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A Dataset for Multilingual Epidemiological Event Extraction

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Abstract

This paper proposes a corpus for the development and evaluation of tools and techniques for identifying emerging infectious disease threats in online news text. The corpus can not only be used for information extraction, but also for other natural language processing (NLP) tasks such as text classification. We make use of articles published on the Program for Monitoring Emerging Diseases (PROMED) platform, which provides current information about outbreaks of infectious diseases globally. Among the key pieces of information present in the articles is the uniform resource locator (URL) to the online news sources where the outbreaks were originally reported. We detail the procedure followed to build the dataset, which includes leveraging the source URLs to retrieve the news reports and subsequently pre-processing the retrieved documents. We also report on experimental results of event extraction on the dataset using the Data Analysis for Information Extraction in any Language(DANIEL) system. DANIEL is a multilingual news surveillance system that leverages unique attributes associated with news reporting to extract events: repetition and saliency. The system has wide geographical and language coverage, including low-resource languages. In addition, we compare different classification approaches in terms of their ability to differentiate between epidemic-related and unrelated news articles that constitute the corpus.

Keywords: Epidemiology, corpus creation, event extraction, classification, multilingual NLP

1. Introduction

Web corpora, describing text corpora created from the Web, have recently become popular due to the availability of a vast amount of electronic texts on the Web. The World Wide Web is a valuable source of data, which enables building corpora with wide-ranging attributes such as varying sizes, languages and domains. Such corpora can be analyzed and utilized in key application areas, among which epidemic intelligence.

Epidemic intelligence is an integral component of infectious disease early-warning mechanisms. It involves the collection, analysis, and dissemination of key information related to disease outbreaks, with the objective of detecting outbreaks and providing early warning to public health stakeholders (World Health Organization, 2014). Disease surveillance mechanisms can broadly be classified as either indicator- or event-based surveillance (Huff et al., 2016).

Indicator-based surveillance is the conventional type of surveillance systems which rely predominantly on local health practitioners to identify infectious disease outbreaks, where suspected outbreak cases are subjected to laboratory tests for confirmation. A key determinant of the efficiency of such surveillance methods is the underlying health care infrastructure. Poor infrastructure can result in inaccurate and irrelevant information being disseminated, with a likelihood of significant time delays in the dissemination of key information relevant to disease outbreaks (Zhou et al., 2011). Inadequate health infrastructure directly often leads to incomplete geographical coverage when reporting epidemics (Huff et al., 2016; World Health Organization, 2014). Time delays and incomplete coverage may hinder the deployment of effective health interventions, potentially leading to loss of lives.

Today, using NLP to monitor informal information sources, such as social media, search queries, online news outlets, and blogs has become an essential part of epidemic surveillance (Salathé et al., 2013; Bernardo et al., 2013). Advancements in NLP present an opportunity to efficiently collect, process and analyze large textual data from the Web, to detect disease-related features from the text. Near real-time data-driven surveillance systems, commonly referred to as event-based surveillance (EBS) systems can now be easily developed and deployed. EBS encompasses analyzing textual data mostly generated via the Web, for incidences of events related to disease outbreaks (Huff et al., 2016). A more plausible approach is to utilise a combination of formal and informal sources for the timely and accurate detection of infectious disease outbreak (O'Shea, 2017). As such, it has been determined that event-based surveillance methods can complement traditional surveillance methods, for timely and accurate detection of epidemics (Chunara et al., 2012; O'Shea, 2017).

However, despite the rise in the use of advanced text processing and analysis approaches, such as deep learning, a limited number of corpora exists for the training and evaluation of disease events extraction models. The few available datasets are relatively small in size and predominantly in English language. A key requirement for training deep learning models that give satisfactory results is having large-scale datasets. This is further compounded by the fact that epidemic reports originate from a wide range of sources and languages.

In view of the above, we attempt to address the dearth of data for epidemic event extraction, by creating a corpus that can be used by researchers and practitioners in building and evaluate epidemic event extraction algorithms and applications. We leverage the Program for Monitoring Emerging Diseases (PROMED) reporting platform to create the corpus. PROMED aggregates disease outbreak reports across the world and is open and publicly available. The PROMED articles undergo a review and verification process by experts before being published on the

platform. The aggregation of the reports by subject matter experts makes the articles suitable for use as ground truth to evaluate epidemiological information extraction systems. The multilingual dataset we extracted from PROMED comprises articles in English, French, Portuguese and Spanish languages. To the best of our knowledge, this is among the largest datasets of this nature that is available for developing and evaluating multilingual epidemic surveillance tools and techniques.

The paper is organized as follows. We review related work on event extraction in Section 2., while the methodology used to create the corpus is described in Section 3. The experiments to train the corpus in a text classification task are detailed in Section 4. Additionally, we evaluate event extraction over the corpus using the DANIEL system. The results are discussed in Section 5., before conclusions are drawn and future work presented in Section 6.

2. Related Work

Event extraction (EE) is an important information extraction (IE) task that focuses on identifying an event mention from text and extracting information relevant to the event. Typically, this entails predicting event triggers, the occurrence of events with specific types, and extracting arguments associated with an event.

While event extraction is a crucial sub-task of information extraction, it still remains quite a challenging task due to the difficulties associated with encoding words semantics in various context (Zhan and Jiang, 2019). For instance, the same event might appear in the form of various trigger expressions or expressions might represent different event types in different contexts.

Event extraction methods are classified into three types, namely pattern-based, data-driven and hybrid methods (Hogenboom et al., 2011). Pattern-based methods use rules and templates to extract events from text through representation and exploitation of expert knowledge. On the other hand, data-driven approaches use statistical techniques to discover the relations in text. Recently, methods based on deep learning have gained popularity among researchers in the field (Zhan and Jiang, 2019).

Specific to epidemiological event extraction, there exist a number of empirical works targeted to extract events related to disease outbreaks. Among them is Data Analysis for Information Extraction in any Language (DANIEL), a multilingual news surveillance system that leverages repetition and saliency, properties that are common in news writing (Lejeune et al., 2015). The multilingual nature of the system enables global and timely detection of epidemic events since it eliminates the requirement for translating local news to other languages for subsequent transmission. The system can easily be adapted and scaled to extract events across languages, therefore, being able to have a wider geographical coverage. Reactivity and geographic coverage are of paramount importance in epidemic surveillance (Lejeune et al., 2015).

Similar to DANIEL are BIOCASTER (Collier, 2011; Collier et al., 2008) and PULS (Du et al., 2011) which have produced good results in analysing disease-related news reports and providing a summary of the epidemics. The EcoHealth Alliance Global Rapid developed the Identification Tool System (GRITS), an application that provides automatic analyses of epidemiological texts. The system extracts important information about a disease outbreak, such as the most likely disease, dates, and countries where the outbreak originates. The pipeline for GRIT entails transforming words to vectors using TF-IDF, extracting features using pattern-matching tools, before applying the binary relevance-based classifier to predict the available disease in the text (Huff et al., 2016).

Internet search data has also been exploited for disease surveillance. In one study, internet searches for specific cancers were found to correlate with their estimated incidence and mortality (Cooper et al., 2005). Monitoring influenza outbreak using data drawn from the Web has also been previously explored. Two different studies, one utilizing GOOGLE (Ginsberg et al., 2009) and the other YAHOO (Polgreen et al., 2008) search queries, analyzed the searches and estimated the number of reported influenza cases. In recent years, a flurry of work has utilized social media data for infectious disease surveillance (Paul et al., 2016; Charles-Smith et al., 2015). Mostly, Twitter data, has been used for disease tracking (Lamb et al., 2013; Collier et al., 2011; Culotta, 2010), outbreak detection (Li and Cardie, 2013; Bodnar and Salathé, 2013; Diaz-Aviles et al., 2012; Aramaki et al., 2011) and predicting the likelihood of individuals falling sick (Sadilek et al., 2012). News media has also been used to give early warning of increased disease activity before official sources have reported (Brownstein et al., 2008). The studies have demonstrated the potential value of harnessing data-driven approaches for epidemic surveillance.

3. Methods

In this section, we describe the procedure followed to create the corpus. We also detail the process for evaluating event extraction and classification models over the corpus.

3.1. Corpus Creation

We retrieved PROMED articles in English, French, Spanish and Portuguese languages, for the period August 1, 2013, to August 31, 2019. PROMED reports global outbreaks of infectious diseases. The articles contain various key meta-data such as title, description, location, date and source URL where the article was originally published. The source URLs present in the PROMED articles were extracted and their corresponding source documents downloaded. Figure 1 shows the percentage of documents still available online for each year in the date range 01-08-2013 to 31-08-2019. The source URLs, together with the other meta-data were formatted and stored in JSON format making corpus[1] easily reusable and reproducible. Therefore, this makes it easy for any interested researcher to process the dataset and use it in modeling epidemiological event extraction or any other related NLP tasks.

Various processing tasks were performed on the extracted Web data to transform it into a clean text corpus. Firstly,

[1]Available online at `https://zenodo.org/record/3709617`.

language filtering was performed to ensure that only documents belonging to the languages of interest were retained. The documents were grouped into different clusters using the K-means clustering algorithm. This enabled filtering documents with little to no textual content. The silhouette coefficient was computed to quantify the appropriate number of clusters for each set of data. This coefficient measures how well data is assigned to its own cluster and how far it is from other clusters (Rousseeuw, 1987). A coefficient close to 1 (one) means the data sample is located in the appropriate cluster while -1 (negative one) implies data has been assigned to the wrong cluster. Elimination of boilerplate content from the corpus was among the data cleaning tasks. Content such as navigation links, headers and footers were removed from HTML pages using the JUSTEXT library (Pomikálek, 2011). Removal of boilerplate content is highly desirable, since such content rarely provides useful evidence about the phenomenon being investigated. On the contrary, the high frequency of the boilerplate content could introduce bias into the text data, hence negatively impacting the performance of derived applications (Vogels et al., 2018). The final pre-processing task was deduplication. Deduplication involves eliminating perfect duplicate and near-duplicate content so that only one instance of each text was preserved. The ONION (ONe Instance ONly tool (Pomikálek, 2011)), which deduplicates text data by measuring the similarity of paragraphs or entire document was used. It is based on a n-gram-based one-pass deduplication algorithm, where for each document all word n-grams are extracted (10-grams by default) and compared with the set of previously seen n-grams (Pomikálek, 2011).

Another dataset was specifically prepared for training a text classification model as described in Section 3.3.2. This dataset is composed of news articles from the News Category Dataset (Misra, 2018), consisting of around 200,000 English news articles. These news articles, which do not have mentions of disease outbreaks, were published on the HuffPost news website between the years 2012 and 2018. The dataset categorizes news articles based on their headlines and short descriptions. The news articles are grouped into various categories such as politics, wellness, travel, entertainment, sports and healthy living, among others. A total of 5,000 articles from the categories politics, entertainment, and sports were randomly selected and downloaded from the HuffPost news platform. They form the set of irrelevant documents, completed by a random selection of 5,000 documents from the PROMED dataset. Together with 444 evaluation documents from DANIEL, this forms the English part of the data set described in Table 3.

3.2. Corpus Statistics

The corpus statistics, PROMED and source documents, are presented on Table 1 and Table 2 respectively.

Table 3 presents statistics for the corpus used for training and evaluating text classification models. The dataset is composed of epidemic relevant articles from ProMED and non-relevant documents from News Category Dataset, described in Section 3.2. A total of 10,000 and 2,996 documents in English and French language, comprising relevant and non-relevant documents formed the training set.

Language	#Documents	#Sentences	#Words
English (en)	19,149	558,448	53,325,455
French (fr)	1,849	28,823	5,593,184
Spanish (es)	3,453	27,918	4,458,533
Portuguese (pt)	3,451	48,591	5,994,583

Table 1: Statistics for Retrieved PROMED Documents

Language	#Documents	#Sentences	#Words
English	13,275	320,613	8,749,272
French	1,395	13,777	439,153
Spanish	1,994	27,751	863,672
Portuguese	1,562	14,424	528,701

Table 2: Statistics for PROMED documents retrieved from their source

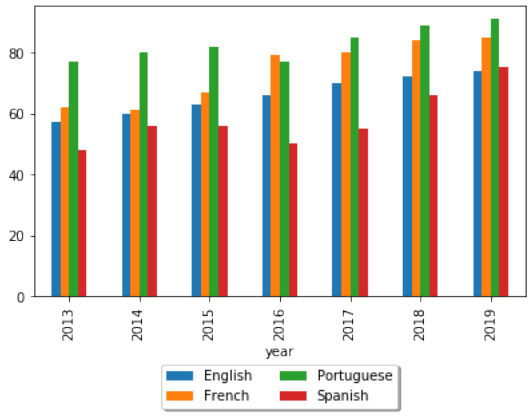

Figure 1: Percentage of ProMED sources accessible by year.

The relevant and non-relevant documents were equally distributed among the two classes.

Human-annotated datasets (Lejeune et al., 2015) in English and French provided the ground truth to evaluate the models. The availability of the annotated dataset for the two languages informed the decision for their consideration in our experiments. The two other languages, Spanish and Portuguese, which currently do not have ground truth data will be considered in our future studies. The annotated datasets comprising 444 and 2,722 documents for English and French languages respectively. The test data had a high degree of imbalance between the classes. The 444 English test documents had 31 relevant and 413 non-relevant documents. The French test corpus comprised 299 relevant and 2,207 non-relevant documents. The highly imbalanced nature of the data was important in helping depict the models' ability to classify the documents into their respective classes.

3.3. Evaluation

In this subsection, we describe the procedure for extracting epidemic events present in the corpus using DANIEL. We use supervised approaches to classify the retrieved documents as either being epidemic-related or not. Naive Bayes, Random Forest and Neural Network classification models

were trained on the extracted text and evaluated on a manually annotated dataset to ascertain the models ability to generalize on unseen data.

3.3.1. The DANIEL System

We evaluated the performance of the DANIEL system in extracting epidemic events present in the corpus. The DANIEL processing pipeline comprises three steps: news article segmentation, event detection, and event localization. DANIEL adopts a discourse-level event extraction approach, where the global structure of news is exploited (Lejeune et al., 2015). The system relies on properties that are common to the journalistic genre regardless of the language. The most useful features are repetition and saliency, which defines the relative importance of prominence of news contents. While the majority of systems extract events at the sentence level, by harnessing the morphological, syntactical and semantic features of a sentence, hence dependent on language-specific modules, DANIEL uses language-agnostic text-level features. It is character-based, hence handles text as a sequence of characters rather than as a sequence of words. Rather than exploiting keywords, the system exploits strings of text, but only if the strings have been repeated in pre-defined salient zones in text. The output of the DANIEL system is a disease-location pair describing an event as a disease outbreak and the place where it occurred. Recall and precision scores were obtained to determine the performance. The results are presented in Section 4.

For further evaluation, subsets of the English and French language datasets were subjected to annotation by three native speakers for each language. These annotators had to judge whether documents presented to them had mentions of an infectious disease outbreak or not. Subsequently, for the relevant documents, the annotators were requested to specify the disease name and location. We measured the inter-annotator agreement using Cohen's kappa coefficient. The inter-annotator agreement determines the extent to which annotators assign the same score to the same variable (McHugh, 2012). Finally, leveraging the generated ground truth, the evaluation was quantitatively measured against the annotators' judgments on the evaluation corpus.

3.3.2. Text Classification Model

We train and evaluate text classification models using datasets described in Table 3. The models classify a news article as either relevant or non-relevant, depending on whether it alerts about a disease outbreak or not. The training data comprised 10,000 and 2,722 news articles in English and French languages respectively, with documents equally distributed among the two classes. Pre-processing of the text input was undertaken which included filtering of stopwords and tokenizing the data.

A human-annotated dataset presented in Table 3 was used as the test set to evaluate the performance of the classification models. With the data ready, we trained multinomial naive Bayes, random forest and neural network classifiers over the created corpus. The naive Bayes classifier was used as the base model. Naive Bayes has been proven to be viable for text classification and information retrieval in general (Le et al., 2019). Parameter tuning was undertaken for the random forest, with the aim of enhancing its performance. Finally, the models were evaluated to determine their performance using the human-annotated test data. Due to the imbalanced nature of the data, we considered recall, precision, and F-measure metrics, which are more appropriate if there exists a greater degree of imbalance in the classes (Bunker and Thabtah, 2017)

Dataset	#Documents	#Sentences	#Words
Train-en	10,000	317,862	9,879,559
Train-fr	2,996	43,257	1,959,584
Test-en	444	4,728	230,353
Test-fr	2,722	75,479	2,058,941

Table 3: Statistics for train and test datasets used in training and evaluating the text classification models

4. Results

The DANIEL system attained an F-score of 75% for documents both in English and French. For the documents in the English, the system achieved a precision of 60% and was able to correctly identify all the relevant documents. Precision and recall scores of 74% and 83% were obtained on the French language documents.

The results for text classification models trained and evaluated using the datasets built in this study are presented in Table 4 and Table 5 for English and French datasets respectively. The models' F-score on the English test data was 74%, 63% and 53% for Random Forest, Neural Network and Naive Bayes model respectively. For the French documents, an F-score of 67%, 63%, and 50% was obtained for Random Forest, Naive Bayes and Neural Network model respectively.

Classifier	Precision	Recall	F-measure
Naive Bayes	57%	75%	53%
Random Forest	80%	70%	74%
Neural Network	68%	76%	61%

Table 4: Text Classification Report for the English Documents

Classifier	Precision	Recall	F-measure
Naive Bayes	62%	74%	63%
Random Forest	80%	63%	67%
Neural Network	64%	52%	50%

Table 5: Text Classification Report for the French Documents

5. Discussion

We developed and evaluated baseline models on detection and extraction of epidemic events from online news articles. Overall, the random forest model gave the highest prediction, in classifying news articles as either reporting an epidemic event or not. However, for French documents, the model could predict only one class using the default classification threshold of 0.5. This necessitated experimenting

with a lower threshold of 0.3, which produced superior results compared to the other models. This can be attributed to the fine-tuning of the model's parameters and its ability to learn discriminating and reliable features from the text corpus. However, the process of tuning the parameters required significant effort and time.

The neural network model did not give strong results compared to the random forest model. Possible approaches towards improving the performance of the model could include using more advanced model architectures and transfer learning. In natural language processing (NLP), transfer learning is achieved via pre-trained language models, for instance the bidirectional encoder representations from transformers (BERT). Such language models enable to learn contextualized representations which upon fine-tuning for tasks such as classification usually result in significant performance gains. Typically, language models are trained on large text corpora, hence being able to adequately capture linguistic features and representations, which result in improved performance in downstream tasks.

The performance of the DANIEL event extraction system was consistently good for both languages. This can be attributed to the fact that DANIEL's rule-based inference engine leverages language and disease text resources, which are readily available for all languages.

6. Conclusion

Early detection of disease outbreaks is critical for the deployment of effective public health interventions. Delayed interventions may result in severe consequences including loss of lives. In addition to reactivity, the coverage of epidemiological event detection systems is of paramount importance, particularly because outbreaks are reported from different parts of the world in different languages. Taking this into account, multi- and cross-lingual computational approaches are relevant solutions, referred to in this paper as event-based surveillance systems. A key requirement for the development of such systems is the availability of large multi-lingual datasets to train and evaluate high-performance machine learning models. Such large and multi-lingual datasets are not readily available especially for epidemiological surveillance settings. In this study, we attempt to contribute towards solving this challenge by developing and making available a large multi-lingual dataset suitable for training and evaluating epidemiological event extraction models. The dataset can also be used for other natural language processing tasks such as text classification or text summarization, among others.

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