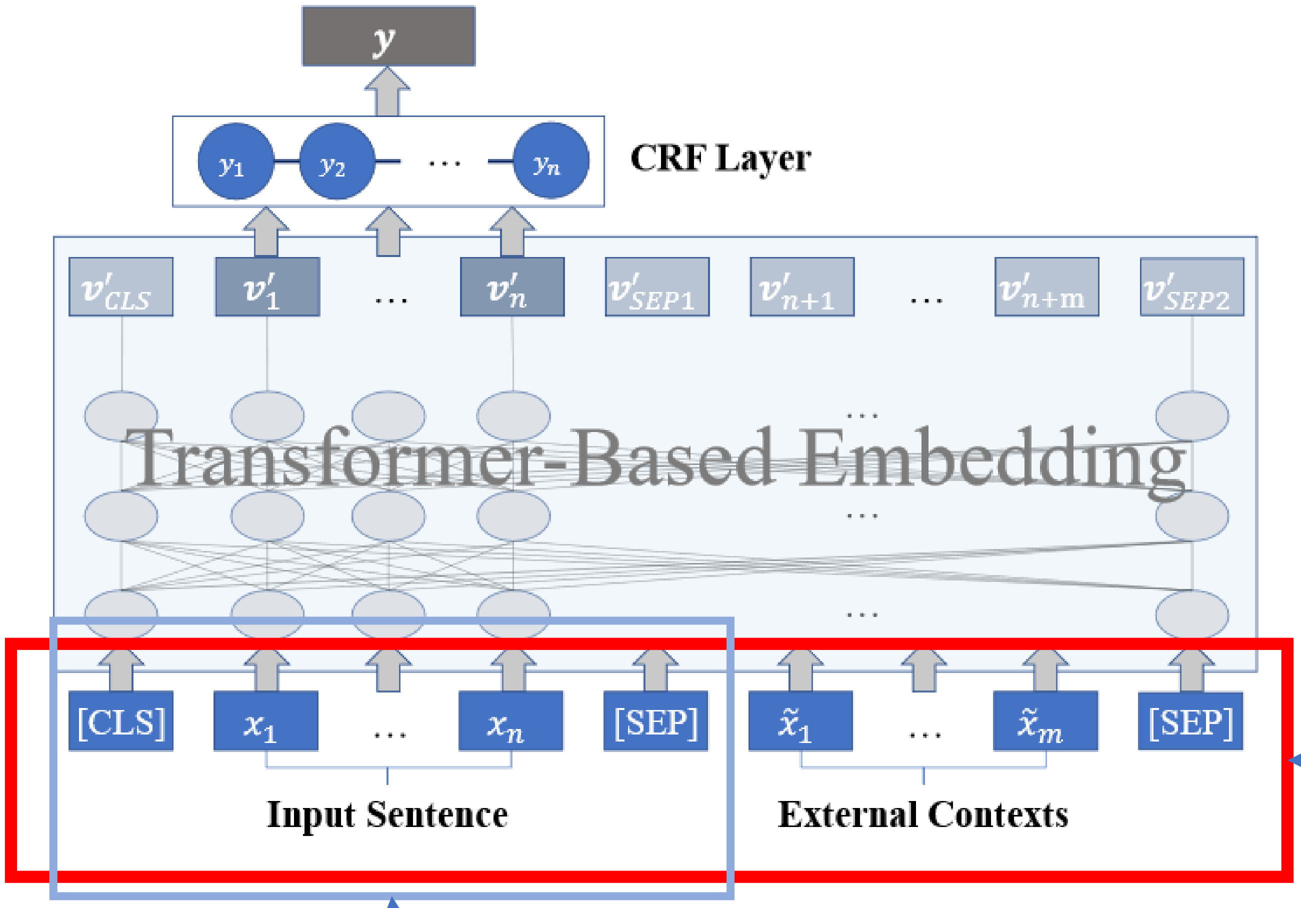


NER Model



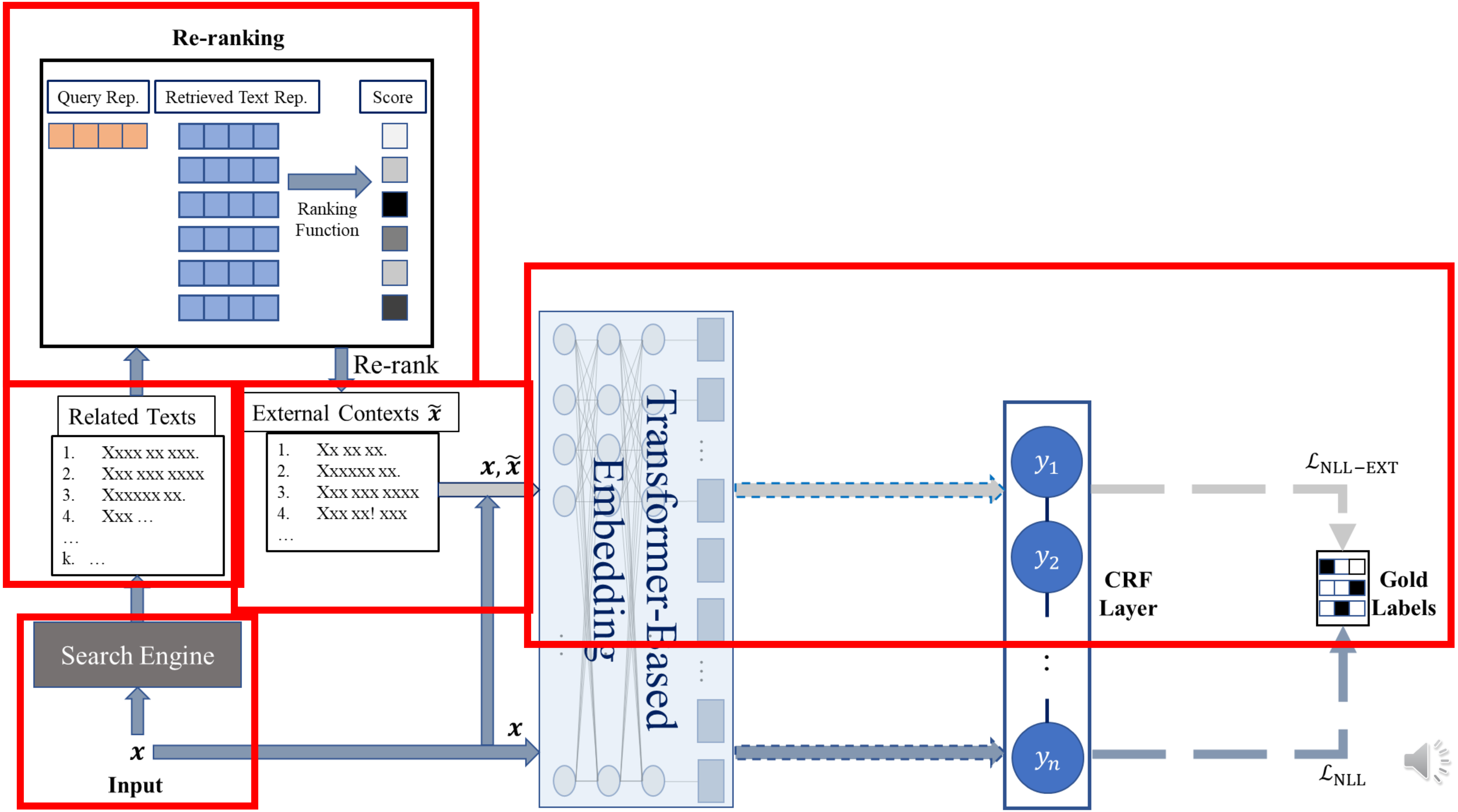
y
CRF Layer
y_1
y_2
y_n
v'_{CLS}
v'_1
v'_n
v'_{SEP1}
v'_{n+1}
v'_{n+m}
v'_{SEP2}
Transformer-Based Embedding
[CLS]
x_1
x_n
[SEP]
$\tilde{x}_1$
$\tilde{x}_m$
[SEP]
Input Sentence
External Contexts

NER Model



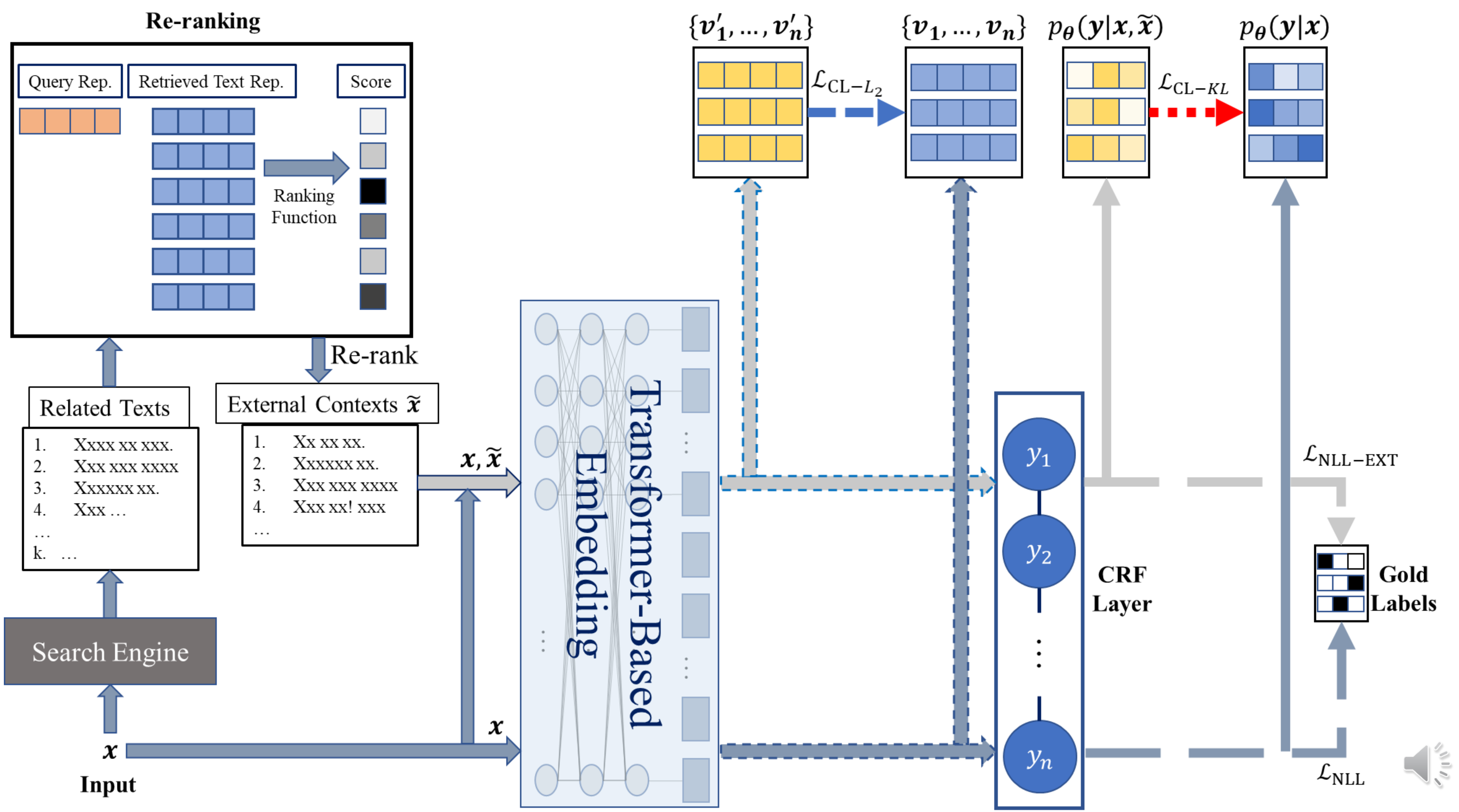
Retrieval-based Input View

Original Input View


Re-ranking
Query Rep.
Retrieved Text Rep.
Score
Ranking Function
Re-rank
Related Texts
1. Xxxx xx xxx.
2. Xxx xxx xxxx
3. Xxxxxx xx.
4. Xxx …
…
k. …
External Contexts $\tilde{x}$
1. Xx xx xx.
2. Xxxxxx xx.
3. Xxx xxx xxxx
4. Xxx xx! xxx
…
$x, \tilde{x}$
Search Engine
x
Input
x
Transformer-Based Embedding
y_1
y_2
y_n
CRF Layer
$\mathcal{L}_{\mathrm{NLL-EXT}}$
Gold Labels
$\mathcal{L}_{\mathrm{NLL}}$

Cooperative Learning

- Limitations
  - What if search engines are not available?
  - What about time-critical scenarios (no time to invoke search engines or to process the returned contexts that can be very long)?
- Solution
  - Cooperative learning (CL) between the retrieval-based input view and the original no-context input view
- Result
  - Both views are improved!



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Search Engine
x
Input
$x, \tilde{x}$
x
Transformer-Based Embedding
$\{v'_1, \ldots, v'_n\}$
$\{v_1, \ldots, v_n\}$
$p_\theta(y|x, \tilde{x})$
$p_\theta(y|x)$
$\mathcal{L}_{\text{CL}-L_2}$
$\mathcal{L}_{\text{CL}-KL}$
y_1
y_2
y_n
CRF Layer
$\mathcal{L}_{\text{NLL-EXT}}$
Gold Labels
$\mathcal{L}_{\text{NLL}}$

Cooperative Learning

- Objective Function:

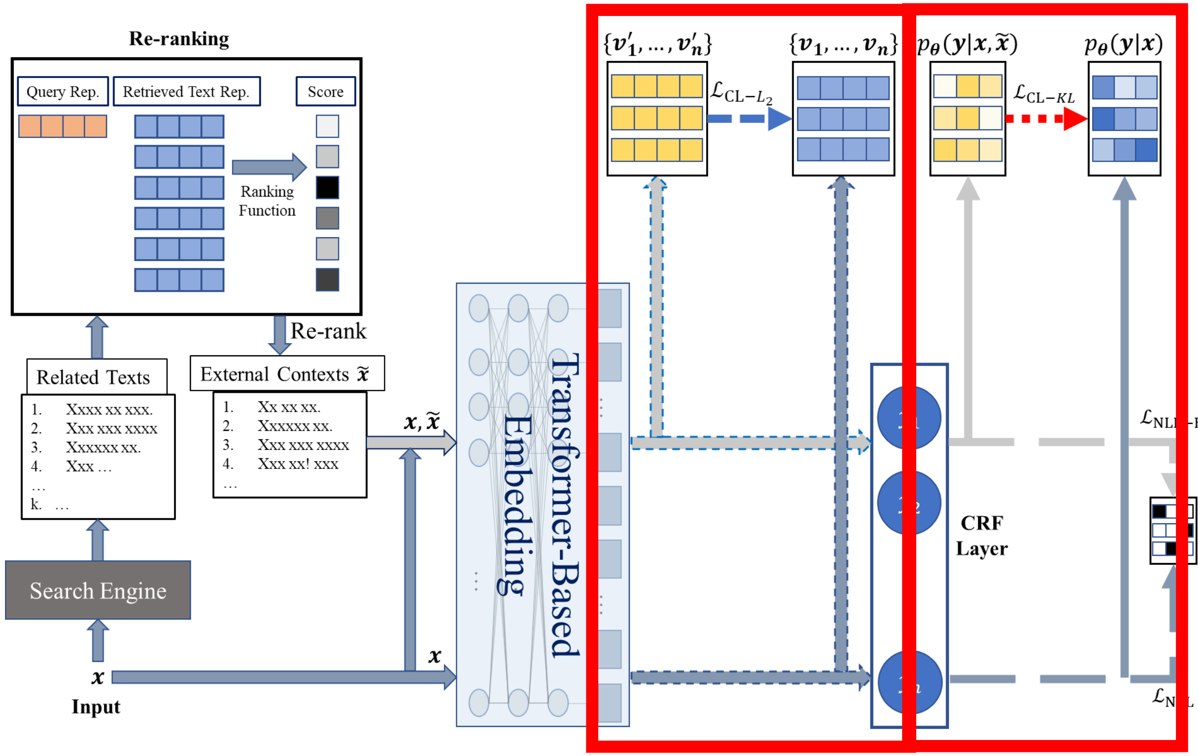
$$\mathcal{L}_{\text{CL}}(\theta) = D(h([\boldsymbol{x};\tilde{\boldsymbol{x}}]), h([\boldsymbol{x}]))$$

- Token Representations:

$$\mathcal{L}_{\text{CL-}L_2}(\theta) = \sum_{i=1}^{n} ||\boldsymbol{v}'_i - \boldsymbol{v}_i||_2^2$$

- Label Distributions:

$$\mathcal{L}_{\text{CL-KL}}(\theta)=\sum_{\boldsymbol{y}\in\mathcal{Y}(\boldsymbol{x})} \text{KL}(p_\theta(\boldsymbol{y}|\boldsymbol{x},\tilde{\boldsymbol{x}})||p_\theta(\boldsymbol{y}|\boldsymbol{x}))$$



Optimization

- Base Model (with original input view):

$$\mathcal{L}_{\text{NLL}}(\theta) = -\log p_\theta(\boldsymbol{y}^*|\boldsymbol{x})$$

- Training with External Contexts (with retrieval-based input view):

$$\mathcal{L}_{\text{NLL-EXT}}(\theta) = -\log p_\theta(\boldsymbol{y}^*|\boldsymbol{x}, \tilde{\boldsymbol{x}})$$

- Cooperative Learning (with both input views):

$$\mathcal{L}(\theta) = \mathcal{L}_{\text{NLL}}(\theta) + \mathcal{L}_{\text{NLL-EXT}}(\theta) + \mathcal{L}_{\text{CL}}(\theta)$$

Results

	Social Media		News		Biomedical		E-commerce
	WNUT-16	WNUT-17	CoNLL-03	CoNLL++	BC5CDR	NCBI	
Zhou et al. (2019)	55.43	42.83	-	-	-	-	-
Nguyen et al. (2020)	52.10	56.50	-	-	-	-	-
Nie et al. (2020)	55.01	50.36	-	-	-	-	-
Baevski et al. (2019)	-	-	93.50	-	-	-	-
Wang et al. (2019)	-	-	93.43	94.28	-	-	-
Li et al. (2020)	-	-	93.33	-	-	-	-
Nooralahzadeh et al. (2019)	-	-	-	-	89.93	-	-
Bio-Flair (2019)	-	-	-	-	89.42	88.85	-
Bio-BERT (2020)	-	-	-	-	-	87.70	-
			Evaluation: w/o Context				
LUKE (2020)	54.04	55.22	92.42	93.99	89.18	87.62	77.64
w/o Context	56.04	57.86	93.03	94.20	90.52	88.65	81.47
CL-L_2	57.35†	58.68†	93.08	94.38†	90.70†	89.20†	82.43†
CL-KL	58.14†	59.33†	93.21†	94.55†	90.73†	**89.24**†	82.31†
			Evaluation: w/ Context				
w/ Context	57.43†	60.20†	93.27†	94.56†	90.76†	89.01†	83.15†
CL-L_2	58.61†	60.26†	93.47†	94.62†	**90.99**†	89.22†	83.87†
CL-KL	**58.98**†	**60.45**†	**93.56**†	**94.81**†	90.93†	88.96†	**83.99**†

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Transfer Learning

	Evaluation **Science and Technology**	
Approach	W/O CONTEXT	W/ CONTEXT
Jia et al. (2019)	73.59	-
W/O CONTEXT	75.87	75.74
W/ CONTEXT	75.72	75.94
CL-L_2	76.16	76.10
CL-KL	**76.37**	**76.38**

Semi-supervised Learning on E-Commerce

	Evaluation	
Approach	W/O CONTEXT	W/ CONTEXT
CL-L_2	82.43	83.87
CL-KL	82.31	83.99
CL–L_2+SEMI	**82.88**†	83.92
CL-KL+SEMI	82.58†	**84.10**

How the Context Quality Affects Accuracy?

	WNUT-17
w/ Context (Ours)	**60.20**
w/o Context	57.86
w/ Context (Dataset)	57.21
w/ Context (Generated)	57.71
w/ Context (Random Retrieved)	57.53
w/ Context (Random Data)	47.69

Table 6: A comparison among different contexts types.

Conclusion

- Improving NER models' accuracy by retrieving related contexts
- Cooperative Learning improves the robustness of the models when no external contexts are available
- A state-of-the-art accuracy on the NER datasets over 5 domains