Revelation of the author's identity using machine learning and stylometry

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History

Motivation

- Antiquity: Homer, Demosthenes vs Anaximenes
- Jewish and Christian Bibles: Pentateuch
- England 1694 (end of pre-publication censorship): pseudonyms
- England 1887: the first algorithmic method
- England 1976: evidence in court
- present: analysis of anonymous documents in the Internet, mobiles, ...

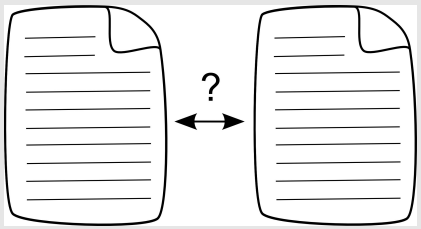
History

Authorship recognition methods

1. **ideological and thematic analysis**
   historical documents, literature
2. **documentary and factual evidence**
   inquisition in the Middle Ages, libraries
3. **language and stylistic analysis** – stylometry
   present

Authorship Verification

Definition



- decide if two documents were written by the same author (1v1)
- decide if a document was written by the signed author (1vN)

Examples

- The Shakespeare authorship question
- The verification of wills

Authorship Verification

The Shakespeare authorship question

Mendenhall, T. C. 1887.
The Characteristic Curves of Composition.
Science Vol 9: 237–49.

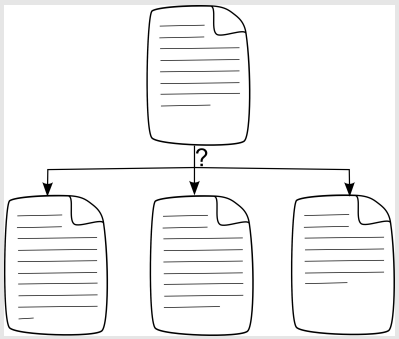
- The first algorithmic analysis
- Calculating and comparing histograms of word lengths

Oxford, Bacon
Derby, Marlowe

http://en.wikipedia.org/wiki/File:ShakespeareCandidates1.jpg

Authorship Attribution

Definition



- find out an author of a document
- candidate authors can be known

Examples

- False reviews
- Anonymous e-mails

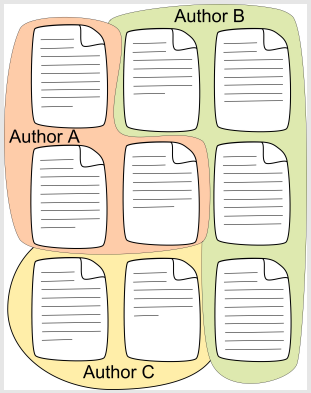
Authorship Attribution

Judiciary

- The police falsify testimonies
  Morton, A. Q. Word Detective Proves the Bard wasn't Bacon. Observer, 1976.
- Evidence in courts of law in Britain, U.S., Australia

Authorship Clustering

Definition



- cluster documents or text paragraphs according to the authors

Examples

- The Bible
- Analysis of anonymous documents

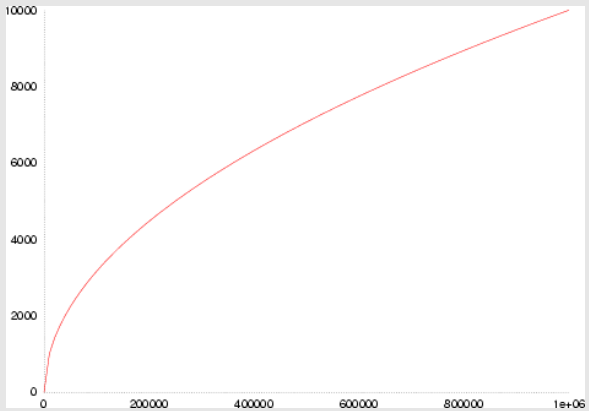
Authorship Clustering

The Bible

K. Grayston and G. Herdan.
The authorship of the pastorals in the light of statistical linguistics. New Testament Studies, VI:1–15, 1959–1960.

Gustav Herdan, statistician and linguist:

- born 1897 in Brno
- author of *Quantitative linguistics*
- mathematical language laws, e.g. the dependence of the number of *distinct words* in a document as a function of the *document length*



Related fields

Computional stylometry

- Online social networks: predicting age and gender
- Plagiarism: co-authorship
- Supportive authentication, biometrics (e.g. in e-learning)
- Native language prediction
- ...

History and motivation

Public security

- Anonymous documents, threats, ...
- Ministry of the Interior of CR within the project VF20102014003

Research for Ministry of the Interior of CR

- authorship detection for Czech
- new author's characteristics and adaptation of existing for flective free-word-order languages
- new techniques for "Internet documents"
- software Authorship Recognition Tool (ART)

Contents

Stylometry

Definition

Computional stylometry techniques that allow us to find out information about the authors of texts on the basis of an automatic linguistic analysis

Motivation

Stylometry analysis is used for

- Linguistic expertise
- Stylome: set of characteristic author's features
- Machine learning: stylometric features $\sim$ attributes for machine learning

Stylometry

Preprocessing

- document crawling
- text and meta data extraction (detect author's label)
- text cleaning
  - deduplication
  - boilerplate removal
  - remove markup tags
- language and encoding detection
- tokenize

Stylometry

Preprocessing

- morphological analysis

```
je       byt      k5eAaImIp3nS
spor     spor     k1gInSc1
mezi     mezi     k7c7
Severem  sever    k1gInSc7
```

- syntactic analysis

```
15      ekonomiky       43      p
16      .       44      p
17      <CP>    20      p
18      <CLAUSE>        20      p
19      <CLAUSE>        20      p
```

Stylometry

Authorship recognition through stylometry

For each text:

1. preprocess text
2. count values of stylometric features (text is represented by a vector of feature values)

Depending on the task:

1. compare two documents, subtract one feature-value vector from the second one
2. characterize label (author), analyze feature-value vectors with the same label (author)

Stylometry-feature categories

Categories

- Morphological
- Syntactic
- Vocabulary
  - semantic words
  - stop-words
- Technical (text formatting, publishing time)
- Other

Author's characteristic features

Word length statistics

- Count and normalize frequencies of selected word lengths (eg. 1–15 characters)
- Modification: word-length frequencies are influenced by adjacent frequencies in histogram, e.g.: `1: 30%, 2: 70%, 3: 0%` is more similar to `1: 70%, 2: 30%, 3: 0%` than `1: 0%, 2: 60%, 3: 40%`

Sentence length statistics

- Count and normalize frequencies of
  - word per sentence length
  - character per sentence length

Author's characteristic features

Author gender

- Detect sentences written in the first person
- Extract author's gender if possible
- *včera jsem byl**a** v Brně a viděl**a***

Wordclass (bigrams) statistics

- Count and normalize frequencies of wordclasses (wordclass bigrams)
- *verb is followed by noun with the same frequency in selected five texts of Karel Čapek*

Author's characteristic features

Morphological tags statistics

- Count and normalize frequencies of selected morphological tags
- *the most consistent frequency has the genus for family and archaic freq in selected five texts of Karel Čapek*

Word repetition

- Analyse which words or wordclasses are frequently repeated through the sentence
- *nouns, verbs and pronous are the most repetetive in selected five texts of Karel Čapek*

Author's characteristic features

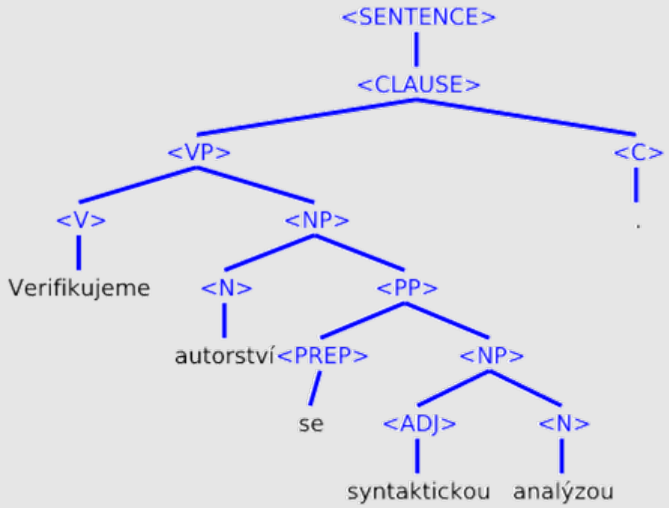
Stopwords

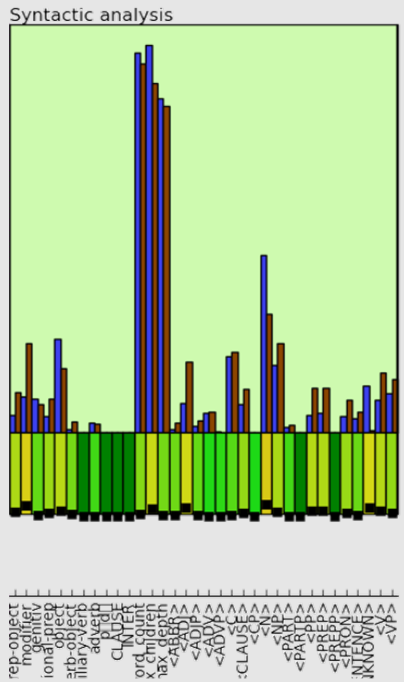
- Count normalized frequency for each word from stopword list
- Stopword $\sim$ general word, semantic meaning is not important, e.g. prepositions, conjunctions, ...
- *stopwords* **ten, by, člověk, že** *are the most frequent in selected five texts of Karel Čapek*

Author's characteristic features

Syntactic Analysis

- Extract features using SET (Syntactic Engineering Tool)





- *syntactic trees have similar depth in selected five texts of Karel Čapek*

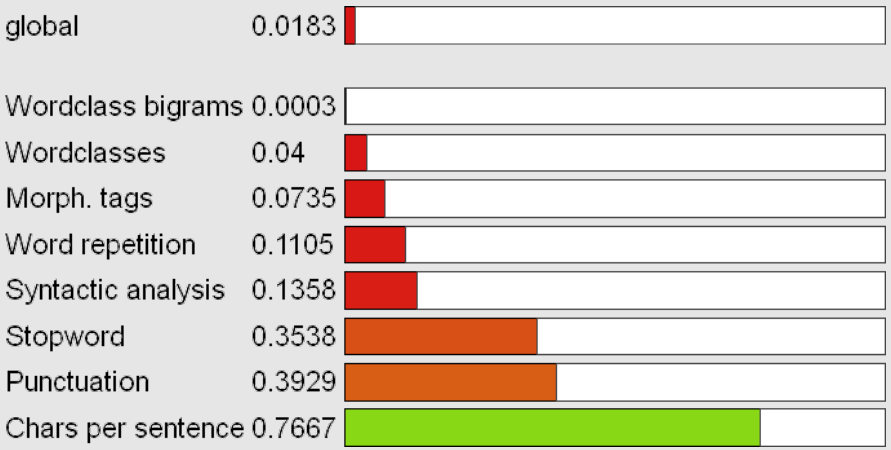
Author's characteristic features

Other stylometric features

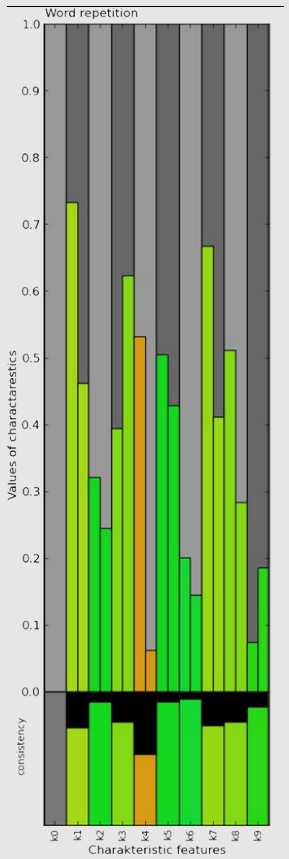
- typography
- formatting richness
- emoticons
- errors
- vocabulary richness

Author's characteristic features

Document comparison

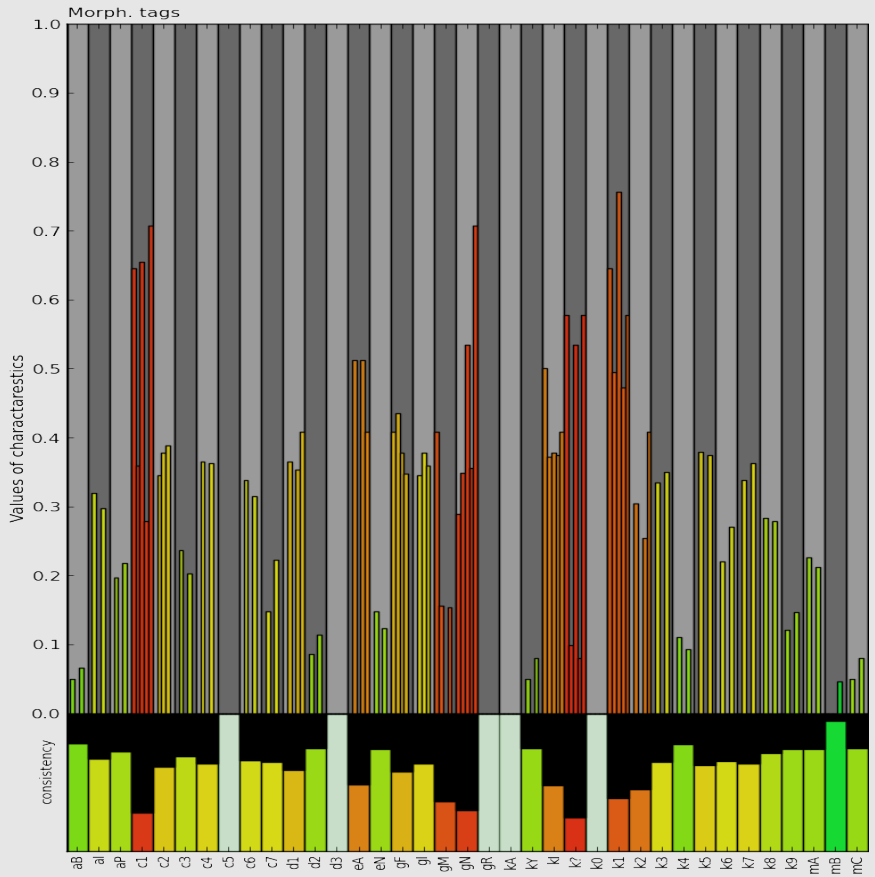


Example: comparison between two different authors



Author writeprint/stylome

Collection of author's documents



Author analysis:

1. Range: typical feature values for that author
2. Consistency (deviation): which features are most important
3. Corpus similarity: which features are uncommon in corpus

Machine learning approach

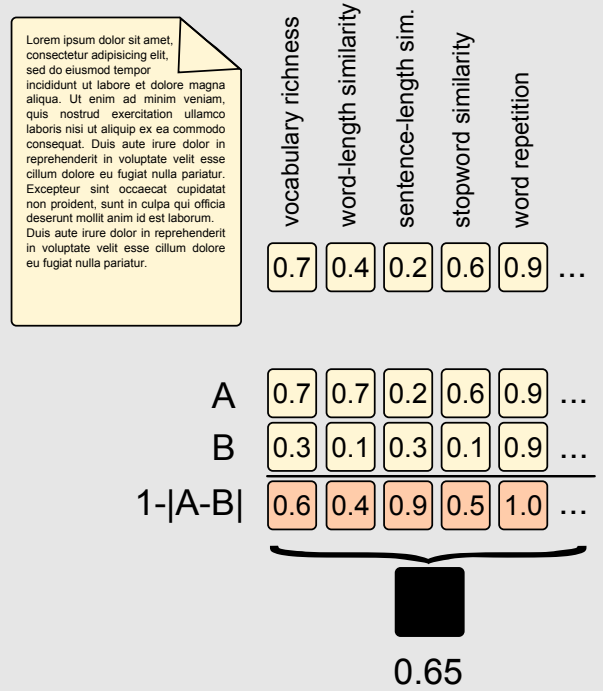
Automatic parameter tuning

- use models with probability estimation only if necessary
- try different techniques (Support vector machines, Nearest neighbors, Naive Bayes)
- try different kernels for SVM
- parameter grid search
- each problem and data type uses different ML model

Machine learning approach

Single-layer ML technique (two-class: same vs different authorship)

1. Extract document features for each author characteristic
2. Compare documents to obtain a similarity vector
3. ML classifier predicts probability of the same authorship



Similarity ranking

Replace similarity features by similarity ranking features

`Book:`

`long coherent text`

`Blog:`

`medium-length text`

`E-mail:`

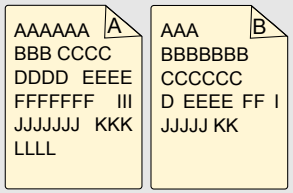
`short noisy text`

- Different "document conditions" are considered
- Attribution: replace similarity by ranking of the author against other authors
- Verification: select random similar documents from corpus and replace similarity by ranking of the document against these selected documents

Double-layer machine learning

Replace heuristics by 2nd machine learning layer

Example:
word-length statistics



word length	doc. A	doc. B	diff.
1	0	2	2
2	0	2	2
3	2	1	1
4	6	1	5
5	0	1	1
6	1	2	1
7	2	0	2

- **Heuristic (proposed by linguist)**:

$$sim = 1 - \frac{1}{7} \cdot \sum_{s \in \langle 1..7 \rangle} \left| \frac{A_s}{|A|} - \frac{B_s}{|B|} \right|$$

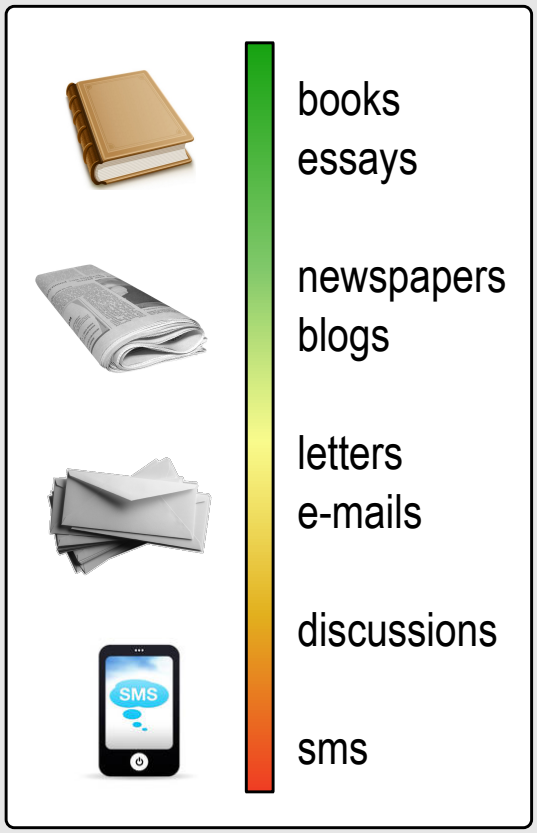
- **New ML layer (replace linguist's heuristic by empirical evidence)**:

$$vector = \left\langle \left| \frac{A_s}{|A|} - \frac{B_s}{|B|} \right| \text{ for } s \in \langle 1..7 \rangle \right\rangle$$

$$sim = classifier(vector)$$

Performance (Czech texts)

Balanced accuracy:



Verification:

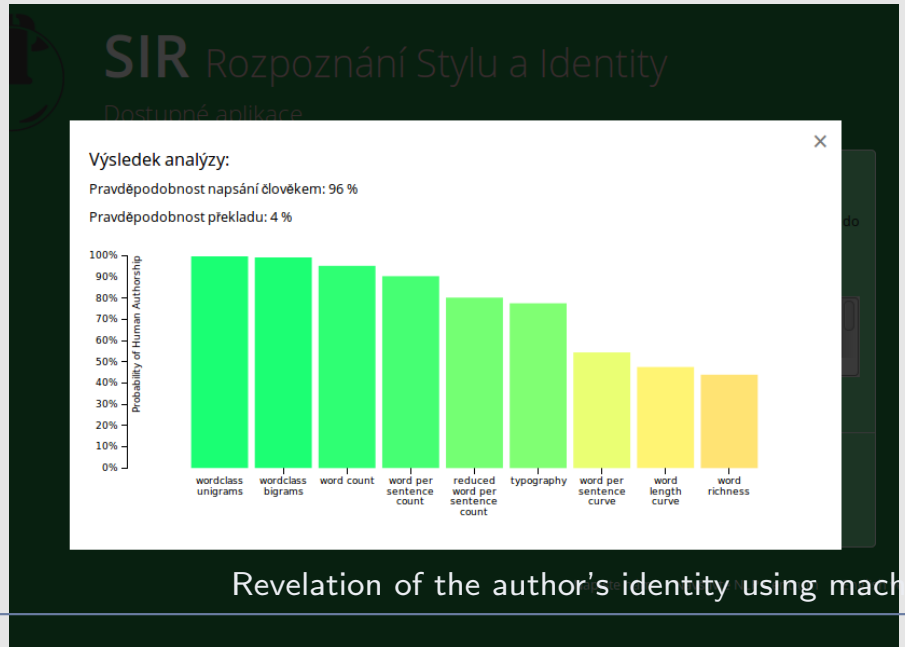
- books, essays: 90 % → 99 %
- blogs, articles: 70 % → 99 %
- tweets: 70 % → 99 % (given enough tweets)

Attribution (depends on the number of candidates, comparison on blogs):

- up to 4 candidates: 80 % → 95 %
- up to 100 candidates: 40 % → 60 %

Current work

- Machine translation detection
  - Recognize texts translated by Google, Bing and other machine translators
  - Remove translations from corpora
  - Detect texts falsely submitted as translated by a human expert
  - `http://nlp.fi.muni.cz/sir`



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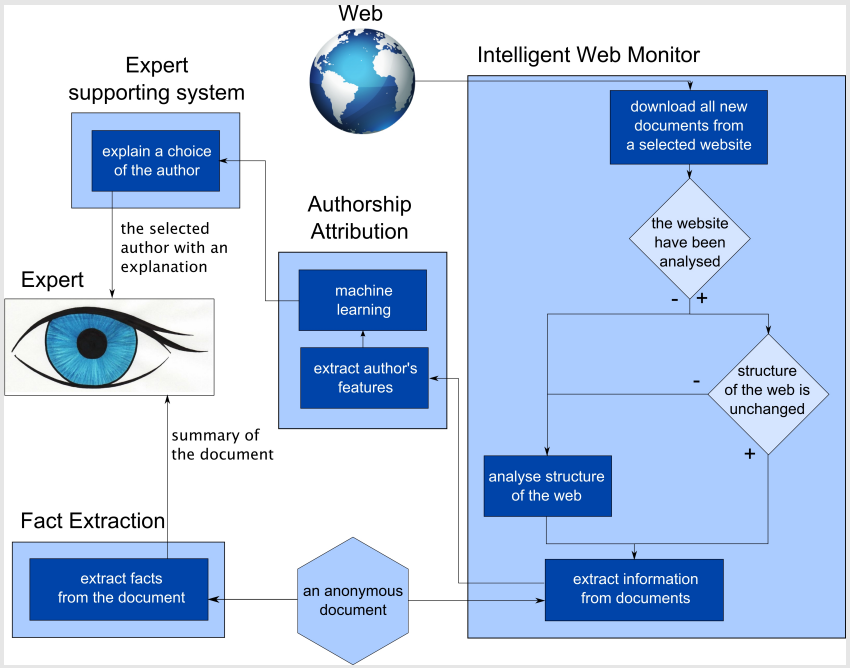
Current work

- Web structure detection
  - Create stylometric corpora
  - Detect web structure and download documents with meta-data (author, gender, age, title, topic)



Current work

- Gender detection
  - Use data from dating services
  - Detect advertisements with a falsely submitted gender
- Authorship detection consultations

Thank you for your attention