

Improving Word Translation via Two-Stage Contrastive Learning

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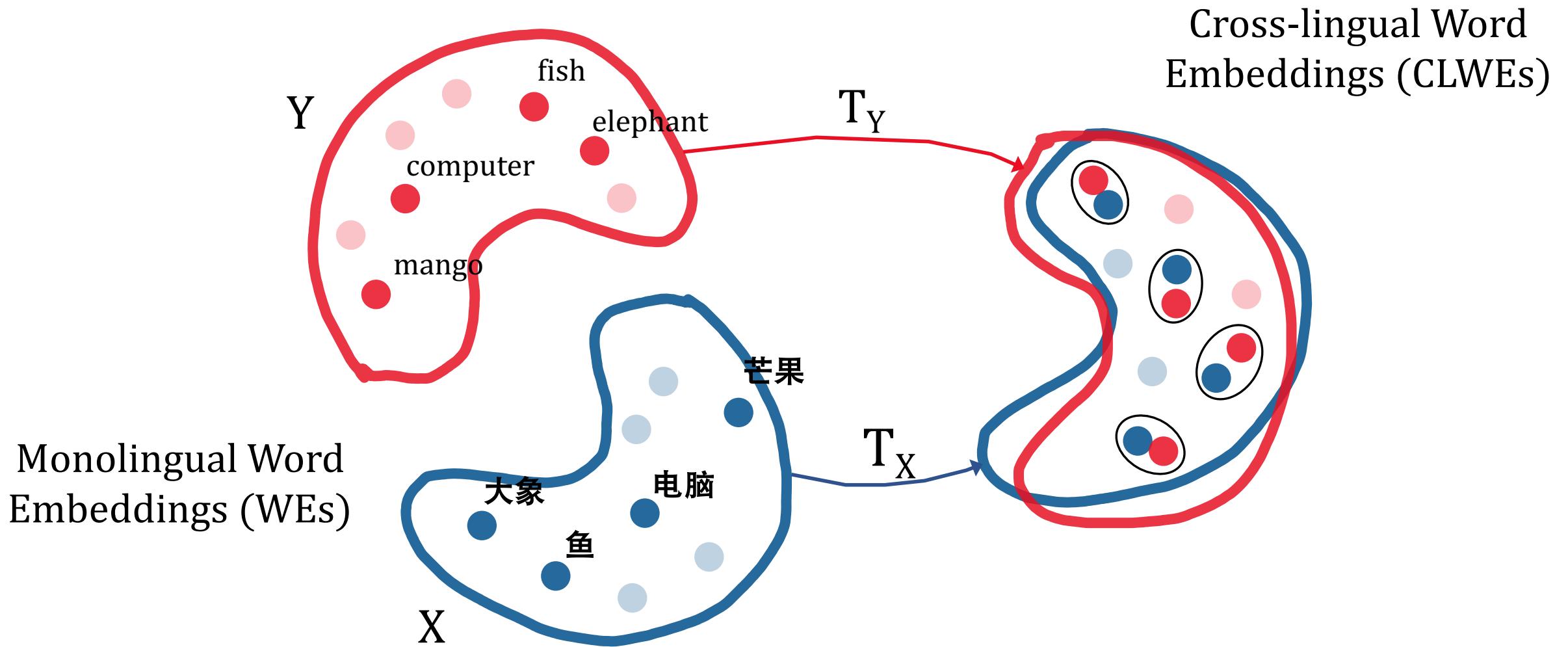


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The Task: Bilingual Lexicon Induction



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- An important and long-standing task
- Applications of BLI
 - Language learning & language acquisition
 - Machine Translation
 - Cross-lingual Transfer Learning
 - Low-resource NLP

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The Task: Bilingual Lexicon Induction

- Supervised
 - 5K pairs
- Semi-supervised
 - 1K pairs
- Unsupervised

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Previous Approaches

- Mapping-based
 - Orthogonal (Xing et al., 2015)
 - Linear (Joulin et al., 2018)
 - Non-linear (Mohiuddin et al., 2020)

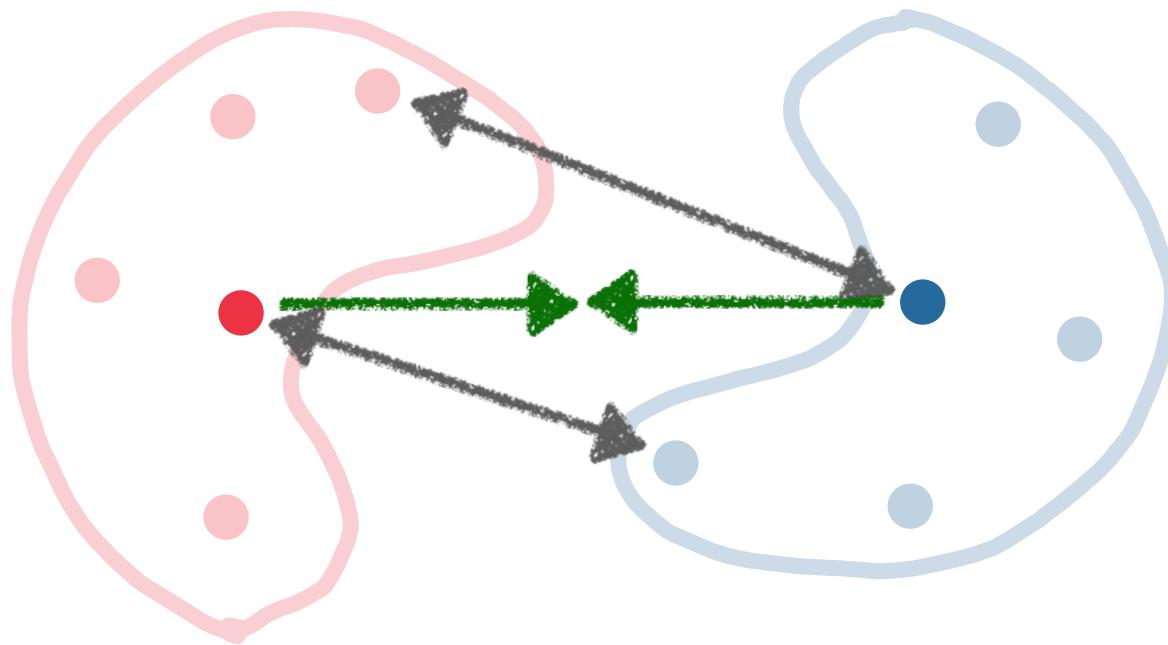
Previous Approaches

- Mapping-based
 - Orthogonal (Xing et al., 2015)
 - Linear (Joulin et al., 2018)
 - Non-linear (Mohiuddin et al., 2020)
- Static WEs > pretrained LMs
 - fastText > monolingual BERT (Vulić et al., 2020)
 - fastText > multilingual LMs (e.g. mBERT) (Gonen et al., 2020)
 - Why?

Motivation

- Contrastive Learning (CL)
 - Success in sentence encoders (Gao et al., 2021; Liu et al., 2021)
 - BLI ?

→ ← Attract
← → Repel



Motivation

- We propose a novel two-stage CL approach.
 - Stage C1 can be evaluated independently
 - Stage C2, further improvement

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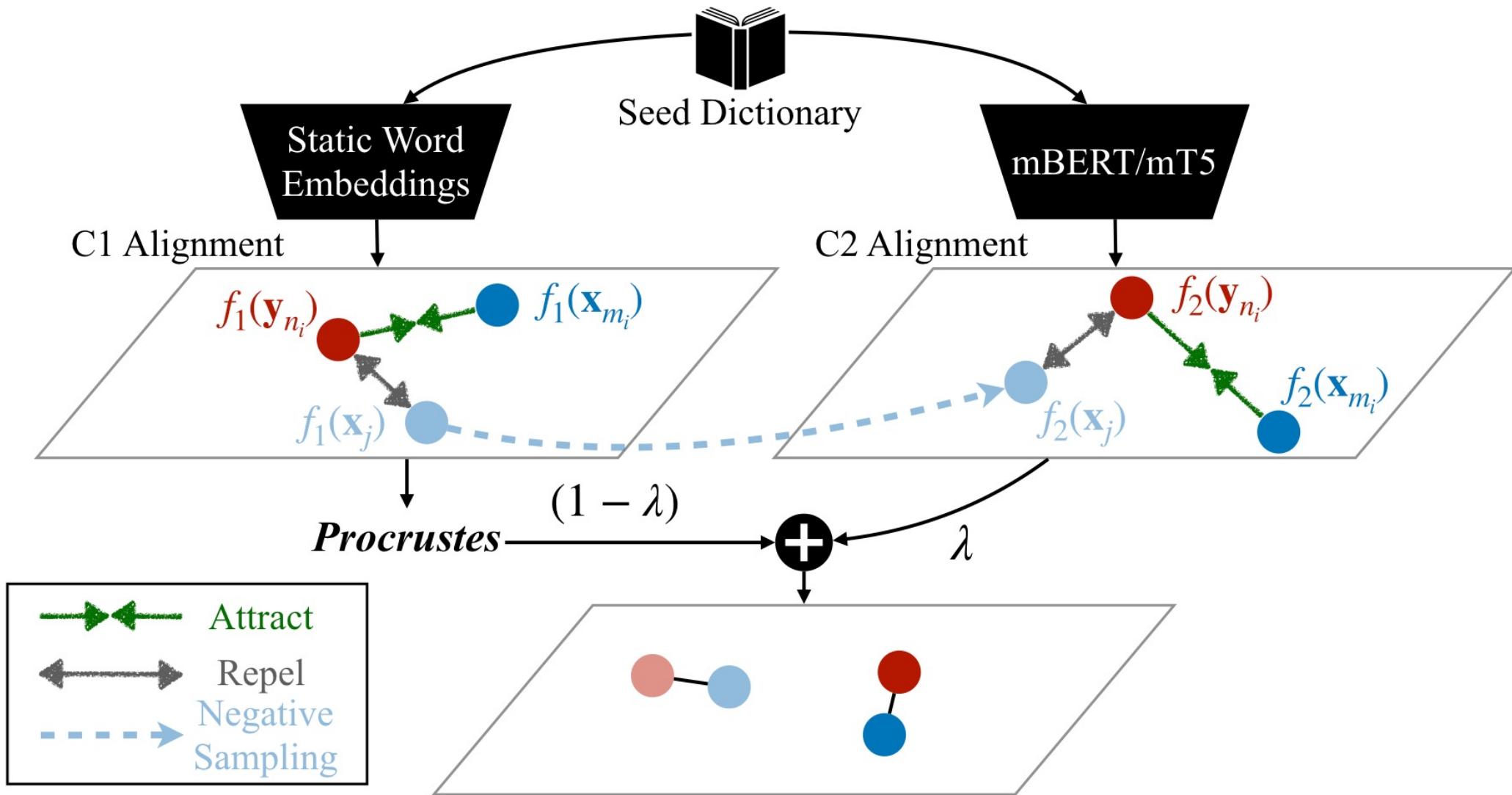


Motivation

- We propose a novel two-stage CL approach.
 - Stage C1 can be evaluated independently
 - Stage C2, further improvement
- Stage C1
 - Static WEs + CL → SotA (RQ 1)
- Stage C2
 - LMs + CL → lexical encoders (RQ 2)
 - CL exposes translation knowledge (RQ 2)
 - CLWEs (static) + LMs → extra gains (RQ 3)



Method: Two-Stage CL



Method: CL in Stage C1 (Static WEs)

Linear Map on L_x WE

Linear Map on L_y WE

$$s_{i,j} = \exp(\cos(x_i \mathbf{W}_x, y_i \mathbf{W}_y) / \tau)$$

$$p_i = \frac{s_{m_i, n_i}}{\sum_{w_j^y \in \{w_{n_i}^y\} \cup \bar{w}_{n_i}^y} s_{m_i, j} + \sum_{w_j^x \in \bar{w}_{m_i}^x} s_{j, n_i}}$$

$$\min_{\mathbf{W}_x, \mathbf{W}_y} - \mathbb{E}_{(w_{m_i}^x, w_{n_i}^y) \in \mathcal{D}_{CL}} \log(p_i)$$

A Positive Pair

Hard Negative Pairs

Method: CL in Stage C2 (Multilingual LMs)

Encoder L_x Word with LM

Encode L_y Word with LM

$$s'_{i,j} = \exp(\cos(f_\theta(w_i^x), f_\theta(w_j^y))/\tau)$$

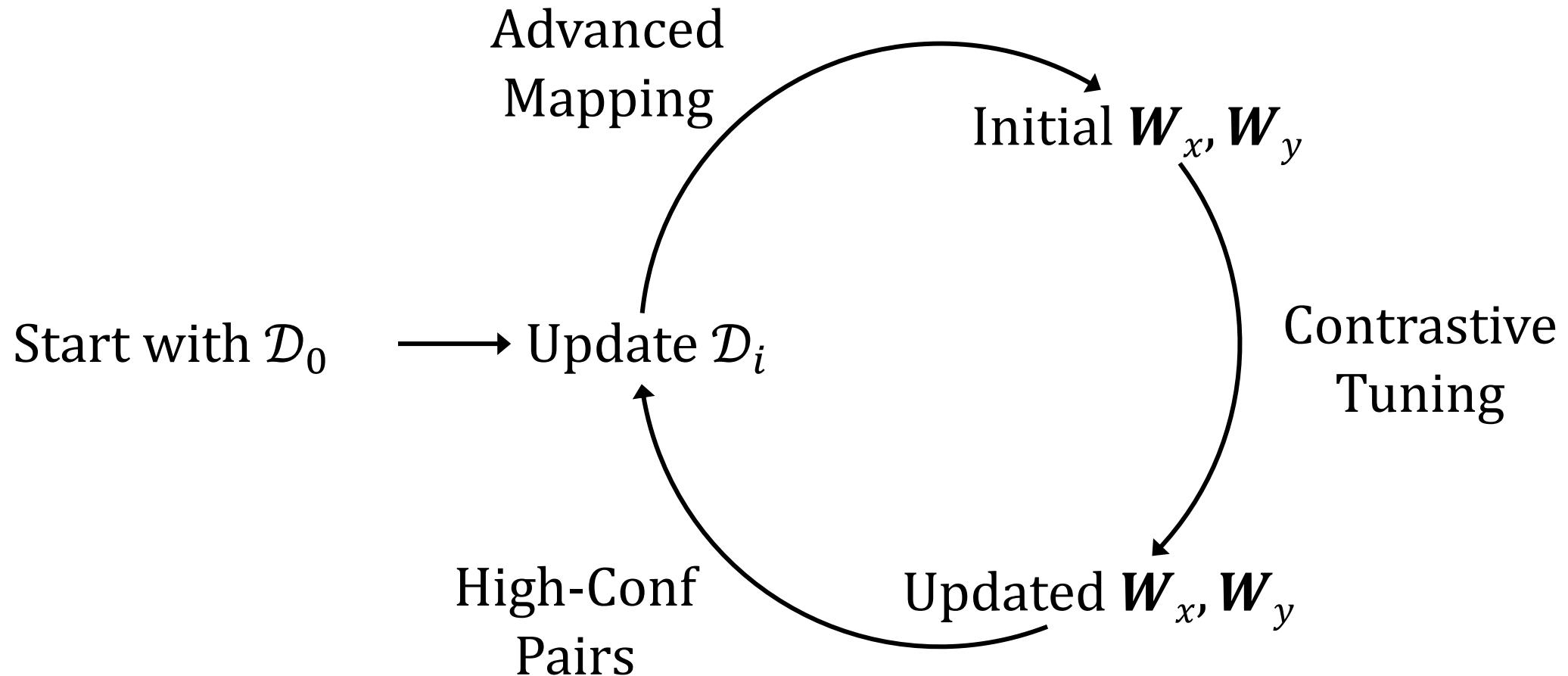
$$p'_i = \frac{s'_{m_i, n_i}}{\sum_{w_j^y \in \{w_{n_i}^y\} \cup \bar{w}_{n_i}^y} s'_{m_i, j} + \sum_{w_j^x \in \bar{w}_{m_i}^x} s'_{j, n_i}}$$

$$\min_{\theta} - \mathbb{E}_{(w_{m_i}^x, w_{n_i}^y) \in \mathcal{D}_{CL}} \log(p'_i)$$

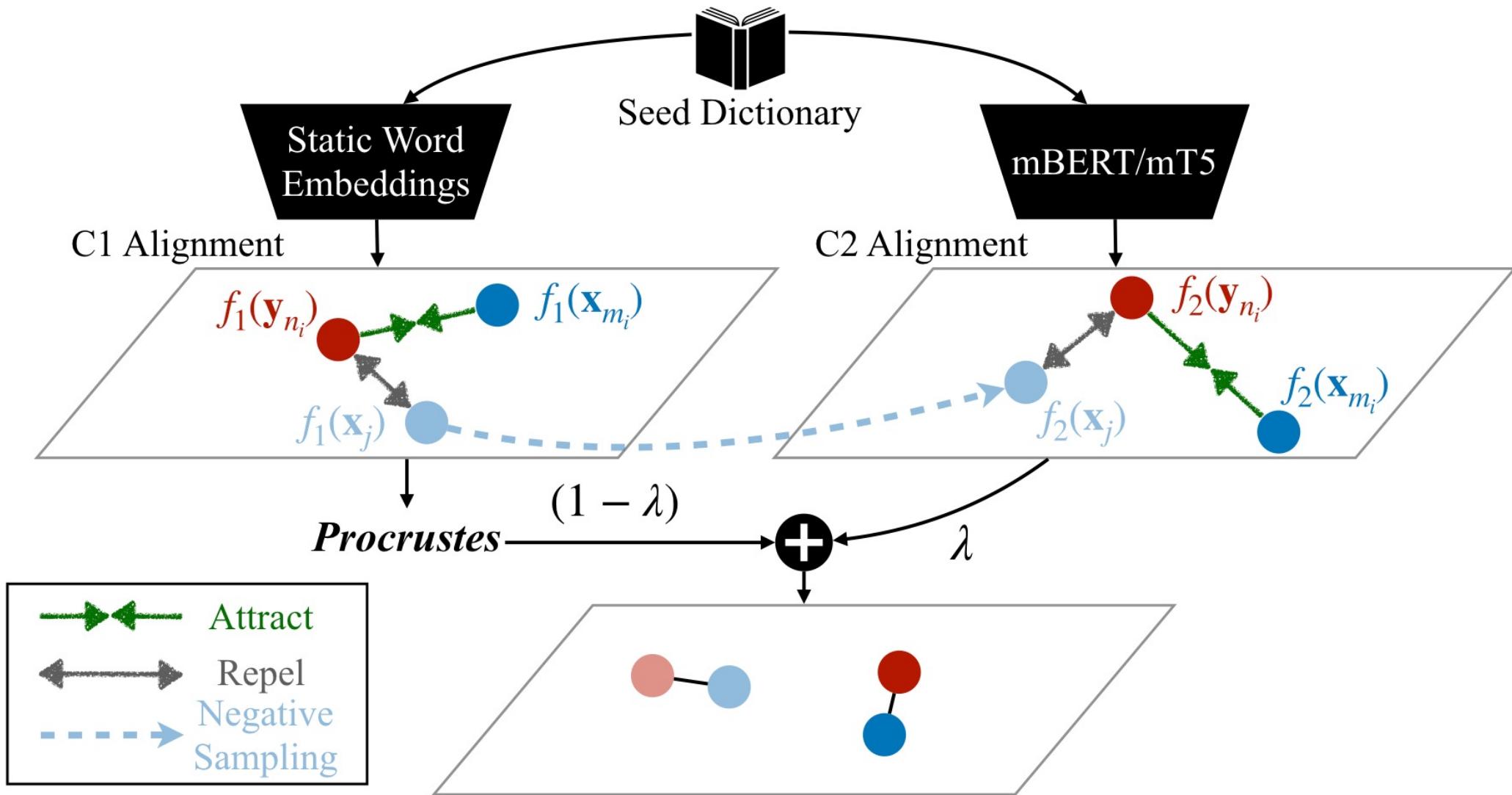
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Method: Stage C1



Method: Stage C2



Evaluation

- Datasets
 - XLING (112 setups) (Glavaš et al., 2019)
 - PanLex-BLI (lower-resource languages) (Vulić et al., 2019)
 - Vocabulary size: 200K

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- Datasets
 - XLING (112 setups) (Glavaš et al., 2019)
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 - Vocabulary size: 200K
- Baselines
 - RCSLS (w/o SL) (Joulin et al., 2018)
 - VecMap (w/ SL) (Artetxe et al., 2018)
 - LNMap (w/ SL) (Mohiuddin et al., 2020)
 - FIPP (w/ SL) (Sachidananda et al., 2021)

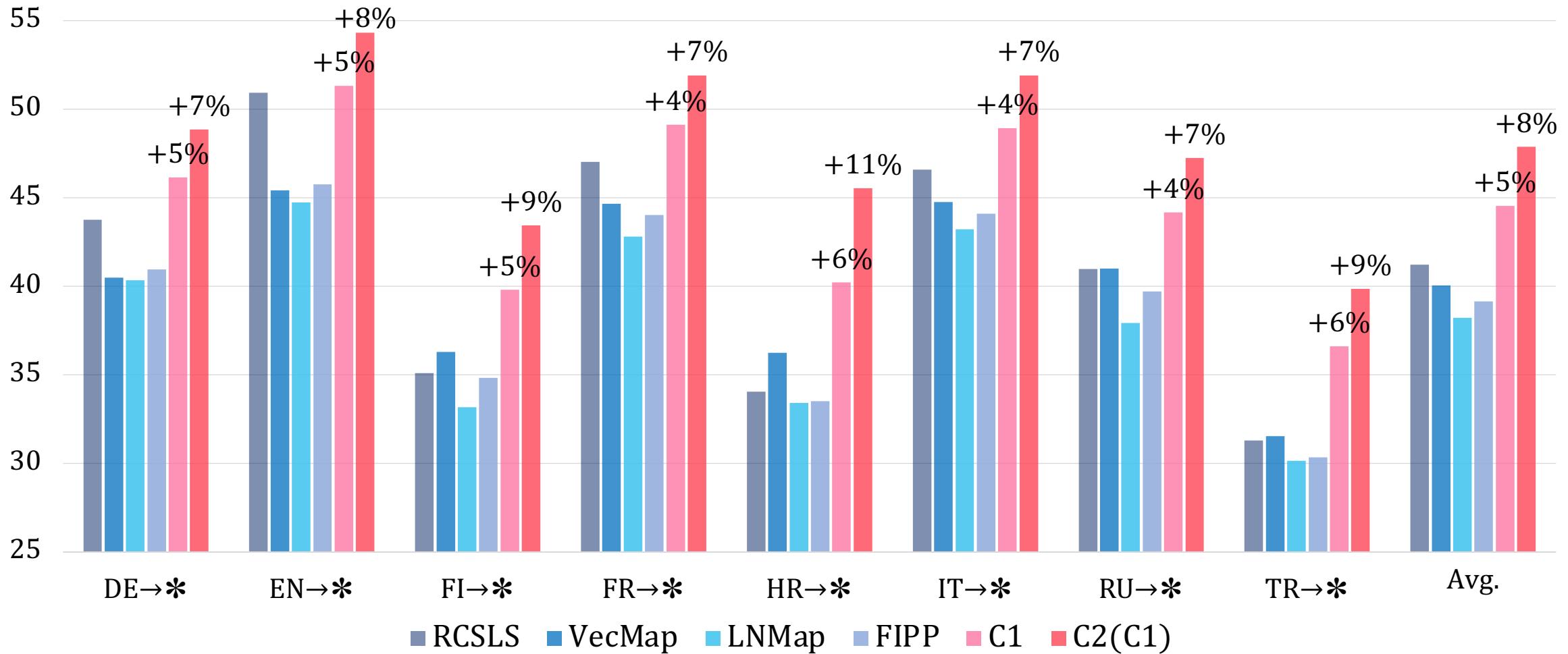
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 - fastText
 - mBERT (main); XLM, mT5 (comparison)

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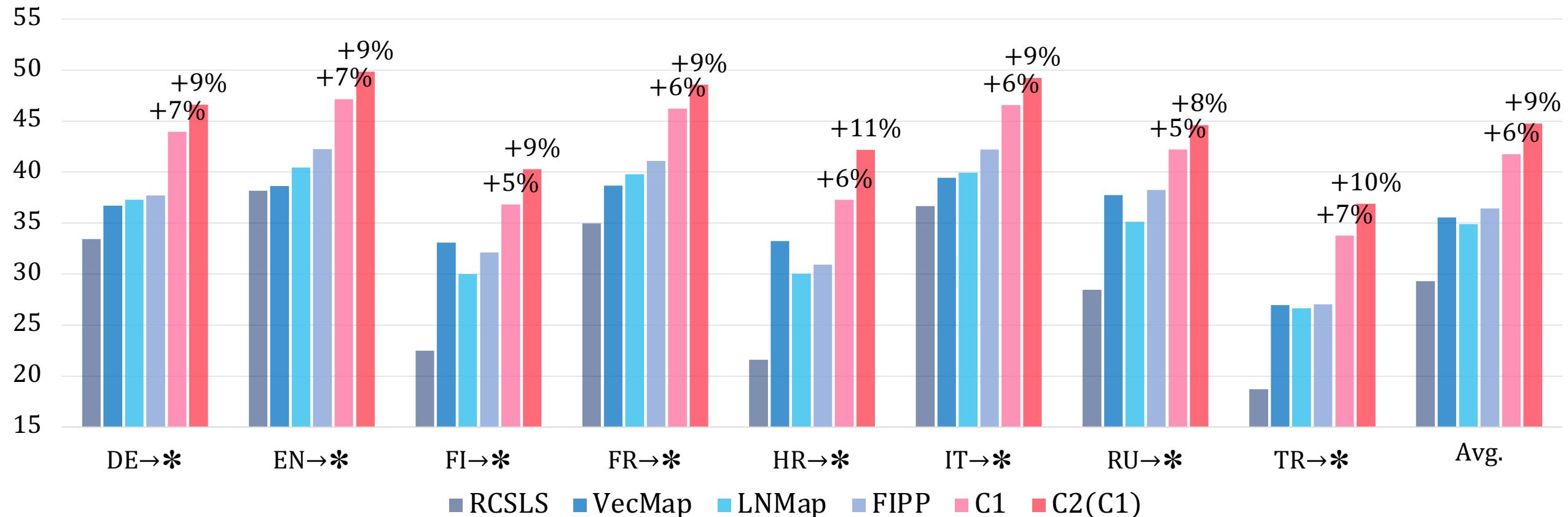
- Statics WEs & multilingual LMs
 - fastText
 - mBERT (main); XLM, mT5 (comparison)
- Hyperparameters
 - Tuned on EN→TR
 - $\lambda=0.2$ (fixed)

Evaluation: XLING 5K



- C1: $\approx 5\%$ higher than SotA (Avg. of 4 Baselines)
- C2: $\approx 8\%$ higher than SotA (Avg. of 4 Baselines)

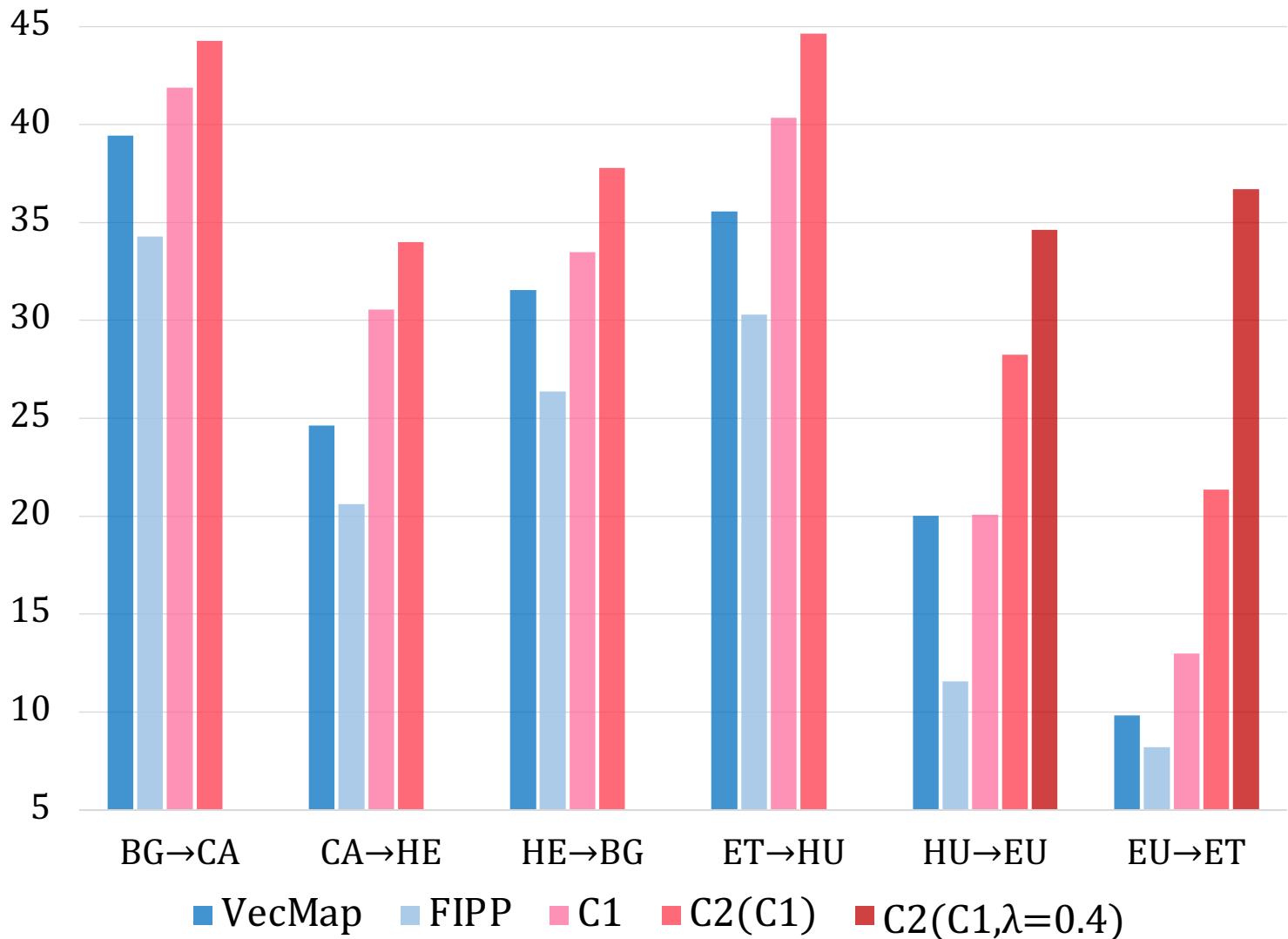
Evaluation: XLING 1K



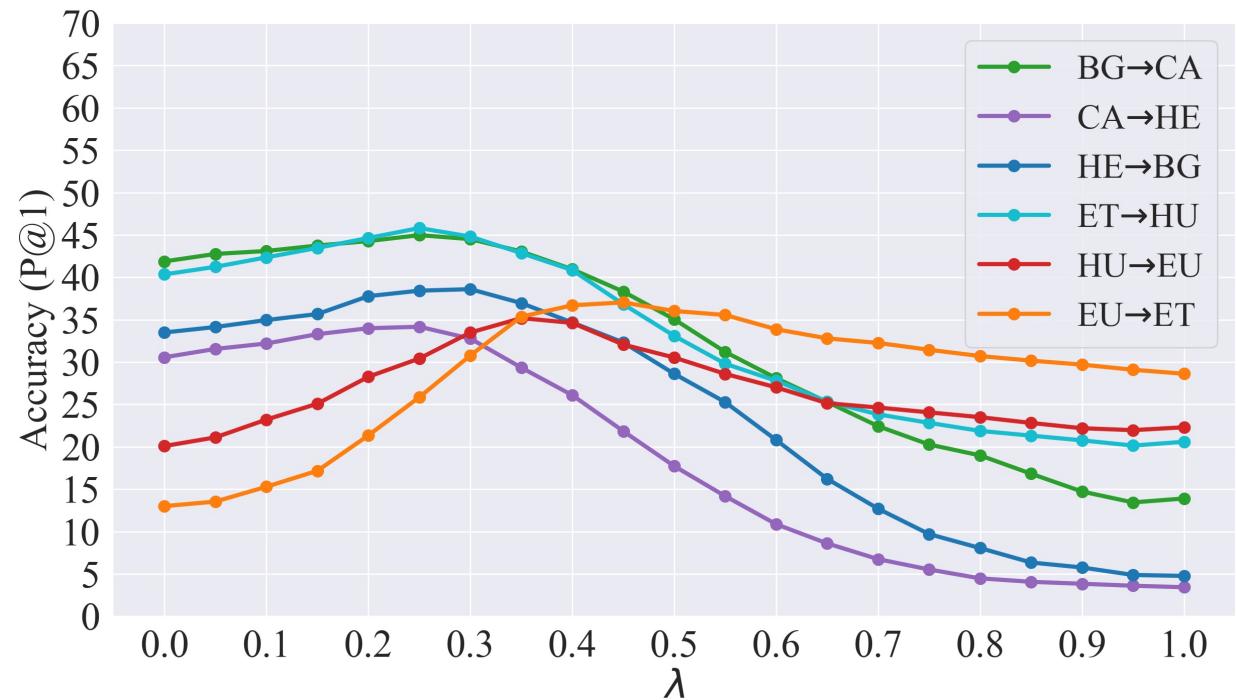
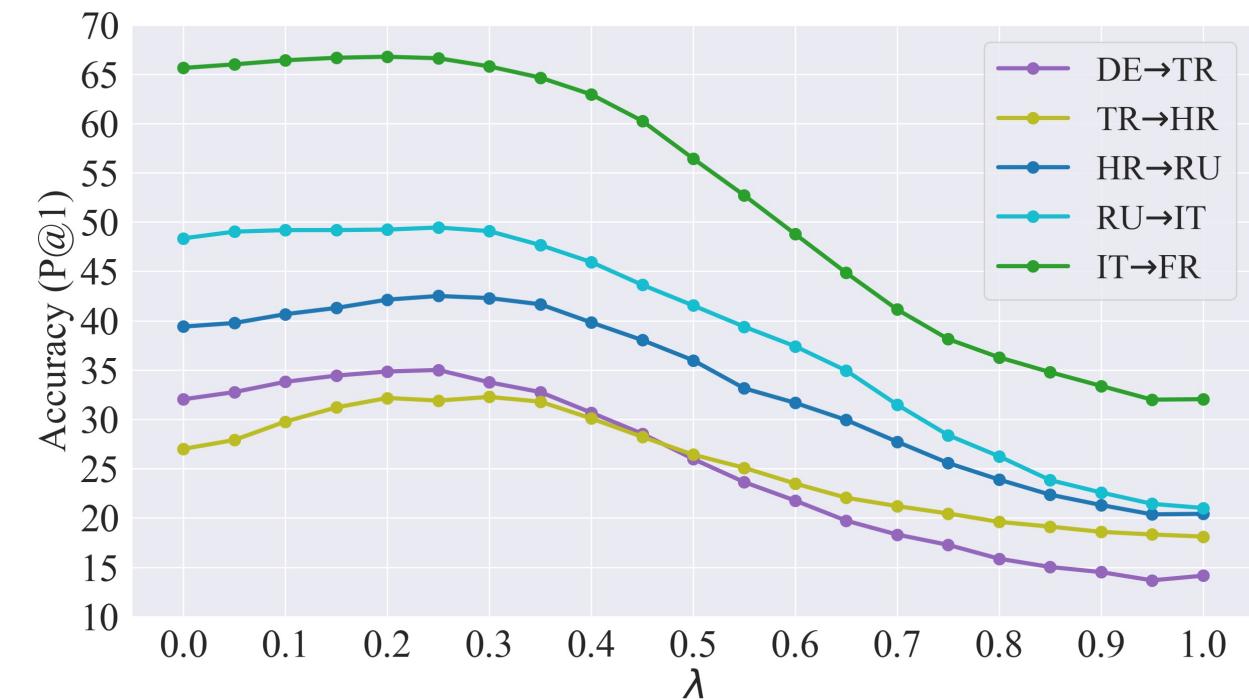
- C1: $\approx 6\%$ higher than SotA (Avg. of 3 stronger baselines)
- C2: $\approx 9\%$ higher than SotA (Avg. of 3 stronger baselines)

Evaluation: PanLex-BLI 1K

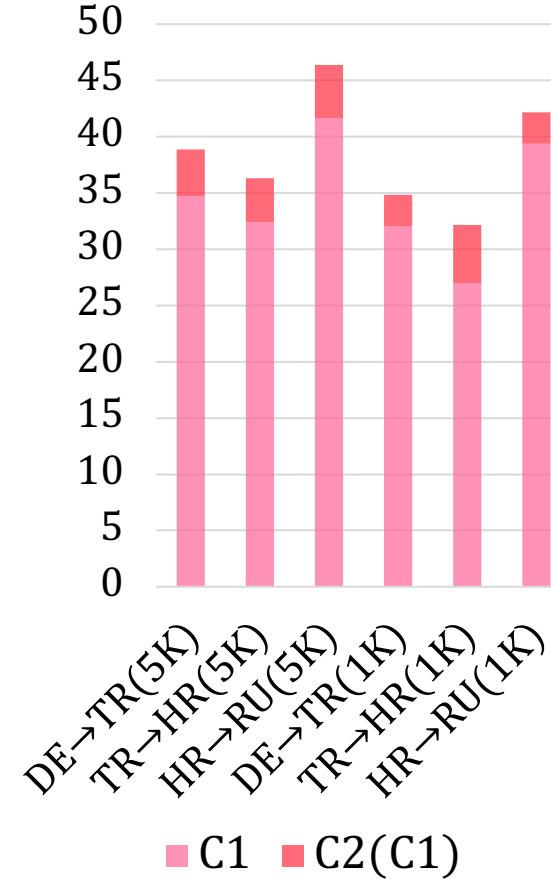
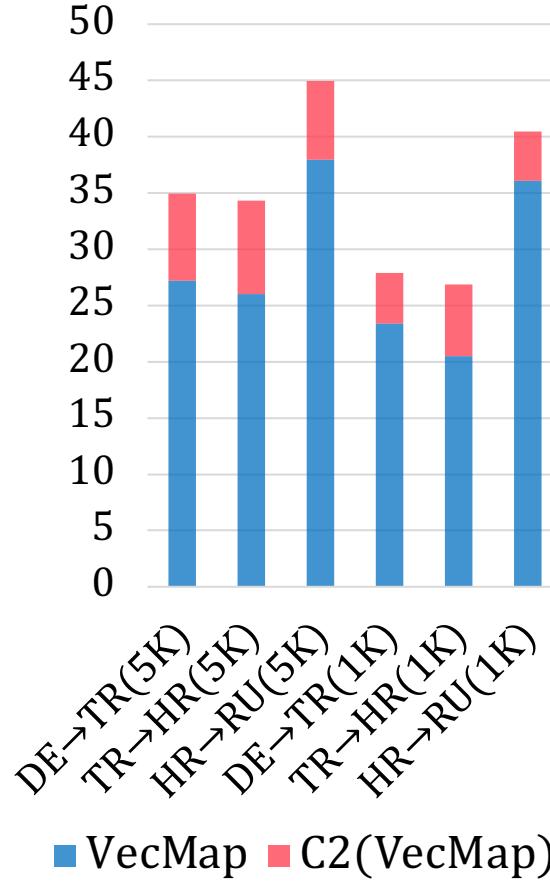
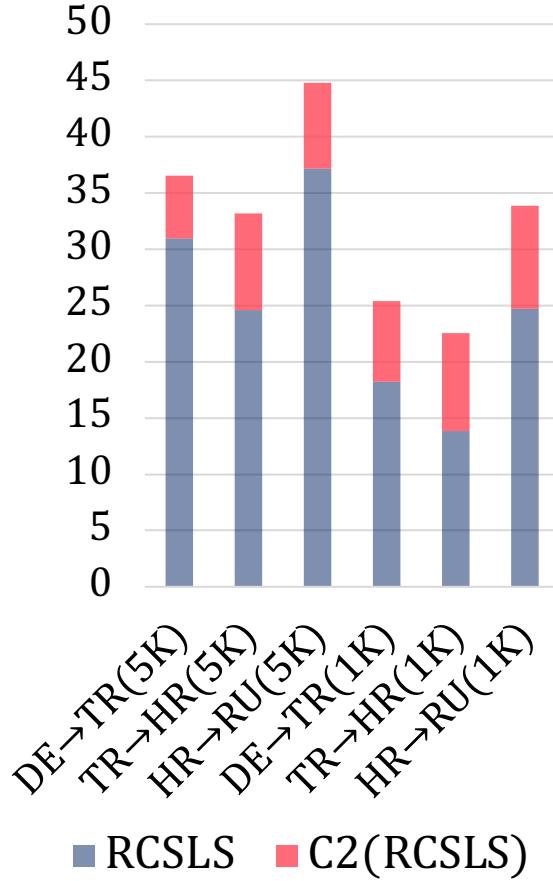
- Same trends
- PLMs more useful?
 - Lower-resource



Analysis: λ Values

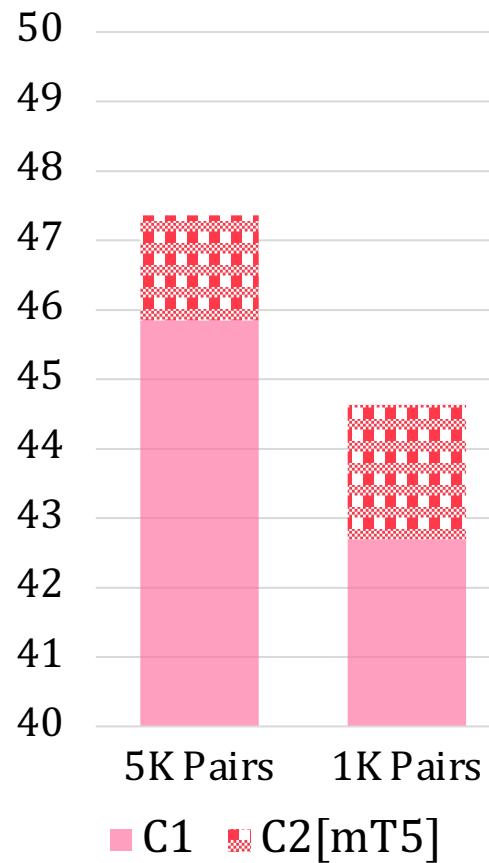
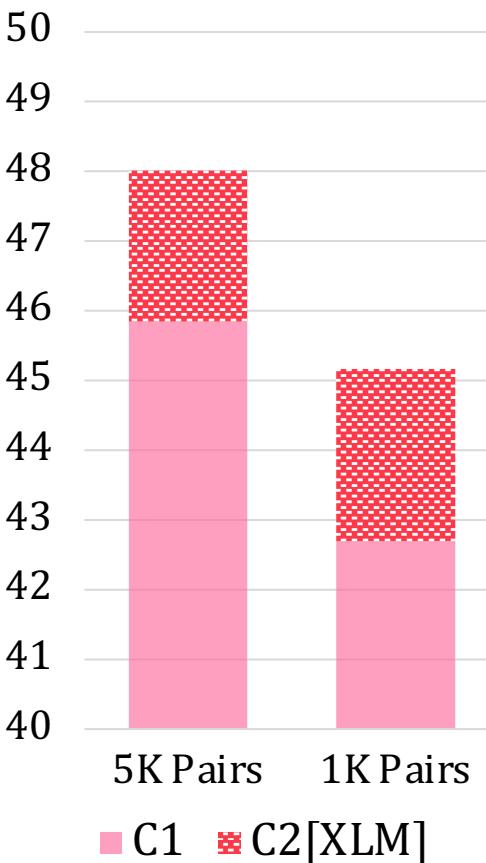
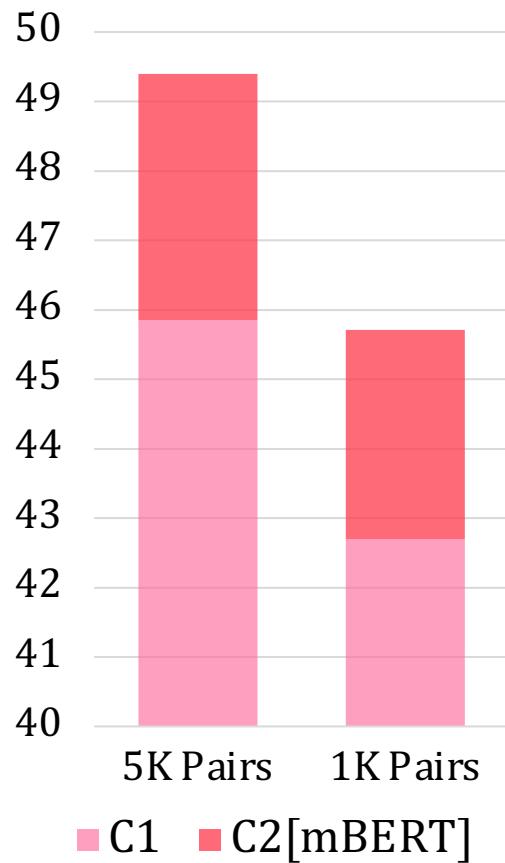


Analysis: Different ‘Support’ Methods



- C2(mod)
 - C2(RCSLS) ✓
 - C2(VecMap) ✓
 - C2(C1) ✓

Analysis: Different Multilingual LMs

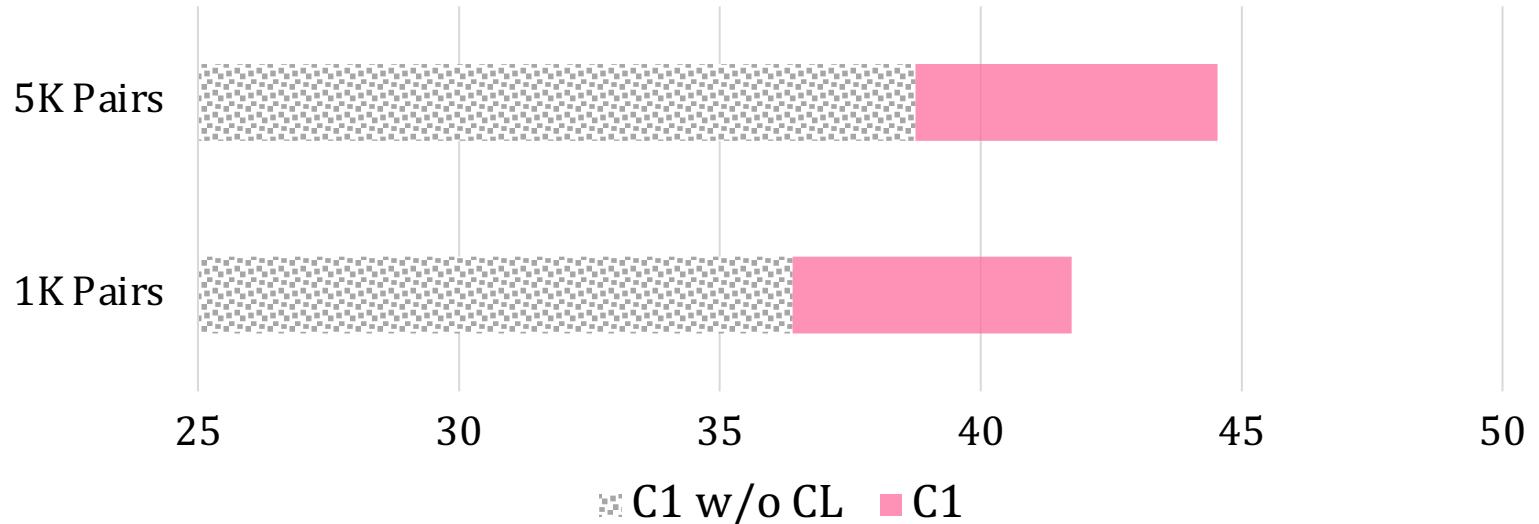


- C2[LM]
 - C2[mBERT] ✓
 - C2[XLM] ✓
 - C2[mT5] ✓

Analysis: Ablation Study — Stage C1

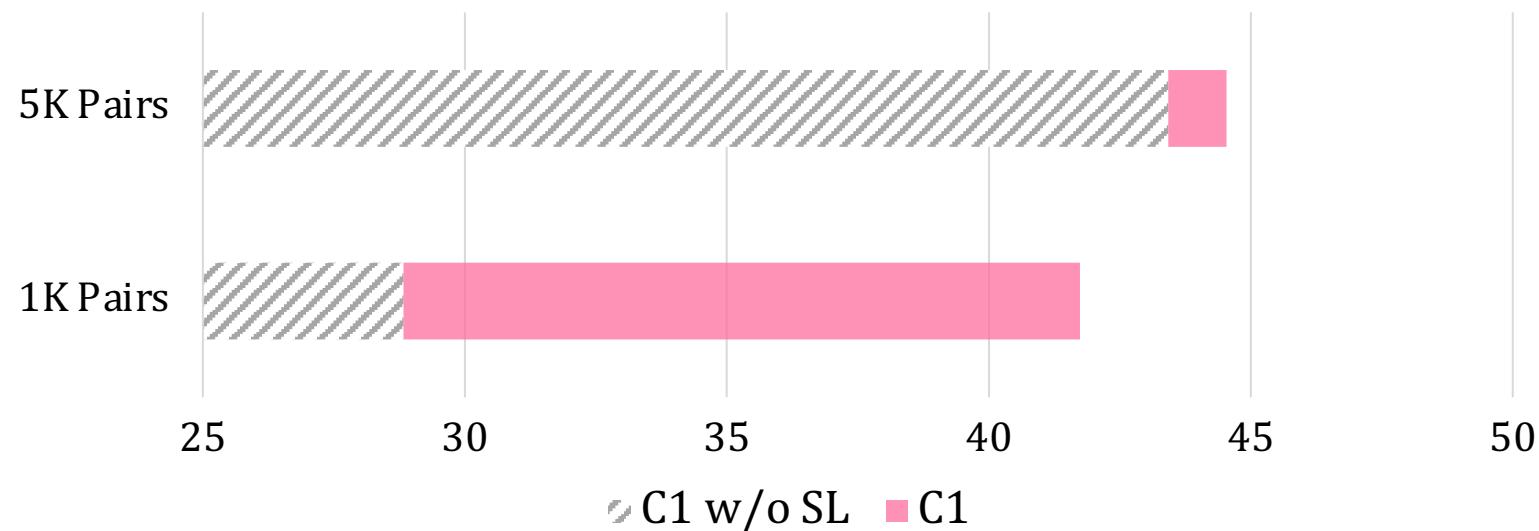
- Contrastive Learning

- 5K ✓
- 1K ✓



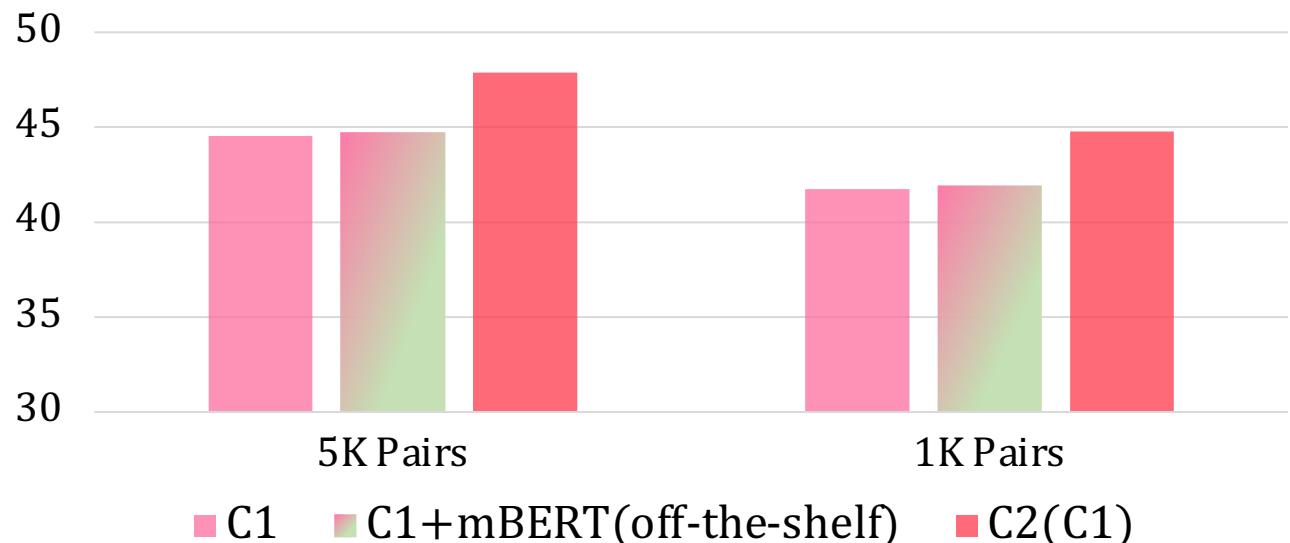
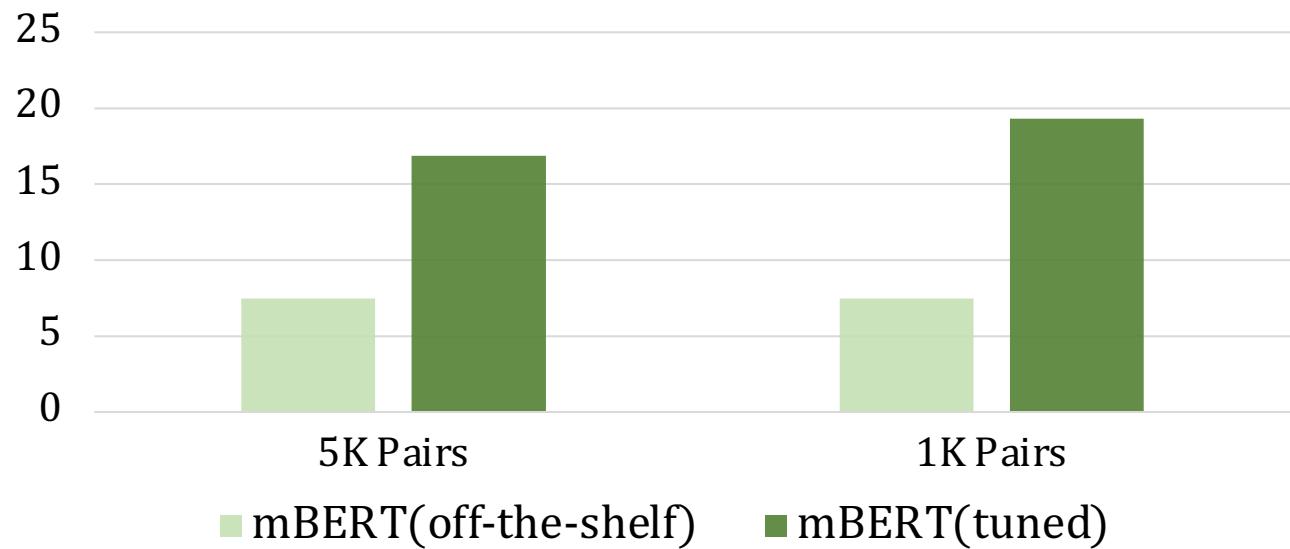
- Self-Learning

- 5K (slight gains)
- 1K ✓

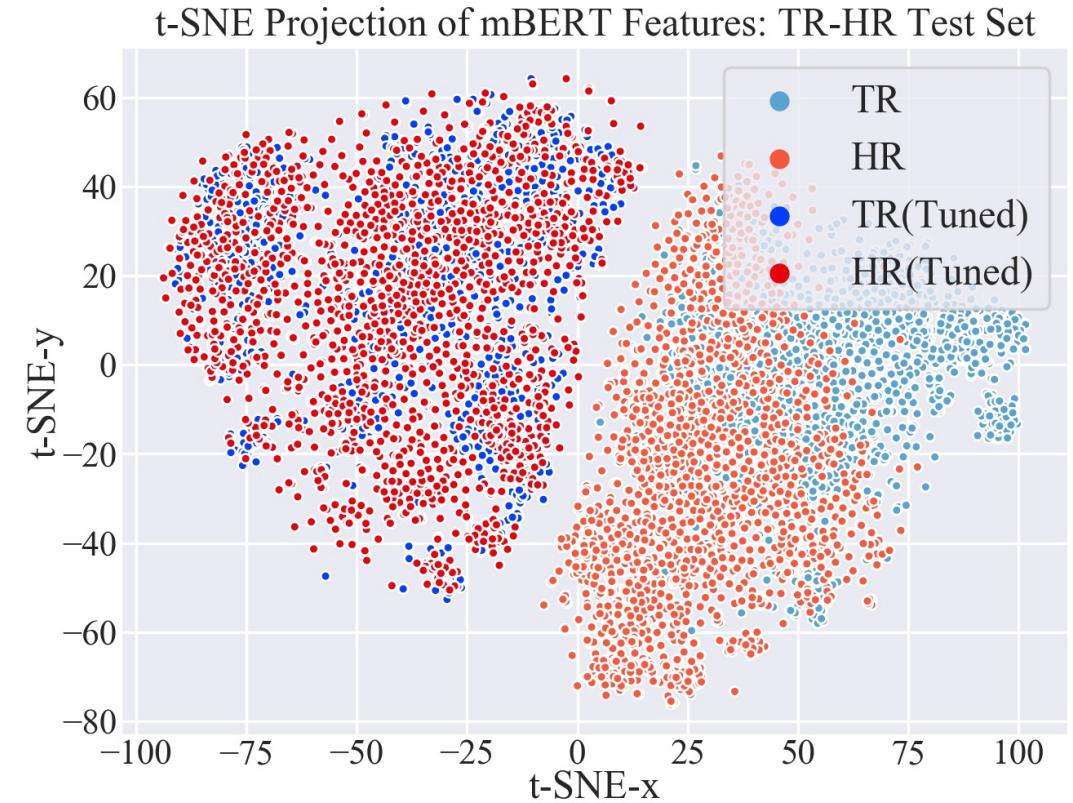
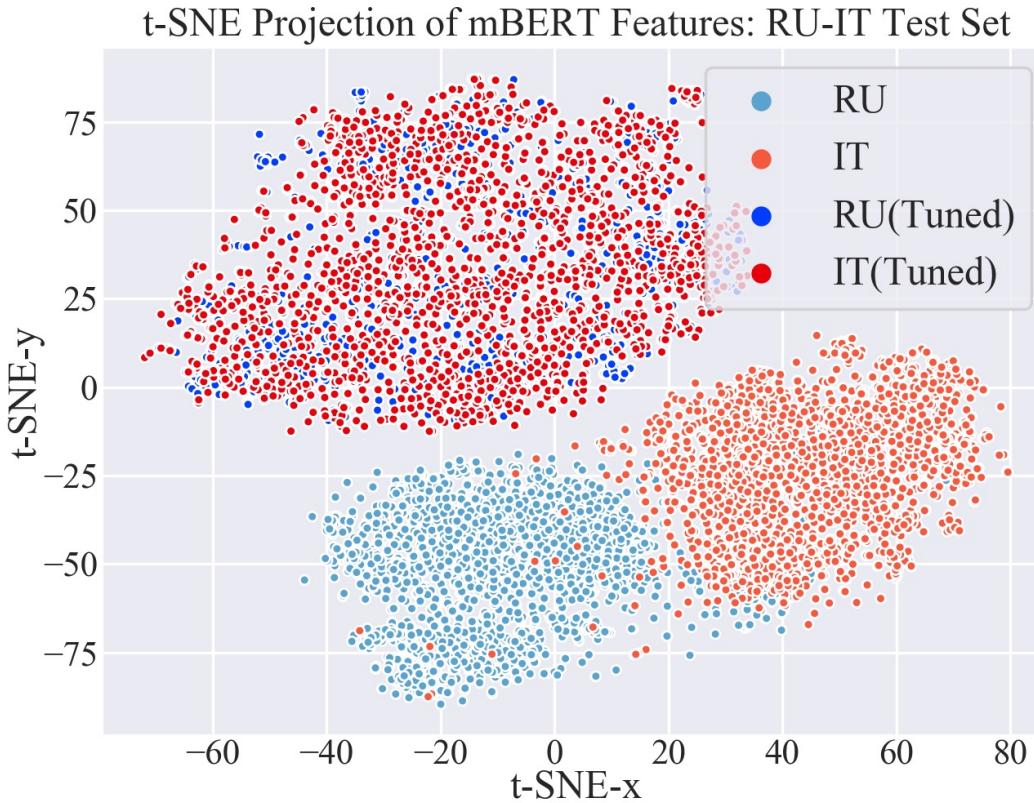


Analysis: Ablation Study — Stage C2

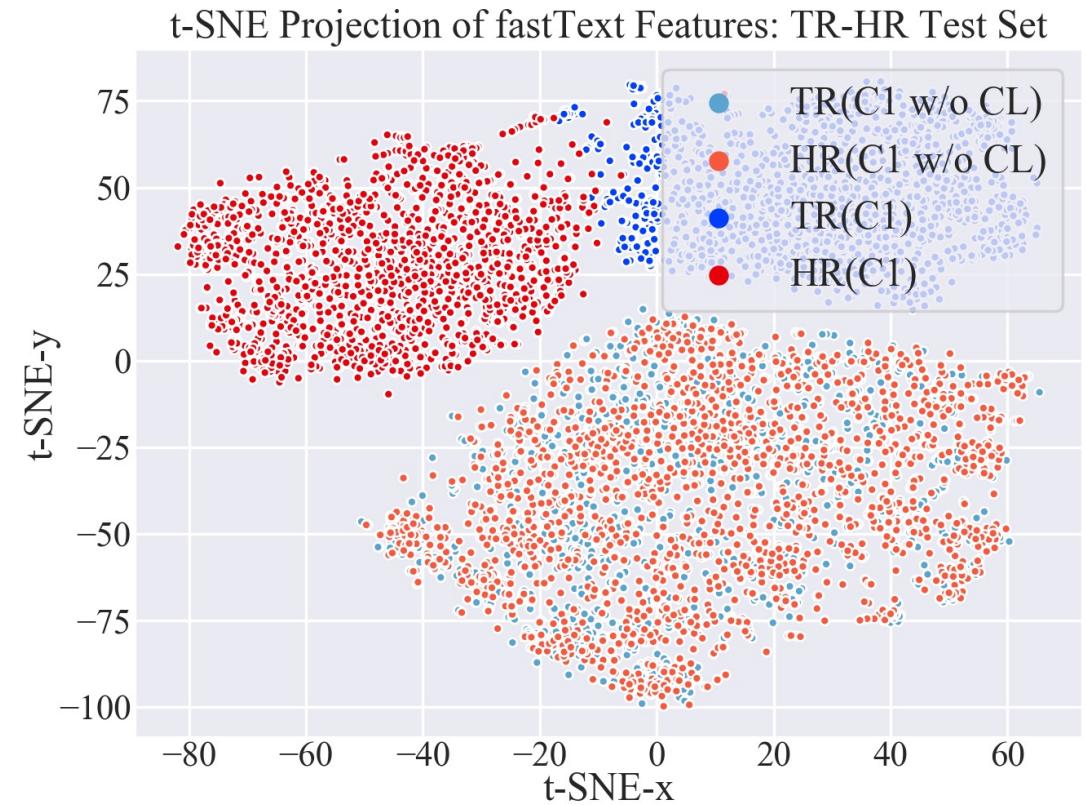
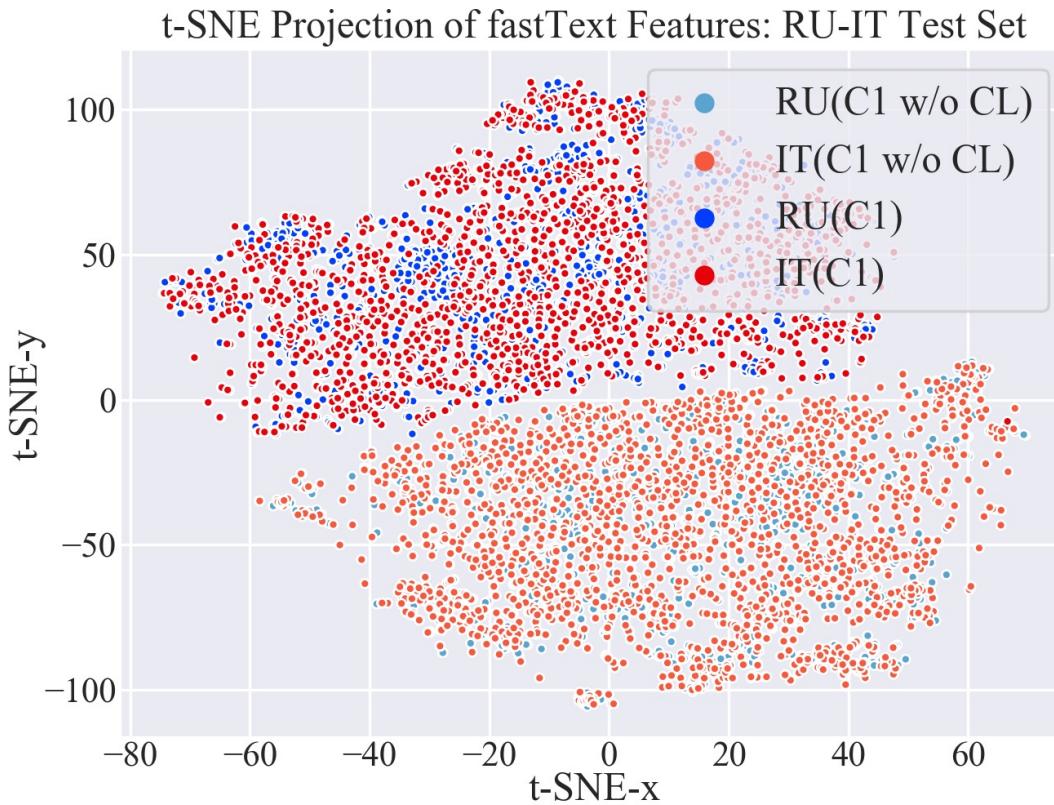
- Contrastive Tuning
 - Tuned > off-the-shelf
 - fastText (C1) > mBERT
- Combing C1 & mBERT
 - CL exposes word translation knowledge in mBERT



Analysis: Effectiveness of CL (Stage C2)



Analysis: Effectiveness of CL (Stage C1)



Summary

- A two-stage framework for BLI
 - Simple, effective and robust

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 - Static WEs only, e.g., fastText
 - SotA \leftarrow evaluated independently
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 - CLWEs (static) + multilingual LMs, e.g., mBERT
 - Extra gains

Summary

- A two-stage framework for BLI
 - Simple, effective and robust
- Stage C1
 - Static WEs only, e.g., fastText
 - SotA \leftarrow evaluated independently
- Stage C2
 - CLWEs (static) + multilingual LMs, e.g., mBERT
 - Extra gains
- A series of analyses & ablation studies

Summary (Technically)

- Contrastive Learning



Static WEs (C1)

Multilingual LMs (C2)



Summary (Technically)

- Contrastive Learning

Static WEs (C1) Multilingual LMs (C2)



- Self-Learning
 - Semi-supervised
 - Multilingual LMs
 - Word translation knowledge



The figure is a word cloud centered around the words "fast" and "Text". The size of each word represents its frequency or importance in the comparison between the two models. The words are color-coded by language family or origin:

- Georgian** (Large, red)
- Aramaic** (Large, blue)
- Finnish** (Large, green)
- Simplified Chinese** (Medium, red)
- Chinese** (Medium, blue)
- Tsonga** (Medium, green)
- Portuguese** (Medium, red)
- Yiddish** (Medium, blue)
- Tajik** (Medium, green)
- Southern Sotho** (Large, red)
- Walloon** (Medium, blue)
- Lower Sorbian** (Medium, green)
- Korean** (Medium, red)
- Lithuanian** (Medium, blue)
- Cantonese** (Medium, green)
- Maltese** (Medium, red)
- Bavarian** (Medium, blue)
- Ndonga** (Medium, green)
- Armenian** (Medium, red)
- Ukrainian** (Medium, blue)
- Serbian** (Medium, green)
- Sindhi** (Medium, red)
- Inuktitut** (Medium, blue)
- Lezgian** (Medium, green)
- Croatian** (Medium, red)
- Hindi** (Medium, blue)
- Urdu** (Medium, green)
- Komi** (Medium, red)
- Persian** (Medium, blue)
- Permyak** (Medium, green)
- Venda** (Medium, red)
- Western Punjabi** (Medium, blue)
- Najavo** (Medium, green)
- Kazakhstani** (Medium, red)
- Aromakanian** (Medium, blue)
- FastText** (Very Large, red)
- Text** (Very Large, red)
- word2Vec** (Medium, blue)

Below the word cloud, the text "FastText Vs word2Vec" is displayed.

- Might be useful for future BLI research: CL, SL, and multilingual (also monolingual) LMs.

Thanks for Watching!

Code: <https://github.com/cambridgetl/ContrastiveBLI>

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