On the Downstream Performance of Compressed Word Embeddings

Avner May, Jian Zhang, Tri Dao, Chris Ré

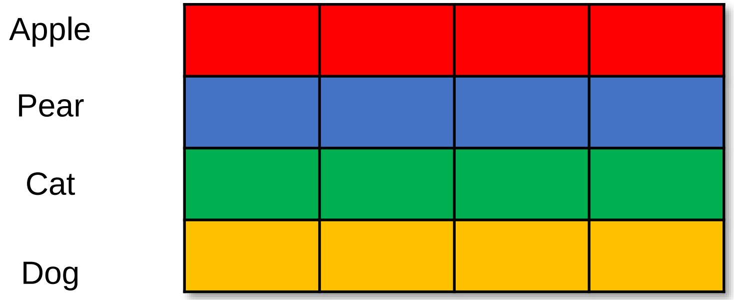
Stanford University

Word Embeddings

Pretraining

Downstream models

1



Word embeddings

2

Word embeddings take a lot of memory

1. Freepik 2. slideshare

Word Embedding Compression

Critical for deployment **under memory constraints**

- Deep compositional code learning (DCCL)[1]
- Kmeans[2]
- Uniform quantization[3]
- Dimension reduction (e.g. PCA)[4]

1. Shu et al. 2017 2. Andrews et al. 2015 3. Gersho et al. 1977 4. Pearson et al. 1901

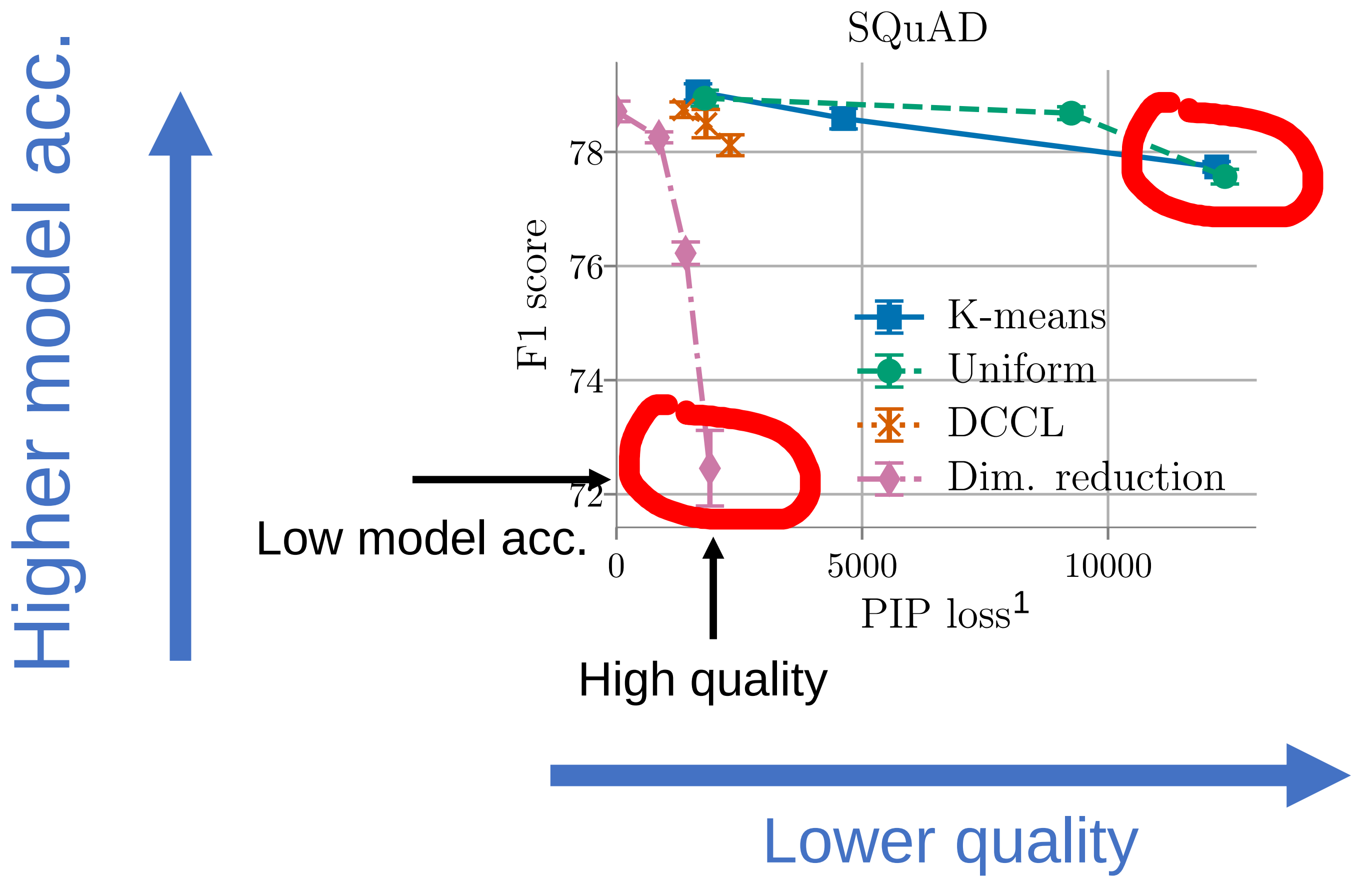
What determines the ***model accuracy*** attained by different ***compressed word embeddings?***

&

Can the insights guide the selection of ***compressed word embeddings*** under ***memory constraints?***

Existing quality measures

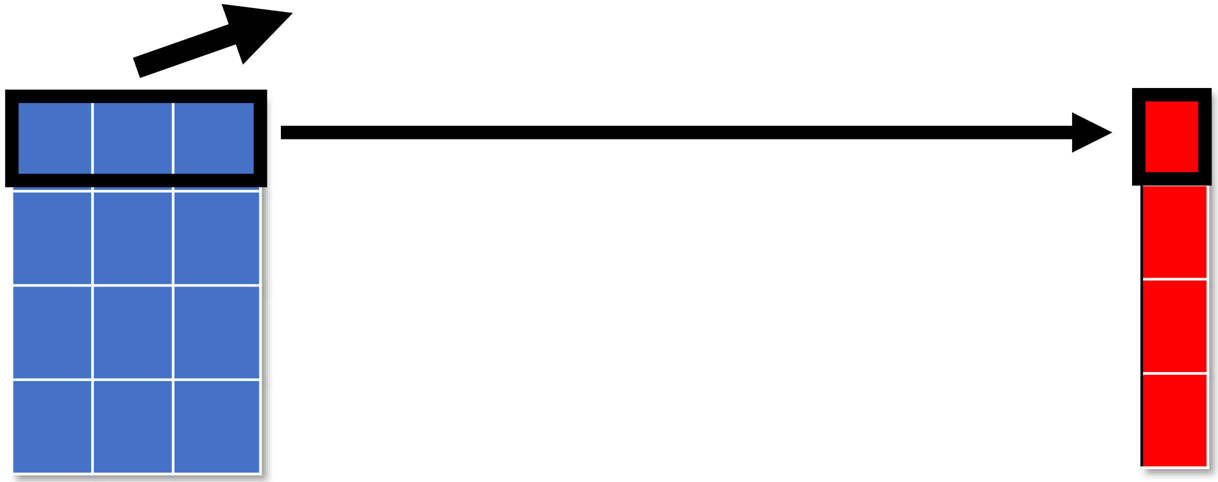
Can’t explain the relative model accuracy **across compression methods**



1. Yin et al. 2018

Setting to derive a new quality measure

Word vector as feature



Compressed word embedding
$X \in \mathbb{R}^{n \times d}$

Regression label
$y \in \mathbb{R}^{n}$

Model accuracy

Test mean square error (MSE) rel. to uncompressed embedding

In the setting of *linear regression*

Fixed design linear regression (simple and classic setup):[1,2,3]
Same set of data points for train and test; noisy training label; noiseless test label

Test time prediction $= UU^T y$

Compressed word embedding $X \in \mathbb{R}^{n\times d}$

SVD $X = U\Lambda V^T$

Training label $y \in \mathbb{R}^n$

Observation

Prediction highly depends on ***U, the left singular vectors***

1. Avron et al. 2018 2. Bach et al. 2013 3. Cortes et al. 2010

A new quality measure of compression word embedding

Eigenspace overlap (EO)

$$\mathcal{E}(X, \tilde{X}) := \frac{1}{\max(d,k)} \|U^T \tilde{U}\|_F^2$$

Compressed $X \in \mathbb{R}^{n\times d}$ uncompressed $\tilde{X} \in \mathbb{R}^{n\times k}$

SVD $X = U\Lambda V^T, \ \tilde{X} = \tilde{U}\tilde{\Lambda}\tilde{V}^T$

Intuition

More ***similar left singular vectors***,

better model acc. relative to uncompressed embeddings

In the setting of *linear regression*

$$\mathbb{E}_{\bar{y}}\left[\underbrace{\mathcal{R}_{\bar{y}}(\tilde{X}) - \mathcal{R}_{\bar{y}}(X)}^{\text{Test MSE rel. to uncompressed embedding}}\right] = \mathcal{O}\Big(1 - \mathcal{E}(X, \tilde{X})\Big)$$

Target label vector sampled from $\mathrm{Span}(U)$

Uncompressed embedding X

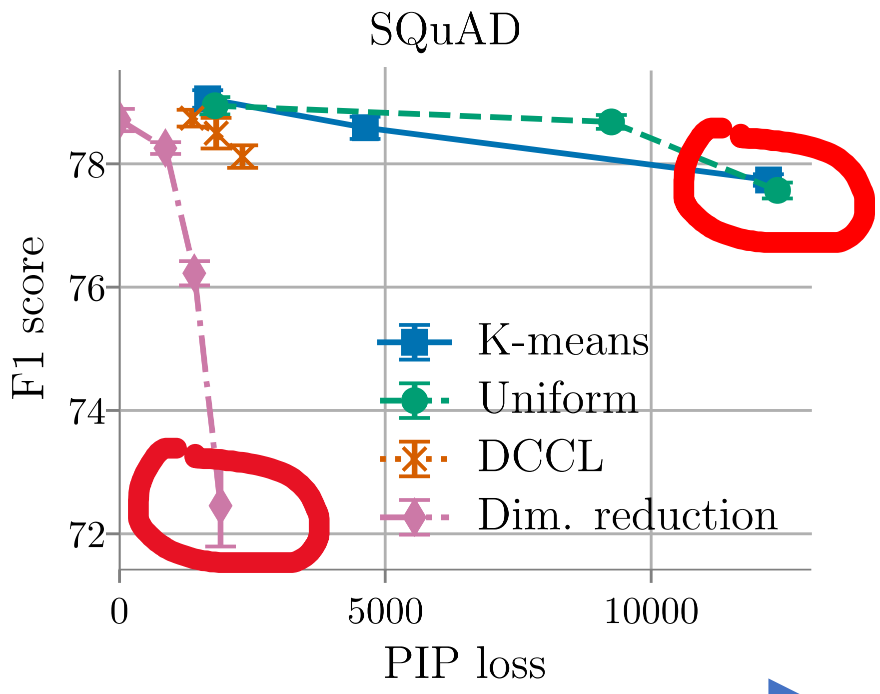
Compressed embedding $\tilde{X}$

Theory connection (sketch)

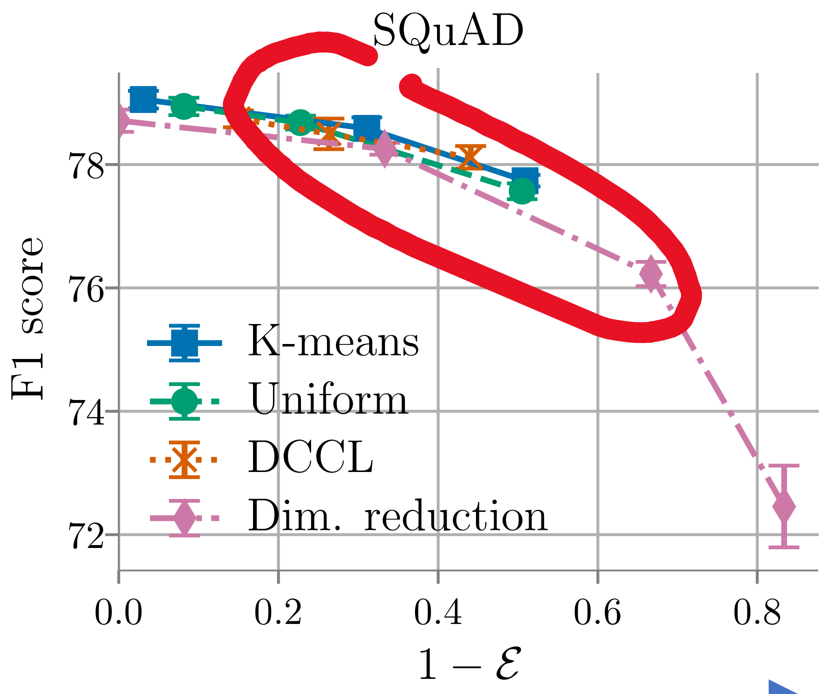
Model acc. can be bounded in terms of ***eigenspace overlap***

Empirical correlation beyond ***the regression setting***

Higher model acc.



Lower quality



Lower quality

Empirical correlation

EO attains ***better correlation*** with downstream ***model acc.***

What determines the ***model accuracy*** attained by different ***compressed word embeddings?***

&

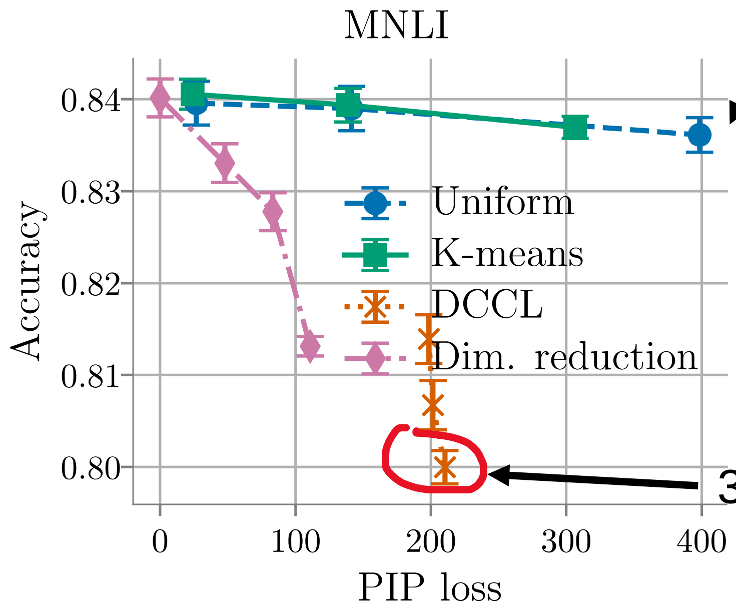
Can the insights guide the selection of ***compressed word embeddings*** under ***memory constraints?***

Eigenspace overlap as a selection criterion

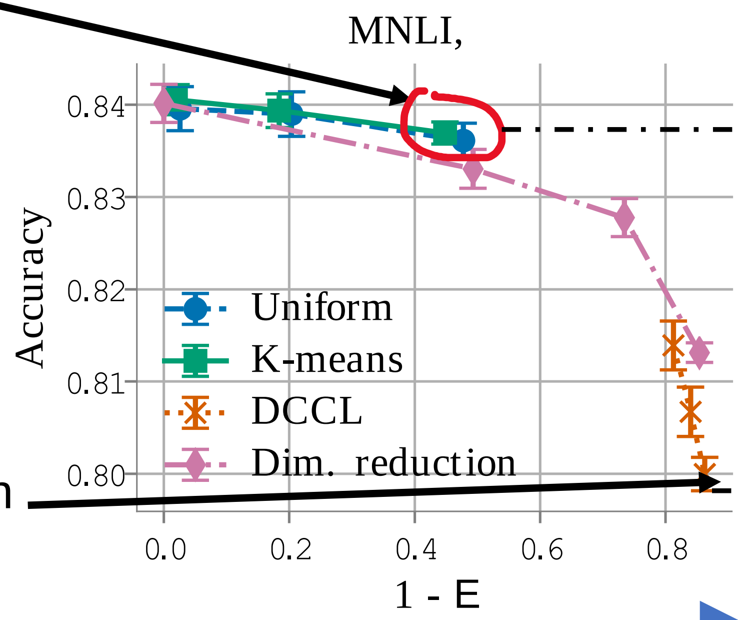
Selecting the right embedding → **better model acc.** under **memory budgets**

Case study

32X compression



32X compression



3.5 pt. higher acc.

Lower quality

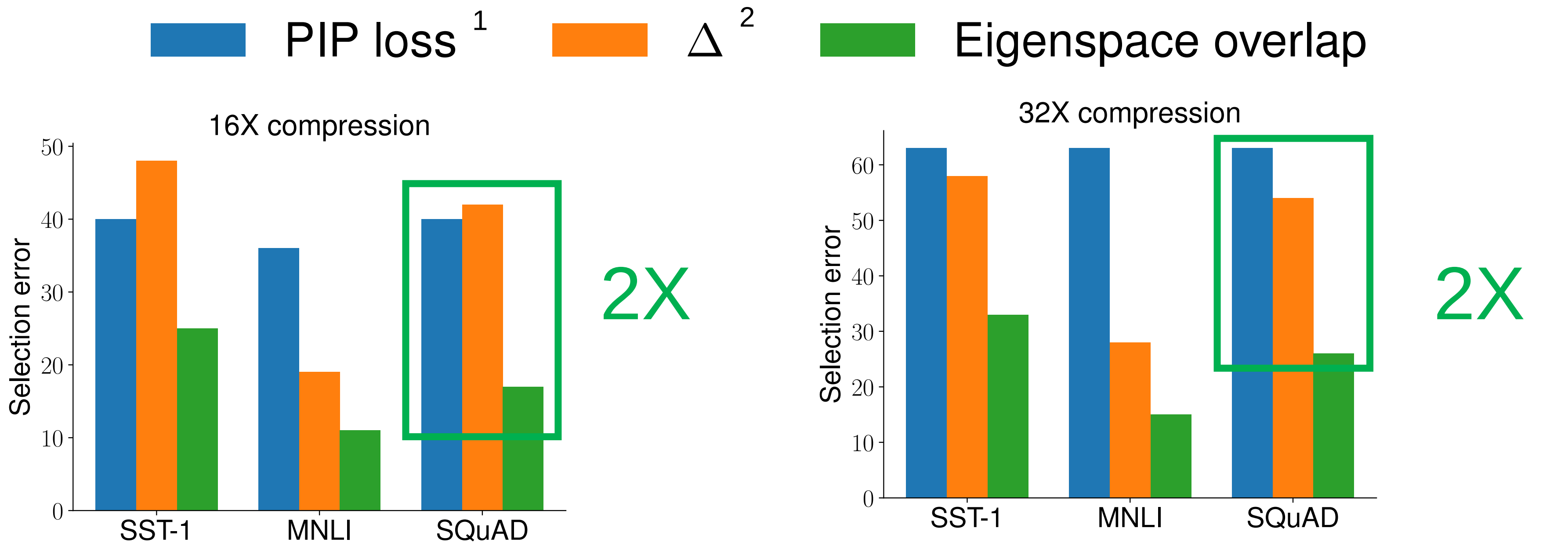
Lower quality

Eigenspace overlap vs. PIP loss → ***higher acc.*** at ***32X compression***

Eigenspace overlap as a selection criterion

Selection error

Fraction of cases when ***failing to select*** the embedding with ***better model acc.***



Utility under memory budgets

Up to **2X lower selection error** at up to 32X compression

1. Yin et al. 2018 2. Avron et al. 2018

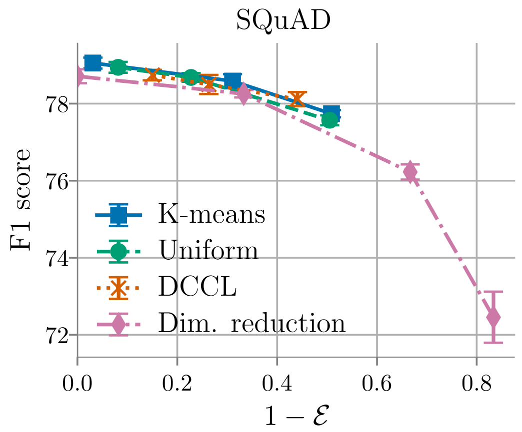
Summary

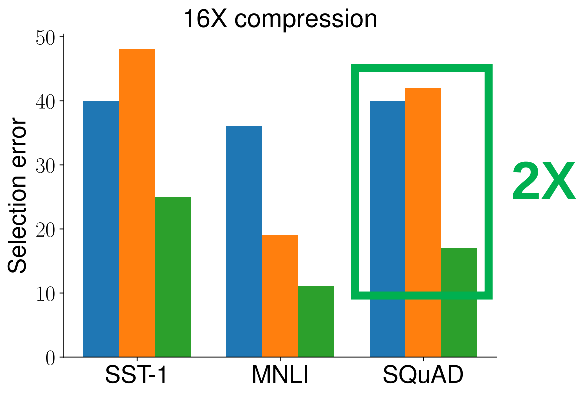
Theoretical connection ***in a regression setting***

Empirical correlations in ***a wide range of models / tasks***

Guide the ***selection*** of compressed word embeddings

$$\mathbb{E}_{\bar{y}}\left[\mathcal{R}_{\bar{y}}(\tilde{X}) - \mathcal{R}_{\bar{y}}(X)\right] = \mathcal{O}\left(1 - \mathcal{E}(X, \tilde{X})\right)$$





Left singular vector is important, EO captures it

Utility under memory constraints

THANK YOU!

Spotlight: Thursday, Dec 12, 4:05 pm
Poster: Thursday, Dec 12, 5-7 pm