Joint Embedding of Words and Labels for Text Classification

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Code: bit.ly/LEAM-Duke

Motivation

- Text classification as a label-word joint embedding problem
- Use label information to construct text-sequence representations

Contribution

- **Label Embedding Attentive Model (LEAM)**
- **High accuracy** in standard benchmarks and clinical dataset
- Only basic algebraic operation involved, hence retains interpretability
- **Fewer parameters and less computation**

Traditional Models

- Given training set $\mathcal{S} = \{(\mathbf{X}_n, \boldsymbol{y}_n)\}_{n=1}^{N}$ of pair-wise data, where
  - $\mathbf{X} \in \mathcal{X}$ is the text sequence,
  - $\boldsymbol{y} \in \mathcal{Y}$ is its corresponding label
- Goal: learn a function $f : \mathcal{X} \mapsto \mathcal{Y}$ by

$$\min_{f \in \mathcal{F}} \frac{1}{N} \sum_{n=1}^{N} \delta(\boldsymbol{y}_n, f(\mathbf{X}_n))$$

- A typical text classification can be presented as a function decomposition

$$f = f_0 \circ f_1 \circ f_2$$

$f_0 : \mathbf{X} \mapsto \mathbf{V}$ represents text sequence as its word-embedding form

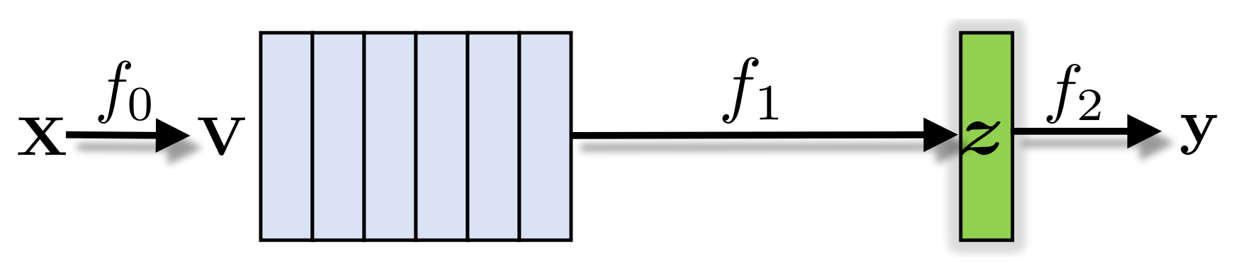
$f_1 : \mathbf{V} \mapsto \boldsymbol{z}$, aggregates word embeddings into a vector representation

$f_2 : \boldsymbol{z} \mapsto \boldsymbol{y}$, annotates the text representation with a label

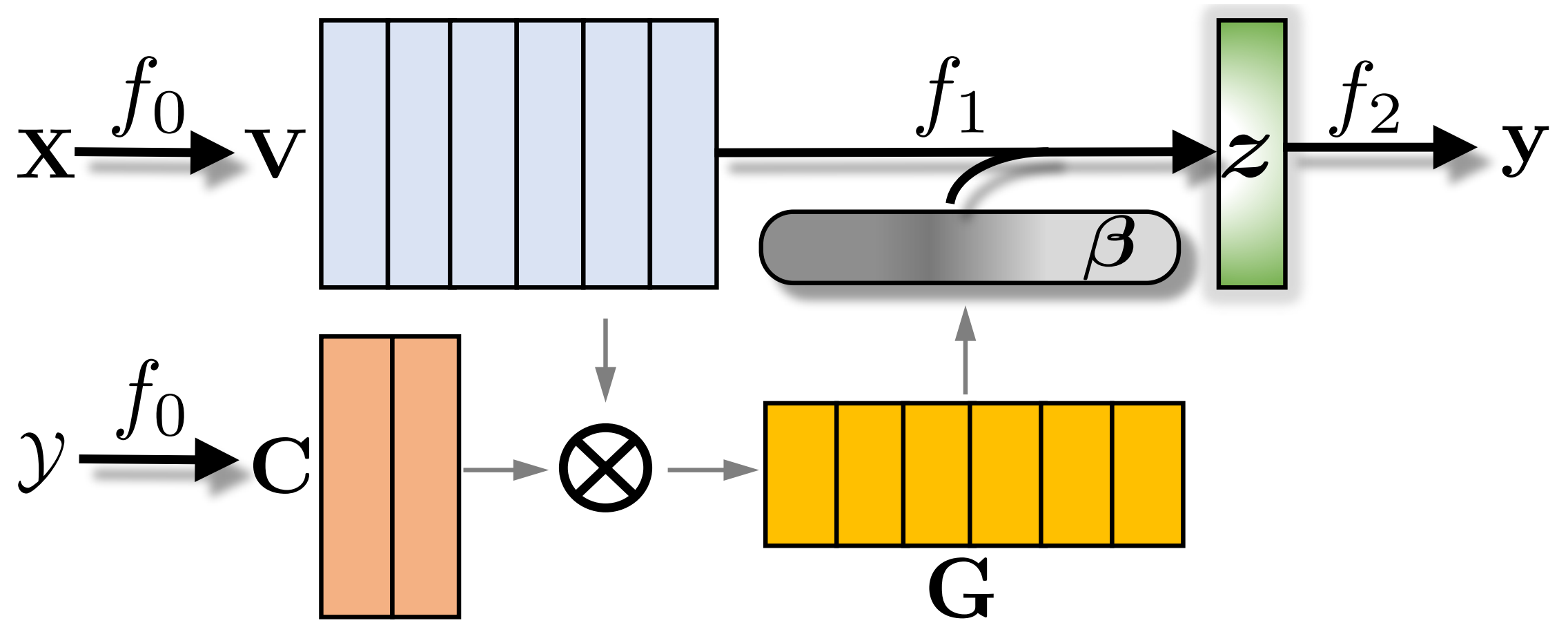
Complexity (Fewer parameters & Less computation)

Model	Parameters	Complexity	Seq.
CNN	$m \cdot h \cdot P$	$O(m \cdot h \cdot L \cdot P)$	$O(1)$
LSTM	$4 \cdot h \cdot (h + P)$	$O(L \cdot h^2 + h \cdot L \cdot P)$	$O(L)$
SWEM	0	$O(L \cdot P)$	$O(1)$
Bi-BloSAN	$7 \cdot P^2 + 5 \cdot P$	$O(P^2 \cdot L^2/R + P^2 \cdot L + P^2 \cdot R^2)$	$O(1)$
LEAM	$K \cdot P$	$O(K \cdot L \cdot P)$	$O(1)$

Model	# Para	Time(s)
CNN	541k	171
LSTM	1.8M	598
SWEM	61K	63
Bi-BloSAN	3.6M	292
LEAM	65K	65



Traditional Models



$\mathbf{X} \xrightarrow{f_0} \mathbf{V}$
f_1
β
z
f_2
$\mathbf{y}$
$\mathcal{Y} \xrightarrow{f_0} \mathbf{C}$
$\otimes$
$\mathbf{G}$

LEAM

Proposed Model : LEAM

- Word embeddings $\mathbf{V}$ and the label embeddings $\mathbf{C}$ in a joint space

1. Measure the *compatibility* of label-word pairs via cosine similarity

$$\mathbf{G} = (\mathbf{C}^\top \mathbf{V}) \oslash \hat{\mathbf{G}}$$

2. *Local spatial information* among consecutive words (phrases)

$$\mathbf{u}_l = \mathrm{ReLU}(\mathbf{G}_{l-r:l+r}\mathbf{W} + \mathbf{b})$$

3. The *compatibility/attention score* $\quad \beta = \mathrm{Softmax}(\mathbf{m})$

   where the largest compatibility value is pooled: $m_l = \text{max-pooling}(\mathbf{u}_l)$

4. The *text sequence representation is weighted average* of word embeddings weighted by label-based attention score

$$\mathbf{z} = \sum_l \beta_l \mathbf{v}_l$$

- Single-label problem: training object is $\displaystyle \min_{f \in \mathcal{F}} \frac{1}{N} \sum_{n=1}^{N} \mathrm{CE}(\boldsymbol{y}_n, f_2(\boldsymbol{z}_n))$
- Multi-label problem: training object is $\displaystyle \min_{f \in \mathcal{F}} \frac{1}{NK} \sum_{n=1}^{N} \sum_{k=1}^{K} \mathrm{CE}(\boldsymbol{y}_{nk}, f_2(\boldsymbol{z}_{nk}))$
- **Regularization**: To force the label embedding as the anchor points for each classes, we regularize the learned label embeddings to be on its corresponding manifold

$$\min_{f \in \mathcal{F}} \frac{1}{K} \sum_{n=1}^{K} \mathrm{CE}(\boldsymbol{y}_k, f_2(\boldsymbol{c}_k)).$$

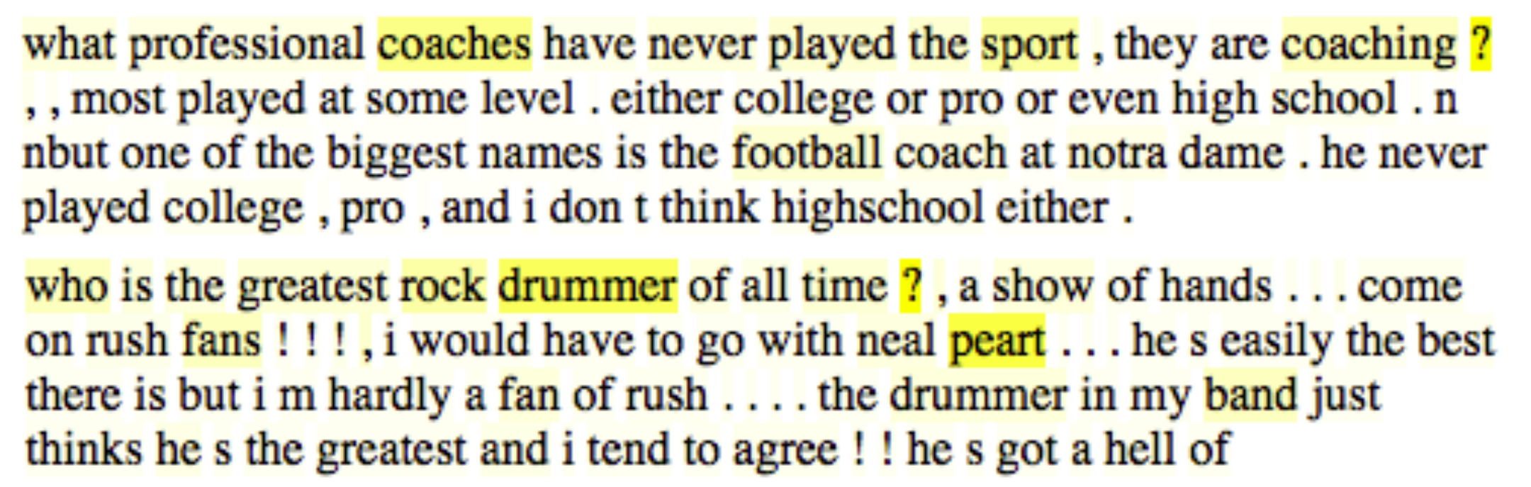
Experimental Results

Benchmark Classification Accuracy

Model	Yahoo	DBPedia	AGNews	Yelp P.	Yelp F.
Bag-of-	68.9	96.6	88.8	92.2	58
CNN	70.94	98.28	91.45	95.11	59.48
LSTM	70.84	98.55	86.06	94.74	58.17
Deep CNN	73.43	98.71	91.27	**95.72**	**64.26**
SWEM	73.53	98.42	92.24	93.76	61.11
fastText	72.3	98.6	92.5	95.7	63.9
HAN	75.8				
Bi-BloSAN	76.28	98.77	**93.32**	94.56	62.13
LEAM	**77.42**	**99.02**	92.45	95.31	64.09

Test Accuracy on document classification tasks, in percentage

Interpretability

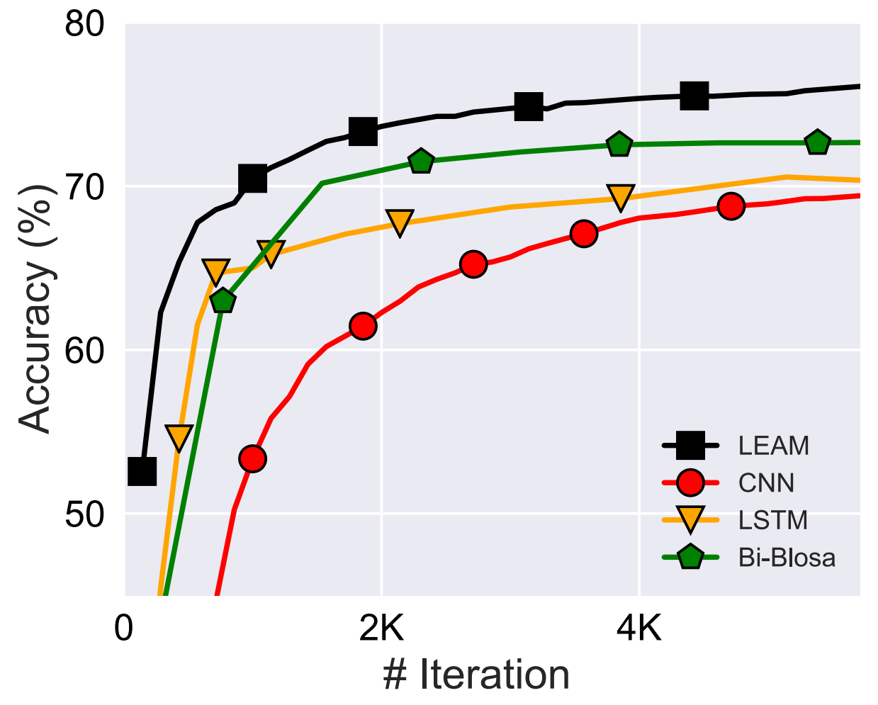


what professional coaches have never played the sport , they are coaching ? , , most played at some level . either college or pro or even high school . n nbut one of the biggest names is the football coach at notra dame . he never played college , pro , and i don t think highschool either .

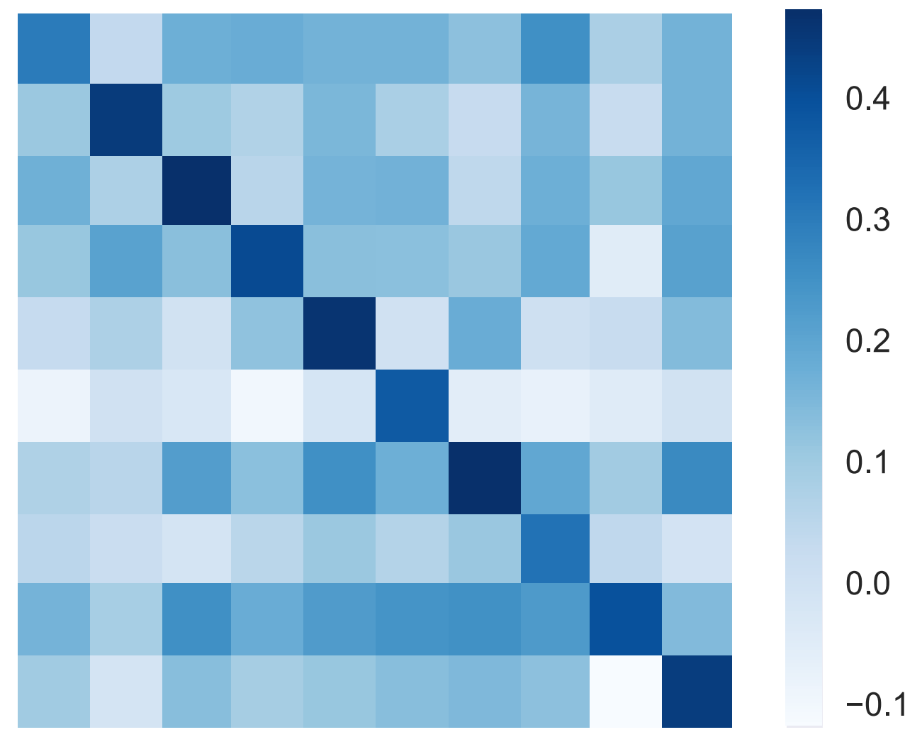
who is the greatest rock drummer of all time ? , a show of hands . . . come on rush fans ! ! ! , i would have to go with neal peart . . . he s easily the best there is but i m hardly a fan of rush . . . . the drummer in my band just thinks he s the greatest and i tend to agree ! ! he s got a hell of

Attention score example

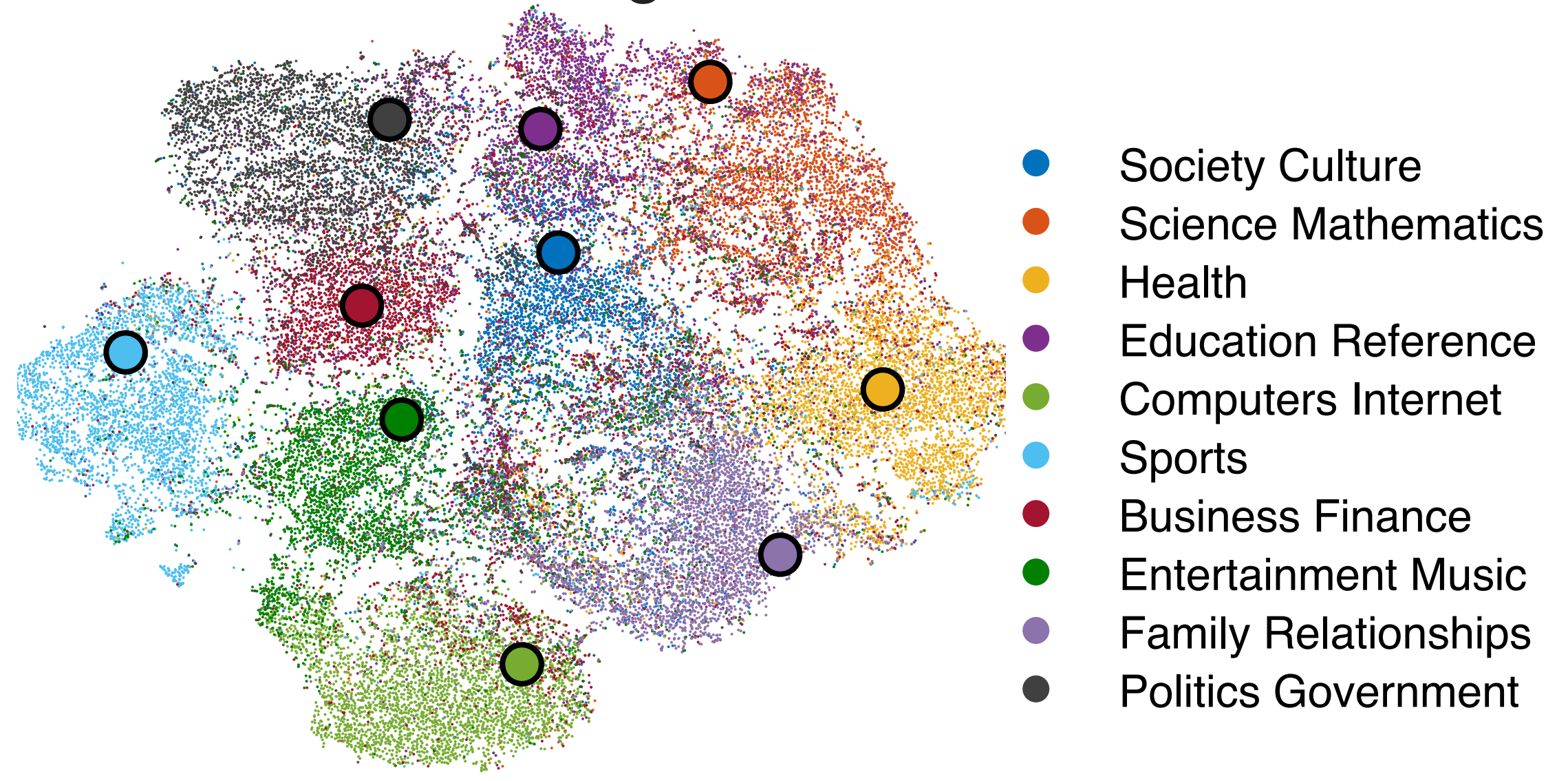
Convergence Speed



Cos similarity matrix: text and label embedding



t-SNE plot of joint embedding, point clouds for texts and large dots for labels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