

Token-level author diarization using clustering of stylistic contexts

Ivan Grubišić, Milan Pavlović, Author3

University of Zagreb, Faculty of Electrical Engineering and Computing

Unska 3, 10000 Zagreb, Croatia

{ivan.grubisic, milan.pavlovic, }@fer.hr

Abstract

This document provides the instructions on formatting the TAR system description paper in \LaTeX . This is where you write the abstract (i.e., summary) of the work you carried out within the project. The abstract is a paragraph of text ranging between 70 and 150 words. This document provides the instructions on formatting the TAR system description paper in \LaTeX . This is where you write the abstract (i.e., summary) of the work you carried out within the project. The abstract is a paragraph of text ranging between 70 and 150 words.

1. Introduction

In this paper we will focus on the author diarization task proposed on PAN 2016 competition¹. The aim of this task is to decompose a document into its authorial parts, i.e. to split a text into segments and assign an author to every segment (Koppel et al., 2011; Aldebei et al., 2015). This is one of the unsupervised variants of a well known authorship attribution problem since text samples of known authorship are not available (Rosso et al., 2016). As we will describe, in two out of three subtasks of this task only a correct number of authors for a given document is known.

The simplest variant of authorship attribution problem is about finding the most likely author for a given document, from a set of candidate authors whose authentic writing examples are available (Stamatatos, 2009b; Stein et al., 2011; Ding et al., 2016). Such described problem can be tackled with supervised machine learning techniques as a single-label multiclass text classification problem, where one class represents one author (Stamatatos, 2009b).

Authorship attribution problem is also known as authorship identification and it is a part of authorship analysis (Stamatatos, 2009b; Ding et al., 2016). Authorship analysis is a field of stylometry and studies information about the authorship of a document, based on features derived from that document (Layton et al., 2013). Moreover, stylometry analyzes literary style with statistical methods (Stein et al., 2011).

Rosso et al. (2016) divided PAN 2016 author diarization task into three subtasks. First subtask is traditionally called intrinsic plagiarism detection (IPD). The goal of this task is to find plagiarized parts of a document in which 70% of text is written by main author and the rest by one or more other authors. The term *intrinsic* means that a decision whether plagiarized parts exist or not has to be made only by analysing a given document, without any comparisons with external sources. In the rest of the paper we refer to this subtask as a task *a*.

Other two subtasks are more related to the general task of author diarization. In the second subtask we need to segment a given document and group identified segments by author. In the rest of the paper we refer to the second subtask as a task *b*. Third subtask differs from the second one

Table 1: Basic characteristics of train datasets

Task	Number of documents	Average length (in tokens)	(min, max) authors
Task <i>a</i>	71	1679	(2, 2)
Task <i>b</i>	55	3767	(2, 10)
Task <i>c</i>	54	3298	(2, 10)

in the fact that exact number of authors is unknown. In the rest of the paper we refer to the third subtask as a task *c*.

For all three subtasks a different training datasets are publicly available¹. Rosso et al. (2016) explain that they are collections of various documents which are part of Webis-TRC-12 dataset (Potthast et al., 2013). Every document in that dataset is constructed from texts of various search results (i.e. authors) for one of the 150 topics in total. By varying different parameters such as the number and proportion of the authors, places in a document where an author switch occurs (between words, sentences or paragraphs), three training and test datasets were generated (Rosso et al., 2016). Test datasets are currently not publicly available and we could not use them for evaluation of our approach. Some basic characteristics of training datasets are shown in Table 1.

2. Related work

The basic assumption in authorship analysis is that texts of different authors are mutually separable because each author has more or less unique writing style (Stamatatos, 2009b; Ding et al., 2016). More precisely, Koppel et al. (2009) explain that methods used in authorship analysis must be able to distinguish writing styles, but also tolerate shallow differences inside the same style because an author's stylistic habits can consciously or unconsciously vary over time. Therefore, most of related work tries to find the better features and methods which writing style will be quantified and measured with.

Zu Eissen and Stein (2006) manually created a labeled corpus of plagiarized documents and used it for intrinsic plagiarism detection task. They used average sentence

¹<https://tinyurl.com/y9m4zntm>

length, part of speech tags, average stopword number and the averaged word frequency class as input features for their linear discriminant analysis and support vector machine (SVM) models. They approached that task in a supervised fashion.

Stamatatos (2009a) created a feature vector of normalized occurrence of character tri-grams in the whole document. That vector represented a document's profile. Using a sliding window of fixed length he created same profiles for every window and compared them with the profile of the whole document. Result of comparison was an output from a style change function whose peaks were indicators of place in a document where style change occurs. All values above the predefined passage criterion were considered a result of plagiarism. That approach was unsupervised.

Rahman (2015) classified sections of documents from PAN 2011 dataset with the help of SVM. Those sections were again obtained by sliding a window of fixed length over the document. He also proposed new kind of information theoretical features - entropy, relative entropy, correlation coefficient and n-gram frequency class calculated from character tri-gram frequency profiles of each window and the whole document. He also used function word bi-gram and tri-gram frequency profiles with 1, 2, 3 and 4 skips. The value of style change function introduced by Stamatatos (2009a) was also incorporated in feature vectors.

Stein et al. (2011) defined IPD as the one class classification problem where the text of main author belongs to a one target class and the rest are outliers. To find them, they estimated probability distributions of various stylistic features for the target class and outliers. Then a naive Bayes' algorithm was applied to feature vectors whose values lie outside the predefined uncertainty intervals. An additional outlier post-processing methods were also tested. The most successful was the unmasking technique described by Koppel et al. (2009). The main sense of unmasking is to iteratively remove the best features that distinguish two classes and observe the speed with which cross-validation accuracy of again trained classifier drops. If the drop is slow and smooth, the outliers are indeed outliers because after n iterations of removing discriminative features they are still separable from the main author's work.

Koppel et al. (2011) used two staged approach in clustering of pre-segmented mixed biblical text written by two authors. First they used normalized cuts algorithm with cosine similarity to obtain initial clusters of segments which were represented only by normalized counts of synonyms from Hebrew synsets. Samples from initial clusters were separated in core and non-core samples via an iterative procedure, and core ones were labeled. SVM classifier was used to classify non-core samples, but now a bag-of-words feature vectors were used. The whole approach resulted with very good clusters. They also tried this method on an unsegmented case. Text was first splitted in a way that minimizes doubly-represented synonyms in segments and the same procedure was repeated. The clustering performance was lower than in pre-segmented case.

Brooke et al. (2013) concluded that a very good initial segmentation of text, at least in poems written by T. S. El-

liot, is needed for a good performance of their modified k-means algorithm in clustering of voices. Except often character, lexical and syntactic features, they used features such as average frequency in a large external corpus (Brants and Franz, 2006). One of the most promising feature they considered is the centroid of 20 dimensional distributional vectors obtained by applying latent semantic analysis on a large web corpus (Landauer and Dumais, 1997).

The works by Kuznetsov et al. (2016) and Sittar et al. (2016) were submitted on the PAN 2016 competition for three aforementioned tasks. For the task *a*, Kuznetsov et al. (2016) trained a Gradient Boosting Regression Trees (GBRT) model on PAN 2011 dataset as a style change function used for threshold based outlier detection. Every sentence was vectorized using word frequencies, n-gram frequencies, punctuation symbols and the universal POS tags count, sentence length and mean length of sentence words. The final input to the model was concatenation of center sentence vector and ones from context of size ± 2 . In task *b* they used a Hidden Markov Model with Gaussian Emissions for document segmentation over the same sentence scores from task *a*. To estimate the unknown number of authors n in task *c*, they chose n from 2 to 20 which maximizes their cluster discrepancy measure $Q(n)$.

Sittar et al. (2016) used k-means algorithm to cluster *ClustDist* scores of each sentence, where the number of groups was equal to the known number of authors in tasks *a* and *b*. In task *c*, a number of groups was generated randomly. Although they defined a *ClustDist* score for a single sentence as an average distance between current and every other sentence vector, which is again a similar concept like a style change function, in provided example they used only a sum of unknown distance measures. Fifteen features in total were used for sentence vectorization, including average word and sentence lengths, count and ratios of characters, digits uppercase letters, spaces and tabs.

The most of described approaches combine supervised and unsupervised methods and operate on the level of longer text segments or sentences. We were inspired by Brooke et al. (2013) who said that a more radical approach would not separate those tasks in segmentation and clustering steps, but rather build an authorial segments that would also form good clusters. Since the style change in our tasks can occur even between two tokens in a same sentence, we wanted our model should be able to work on the token level. Instead of clustering tokens directly, we decided to cluster their vectorized stylistic contexts because they obviously contain more valuable stylistic information than tokens alone.

3. The proposed approaches

clustering, sliding window pipeline: preprocessing (tokenization) -> basic features -> transformed features (including scaling) -> clustering

clustering metric

- a

- b

features

differences: fixed features + transformation vs document-dependent features

Table 2: This is the caption of the table. Table captions should be placed *above* the table.

Model	R	P	F_1
Dummy	0	1	2
One	0	1	2
One	0	1	2
One	0	1	2

4. Experimental results

1 baselines

Mention cofidences.

4.1. Intrinsic plagiarism detection

setup results

4.2. Author diarization with known numbers of authors

setup

4.3. Author diarization with unknown numbers of authors

setup

5. Conclusion

Conclusion is the last enumerated section of the paper. It should not exceed half of a column and is typically split into 2–3 paragraphs. No new information should be presented in the conclusion; this section only summarizes and concludes the paper.

Acknowledgements

If suitable, you can include the *Acknowledgements* section before inserting the literature references in order to thank those who helped you in any way to deliver the paper, but are not co-authors of the paper.

References

Khaled Aldebei, Xiangjian He, and Jie Yang. 2015. Unsupervised Decomposition of a Multi-Author Document Based on Naive-Bayesian Model. *Proceedings of the 53rd Annual Meeting of the Association for Computational Linguistics and the 7th International Joint Conference on Natural Language Processing (Short Papers)*, pages 501–505.

Thorsten Brants and Alex Franz. 2006. Web 1t 5-gram corpus version 1.1. *Google Inc.*

Julian Brooke, Graeme Hirst, and Adam Hammond. 2013. Clustering voices in the Waste Land. In *Proceedings of the 2nd Workshop on Computational Literature for Literature (CLFL’13)*, Atlanta.

Steven HH Ding, Benjamin Fung, Farkhund Iqbal, and William K Cheung. 2016. Learning stylometric representations for authorship analysis. *arXiv preprint arXiv:1606.01219*.

Moshe Koppel, Jonathan Schler, and Shlomo Argamon. 2009. Computational methods in authorship attribution. *Journal of the American Society for information Science and Technology*, 60(1):9–26.

Moshe Koppel, Navot Akiva, Idan Dershowitz, and Nachum Dershowitz. 2011. Unsupervised decomposition of a document into authorial components. In *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies-Volume 1*, pages 1356–1364. Association for Computational Linguistics.

Mikhail Kuznetsov, Anastasia Motrenko, Rita Kuznetsova, and Vadim Strijov. 2016. Methods for intrinsic plagiarism detection and author diarization. *Working Notes Papers of the CLEF*.

Thomas K Landauer and Susan T Dumais. 1997. A solution to plato’s problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological review*, 104(2):211.

Robert Layton, Paul Watters, and Richard Dazeley. 2013. Automated unsupervised authorship analysis using evidence accumulation clustering. *Natural Language Engineering*, 19(01):95–120.

Martin Potthast, Matthias Hagen, Michael Völske, and Benno Stein. 2013. Crowdsourcing interaction logs to understand text reuse from the web. In *ACL (1)*, pages 1212–1221.

Rashedur Rahman. 2015. Information Theoretical and Statistical Features for Intrinsic Plagiarism Detection. In *16th Annual Meeting of the Special Interest Group on Discourse and Dialogue*, page 144.

Paolo Rosso, Francisco Rangel, Martin Potthast, Efstathios Stamatatos, Michael Tschuggnall, and Benno Stein. 2016. Overview of pan’16. In *International Conference of the Cross-Language Evaluation Forum for European Languages*, pages 332–350. Springer.

Abdul Sittar, Hafiz Rizwan Iqbal, and A. Nawab. 2016. Author Diarization Using Cluster-Distance Approach. *Working Notes Papers of the CLEF*.

Efstathios Stamatatos. 2009a. Intrinsic plagiarism detection using character n-gram profiles. *threshold*, 2(1,500).

Efstathios Stamatatos. 2009b. A survey of modern authorship attribution methods. *Journal of the American Society for information Science and Technology*, 60(3):538–556.

Benno Stein, Nedim Lipka, and Peter Prettenhofer. 2011. Intrinsic plagiarism analysis. *Language Resources and Evaluation*, 45(1):63–82.

Sven Meyer Zu Eissen and Benno Stein. 2006. Intrinsic plagiarism detection. In *European Conference on Information Retrieval*, pages 565–569. Springer.