CS 224N: Assignment 2

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Problem 1: Tensorflow Softmax (25 points)

1.1 (a) Implement Softmax use Tensorflow (5 points, coding)

Answer:
See code: ~/q1_softmax.py.

1.2 (b) Implement Cross-Entropy use Tensorflow (5 points, coding)

Answer:

See code: ~/q1_softmax.py.

1.3 (c) Tensorflow Placeholder and Feed Dictionary (5 points, coding/written)

Answer:

See code: ~/q1_classifier.py.

Explanation:

1.4 (d) Implement Classifier (5 points, coding)

Answer:
See code: ~/q1_classifier.py.

1.5 (e) Implement Model (5 points, coding/written)

Answer:
See code: ~/q1_classifier.py.

Explanation:

Problem 2: Neural Transition-Based Dependency Parsing (50 points + 2 bonus points)

2.1 (a) Dependency Parsing (6 points, written)

Answer:

$$
\begin{aligned}
\frac{d\sigma(x)}{dx} &= \frac{d}{dx}\left(\frac{1}{1+e^{-x}}\right) \\
&= -\frac{1}{(1+e^{-x})^2}\frac{d}{dx}(1+e^{-x}) = \frac{-1}{(1+e^{-x})^2}\frac{d}{dx}e^{-x} = \frac{-1}{(1+e^{-x})^2}\frac{-1}{(e^{x})^2}\frac{d}{dx}e^{x} \\
&= \frac{-1}{(1+e^{-x})^2}\frac{-1}{(e^{x})^2}e^{x} = \frac{1}{(1+e^{-x})^2(e^{x})^2}e^{x} \\
&= \frac{e^{-x}}{(1+e^{-x})^2} = \frac{1+e^{-x}-1}{(1+e^{-x})^2} = \frac{1}{1+e^{-x}} - \frac{1}{(1+e^{-x})^2} \\
&= \left(\frac{1}{1+e^{-x}}\right)\left(1-\frac{1}{1+e^{-x}}\right) \\
&= \sigma(x)(1-\sigma(x))
\end{aligned}
$$

2.2 (b) How many steps (2 points, written)

Answer:

With above equations,

$$\frac{\partial CE(\boldsymbol{\theta})}{\partial \boldsymbol{\theta}} = -\mathbf{y} + \hat{\mathbf{y}}$$

2.3 (c) Parser Step (6 points, coding)

See code: ~/q2_parser_transitions.py.

2.4 (d) Parser Transitions (6 points, coding)

See code: ~/q2_parser_transitions.py.

2.5 (e) Xavier Initialization (4 points, coding)

See code: ~/q2_initialization.py.

2.6 (f) Dropout (2 points, written)

Answer:

2.7 (g) Adam Optimizer (4 points, written)

2.7.1 i) Momentum

Answer:

2.7.2 ii) Adaptive Learning Rates

Answer:

2.8 (h) Parser Model (20 points, coding/written)

Answer: See code: ~/q2_parser_model.py. *Report the best UAS*
List of predicted labels

2.9 (i) Bonus (2 points, coding/written)

Answer:

Problem 3: Recurrent Neural Networks (25 points + 1 bonus point)

3.1 (a) Perplexity (4 points, written)

3.1.1 i) Derive Perplexity (2 points)

Answer:

3.1.2 ii) Equivalent (1 point)

Answer:

3.1.3 iii) Perplexity for a single word (1 point)

Answer:

3.2 (b) Gradients on Single Point (7 points, written)

Answer:

$$
\begin{aligned}
\frac{\partial J}{\partial \boldsymbol{v}_c} &= \frac{\partial}{\partial \boldsymbol{v}_c}((-log(\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))) - \sum_{k=1}^{K} log(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c))) \\
&= -\frac{\partial}{\partial \boldsymbol{v}_c}(log(\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))) - \sum_{k=1}^{K} \frac{\partial}{\partial \boldsymbol{v}_c} log(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c)) \\
&= \frac{-1}{\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c)}(\frac{\partial}{\partial \boldsymbol{v}_c}\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c)) - \sum_{k=1}^{K} \frac{1}{\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c)} \frac{\partial}{\partial \boldsymbol{v}_c}\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c) \\
&= -(1 - \sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))\boldsymbol{u}_o - \sum_{k=1}^{K} (1 - \sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c))(-\boldsymbol{u}_k) \\
&= (\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c) - 1)\boldsymbol{u}_o - \sum_{k=1}^{K} (\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c) - 1)\boldsymbol{u}_k
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial J}{\partial \boldsymbol{u}_o} &= \frac{\partial}{\partial \boldsymbol{u}_o}((-log(\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))) - \sum_{k=1}^{K} log(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c))) \\
&= \frac{-1}{\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c)}(\frac{\partial}{\partial \boldsymbol{u}_o}\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c)) - 0 \\
&= -(1 - \sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))\frac{\partial}{\partial \boldsymbol{u}_o}(\boldsymbol{u}_o^T \boldsymbol{v}_c) \\
&= (\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c) - 1)\boldsymbol{u}_o \\
\frac{\partial J}{\partial \boldsymbol{u}_k} &= \frac{\partial}{\partial \boldsymbol{u}_k}((-log(\sigma(\boldsymbol{u}_o^T \boldsymbol{v}_c))) - \sum_{k=1}^{K} log(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c))) \\
&= 0 - \frac{\partial}{\partial \boldsymbol{u}_k} log(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c)) \\
&= -\frac{1}{\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c)}\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c)(1 - \sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c))\frac{\partial}{\partial \boldsymbol{u}_k}(-\boldsymbol{u}_k^T \boldsymbol{v}_c) \\
&= -(\sigma(-\boldsymbol{u}_k^T \boldsymbol{v}_c) - 1)\boldsymbol{v}_c) \\
&= (\sigma(\boldsymbol{u}_k^T \boldsymbol{v}_c)\boldsymbol{v}_c, \text{ for all } k \neq o
\end{aligned}
$$

Negative sampling is faster than softmax-CE loss at speed up ratio $\frac{V}{K}$, where V is all words in dictionary count, and K is the sampling size.

3.3 (c) Gradients (7 points, written)

Answer:

3.4 (d) How Many Operations for Single Timestep (3 points, written)

Answer:

Derivatives for the skip-gram model

$$\frac{J_{skip-gram}(word_{c-m\ldots c+m})}{\partial \boldsymbol{v}_c} = \sum_{-m \leqslant j \leqslant m, j \neq 0} \frac{\partial F(\boldsymbol{w}_{c+j}, \boldsymbol{v}_c)}{\partial \boldsymbol{v}_c}$$

$$\frac{J_{skip-gram}(word_{c-m\ldots c+m})}{\partial \boldsymbol{v}_j} = 0, \forall j \neq c$$

$$\frac{J_{skip-gram}(word_{c-m\ldots c+m})}{\partial \boldsymbol{U}} = \sum_{-m \leqslant j \leqslant m, j \neq 0} \frac{\partial F(\boldsymbol{w}_{c+j}, \boldsymbol{v}_c)}{\partial \boldsymbol{U}}$$

Derivatives for the CBOW model

$$\frac{J_{CBOW}(word_{c-m\ldots c+m})}{\partial \boldsymbol{v}_j} = \frac{\partial F(\boldsymbol{w}_c, \hat{\boldsymbol{v}})}{\partial \hat{\boldsymbol{v}}}, \forall (j \neq c) \in \{c-m \ldots c+m\}$$

$$\frac{J_{CBOW}(word_{c-m\ldots c+m})}{\partial \boldsymbol{v}_j} = 0, \forall (j \neq c) \notin \{c-m \ldots c+m\}$$

$$\frac{J_{CBOW}(word_{c-m\ldots c+m})}{\partial \boldsymbol{U}} = \frac{\partial F(\boldsymbol{w}_c, \hat{\boldsymbol{v}})}{\partial \boldsymbol{U}}$$

3.5 (e) How Many Operations for Entire Sequence (3 points, written)

Answer: See code: ~/q3_word2vec.py.

3.6 (f) Which largest? Term RNN? (1 point, written)

Answer: See code: ~/q3_sgd.py.

3.7 (g) Bonus (1 point, written)

Answer:

Explain: In the Word Vectors image, words clustered at similarity, such as the emotion words "amazing", "wonderful" and "great" are very close to each other. The word "well" a little further but still close to "amazing" , the connection characters and words "the" "a" "," etc are spread around alone.