PAN 2016 shared task

Author identification

Can a clustering sandwich help a neural network

in establishing authorship links?

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Abstract

Faced with the problem of having an unknown number of authors writing an unknown number of documents that might but do not necessarily have the same topic, we came up with a pipeline of a K-means clustering algorithm informing a neural network to establish document similarity and which then informs a Meanshift algorithm that outputs the final clusters (each cluster representing an author and enveloping one or more documents). The data provided by PAN consists of 18 problems that each consist of 50-100 documents from various authors. Every problem has either news articles or reviews, and is written in English, Dutch or Greek. Document length differs from 130 to 1000 words. This is not enough training data for a neural network, so character based features were created for training. Also, the task itself limited feature selection to character-only as well. If words or word n-grams would have been used, the initial assumption was that the system would be tricked easily into clustering on topic instead of author. As all documents within a problem have one genre, it is not unimaginable that documents from different authors have the same topic, and are therefore grouped together. Preventing the system from topic clustering and aiming it at author clustering was one of the biggest challenges in this task.  
The most promising feature for this task were character based skipgrams [1] pairing every character with either a neighboring one (positive sample) or one further away (negative sample). The embeddings thus created informed the neural network with underlying information regarding character sequences and structures. Although the task is to cluster all documents of a single author, the chosen approach was to train the neural network with every possible document pair, like the PAN 2015 task for author identification. The baseline thus created was very high (94%), resulting in a default decision to most frequent class (negative) for all samples. The K-means clusterer was added to see if the number of pairs could be cut back, as a set of 50 documents already results in over 1200 possible pairs. K-means was run with an iterative setting of [1:n-1] clusters, after which the total of document clusters was counted. If two documents were never clustered together, they were stripped from the input for the neural network. This lead to a 50% reduction in document pairs, but also a 25% reduction of correct pairs. Although this improved the baseline slightly, the data was still to biased for the neural network to be able to detect correct pairs in the training data. This lead to a useless output of the network, which gave the Meanshift no additional features to work with. Based on only character based preprocessed data, as this lead to the best result in the PAN task of 2015 [2], Meanshift output had a precision of 0.12 on average. Using a Sklearn Countvectorizer for preprocessing the data with both word Ngram counts and normal word counts, the BCubed precision was 0.256, with a BCubed F-score of 0.376 (8th out of 9 participants). This measure was also applied by the task committee and although the system was not submitted, results could be compared with other participants afterwards [3]. The second part of the task, the ranking of links within clusters resulted in a mean average precision of 0.014 (5th place)

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# Introduction

With the publishing and sharing of documents being accessible to everybody, the need to verify what was written by who becomes apparent. Not only to prevent plagiarism, but also to prevent texts from being attributed to an author they do not belong to. Since 2011, PAN[[1]](#footnote-1) contains a shared task regarding automatic authorship identification. Where in recent years the task focused on determining whether or not a certain document belongs to a set of known documents of an author, the 2016 task is to cluster documents per author, without knowing the number of contributing authors. Additionally, the task also comprises a second step, in which the certainty of links has to be established between the different documents within a cluster/author. This second step is comparable with the earlier shared tasks, as it is a one on one comparison of documents. Depending on the similarity of two documents, the certainty of the author of both can be established (Figure 1). If the results of this shared task are satisfactory, the method can be applied on, for example, a portfolio of documents of students, to see if the author of all documents is the same. To make sure both steps are executed properly and no work is duplicated, the following research question will be the foundation of this research:

“Can an artificial neural network cluster documents per author?”

To back up the main questions, the following sub questions can be formulated:

- What features are important for the initial clustering per author?

- What features are important for establishing links between documents?

- Can the system be prevented from clustering based on obvious but wrong patterns such as topic?

In this thesis, at first related work and literature will be explored, based on which the approach to tackle the problem and answering the research question will be explained, followed by the results and the conclusion based on those results.

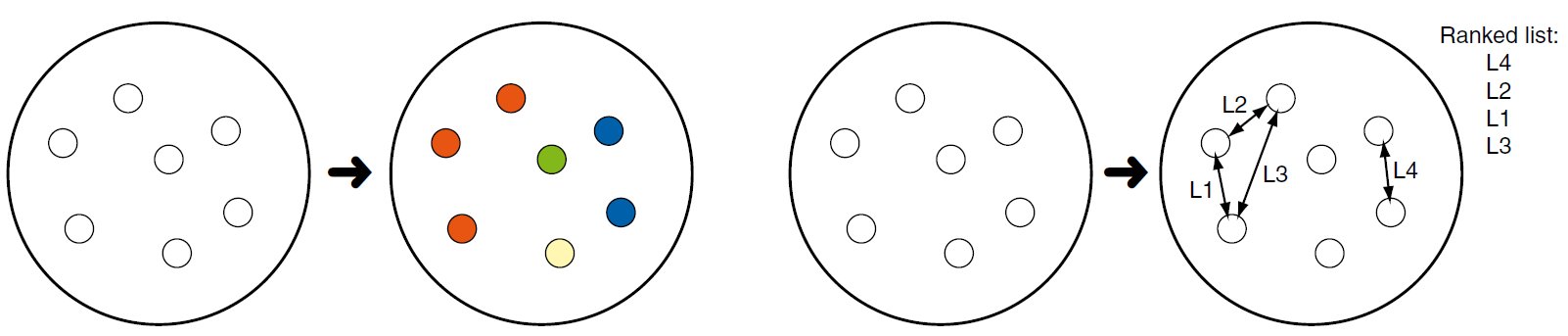


Figure 1: Examples of complete clustering (left) and authorship-link ranking (right). [3]

# Method

Plagiarism detection is a hot topic in scientific research, as it is now easier than ever to copy work someone else did and claim the results for yourself. Detectors are available for a long time, with plenty of research done on best practices and approaches, depending on the structure and the type of the available data. For this task, the data is split into 18 problems. Every problem has 50-100 documents that all have the same genre (news or review) and language (English, Dutch or Greek), equally distributed over the problems (Table 1). Every problem also has a r of either 0.5, 0.7 or 0.9. R in indicative for the number of clusters with multiple authors; the lower r, the higher the chance that the problem has multi-author clusters. R correlates with max C, the maximum number of documents in a cluster.

The small amount of data excludes the most promising solutions, as artificial neural networks combined with word embeddings are state of the art in solving practically any language related problem. Therefore, a less explored approach will be sought in this chapter.

Table 1: Evaluation datasets (left=training, right=test).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ID** | **Lang** | **Genre** | **r** | **N** | **k** | **Links** | **max C** | **Words** |  | **ID** | **Lang** | **Genre** | **r** | **N** | **k** | **Links** | **max C** | **Words** |
| 001 | English | articles | 0.70 | 50 | 35 | 26 | 5 | 752.3 |  | 001 | English | articles | 0.71 | 70 | 50 | 33 | 5 | 582.4 |
| 002 | English | articles | 0.50 | 50 | 25 | 75 | 9 | 756.2 |  | 002 | English | articles | 0.50 | 70 | 35 | 113 | 8 | 587.3 |
| 003 | English | articles | 0.86 | 50 | 43 | 8 | 3 | 744.7 |  | 003 | English | articles | 0.91 | 70 | 64 | 7 | 3 | 579.8 |
| 004 | English | reviews | 0.69 | 80 | 55 | 36 | 4 | 977.8 |  | 004 | English | reviews | 0.73 | 80 | 58 | 30 | 4 | 1,011.2 |
| 005 | English | reviews | 0.88 | 80 | 70 | 12 | 3 | 1,089.7 |  | 005 | English | reviews | 0.90 | 80 | 72 | 10 | 3 | 1,030.4 |
| 006 | English | reviews | 0.50 | 80 | 40 | 65 | 5 | 1,029.4 |  | 006 | English | reviews | 0.53 | 80 | 42 | 68 | 5 | 1,003.7 |
| 007 | Dutch | articles | 0.89 | 57 | 51 | 7 | 3 | 1,074.7 |  | 007 | Dutch | articles | 0.74 | 57 | 42 | 24 | 4 | 1,172.1 |
| 008 | Dutch | articles | 0.49 | 57 | 28 | 76 | 7 | 1,321.9 |  | 008 | Dutch | articles | 0.88 | 57 | 50 | 8 | 3 | 1,178.4 |
| 009 | Dutch | articles | 0.70 | 57 | 40 | 30 | 4 | 1,014.8 |  | 009 | Dutch | articles | 0.53 | 57 | 30 | 65 | 7 | 945.2 |
| 010 | Dutch | reviews | 0.54 | 100 | 54 | 77 | 4 | 128.2 |  | 010 | Dutch | reviews | 0.88 | 100 | 88 | 16 | 4 | 151.7 |
| 011 | Dutch | reviews | 0.67 | 100 | 67 | 46 | 4 | 134.9 |  | 011 | Dutch | reviews | 0.51 | 100 | 51 | 76 | 4 | 150.3 |
| 012 | Dutch | reviews | 0.91 | 100 | 91 | 10 | 3 | 125.3 |  | 012 | Dutch | reviews | 0.71 | 100 | 71 | 37 | 4 | 155.9 |
| 013 | Greek | articles | 0.51 | 55 | 28 | 38 | 4 | 748.9 |  | 013 | Greek | articles | 0.71 | 70 | 50 | 24 | 4 | 720.5 |
| 014 | Greek | articles | 0.69 | 55 | 38 | 25 | 5 | 741.6 |  | 014 | Greek | articles | 0.50 | 70 | 35 | 52 | 4 | 750.3 |
| 015 | Greek | articles | 0.87 | 55 | 48 | 8 | 3 | 726.8 |  | 015 | Greek | articles | 0.89 | 70 | 62 | 9 | 3 | 737.6 |
| 016 | Greek | reviews | 0.91 | 55 | 50 | 6 | 3 | 523.4 |  | 016 | Greek | reviews | 0.73 | 70 | 51 | 24 | 4 | 434.8 |
| 017 | Greek | reviews | 0.51 | 55 | 28 | 55 | 8 | 633.9 |  | 017 | Greek | reviews | 0.91 | 70 | 64 | 7 | 3 | 428.0 |
| 018 | Greek | reviews | 0.73 | 55 | 40 | 19 | 3 | 562.9 |  | 018 | Greek | reviews | 0.53 | 70 | 37 | 44 | 4 | 536.9 |

## Related work

Most recent work focused on comparing a new document to a set of known documents from one author, as that is the most logical approach if there is data available. The decision making was binary which does not make it a good source for this research. Instead, the method used by the winning team of PAN 2015 offers an interesting view on the problem. Using multi headed artificial neural networks[4], he was able to link two documents together if they belonged to the same author. Using this approach for clustering would of course take a lot of processing time as all possible pairs must be compared, but if it works it might be very good at clustering all the right documents together.   
Although primarily applied on other topics, clustering itself is of course well explored. Many algorithms have been developed that can find the center of dense clusters and compute to what range the cluster extends. In most cases however, the algorithm needs to know on beforehand how many clusters it is supposed to use to be able to find the right centers. An exception on this is Meanshift [5], a hill climbing algorithm that keeps looking for better centroids and is able to add more clusters if necessary. Meanshift is proven to be effective in determining the number of clusters and has several software implementations that can be used off the shelf. Before Meanshift was developed, the research of Holmes and Forsyth already tried to achieve a very similar result [6]. They tested their method on the very famous (and notorious in NLP tasks) federalist papers, a set of articles about the American constitution written by three authors. Their dataset is comparable to the one used for this research, which makes their approach relevant. Many of the features used by Holmes and Forsyth are quite common these days, such as word frequency counting, like tf-idf now, and trying to find stylistic patterns for authors in documents. This last feature is especially important for this task; most clustering algorithms will look for word or ngram similiarity when trying to find similar documents. Similar words still can be an indication for similar documents, but there is a risk that although the documents are alike, they are not from the same author because they all have the same genre. A field in which stylistic features are even more important is engineering, where many articles are written on the same topic and genre. This makes the research of Berry and Sazonov about the clustering of technical documents an interesting and reliable source. The nature of the documents in their dataset makes them highly structured and restricted [7], making the effect of stylistic feature selection extra visible. Although less technical, the documents in the current dataset can also be identical in structure and covered subjects. Berry and Sazonov say that sometimes the preference of an author for one word over another can be enough to distinguish who wrote what. This high influence of small features is something to keep in mind in this approach, as it can change the outcome in a very strong way.

## Approach

Based on the earlier work and proven concepts, a combined approach of all will be attempted. The largest restriction is that the entire system will have to be built in Python, as both the thesis and the shared task are on a tight schedule. This leaves no room for learning a new programming language. Python does provide all necessary tools for the task, and has modules for all desired features. Scikit-learn[[2]](#footnote-2) provides an excellent API for several clustering algorithms and preprocessing steps, and Keras[[3]](#footnote-3) allows for building an artificial neural network on either the TensorFlow or the Theano backend.

In order to train the system, the most promising features must be selected and applied. As the approach will be based on Bagnall’s, his feature selection also applies for this problem. Training a neural network requires vast amounts of data, so the only way to do this is by looking at characters instead of words. On character level you can apply almost all techniques used on words, like the relative and absolute frequency of characters per document and the full corpus (tf-idf). Metadata about the documents will also be added, informing the system about the average sentence and word length, punctuation usage and number of mid-sentence capital letters. These stylistic features can be very indicative about an author, but according to Bagnall they should not be fed raw into the neural network. This could lead to the network assigning a too great weight to a small feature, and negatively influence decision making. Therefore, Bagnall proposes to normalize all uncommon characters [4]. Different commas, ellipses (…), quotation marks (single and double) and dashes (longer and shorter) all should be converted to a single style. Furthermore, additional whitespace must be stripped and all numbers and Latin characters in Greek texts should be normalized to a common placeholder to keep their weight evenly distributed. As final step, Bagnall recommends to convert every character into the NFKD unicode normal form. This form describes the character instead of displaying it, splitting it up if it has an accent on it to describe the accent separately (Figure 1).

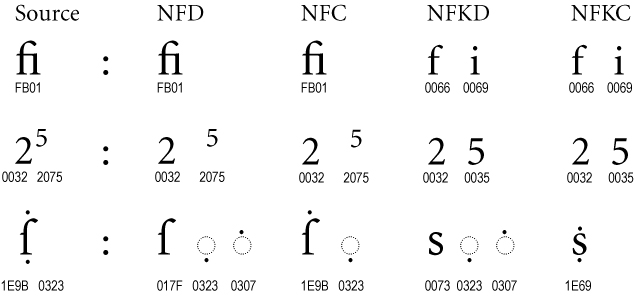


Figure 2: Different unicode forms and their output.

The result of all normalization steps is a human unreadable list of strings per document, that can be used by both Keras an Scikit-learn for further preprocessing the data.  
The assumption is that clustering and an artificial neural network can inform each other in order to achieve better results on the data. The idea of Bagnall to use a neural network for ranking document similarity is very promising, but time consuming on this many document pairs. Each of the 18 problems has at least 50 documents, which leads to at least 1225 unique pairs per problem that need to be processed. It would therefore be very useful to remove certain pairs that are highly unlikely from the initial set. This removal should be done discreetly, as it is better to remove too less faulty pairs than too much pairs that should be together. This will make the training data less skewed, and cut back the processing time as well. The pairs can be shifted using a K-means clusterer with an unspecified number of clusters. K-means expects the user to set the desired number of clusters (k), so by iterating through a k of [1:n-1], all possibilities will be tried. The cluster output can then be added together, to see which documents are never clustered together. That particular pair can then be removed from the full set. Once the set of document pairs has been trimmed, the remaining texts can be preprocessed to be fed into Keras’s Long Short-Term Memory, or LSTM, neural network [8]. LSTM is a type of recurrent neural network that is especially good in processing and predicting texts, as it looks back at everything it learned until now. This means that an LSTM is able to learn rules from a correct pair and apply them on the current pair, even if there is a high number of incorrect pairs in between. Given the skewed data for this task, it is important that the network remembers the sparse correct pairs as good and as long as possible. LSTM’s do have limitations on length however, so it might be that the long sequences of characters are too much for it to keep learning correctly. But just like any other implementation in Keras, LSTM’s are stackable and should be able to fit the entire sequence of characters in the documents. LSTM expects the data in three dimensions of (nb\_sequences, nb\_samples, input\_dim). Sequences is defined by the total number of sequences, samples by the length of one document and input dimension by the total of different characters in the vocabulary, so 26 + some special ones. The data itself must be one-hot encoded, with each character being represented by a number in range[input\_dim]. Once encoded, the entire dataset will be converted into a 3D matrix by Keras’s preprocessing tools for the network to use. As an extra feature, character embeddings will be constructed using skipgrams [1]. By encoding all possible character pairs with either 1 if they are neighbors, and 0 if the pairs are far apart, a vector can be built of what characters are likely and unlikely to occur together.   
The ratings of one document versus every other will be used as an additional feature for the Meanshift algorithm. Experiments will have to point out whether the feature should be shaped like a list with 1’s and 0’s, or more like a dictionary with one document as key and all its matches as values. The Meanshift implementation in Scikit-learn offers few parameters, and is able to calculate the bandwidth it should use based on the data. A too small bandwidth results in many clusters while there might be overlapping ones, and a too large bandwidth merges too many clusters, resulting in only a few final clusters. The output of Meanshift will be a list of documents per cluster, that can be transformed in the same JSON format the task committee provides the truth data in. Using the online review environment Tira [9], automatic evaluation of the answers given versus the gold standard data will be done. Evaluation results will be according to the Bcubed score [10], a measure that combines the scores within a cluster with the ones across clusters for computing precision and recall (Figure 2). This results in different scores per language and per genre, with a total score over all problems that all will be described in the next chapter.

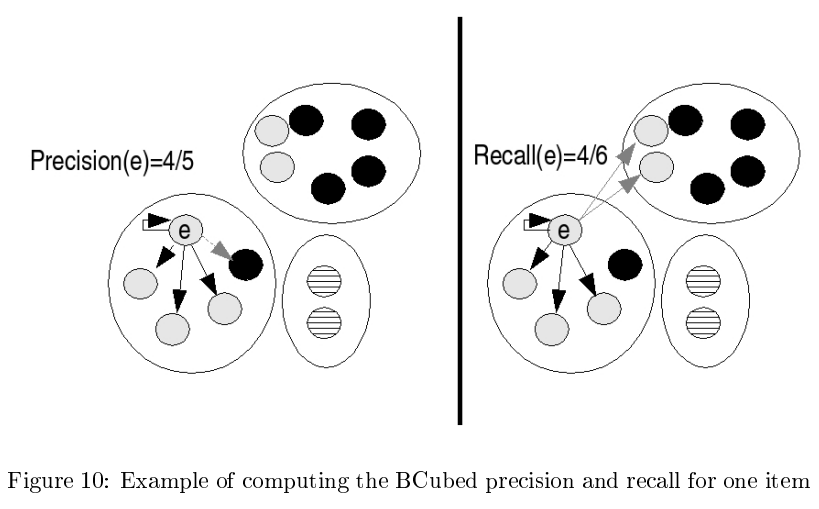


Figure 3: Calculation of Bcubed precision and recall

# Results

When coding the software based on the dataflow from the previous chapter, it soon turned out that the sequences of characters were in fact too long for a LSTM recurrent neural network to process. The correct pairs were just too sparse for the network to remember the previous one when encountering a new one, resulting in a preference for the most frequent class with no apparent learning. This was only worsened by using the pairwise comparison in the neural network. With the aforementioned example of 1200 pairs, created from just 50 documents, only about 70 of 1200 would be correct pairs. This gives a tough to beat baseline of 94%, with far too little correct data for the network to learn from. Using the K-means clusterer to strip unlikely pairs was successful, removing about half of the total, but at a cost of 25% of correct pairs. In absolute numbers it was a very successful method, but relatively without effect to lower the most frequent class baseline. Meanwhile, during the development of the system and continuous tweaks to get the neural network going, the deadline for the shared task expired. No working software was submitted because the pipeline could not be completed in time, which made official evaluation at that point impossible too. Unofficial measures show a precision of 0.1 per problem on average over the 20 most common pairs in a cluster. This means that, of all clusters returned from the K-means iterations, only the top 20 is taken into account. Of this 20, only 10% (so 2 pairs) would usually be correct according to the gold standard. So K-means was an outstanding preprocessor if executed before the neural network, but performed bad if its output was used as final data. Meanshift on the other hand performed rather well, and was implemented as final solution. Because no ranking within clusters could be made with the algorithm, it was decided to give every link of two documents within a cluster a certainty of 1, trusting on the accuracy of Meanshift. Due to the presentation of the overview paper [3] of the 2016 shared task, the evaluation script also was made available for comparison (Table 2). Note that the results in the table are presumably on the test set, while our results are on the development set. As seen before the two datasets are very alike (Table 1). The results of Meanshift are surprisingly good for the simple implementation via Scikit-learn, although only Bcubed recall for clustering and mean average precision for ranking are above the baseline. Especially Singleton baseline performed very well on clustering, as the large majority of clusters only consisted of a single document. Only Bagnall, also winner of last year and following a similar approach as this research, and Kocher were able to beat it in Bcubed F-score, and only just.

Table 2: FInal results of the PAN 2016 shared task for author clustering. [3]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant** | **Complete clustering** | | |  | **Authorship-link ranking** | | | **Runtime** |
|  | B3 F | B3 rec. | B3 prec. |  | MAP | RP | P@10 |  |
| Bagnall | **0.822** | 0.726 | 0.977 |  | **0.169** | **0.168** | **0.283** | 63:03:59 |
| Gobeill | 0.706 | 0.767 | 0.737 |  | 0.115 | 0.131 | 0.233 | 00:00:39 |
| Kocher | **0.822** | 0.722 | **0.982** |  | 0.054 | 0.050 | 0.117 | 00:01:51 |
| Kuttichira | 0.588 | 0.720 | 0.512 |  | 0.001 | 0.010 | 0.006 | 00:00:42 |
| Louwaars MS | 0.376 | 0.877 | 0.256 |  | 0.014 | - | - | ? |
| Mansoorizadeh *et al.* | 0.401 | 0.822 | 0.280 |  | 0.009 | 0.012 | 0.011 | 00:00:17 |
| Sari & Stevenson | 0.795 | 0.733 | 0.893 |  | 0.040 | 0.065 | 0.217 | 00:07:48 |
| Vartapetiance & Gillam | 0.234 | **0.935** | 0.195 |  | 0.012 | 0.023 | 0.044 | 03:03:13 |
| Zmiycharov *et al.* | 0.768 | 0.716 | 0.852 |  | 0.003 | 0.016 | 0.033 | 01:22:56 |
| BASELINE-Random | 0.667 | 0.714 | 0.641 |  | 0.002 | 0.009 | 0.013 | – |
| BASELINE-Singleton | 0.821 | 0.711 | **1.000** |  | – | – | – | – |
| BASELINE-Cosine | – | – | – |  | 0.060 | 0.074 | 0.139 | – |

Detailed results per genre and language for clustering can be found in Table 3. Interesting in these results is the high difference in languages where most teams have an almost equal score for all three. Although the system was only working with character features, somehow it was much better in clustering Dutch texts than Greek or English. A possible explanation might be that Dutch has more accented letters than the others, but this does not explain why other competitors did not encounter the same.

Table 3: Evaluation results (mean BCubed F-score) for the complete author clustering task. [3]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant** | **Overall** | **Articles** | **Reviews** | **English** | **Dutch** | **Greek** | ***r****≈***0.9** | ***r****≈***0.7** | ***r****≈***0.5** |
| Bagnall | **0.822** | **0.817** | **0.828** | **0.820** | **0.815** | 0.832 | 0.931 | 0.840 | **0.695** |
| Kocher | **0.822** | **0.817** | 0.827 | 0.818 | **0.815** | **0.833** | **0.933** | **0.843** | 0.690 |
| BASELINE-Singleton | 0.821 | **0.819** | 0.823 | **0.822** | **0.819** | 0.822 | **0.945** | 0.838 | 0.680 |
| Sari & Stevenson | 0.795 | 0.789 | 0.801 | 0.784 | 0.789 | 0.813 | 0.887 | 0.812 | 0.687 |
| Zmiycharov *et al.* | 0.768 | 0.761 | 0.776 | 0.781 | 0.759 | 0.765 | 0.877 | 0.777 | 0.651 |
| Gobeill | 0.706 | 0.800 | 0.611 | 0.805 | 0.606 | 0.707 | 0.756 | 0.722 | 0.639 |
| BASELINE-Random | 0.667 | 0.666 | 0.667 | 0.668 | 0.665 | 0.667 | 0.745 | 0.678 | 0.577 |
| Kuttichira | 0.588 | 0.626 | 0.550 | 0.579 | 0.584 | 0.601 | 0.647 | 0.599 | 0.519 |
| Mansoorizadeh *et al.* | 0.401 | 0.367 | 0.435 | 0.486 | 0.256 | 0.460 | 0.426 | 0.373 | 0.403 |
| Louwaars | 0.376 | 0.386 | 0.367 | 0.27 | 0.465 | 0.394 | ? | ? | ? |
| Vartapetiance & Gillam | 0.234 | 0.284 | 0.183 | 0.057 | 0.595 | 0.049 | 0.230 | 0.241 | 0.230 |

Table 4: Evaluation results (MAP) for the authorship-link ranking task. [3]

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Participant** | **Overall** | | **Articles** | **Reviews** | **English** | **Dutch** | **Greek** | ***r****≈***0.9** | ***r****≈***0.7** | ***r****≈***0.5** |
| Bagnall | **0.169** | | **0.174** | **0.163** | **0.126** | **0.109** | **0.272** | **0.064** | **0.186** | **0.257** |
| Gobeill | 0.115 | | 0.119 | 0.110 | 0.097 | 0.079 | 0.168 | 0.040 | 0.105 | 0.198 |
| BASELINE-Cosine | 0.060 | | 0.063 | 0.057 | 0.053 | 0.053 | 0.074 | 0.019 | 0.054 | 0.107 |
| Kocher | 0.054 | | 0.047 | 0.061 | 0.032 | 0.044 | 0.085 | 0.042 | 0.058 | 0.063 |
| Sari & Stevenson | 0.040 | | 0.033 | 0.047 | 0.009 | 0.042 | 0.069 | 0.017 | 0.041 | 0.062 |
| Louwaars | 0.014 |  | 0.015 | 0.013 | 0.016 | 0.007 | 0.018 | ? | ? | ? |
| Vartapetiance & Gillam | 0.012 | | 0.010 | 0.014 | 0.014 | 0.006 | 0.016 | 0.010 | 0.008 | 0.017 |
| Mansoorizadeh *et al.* | 0.009 | | 0.013 | 0.004 | 0.006 | 0.010 | 0.010 | 0.002 | 0.009 | 0.014 |
| Zmiycharov *et al.* | 0.003 | | 0.002 | 0.004 | 0.001 | 0.000 | 0.009 | 0.002 | 0.003 | 0.004 |
| BASELINE-Random | 0.002 | | 0.002 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 |
| Kuttichira | 0.001 | | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.002 | 0.001 |

# Discussion

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2. http://scikit-learn.org/stable/ [↑](#footnote-ref-2)
3. http://keras.io/ [↑](#footnote-ref-3)