

# Deep Models for Arabic Dialect Identification on Benchmarked Data

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## Abstract

The Arabic Online Commentary (AOC) (Zaidan and Callison-Burch, 2011) is a large-scale repository of Arabic dialects with manual labels for 4 varieties of the language. Existing dialect identification models exploiting the dataset pre-date the recent boost deep learning brought to NLP and hence the data are not benchmarked for use with deep learning, nor is it clear how much neural networks can help tease the categories in the data apart. We treat these two limitations: We (1) benchmark the data, and (2) empirically test 6 different deep learning methods on the task, comparing performance to several classical machine learning models under different conditions (i.e., both binary and multi-way classification). Our experimental results show that variants of (attention-based) bidirectional recurrent neural networks achieve best accuracy (acc) on the task, significantly outperforming all competitive baselines. On blind test data, our models reach 87.65% acc on the binary task (MSA vs. dialects), 87.4% acc on the 3-way dialect task (Egyptian vs. Gulf vs. Levantine), and 82.45% acc on the 4-way variants task (MSA vs. Egyptian vs. Gulf vs. Levantine). We release our benchmark for future work on the dataset.

## 1 Introduction

Dialect identification is a special type of language identification where the goal is to distinguish closely related languages. Explosion of communication technologies and the accompanying pervasive use of social media strongly motivates need for technologies like language, and dialect, identification. These technologies are useful for applications ranging from monitoring health and well-being (Yepes et al., 2015; Nguyen et al., 2016; Nguyen et al., 2017; Abdul-Mageed et al., 2017), to real-time disaster operation management (Sakaki et al., 2010; Palen and Hughes, 2018), and analysis of human mobility (Hawelka et al., 2014; Jurdak et al., 2015; Louail et al., 2014). Language identification is also an enabling technology that can help automatically filter foreign text in some tasks (Lui and Baldwin, 2012), acquire multilingual data (e.g., from the web) (Abney and Bird, 2010), including to enhance tasks like machine translation (Ling et al., 2013).

**Arabic.** In this paper our focus is on *Arabic*, a term that refers to a wide collection of varieties. These varieties are the result of the interweave between the native languages of the Middle East and North Africa and Arabic itself. Modern Standard Arabic (MSA), the modern variety of the language used in pan-Arab news outlets like AlJazeera and in educational circles in the Arab world, differs phonetically, phonologically, lexically, and syntactically from the varieties spoken in everyday communication by native speakers of the language (Diab et al., 2010; Habash, 2010; Abdul-Mageed, 2015; Abdul-Mageed, 2017). These ‘everyday’ varieties constitute the *dialects* of Arabic. Examples of these are Egyptian (EGY), Gulf (GLF), Levantine (LEV), and Moroccan (MOR). In addition to MSA and dialects, Classical Arabic also exists and is the variety of historical literary texts and religious discourse.

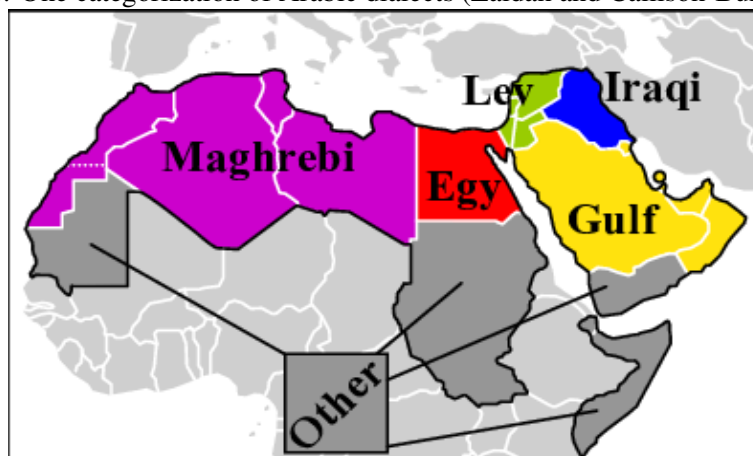
**Arabic Dialects.** Language varieties, including those of Arabic, can be categorized based on shared linguistic features. For Arabic, one classical categorization is based on geographical locations. For example, in addition to MSA, Habash et al. (2012), provides 5 main categories, as shown in Figure 1. This same classification is also common in the literature, and includes:

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- **Egyptian:** The variety spoken in Egypt, which is widely spread due to the historical impact of Egyptian media
- **Gulf:** A variety spoken primarily in Saudi Arabia, UAE, Kuwait and Qatar
- **Iraqi:** The variety spoken by the people of Iraq
- **Levantine:** The variety spoken primarily by the Levant (i.e., people of Syria, Lebanon, and Palestine)
- **Maghrebi:** The variety spoken by people of North Africa, excluding Egypt

Figure 1: One categorization of Arabic dialects (Zaidan and Callison-Burch, 2011)



**Arabic dialectal data.** For a long time, Arabic dialects remained mostly spoken. Dialects started to find their way in written form with the spread of social media, thus affording an opportunity for researchers to use these data for NLP. This motivated Zaidan and Callison-Burch (2014) to create a large-scale repository of Arabic texts, the Arabic Online Commentary (AOC). The resource is composed of  $\sim 3\text{M}$  MSA and dialectal comments on a number of Arabic news sites. A portion of the data ( $> 108\text{K}$  comments) is manually annotated via crowdsourcing. The dataset was exploited for dialect identification in Zaidan and Callison-Burch (2014) and later in Cotterell and Callison-Burch (2014). These works, however, pre-date the current boom in NLP where deep neural networks enable better learning (given sufficiently large training data). Cotterell and Callison-Burch (2014) use  $n$ -fold cross validation in their work, thus making it costly to adopt the same data split procedure to develop deep learning models. This is the case since deep models can take long times to train and optimize. For this reason, it is desirable to benchmark the AOC dataset for deep learning research. This motivates our work. We also ask the empirical question: To what extent can we tease apart the Arabic varieties in AOC using neural networks. Especially given (a) the morphological richness of Arabic and (b) the inter-relatedness (e.g., lexical overlap) between Arabic varieties, it is not clear how accurately these varieties can be automatically categorized (using deep learning methods). To answer these important questions, we investigate the utility of several traditional machine learning classifiers and 6 different deep learning models on the task. Our deep models are based on both recurrent neural networks and convolutional neural networks, as well as combinations (and variations) of these.

Overall, we offer the following contributions: (1) We benchmark the AOC dataset, especially for deep learning work, (2) we perform extensive experiments based on deep neural networks for identifying the 4 Arabic varieties in AOC under various classification conditions, allowing us to perform well on the task, and (3) we carry out an analysis to uncover how the varieties in the data relate to one another based on shared lexica. The rest of the paper is organized as follows: In Section 2 we review related work, in Section 3 we briefly describe the AOC dataset. In Section 4 we describe our models, Section 5 is

Variety	Example
MSA	<p>شذوا المهمة يا منتخبنا ، انتم لا تسرون وحدكم (1)  Go, go, our team; you've our passionate support.  بصراحة لقد عجزت عن الكلام فلا الجبل يبرر هذه الفعلة ولا حتى اي سبب اخر (2)  Frankly, I'm speechless. Neither ignorance nor any other reason justify this action.</p>
EGY	<p>بتقولوا ان اعلامنا وفضائيتنا نجروا الازمة وكانوا مجرمين في نظركم (3)  You say our media and satellite channels initiated the crisis and were criminals in your review.  قمر صناعي ولا قمر ١٤ ، في الشمس لو عرف القمر يلف في الجو (3)  Either its a satellite or a full moon [playful for "beautiful female"], it will never rotate in its orbit correctly.</p>
GLF	<p>يعطي العافية على من اقترح هذا القرار ومن ساهم في تطبيقه (5)  Healthy be the one who proposed this decision, and those who contributed in applying it.  عندنا بعض الناس ما يرضيهم شيء ولا يكفيهم ولا يبغون يشتغلون شيء (6)  Nothing would please nor be enough for some of these people; they don't even want to put any efforts.</p>
LEV	<p>وانا كمان لا يصلح سيارتي ولا على بابي وابوي واخوي بيتكفلوا فيها (7)  And I also won't repair my car, nor do I care. My brother and dad will take care of it.  لان مو معقول توصل الامور لهلدرجة وكانت رح تصير مليون مشكلة بسبب اشاعاتهم لطلب الجامعة (8)  Because it isn't reasonable for things to get to that bad. There is a million problems college students have because of their rumors.</p>

Table 1: Example comments from the 4 varieties in the AOC dataset

where we describe our experimental set up, Section 6 provides our experimentation results. Section 7 is a visualization-based analysis of our results. Section 8 is where we conclude our work and overview future directions.

## 2 Related work

Work on Arabic dialect identification has focused on both spoken (Ali et al., 2015; Belinkov and Glass, 2016; Najafian et al., 2018; Shon et al., 2018; Shon et al., 2017; Najafian et al., 2018) and written form (Elfardy and Diab, 2013; Zaidan and Callison-Burch, 2014; Cotterell and Callison-Burch, 2014; Darwish et al., 2014; Abdul-Mageed et al., 2018). Early works have focused on distinguishing between MSA and EGY. For example, Elfardy and Diab (2013) propose a supervised method for sentence-level MSA-EGY categorization, exploiting a subset of the AOC dataset (12, 160 MSA sentences and 11, 274 of user commentaries on Egyptian news articles). The authors study the effect of pre-processing on classifier performance, which they find to be useful under certain conditions. Elfardy and Diab (2013) report 85.5% accuracy using 10-fold cross-validation with an SVM classifier, compared to the 80.9% accuracy reported by Zaidan and Callison-Burch (2011). Similarly, Tillmann et al. (2014) exploit the same portion of the AOC data Elfardy and Diab (2013) worked on, to build an MSA-EGY classifier. The authors report an improvement of 1.3% over results acquired by Zaidan and Callison-Burch (2014) using a linear classifier utilizing an expanded feature set. Their features include n-grams defined via part of speech tags and lexical features based on the AIDA toolkit (Elfardy et al., 2014). The work of Darwish et al. (2014) is also similar to these works in that it also focuses on the binary MSA-EGY classification task, but the authors exploit Twitter data. More specifically, Darwish et al. (2014) collected a dataset of 880K tweets on which they train their system, while testing on 700 tweets they labeled for the task. The authors explore a range of lexical and morphological features and report a 10% absolute gain over models trained with n-grams only. Our work is similar to these works in that we exploit the AOC dataset and develop MSA-EGY, binary classifiers. However, we model the task at more fine-grained levels as well (i.e., 3-way and 4-way classification).

Huang (2015) focus on the 4-way classification task using the AOC categories (MSA, EGY, GLF, LEV). The authors report improved classification accuracy using a simple word-level n-gram model trained on the manually annotated portion of AOC as well as unannotated Facebook data. The authors employ an ensemble of co-training and self-training semi-supervised learning methods exploiting 165M data points from Facebook posts. Huang (2015) report an accuracy of 87.8% on 10% of the manually annotated AOC dataset. Our work is similar to Huang (2015) in that we consider the 4-way classification task, but we do not exploit any external data. In addition, Huang (2015) did not release their data splits,

nor benchmark the task on AOC. Their results are not directly comparable to our work for these reasons.

Finally, our work has some similarity to general works on language detection (Jurgens et al., 2017; Jauhiainen et al., 2017; Kocmi and Bojar, 2017; Jauhiainen et al., 2018) and geographical location (Rahimi et al., 2018; Mahmud et al., 2014; Rahimi et al., 2017).

### 3 Dataset: Arabic Online Commentary (AOC)

As we mentioned earlier, our work is based on the AOC dataset. AOC is composed of 3M MSA and dialectal comments, of which 108,173 comments are labeled via crowdsourcing. For our experiments, we randomly shuffle the dataset and split it into 80% training (*Train*), 10% validation (*Dev*), and 10% test (*Test*). Table 2 shows the distribution of the data across the different splits. We were interested in identifying how the 4 varieties relate to one another in terms of their shared vocabulary, and so we performed an analysis on the training split (*Train*) as shown in the heat map in Figure 2. The Figure presents the percentages of shared vocabulary between the different varieties after normalizing for the number of data points in each class. As the Figure shows, both the GLF and LEV dialects are lexically closer to (i.e., share more vocabulary with) MSA than EGY is (does). This finding is aligned with the intuition of native speakers of Arabic that EGY diverges more from MSA than the GLF and LEV varieties. This empirical finding lends some credibility to this intuition.

Table 2: Distribution of classes in our AOC *Train* split

Variety	MSA	EGY	GLF	LEV	ALL
<b>Train</b>	50,845	10,022	16,593	9,081	86,541
<b>Dev</b>	6,357	1,253	2,075	1,136	10,821
<b>Test</b>	6,353	1,252	2,073	1,133	10,812

Figure 2: Heat map for shared vocabulary between different data variants



## 4 Models

### 4.1 Traditional models

Traditional models refer to models based on feature engineering methods with linear and probabilistic classifiers. In our experiments, we use (1) logistic regression, (2) multinomial Naive Bayes, and (3) support vector machines (SVM) classifiers.

### 4.2 Deep Learning Models

Recently, deep learning models have been successfully applied to the tasks of language modeling and text classification. For these reasons, we experiment with a number of popular models, as follows: (1) convolutional neural networks (CNN), (2) long-short term memory (LSTM), (3) convolutional LSTM (CLSTM), (4) bidirectional LSTM (BiLSTM), (5) bidirectional gated recurrent units (BiGRU), and (6)

BiLSTM with attention. While there are other variations of how some of these models learn (Vaswani et al., 2017), we believe these models with the variations we exploit form a strong basis for our benchmarking objective. In all our models, we use pre-trained word vectors based on word2vec to initialize the networks. We then fine-tune weights during learning.

**Word-based Convolutional Neural Network (CNN):** This model is conceptually similar to the one described in Kim (2014), and has the following architecture:

- *Input layer:* an input layer to map word sequence  $w$  into a sequence vector  $\mathbf{x}$  where  $x_w$  is a real-valued vector ( $x_w \in \mathbb{R}^{d_{emb}}$ , with  $d_{emb} = 300$  in all our models) initialized from external embedding model and tuned during training. The embedding layer is followed by a dropout rate of 0.5 for regularization (in this case to prevent co-adaptation between hidden units).
- *Convolution layer:* Two 1-D convolution operations are applied in parallel to the input layer to map input sequence  $\mathbf{x}$  into a hidden sequence  $\mathbf{h}$ . A filter  $k \in \mathbb{R}^{w_{d_{emb}}}$  is applied to a window of concatenated word embedding of size  $w$  to produce a new feature  $c_i$ . Where  $c_i \in \mathbb{R}$ ,  $c_i = k \odot x_{i:i+w-1} + b$ ,  $b$  is the bias  $b \in \mathbb{R}$ , and  $x_{i:i+w-1}$  is a concatenation of  $x_i, \dots, x_{i+w-1}$ . The filter sizes used are 3 and 8 and the number of filters used is 10. After each convolution operation a non-linear activation of type Rectifier Linear Unit (ReLU) (Nair and Hinton, 2010) is applied. Finally different convolution outputs (the two convolutional maps in our case) are concatenated into a sequence  $\mathbf{c} \in \mathbb{R}^{n-h+1}$  (where  $n$  is the number of filters and  $h$  is the dimensionality of the hidden sequence) and passed to a pooling layer.
- *Maxpooling:* Temporal max-pooling, which is the 1-D version of pooling, is applied over the concatenated output of the multiple convolutions  $\mathbf{c}$ , as mentioned above. The sequence  $\mathbf{c}$  is converted into a single hidden vector  $\mathbf{c}'$  by taking the maximum values of extracted feature map  $\mathbf{c}' = \max\{\mathbf{c}\}$ . The size of  $\mathbf{c}'$  is  $\sum_i n_i w_i$  where  $n_i$  is the number of filters and  $w_i$  the width of these filters.
- *Dense layer:* A 100 dimension fully-connected layer with a ReLU non-linear activation is added to map vector  $\mathbf{c}'$  into a final vector  $\mathbf{c}''$ . For regularization, we employ a dropout rate of 0.8 and an l2-norm.
- *Softmax layer:* Finally, the hidden units  $\mathbf{c}''$  is converted into probability distribution over  $l$  via softmax function, where  $l$  is the number of classes.

**Long-Short Term Memory (LSTM):** In our experiments, we use different variations of recurrent neural networks. The first one is LSTM (Hochreiter and Schmidhuber, 1997). We use a word-based LSTM, with the following architecture:

- *Input layer:* The input layer is exactly the same as the one described in the CNN model above.
- *LSTM layer:* We use a vanilla LSTM architecture consisting of 100 dimensions hidden units. The LSTM is designed to capture long-term dependencies via augmenting a standard RNN with a memory state  $C_t$ , with  $C_t \in \mathbb{R}$  at time step  $t$ . The LSTM takes in a previous state  $h_{t-1}$  and input  $x_t$ , to calculate the hidden state  $h_t$  as follows:

$$\begin{aligned}
 i_t &= \sigma(W_i \cdot [h_{t-1}, x_t] + b_i) \\
 f_t &= \sigma(W_f \cdot [h_{t-1}, x_t] + b_f) \\
 \tilde{C}_t &= \tanh(W_C \cdot [h_{t-1}, x_t] + b_C) \\
 C_t &= f_t \odot C_{t-1} + i_t \odot \tilde{C}_t \\
 o_t &= \sigma(W_o \cdot [h_{t-1}, x_t] + b_o) \\
 h_t &= o_t \odot \tanh(C_t)
 \end{aligned} \tag{1}$$

where  $\sigma$  is the sigmoid,  $\tanh$  is the hyperbolic tangent function, and  $\odot$  is the dot product between two vectors. The  $i_t$ ,  $f_t$ ,  $o_t$  are the *input*, *forget*, and *output* gates, and the  $\tilde{C}_t$  is a new memory cell

vector with candidates that could be added to the state. We use the same regularization as we apply on the dense layer in the CNN model mentioned above.

- *Softmax layer*: Similar to that of the CNN above as well.

**Convolution LSTM (CLSTM)**: This model is described in Zhou et al. (2015). The model architecture is similar to the CNN described earlier, but the fully-connected (dense) layer is replaced by an LSTM layer. The intuition behind the CLSTM is to use the CNN layer as a feature extractor, and directly feed the convolution output to the LSTM layer (which can capture long-term dependencies).

**Bidirectional LSTM (BiLSTM)**: One limitation of conventional RNNs is that they are able to make predictions based on previously seen content only. Another variant of RNNs that addresses this problem is Bidirectional RNNs (BRNNs), which process the data in both directions in two separate hidden layers. These two hidden layers are then fed forward to the same output layer. BRNNs compute three sequences; a forward hidden sequence  $\vec{h}$ , a backward hidden sequence  $\overleftarrow{h}$ , and the output sequence  $y$ . The model transition equations are as below:

$$\begin{aligned}\vec{h} &= \mathcal{H}(W_{x\vec{h}}x_t + W_{\vec{h}\vec{h}}\vec{h}_{t+1} + b_{\vec{h}}) \\ \overleftarrow{h} &= \mathcal{H}(W_{x\overleftarrow{h}}x_t + W_{\overleftarrow{h}\overleftarrow{h}}\overleftarrow{h}_{t+1} + b_{\overleftarrow{h}}) \\ y_t &= W_{\vec{h}y}\vec{h}_t + W_{\overleftarrow{h}y}\overleftarrow{h}_t + b_y\end{aligned}\quad (2)$$

Where  $\mathcal{H}$  can be any activation function. Combining BRNN and LSTM gives the BiLSTM model. In our experiments we use a 100 hidden units dimension to ensure a fair comparison with LSTM's results. We apply the same regularization techniques applied for the LSTM layer described above.

**Bidirectional Gated Recurrent Units (BiGRU)**: Gated Recurrent Unit (GRU) (Chung et al., 2014) is a variant of LSTMs that combines the *forget* and *input* gates into a single update gate  $z_t$  by primarily merging the *cell* state and *hidden* state. This results in a simpler model composed of an *update* state  $z_t$ , a *reset* state  $r_t$ , and a new simpler *hidden* state  $h_t$ . The model transition equations are as follows:

$$\begin{aligned}z_t &= \sigma(W_z.[h_{t-1}, x_t]) \\ r_t &= \sigma(W_r.[h_{t-1}, x_t]) \\ \tilde{h}_t &= \tanh(W.[r_t * h_{t-1}, x_t]) \\ h_t &= (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t\end{aligned}\quad (3)$$

The Bidirectional GRU (BiGRUs) can be obtained by combining two GRUs, each looking at a different direction similar to the case of BiLSTMs above. We employ the same regularization techniques applied to the LSTM and BiLSTM networks.

### Attention-based BiLSTM

Recently, using an attention mechanism with a neural networks has resulted in notable success in a wide range of NLP tasks, such as machine translation, speech recognition, and image captioning (Bahdanau et al., 2014; Xu et al., 2015; Chorowski et al., 2015). In this section, we describe an attention mechanism that we employ in one of our models (BiLSTM) that turned out to perform well without attention, hoping the mechanism will further improve model performance. We use a simple implementation inspired by Zhou et al. (2016) where attention is applied to the output vector of the LSTM layer. If  $H$  is a matrix consisting of output vectors  $[h_1, h_2, ..h_T]$  (where  $T$  is the sentence length), we can compute the attention vector  $\alpha$  of the sequence as follows:

$$\begin{aligned}\mathbf{e}_t &= \tanh(h_t) \\ \alpha_t &= \frac{\exp(e_t)}{\sum_{i=1}^T \exp(e_i)}\end{aligned}\quad (4)$$

Finally, the representation vector for input text  $\mathbf{v}$  is computed by a weighted summation over all the time steps, using obtained attention scores as weights.

$$\mathbf{v} = \sum_{i=1}^T \alpha_i h_i \quad (5)$$

The vector  $\mathbf{v}$  is an encoded representation of the whole input text. This representation is passed to the *softmax* layer for classification.

## 5 Experiments

We perform 3 different classification tasks: (A) *binary classification*, where we tease apart the MSA and the dialectal data, (B) *3-way dialects*, where we attempt to distinguish between EGY, GLF, and LEV; and (C) *4-way variants* (i.e., MSA vs. EGY vs. GLF vs. LEV). Since our goal in this work is to explore how several popular traditional settings and deep learning model architectures fare on the dialect identification task, we use classifiers with pre-defined hyper-parameters inspired by previous works as described in Section 4. As we mention in Section 3, we split the data into 80% *Train*, 10% *Dev*, and 10% *Test*. While we train on *Train* and report results on both the *Dev* and *Test* sets in the current work, our goal is to invest on hyper-parameter tuning based on the development set in the future. Benchmarking the data is thus helpful as it facilitates comparisons in future works.<sup>1</sup>

### 5.1 Pre-processing

We process our data the same way across all our traditional and deep learning experiments, as follows:

- **Tokenization and normalization:** We tokenize our data based on white space, excluding all non-unicode characters. We then normalize *Alif maksura* to *Ya*, reduce all *hamzated Alif* to plain *Alif*, and remove all non-Arabic characters/words (e.g., “very”, “50\$”).
- **Input sequence quantization:** In our experiments, we fix the vocabulary at the most frequent 50K words. The input tokens are then converted into indices ranging from 1 to 50K based on our look-up vocabulary.
- **Padding:** For the deep learning classifiers, all input sequences are truncated to arbitrary maximum sequence length of 30 words per comment. Comments of length  $< 30$  are zero-padded. This number can be tuned in future work.

### 5.2 Traditional Classifier Experiments

We have two settings for the traditional classifiers: (1) presence vs. absence (0 vs. 1) vectors based on combinations of unigrams, bigrams, and trigrams; and (2) term-frequency inverse-document-frequency (TF-IDF) vectors based on combinations of unigrams, bigrams, and trigrams (Sparck Jones, 1972). We use scikit-learn’s (Pedregosa et al., 2011) implementation of these classifiers.

### 5.3 Deep Learning Experiments

All our deep models are trained for 10 epochs using the RMSprop optimizer. The model’s weights  $W$  are initialized from a normal distribution  $W \sim N$  with a small standard deviation of  $\sigma = 0.05$ . Our models are trained using the Keras (Chollet and others, 2015) library with a Tensorflow (Abadi et al., 2016) backend. We train each of our 6 deep learning classifiers across 3 different settings pertaining the way we initialize the embeddings for the input layer in each network. The three embedding settings are:

1. **Random embeddings:** Where we initialize the input layer randomly.
2. **AOC-based embeddings:** We make use of the  $\sim 3M$  unlabeled comments in AOC by training a “continuous bag of words” (CBOW) (Mikolov et al., 2013) model exploiting them. We adopt the settings in Abdul-Mageed et al. (2018) for training our model to acquire 300 dimensional word vectors.

<sup>1</sup>The benchmarked data can be obtained by emailing the authors. See also project repository at: [https://github.com/UBC-NLP/aoc\\_id](https://github.com/UBC-NLP/aoc_id).

Method	Binary		Three-way		Four-way	
	<i>Dev</i>	<i>Test</i>	<i>Dev</i>	<i>Test</i>	<i>Dev</i>	<i>Test</i>
<b>Traditional Classifiers</b>						
Baseline (majority class in <i>Train</i> )	58.75	58.75	58.75	58.75	46.49	46.49
Logistic Regression (1+2+3 grams)	84.18	83.71	86.91	85.75	75.75	78.24
Naive Bayes (1+2+3 grams)	84.97	84.53	87.51	<b>87.81</b>	80.15	77.75
SVM (1+2+3 grams)	82.79	82.41	85.51	84.27	74.5	75.82
Logistic Regression (1+2+3 grams TF-IDF)	83.96	83.24	86.71	85.51	75.81	78.24
Naive Bayes (1+2+3 grams TF-IDF)	83.52	82.91	86.61	86.87	73.21	75.81
SVM (1+2+3 grams TF-IDF)	84.07	83.61	86.76	85.93	76.65	78.61
<b>Deep Learning - Random Embeddings</b>						
CNN (Kim, 2014)	85.69	85.16	81.63	81.11	66.34	68.86
CLSTM (Zhou et al., 2015)	84.73	84.17	78.91	78.32	64.58	65.25
LSTM	85.41	85.28	78.61	78.51	70.21	68.71
BiLSTM	84.11	83.77	85.82	84.99	75.94	77.55
BiGRU	82.81	82.77	84.88	84.45	74.56	76.51
Attention-BiLSTM	85.5	85.23	86.12	85.93	79.97	80.21
<b>Deep Learning - AOC Embeddings</b>						
CNN (Kim, 2014)	85.02	84.51	76.81	76.53	64.23	64.17
CLSTM (Zhou et al., 2015)	85.17	84.73	76.81	75.71	64.61	63.89
LSTM	85.04	84.07	83.89	82.67	70.01	68.91
BiLSTM	85.33	84.88	86.21	86.01	76.12	78.35
BiGRU	85.39	85.27	86.92	86.57	79.61	80.11
Attention-BiLSTM	85.77	85.71	87.01	86.93	80.25	81.12
<b>Deep Learning - Twitter-City Embeddings (Abdul-Mageed et al., 2018)</b>						
CNN (Kim, 2014)	86.68	86.26	85.51	85.36	74.13	75.61
CLSTM (Zhou et al., 2015)	86.61	86.28	82.77	82.56	79.41	77.51
LSTM	85.52	85.07	84.41	84.61	75.21	78.53
BiLSTM	87.16	86.99	87.31	87.11	82.81	81.93
BiGRU	<b>87.65</b>	<b>87.23</b>	87.11	86.18	83.25	82.21
Attention BiLSTM	87.61	87.21	<b>87.81</b>	87.41	<b>83.49</b>	<b>82.45</b>

Table 3: Experimental results, in accuracy, on our *Dev* and *Test* AOC splits

- Twitter-City embeddings:** This is based on the CBOW word2vec model released by Abdul-Mageed et al. (2018). The authors train their models on a  $\frac{1}{4}$  billion tweets dataset collected from 29 different cities from 10 Arab countries. The authors use a window of size 5 words, minimal word frequency set at 100 words, and 300 dimensional word vectors to train this model.

## 6 Results

Table 3 shows our results in accuracy across the three classification tasks (i.e., *binary*, *3-way*, and *4-way*), as described in Section 5. Our baseline in each task is the majority class in the respective *Train* set. As Table 6 shows, among traditional models, the Naive Bayes classifier achieves the best performance across all three tasks both on *Dev* and *Test* data. As a sole exception, SVMs outperforms Naive Bayes on the *Test* set for the 4-way classification task. As best accuracy, traditional classifiers yield 84.53 (*binary*), 87.81 (*3-way*), and 78.61 (*4-way*) on the *Test* splits.

As Table 3 shows, across the different classification tasks, models initialized with the Twitter-City embeddings (Abdul-Mageed et al., 2018) perform best on the task compared to those initialized randomly or



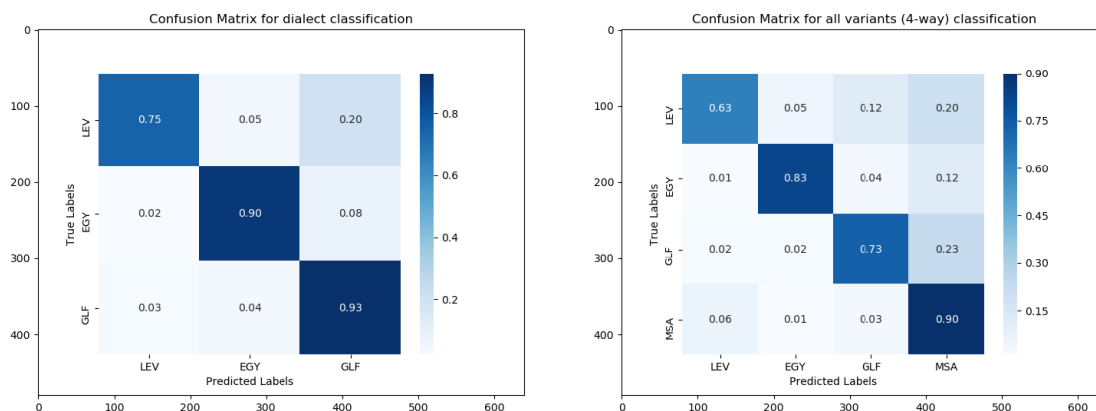
with the AOC embeddings. We also observe that AOC embeddings are better than random initialization. For **binary classification**, as Table 6 shows, BiGRU obtains the best accuracy on both *Dev* (87.65) and *Test* (87.23), with attention-BiLSTM performing quite closely. For the **3-way classification** task (dialect only classifier), while attention-BiLSTM obtains the best result on the *Dev* (87.81), it is slightly outperformed by the Naive Bayes classifier on *Test* (also 87.81). For **4-way classification**, attention-BiLSTM obtained best accuracy on both *Dev* (83.49) and *Test* (82.42).

Aligned with knowledge about deep models, we note the positive effect of larger training data on classification. For example, when we reduce the size of *Train* by excluding the MSA comments (58% of the manually annotated data), traditional classifiers outperform most of the deep learning classifiers on 3-way classification. Similarly, results drop when we thinly spread the data across the 4 categories for 4-way classification.

## 7 Analysis

Figure 3 is a visualization of classification errors acquired with attention-BiLSTM results (best accuracy in the multi-class tasks). The *left-side (3-way/dialects)* matrix shows how LEV is confused 20% of the time with GLF, directly reflecting the closer lexical distance between the two varieties compared to the distance of either of them to EGY. The *right-side (4-way)* matrix shows that 23% of the GLF errors are confused with MSA, followed by LEV errors (confused with MSA 20% of the time). This is a result of the higher lexical overlap between the two dialects and MSA, as we described in our observations around Figure 2. As Table 2 shows, MSA also dominates *Train* and hence these confusions with MSA are expected.

Figure 3: Analysis of Attention-BiLSTM results. **Left:** Confusion matrix for 3-way predictions. **Right:** Confusion matrix for 4-way classification.



## 8 Conclusion

We benchmarked the AOC dataset, a popular dataset of Arabic online comments, for deep learning work focused at dialect identification. We also developed 12 different classifiers (6 traditional and 6 based on deep learning) to offer strong baselines for the task. Results show attention-based BiLSTMs to work well on this task, especially when initialized using a large dialect specific word embeddings model. In the future, we plan to exploit sub-word and further tune hyper-parameters of our models.

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