Style Change Detection using BERT

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Task

This research was submitted as a solution to the Style Change Detection Challenge held by PAN@CLEF.

There were two sub-tasks for the challenge:

1. Given a document, is the document written by multiple authors?

2. Given a sequence of paragraphs of a (supposedly) multi-author document, is there a style change between any of the paragraphs?
DataSet

- All the data was extracted from the StackExchange family of websites
**DataSet**

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- There were two datasets provided for the task:
  - **Dataset-narrow**: Questions and answers from a specific subset of StackExchange sites pertaining to topics of Computer Technology.

<table>
<thead>
<tr>
<th></th>
<th>Narrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train</td>
<td>3,442</td>
</tr>
<tr>
<td>Validation</td>
<td>1,722</td>
</tr>
</tbody>
</table>

*Table 1: Number of documents in each dataset*
DataSet

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- There were two datasets provided for the task:
  - **Dataset-narrow**: Questions and answers from a specific subset of StackExchange sites pertaining to topics of Computer Technology.
  - **Dataset-wide**: Questions and answers from a subset of StackExchange sites that pertained to a wide variety of topics (Technology, Economics, Literature, Philosophy, and Mathematics).

<table>
<thead>
<tr>
<th></th>
<th>Narrow</th>
<th>Wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train</td>
<td>3,442</td>
<td>8,138</td>
</tr>
<tr>
<td>Validation</td>
<td>1,722</td>
<td>4,078</td>
</tr>
</tbody>
</table>

Table 1: Number of documents in each dataset
Figure 1: Distribution of number of style changes in different datasets
Bidirectional Encoder Representations from Transformers (BERT)

BERT is a large-scale pre-trained deep model used for solving a variety of NLP tasks, obtaining state-of-the-art results on various benchmarks.

Of all the BERT models available, the BERT Base Cased model was used (layers= 12, hidden size= 768, self-attention heads= 12, total parameters= 110M).
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<table>
<thead>
<tr>
<th>System</th>
<th>MNLI-(m/mm)</th>
<th>QQP</th>
<th>QNLI</th>
<th>SST-2</th>
<th>CoLA</th>
<th>STS-B</th>
<th>MRPC</th>
<th>RTE</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>392k</td>
<td>363k</td>
<td>108k</td>
<td>67k</td>
<td>8.5k</td>
<td>5.7k</td>
<td>3.5k</td>
<td>2.5k</td>
<td>-</td>
</tr>
<tr>
<td>Pre-OpenAI SOTA</td>
<td>80.6/80.1</td>
<td>66.1</td>
<td>82.3</td>
<td>93.2</td>
<td>35.0</td>
<td>81.0</td>
<td>86.0</td>
<td>61.7</td>
<td>74.0</td>
</tr>
<tr>
<td>BiLSTM+ELMo+Attn</td>
<td>76.4/76.1</td>
<td>64.8</td>
<td>79.8</td>
<td>90.4</td>
<td>36.0</td>
<td>73.3</td>
<td>84.9</td>
<td>56.8</td>
<td>71.0</td>
</tr>
<tr>
<td>OpenAI GPT</td>
<td>82.1/81.4</td>
<td>70.3</td>
<td>87.4</td>
<td>91.3</td>
<td>45.4</td>
<td>80.0</td>
<td>82.3</td>
<td>56.0</td>
<td>75.1</td>
</tr>
<tr>
<td>BERT\textsubscript{BASE}</td>
<td>84.6/83.4</td>
<td>71.2</td>
<td>90.5</td>
<td>93.5</td>
<td>52.1</td>
<td>85.8</td>
<td>88.9</td>
<td>66.4</td>
<td>79.6</td>
</tr>
<tr>
<td>BERT\textsubscript{LARGE}</td>
<td>\textbf{86.7}/\textbf{85.9}</td>
<td>\textbf{72.1}</td>
<td>\textbf{92.7}</td>
<td>\textbf{94.9}</td>
<td>\textbf{60.5}</td>
<td>\textbf{86.5}</td>
<td>\textbf{89.3}</td>
<td>\textbf{70.1}</td>
<td>\textbf{82.1}</td>
</tr>
</tbody>
</table>

Jacob Devlin, Ming-Wei Chang, Kenton Lee, Kristina Toutanova, BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding
Approach

Figure 3: Our approach for generating feature vectors for the two tasks using pretrained BERT
Approach

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Maecenas hendrerit urna id purus rhoncus tincidunt.

Pellentesque dapibus, diam quis efficitur posuere, massa ipsum interdum dui, et consequat mauris ipsum at mauris. Maecenas eu mi ante.

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Approach

Sentence Split

BERT Embeddings
Approach

["Lorem ipsum dolor sit amet, consectetur adipiscing elit."
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"Maecenas eu mi ante."
"Donec consequat nisi at est placerat imperdiet."
"Cras sed arcu nibh."]

Sentence Split

```
[ [ 41.79, -31.81, 26.47, -18.73 ],
  [ 21.91, -43.06, 10.08, -38.33 ] ],
```

```
[ [ 23.86, -38.28, 105.14, -57.55 ],
  [ 5.06, -5.00, 3.69, -17.09 ] ],
```

```
[ [ 5.99, -35.22, 24.02, -5.91 ],
  [ 22.14, -13.30, 10.81, -8.75 ] ]
```

```
[ 20.26, -27.77, 30.04, -24.39 ]
```

Document-level Embeddings

```
[ 23.35, -29.53, 36.35, -32.93 ]
[ 14.46, -22.95, 35.91, -22.32 ]
```

Paragraph-level Embeddings

BERT Embeddings
Classifier

We tried various binary classifiers for Task 1 on Dataset-wide. The results obtained on the validation set are:

<table>
<thead>
<tr>
<th>Classifier</th>
<th>F-1 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVM</td>
<td>0.6504</td>
</tr>
<tr>
<td>Decision Tree</td>
<td>0.6108</td>
</tr>
<tr>
<td>Logistic Regression</td>
<td>0.6533</td>
</tr>
<tr>
<td>Gaussian Naive Baye’s</td>
<td>0.566</td>
</tr>
<tr>
<td>Random Forest</td>
<td><strong>0.7367</strong></td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th></th>
<th>Narrow</th>
<th>Wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document-level</td>
<td>0.7661</td>
<td>0.7575</td>
</tr>
<tr>
<td>Paragraph-level</td>
<td>0.8805</td>
<td>0.8306</td>
</tr>
</tbody>
</table>

Table 2: F1 scores calculated on the validation set for Document-level (task 1) and Paragraph-level (task 2) predictions.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Document-level</td>
<td>0.6401</td>
</tr>
<tr>
<td>Paragraph-level</td>
<td>0.8566</td>
</tr>
</tbody>
</table>

Table 3: Average F1 scores calculated on the test set for Document-level (task 1) and Paragraph-level (task 2) predictions.
Other Methods

Creating a Dataset of sentence pairs: Each data point was a pair of sentences from consecutive paragraphs.
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The label of the data point would be assigned based on the following policy:

- If the two sentences are from the same paragraph → 0
- If the two sentences are from different paragraphs
  - If no style change occurred between the two paragraphs → 0
  - If a style change occurred between the two paragraphs → 1
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The dataset was severely imbalanced at this stage, so it was balanced by removing data points from the majority class at random.
Other Methods

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**Fine-tuning BERT:**
- Fine-tune BERT using the sentence-pair dataset, and then perform the classification
- Accuracy plateaued after a point
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**Convolutional Neural Network:**
- The data points were converted to tensors of size \((l_1 + l_2) \times 768\)
- Then run through kernels of sizes \((2 \times 768), (3 \times 768), \ldots, (5 \times 768)\)
- Experiments are ongoing with this technique
Pitfalls

Some of the disadvantages of our method are:

- **Runtime**
  - All experiments were run in an environment that had access to a GPU
  - Running on the validation set for Dataset-wide took about 2-3 hours
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● **Runtime**
  ○ All experiments were run in an environment that had access to a GPU
  ○ Running on the validation set for Dataset-wide took about 2-3 hours

● **Only focuses on semantic features**
  ○ We believe that the best approach for style change detection would be to combine both semantic and stylistic features, but our method only focuses on semantic features for now.
Future Work

- Fine-tuning BERT
  - Since we only tried fine-tuning it with our custom dataset, it would be interesting to see the results by fine-tuning it with the original dataset
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● **Fine-tuning BERT**
  ○ Since we only tried fine-tuning it with our custom dataset, it would be interesting to see the results by fine-tuning it with the original dataset.

● **Combining Semantic and Syntactic features**
  ○ A more sophisticated approach which takes into consideration both Semantic and Stylistic features would be the next step to improve the current model.
THANK YOU