PA153: Stylometric analysis of texts using machine learning techniques

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Stylometry is the application of the study of linguistic style.

Study of linguistic style:
- Find out text features.
- Define author’s writeprint.

Applications:
- Define the author (person, nationality, age group, ...).
- Filter out text features not usable by selected application.
Examples of application:

- **Authorship recognition**
  - Legal documents (verify the author of last will)
  - False reviews (cluster accounts by real authors)
  - Public security (find authors of anonymous illegal documents and threats)
  - School essays authorship verification (co-authorship)
  - Supportive authentication, biometrics (e-learning)

- **Age** detection (pedophile recognition on children web sites).
- Author **mother language** prediction (public security).
- **Mental disease** symptoms detection (health prevention)
- **HR** applications (find out personal traits from text)
- **Automatic translation** recognition.
Stylometry analysis techniques

1 ideological and thematic analysis
   historical documents, literature

2 documentary and factual evidence
   inquisition in the Middle Ages, libraries

3 language and stylistic analysis –
   3 manual (legal, public security and literary applications)
   3 semi-automatic (same as above)
   3 automatic (false reviews and generally all online stylometry applications)
Stylometry

Stylometry Verification

**Definition**

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

**Examples**

- The Shakespeare authorship question
- The verification of wills
The Shakespeare authorship question

Mendenhall, T. C. 1887.  
*The Characteristic Curves of Composition.*  

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

Oxford, Bacon, Derby, Marlowe

Stylometry Attribution

**Definition**

- find out an author category of a document
- candidate authors’ categories can be known (e.g. age groups, healthy/unhealthy person)
- problems solving unknown candidate authors’ categories are hard (e.g. online authorship, all clustering tasks)

**Examples**

- Anonymous e-mails
Judiciary

- The police falsify testimonies

- Evidence in courts of law in Britain, U.S., Australia

- Expert analysis of courtroom discourse, e.g. testing “patterns of deceit” hypotheses
<table>
<thead>
<tr>
<th><strong>Authorship Recognition Tool</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of the Interior of CR within the project VF20102014003</td>
</tr>
<tr>
<td>Best security research award by Minister of the Interior</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Small projects (bachelor and diploma theses, papers)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>detection of automatic translation, gender detection, ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>TextMiner</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>multilingual stylometry tool + many other features not related to stylometry</td>
</tr>
<tr>
<td>authorship, mother language, age, gender, social group detection</td>
</tr>
</tbody>
</table>
Updated definition

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

Stylometry process steps

1. data acquisition – obtain and preprocess data
2. feature extraction methods – get features from texts
3. machine learning – train and tune classifiers
4. interpretation of results – make machine learning reasoning readable by human
## Techniques

### Data acquisition – collecting

#### Free data
- For big languages only
- Enron e-mail corpus
- Blog corpus (*Koppel, M, Effects of Age and Gender on Blogging*)

#### Manually annotated corpora
- ÚČNK school essays
- FI MUNI error corpus

#### Web crawling
Tokenization, morphology annotation and desambiguation

- morphological analysis

je   byt   k5eAaImIp3nS
spor spor k1gInSc1
mezi mezi k7c7
Severem sever k1gInSc7
a    a    k8xC
Jihem jih k1gInSc7
<g/>
.    .    kIx.
</s>
<s desamb="1">
Jde   jit   k5eAaImIp3nS
Selection of feature extraction methods

Categories

- Morphological
- Syntactic
- Vocabulary
- Other

Analyse problem and select only suitable features. Combine with automatic feature selection techniques (entropy).
Tuning process

Divide data into three independent sets:

- Tuning set (generate stopwords, part-of-speech n-grams, ...)
- Training set (train a classifier)
- Test set (evaluate a classifier)
Word length statistics

- Count and normalize frequencies of selected word lengths (e.g. 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
Techniques

Features examples

Stopwords

- Count normalized frequency for each word from stopword list
- Stopword ~ 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*

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*
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 pronouns are the most repetitive in selected five texts of Karel Čapek*
Techniques

Features examples

**Syntactic Analysis**

- Extract features using SET (Syntactic Engineering Tool)

- syntactic trees have similar depth in selected five texts of Karel Čapek
Other stylometric features

- typography (number of dots, spaces, emoticons, ...)
- errors
- vocabulary richness
def document_to_features(self, document):
    """Transform document to tuple of float features.
    @return: tuple of n float feature values, n=|get_features|""
    features = np.zeros(self.features_count)
    sentences = self.get_structure(document, mode=u'tag')
    for sentence in sentences:
        for tag in sentence:
            if tag and tag[0] == u'k':
                key = self.tag_to_index.get(tag[:2])
                if key: features[key] += 1.
    total = np.sum(features)
    if total > 0: return features / total
    else: return features
Techniques

Machine learning

Tools

- use frameworks over your own implementation (ML is HW consuming and needs to be optimal)
- programming language doesn’t matter, but high-level languages can be better (readability is important and performance is not affected – ML frameworks use usually C libraries)
- for Python, good choice is Scikit-learn (http://scikit-learn.org)
Machine learning tuning

- try different machine learning techniques (Support Vector Machines, Random Forests, Neural Networks)
- use grid search/random search/other heuristic searches to find optimal parameters (use **cross-validation** on train data)
- but **start with the fast and easy to configure** ones (Naive Bayes, Decision Trees)
- **feature selection** (more is not better)
- make experiments **replicable** (use random seed), repeat experiments with different seed to check their performance
- always implement a **baseline** algorithm (random answer, constant answer)
### Machine learning tricks

#### Replace feature values by ranking of feature values

<table>
<thead>
<tr>
<th>Book:</th>
<th>Blog:</th>
<th>E-mail:</th>
</tr>
</thead>
<tbody>
<tr>
<td>long coherent text</td>
<td>medium-length text</td>
<td>short noisy text</td>
</tr>
</tbody>
</table>

- 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
Interpretation of results

Machine learning readable

Explanation of ML reasoning can be important. We can

1. not to interpret data at all (we can’t enforce any consequences)
2. use one classifier per feature category and use feature categories results as a partially human readable solution
3. use ML techniques which can be interpreted:
   - Linear classifiers
     each feature $f$ has weight $w(f)$ and document value $val(f)$,
     \[ \sum_{f \in F} w(f) \times val(f) \geq \text{threshold} \]
   - Extensions of black box classifiers, for random forests
     https://github.com/janrygl/treeinterpreter
4. use another statistical module not connected to ML at all
### Results

#### Performance (Czech texts)

<table>
<thead>
<tr>
<th>Balanced accuracy: Current (CS) → Desired (EN)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verification:</strong></td>
</tr>
<tr>
<td>- books, essays: 95% → 99%</td>
</tr>
<tr>
<td>- blogs, articles: 70% → 90%</td>
</tr>
<tr>
<td><strong>Attribution (depends on the number of candidates, comparison on blogs):</strong></td>
</tr>
<tr>
<td>- up to 4 candidates: 80% → 95%</td>
</tr>
<tr>
<td>- up to 100 candidates: 40% → 60%</td>
</tr>
<tr>
<td><strong>Clustering:</strong></td>
</tr>
<tr>
<td>- the evaluation metric depends on the scenario (50–60%)</td>
</tr>
</tbody>
</table>
How to start

- Select a problem
- Collect data (gender detection data are easy to find – crawler dating service)
- Preprocess texts (remove HTML, tokenize)
- Write a few feature extraction methods
- Use a ML framework to classify data
I want to try it really quick

**Quick start**

**Style & Identity Recognizer**
https://github.com/janrygl/sir.
- In development, but functional.
- Contains data from dating services.
- Contains feature extractors.
- Uses free RFTagger for morphology tagging.
Results

Development at FI

**TextMiner**

- more languages,
- more feature extractors,
- more machine learning experiments,
- better visualization,
- and much more
Results

Thank you for your attention