

Exploiting EuroVoc’s Hierarchical Structure for Classifying Legal Documents

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Abstract. Multi-label document classification is a challenging problem because of the potentially huge number of classes. Furthermore, real-world datasets often exhibit a strongly varying number of labels per document, and a power-law distribution of those class labels. Multi-label classification of legal documents is additionally complicated by long document texts and domain-specific use of language. In this paper we use different approaches to compare the performance of text classification algorithms on existing datasets and corpora of legal documents, and contrast the results of our experiments with results on general-purpose multi-label text classification datasets. Moreover, for the EUR-Lex legal datasets, we show that exploiting the hierarchy of the EuroVoc thesaurus helps to improve classification performance by reducing the number of potential classes while retaining the informative value of the classification itself.

Keywords: document classification · EuroVoc · Eur-Lex · legal domain · word embeddings · deep learning

1 Introduction

Handling unstructured data like text documents is easier for humans than for machines [4], however machines can help to make text accessible and searchable for example by classifying documents into several classes. Text or document classification can be attributed to the research area of text mining [12]. Applications of text classification in various domains range from text filtering, to document organization and to word sense disambiguation [25], etc. In general, text classification is defined as the process of the assignment of a category out of a set of categories to a document [25]. Text classification can be subdivided into binary classification, multi-class classification and multi-label classification [29] tasks which generally exhibit an increasing level of difficulty. While binary classification aims at classifying documents into one out of two classes, multi-class classification aims at assigning one class out of a set of non-overlapping classes

to a document. The hardest task is multi-label classification where the algorithm assigns a set of potentially overlapping labels from the whole label set to a document. Document classification tasks are typically approached with machine learning algorithms, in recent years in particular with deep learning systems. The choice of machine learning algorithms is dependent on the task and the classification problem at hand, and comprise, among others, for instance decision trees, probabilistic or rule-based classifiers [1, 4, 12], or variants of recurrent or convolutional neural networks [13, 14].

Text classification is used in many domains (eg. news, medical) to assign categories to documents, which are domain-specific in terms of the used vocabulary and length. There are many well-known datasets used by researchers to evaluate the performance of text classification approaches, for instance 20Newsgroups⁴ or Reuters-21578⁵ for the news domain or OHSUMED⁶ for the medical domain. Highly interesting, but also challenging is the legal domain – as legal frameworks affect our daily life. Openly available datasets for document classification tasks in the legal domain are for instance the JRC-Acquis⁷ and the EUR-Lex 4K⁸ dataset [19], both containing legal documents from the EUR-Lex⁹ legal database, which is available publicly and free of charge.

In the legal domain a multi-disciplinary and multi-lingual thesaurus called EuroVoc¹⁰ is used to classify legal documents into a large number of overlapping categories, hence presenting a multi-label classification problem: indeed, EuroVoc contains more than 6,000 potential classes, which is a much higher number of classes than for many classic multi-label classification datasets used in previous research. Moreover, text documents are rich in semantic information which can be used in the classification task [5]. What makes the problem of classifying legal texts additionally challenging is the highly domain-specific language used in legal text corpora, with many abbreviations, as legal documents are primarily read by legal experts. We are therefore interested in

1. how standard document classification approaches perform on legal texts and
2. whether the class hierarchy of an external thesaurus can be exploited to improve the classification results.

Previous research carried out in this area with legal documents is treating the problem as a profile-based category ranking task [27], and focuses more on scalability issues of the classification problem than on classification quality [19]. Others approach the task by transforming the problem into a simpler one by assuming that a multi-labelled document is a collection of different documents [8] or by choosing to classify documents according to another scheme which offers

⁴ <http://qwone.com/~jason/20Newsgroups/>

⁵ <http://www.daviddlewis.com/resources/testcollections/reuters21578/>

⁶ <http://disi.unitn.it/moschitti/corpora.htm>

⁷ <https://ec.europa.eu/jrc/en/language-technologies/jrc-acquis>

⁸ <http://www.ke.tu-darmstadt.de/resources/eurlex>

⁹ <http://eur-lex.europa.eu/>

¹⁰ <http://eurovoc.europa.eu/>

less classes [2]. All described approaches show that the main problem is the vast amount of different classes into which documents can be classified and the power-law class label distribution.

From our perspective, the key to approaching a document classification problem is to understand and incorporate the semantics of a document into the classification process. Furthermore, classifying documents into a given thesaurus hierarchy can also be supported by exploiting the hierarchy itself. Therefore, our contributions in this paper can be summarized as follows:

1. we show that legal documents have specific properties that can be exploited for the document classification task;
2. we demonstrate how the hierarchical structure of a thesaurus helps to boost the classification results;
3. we describe the influencing parameters of the legal document classification problem;
4. our results suggest that the advantage of using neural networks for the legal document classification problem at hand is lower compared to text classification in other domains.

The remainder of this paper is structured as follows: Section 2 summarizes previous work in this area. The specific properties of legal documents are discussed in Section 3, followed by a description of the EuroVoc thesaurus in Section 4. We then provide details of the evaluation datasets in Section 5. The approaches we used in this paper are presented in Section 6, evaluation results follow in Section 7. Finally, Section 8 concludes the paper.

2 Related Work

Previous research work on classifying legal documents in the EU mostly focuses on documents from the European legal database EUR-Lex, either based on the JRC-Acquis corpus, a multilingual aligned parallel corpus with 20+ languages containing documents taken from the European legal database [28] or another version provided by the Knowledge Engineering Group of the Technical University Darmstadt [19]. The Joint Research Centre (JRC) of the European Commission published the JRC EuroVoc Indexer JEX tool which treats the classification problem as a profile-based ranking task and reaches – on the former corpus – an F-score between 0.44 and 0.54 depending on the language by ranking the typical features of a class which form the profile [27].

One of the core findings in their work is that adjusting the stopwords to the domain (which is already a strong hint on the special nature of language of the legal domain) is the most efficient way to boost classification results. Another approach is proposed by Boella et al. [7] who transform the multi-label into a single-label problem in order to enable processing by a Support Vector Machine. The authors claim to reach an F-score of 0.75 for the Italian version of the JRC-Acquis corpus, however, the algorithm description of Boella et al. in [8] was not reproducible and the results of an F-score of 0.75 on the classification task

cannot be directly deduced from the paper. While details are vague, we suspect that the high F-score is due to the fact that the authors restrict themselves to only the most commonly used labels (above a certain threshold) which makes the classification task significantly easier: one of the main problems in the JRC and EUR-Lex 4K training corpora is that certain labels hardly appear in the training data and in general the label usage is extremely skewed. Other previous work on document classification in the legal domain also shows the common problem of classification tasks with a vast amount of classes and therefore either confirm the bad performance of classification algorithms [19] or approach the problem by reducing the number of classes to boost the results [2, 23]. An exploratory excursion to an ontology-based training-less classification method by Alkhatib et al. [3] shows the same problems of having a skewed class distribution with a micro F-score of 0.29.

From a more general point of view, while text classification dates back to the 1960s, it started to gain a lot of interest from the information systems community in the 1990s with the large availability of digital documents and the rise of the machine learning (ML) paradigm [26]. Tsoumakas and Katakis [29] provide an early overview of multi-label document classification approaches, and the problem transformation strategies which enable classical methods like SVMs to be applied to the multi-label case, for example using binary classifiers for each class separately. In recent years, a lot of work has focused on *extreme classification*, a term which is used for multi-label classification in situations where there is a large number of classes, often with a skewed class distribution, and potentially a large number of documents [30]. Some benchmark datasets, and also real-world applications, contain hundreds of thousands of classes, therefore the focus of extreme classification is not only on prediction accuracy but also on computational performance. The datasets discussed herein (based on EUR-Lex and EuroVoc) fall into the category of *small* extreme classification datasets. Some extreme classification methods like SLEEC [6] reduce the effective number of classes by projecting the output space into a low-dimensional, continuous subspace [9] – similar to the idea of using word embeddings instead of one-hot encoding. Others use a tree hierarchy as a structural constraint, where trees or forests filter a fraction of classes on each node visited [22]. This leads to logarithmic prediction time. Finally, Yen et al. [30] present a greedy algorithm that combines the low runtime complexity of the primal-dual sparse approach with the simple parallelization of training and the small memory footprint of one-versus-all approaches.

Taking different routes, some authors exploit semantic methods [5] or specific sub-domains like sentiment classification [18]. Many surveys explore the area of text mining in general or describe classification methods in particular [1, 4, 12]. Our idea in the present work is – inspired by these related works – also attempting to take into account both the semantics and the hierarchical tree structure of the EuroVoc thesaurus and its keywords, in order to boost performance of multi-label document classification/labeling.

Table 1. Multi-label datasets

Dataset	Domain	# Doc	# Labels	Avg. # tokens	Std. Dev.	Skewness	Kurtosis
JRC-Acquis V3	Legal	17,519	3,563	3,065.90	8,931.94	8.61	112.82
EUR-Lex 4K	Legal	19,513	3,969	3,021.38	8,606.06	7.74	88.98
Reuters-21578	News	21,578	120	151.05	152.16	7.05	54.37

3 Legal Documents

We consider legal documents as documents with the purpose to transport legal information, from supra-national organizations like the European Union as well as from national governments, such as treaties, regulations or law gazettes. Compared to other corpora typically used for document classification [20], legal documents have linguistic features as they are written in a very domain-specific and typed language (eg. specific terms are always used to indicate the same circumstances to avoid ambiguity problems) and structural features, hence legal documents from specific jurisdictions follow a known structure for each document type.

Table 1 presents some metrics of two legal datasets (JRC-Acquis V3 and EUR-Lex 4K) compared to the popular Reuters-21578 dataset from the news domain, which is comparable in the number of documents in the corpus, but it includes only 120 classes to classify the documents, which is less than 5% of the possible EuroVoc labels in legal datasets. In addition, the length of news documents is much shorter than the documents from the legal domain. The skewness describes the symmetry of the label distribution. A skewness value in the range -0.5 to 0.5 describes a symmetrical distribution and a high positive or negative skewness value indicates highly asymmetrical, hence highly skewed data. Comparing the skewness values for all three datasets we can clearly see that label usage in all three datasets is highly skewed. The kurtosis of a dataset refers to the outliers in the distribution, with a value of 0 showing that the distribution follows the standard distribution. All three datasets have a positive kurtosis indicating larger tails, and a power-law distribution of labels usage.

4 The EuroVoc Thesaurus

The EuroVoc thesaurus¹¹ is published by the Publications Office of the European Union and has been updated regularly since 1982. The goal of the thesaurus is to standardize the language used by EU institutions and to provide a hierarchy of terms organized in 21 domains, 127 microthesauri and more than 500 top terms available in all EU member state languages. The most recent version of the thesaurus is version 4.9 which was released at the end of March 2019. The terms (also called descriptors, classes or labels) can have a hierarchical relationship to

¹¹ <http://eurovoc.europa.eu/>

Listing 1.1. EuroVoc example

```
@prefix ev: <http://eurovoc.europa.eu/> .
@prefix dcterms: <http://purl.org/dc/terms/> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .

ev:100180
  dcterms:identifier ''100180'' ;
  skos:prefLabel ''1216 criminal law''@en ;
  skos:hasTopConcept ev:573 .
ev:573
  dcterms:identifier ''573'' ;
  skos:prefLabel ''criminal law''@en ;
  skos:topConceptOf ev:100180 .
ev:575
  dcterms:identifier ''575'' ;
  skos:prefLabel ''international criminal law''@en ;
  skos:broader ev:573 ;
  skos:inScheme ev:100180 .
```

broader or *narrower* terms as well as an associative relationship to *related* terms. In the creation process of the thesaurus the creators tried to limit the polyhierarchy and all classes are assigned to a single domain or microthesaurus that seemed most logical for an average user [10]. The EuroVoc thesaurus contains around 6,900 concepts and is available for download as Resource Description Framework (RDF) or Extensible Markup Language (XML), as well as accessible via a SPARQL endpoint¹².

The thesaurus is organized using the *Simple Knowledge Organization System (SKOS)*¹³ and *Dublin Core Metadata Initiative (DC)*¹⁴ vocabularies to describe the above-mentioned hierarchical relationships and properties of the classes as illustrated in Listing 1.1, which shows an excerpt of the hierarchy and relationships used in EuroVoc. The identifier of each EuroVoc class is described using the `dcterms:identifier` and labels for the different languages (indicated with a language tag) of the EU member states are available as *preferred* using `skos:prefLabel` and *non-preferred* using `skos:altLabel` terms. Hierarchical relationships are expressed with `skos:topConceptOf` linking the top terms with the associated microthesaurus and `skos:inScheme` to link all concepts of lower hierarchies to the corresponding microthesaurus. The hierarchy below the top terms of the microthesaurus is described using `skos:broader` and `skos:narrower`. Hence the microthesaurus in the shown example is *1216 criminal law* (microthesauri are indicated with a four-digit number) and it has (among others) a top concept *573*, which is called *criminal law*, which itself has a narrower term *international criminal law*. It must be noted that `ev:573` does not have a predicate `skos:narrower` but instead the hierarchy must be approached in a bottom-up manner. The example also illustrates that the top term and the microthesaurus are linked via `skos:topConceptOf` and `skos:hasTopConcept` while the lower terms are only linked to the microthesaurus via `skos:inScheme`.

¹² <http://publications.europa.eu/webapi/rdf/sparql>

¹³ <https://www.w3.org/2004/02/skos/>

¹⁴ <http://www.dublincore.org/specifications/dublin-core/dcmi-terms/>

Table 2. Overview of dataset features

Dataset	Dataset Version	# Doc	# Labels	Label Cardinality	Avg. # Doc / Label
JRC-Acquis V3	Full	17,519	3,563	5.41	26.62
JRC-Acquis V3	Topterms	17,519	489	4.59	164.21
JRC-Acquis V3	Microthesauri	17,519	126	4.60	634.88
EUR-Lex 4K	Full	19,513	3,969	5.39	26.15
EUR-Lex 4K	Topterms	19,513	512	4.65	177.02
EUR-Lex 4K	Microthesauri	19,513	126	4.82	741.59
Reuters-21578	-	21,578	120	1.26	202.57

Due to the limited polyhierarchy (in almost all cases each class belongs to only one superclass) we can exploit the hierarchy to reduce the number of classes that a document can be assigned to. For instance, a document labelled with *international criminal law* can also be labelled with its top term *criminal law* or even the microthesaurus *criminal law*.

5 Datasets

We use two legal corpora for our experiments. The *EU Acquis Communautaire* is the collection of the legal documents and obligations within the European Union containing regulations, directives, decisions, treaties and many more. Version 3 of the JRC-Acquis corpus contains documents in various languages from institutions of the European Union dating from 1958 to 2006. The number of documents per language is around 20,000. The English version, which we use in this paper, contains 20,682 documents in XML format. The documents have been manually classified into the different EuroVoc classes and include the identifiers of the respective EuroVoc classes [28]. The JRC-Acquis corpus, which is the property of the European Commission, is available free of charge for commercial and non-commercial use under the provisions laid out in the Commission Decision of the 12th of December 2011¹⁵. Our second dataset, the EUR-Lex 4K dataset also consists of documents taken from the EUR-Lex database provided by the Technical University of Darmstadt [19]. Both datasets contain documents annotated with EuroVoc classes. The most important dataset properties, of the test datasets we created from these corpora are summarized in Table 2: we created two additional dataset versions from the original (*Full*) datasets, which contain the document and class assignments as they are provided. The *Topterms* and *Microthesauri* versions are based on the original EuroVoc class assignments but exploit the hierarchy to reduce the number of different classes. Note that, although as mentioned above there are 20,682 documents in the original JRC dataset, only 17,519 documents are actually annotated with EuroVoc classes. We pruned non-annotated documents from the dataset and kept only those documents which actually have

¹⁵ https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2011.330.01.0039.01.ENG&toc=OJ:L:2011:330:TOC

EuroVoc classification labels. Furthermore, note that despite the fact that there are more than 6,000 EuroVoc classes available, only 3,563 are actually used by the documents in the full JRC-Acquis dataset. For the creation of the *topterms* version of the dataset we extracted all top terms from the EuroVoc thesaurus and replaced all EuroVoc leaf classes in the full JRC dataset with the top term classes (489) they belong to; similarly the *Microthesauri* version of the dataset is generated by replacing annotations with the unique microthesaurus which they belong to (126). The same approach reduces the number of classes of the EUR-Lex 4k dataset from 3,969 classes to 512 classes for the *Topterms* and again 126 classes for the *Microthesauri* version of the dataset.

The class reduction is based on the hierarchy of the classes in the EuroVoc thesaurus and works as follows: For each EuroVoc class for a given document the *top term* (*microthesaurus*) is looked up and replaced with the found *top term* (*microthesaurus*). Since multiple EuroVoc classes for a document can belong to the same microthesaurus we only take each result once, hence a set. For instance class 575 is a narrower term of class 573, hence we replace 575 with 573. This way we reduce the overall number of classes available for classification by 86% to 489 labels in total. For the *microthesauri* we apply the same procedure and are therefore able to reduce the number of classes to 126. Notice that the EuroVoc thesaurus has 127 microthesauri of which we use only 126. The 127th microthesaurus is a general microthesaurus to which every EuroVoc class belongs. Hence, this missing microthesaurus does not contribute to the classification problem and has therefore been removed.

The label cardinality describes the average number of EuroVoc classes assigned to each document. Documents from the original dataset have 5.41 class labels on average. The decrease of the label cardinality for the *topterms* (4.59) and *microthesauri* (4.6 classes per document) versions of the dataset is caused by going up the hierarchy in the EuroVoc thesaurus and reducing the number of classes. Moreover, some documents are annotated with multiple EuroVoc classes sharing the same top term or microthesaurus. The decrease in available EuroVoc classes also affects the number of documents per class. While in the original full dataset there are on average only 27 documents available per class, we have 164 documents per class in the *topterms* and 635 documents per class in the *microthesauri* version of the dataset.

Since the number of documents remains the same for all three versions of the dataset, the average number of tokens per document of 3,066 as well as the standard deviation of $\pm 8,932$.

For comparison we also use version 1.0 of the Reuters-21578 dataset available for research purposes. It contains documents that appeared in the Reuters Newswire which have been manually annotated with 120 classes. The label cardinality is also much lower compared to the two legal datasets, but the learning process can make use of around 200 documents per label.

6 Approach

As discussed before, most standard approaches proposed in the literature are often applied to datasets with only a few classes, but the EuroVoc thesaurus allows for the classification of documents by thousands of classes in a multi-label setting. In addition, as opposed to many other classification tasks, for many standard approaches we first have to transform the raw text into numeric representations. Afterwards the numeric representation can be used with many machine and particularly deep learning approaches for automatic document classification.

6.1 Preprocessing

The first step is to do the preprocessing of the raw text files not only to reduce the size of the documents but also to reduce the runtime of all subsequent processing steps. We opted to separate this preprocessing step from the actual classification process and runtime measurement. Preprocessing includes lowercasing as well as removing stopwords from the text using the standard English NLTK¹⁶ stopword list. We also remove punctuation and special characters from the text as well as replacing all words with their lemma using the spaCy¹⁷ lemmatizer to reduce the morphological variations of each word to their lemma. In addition to these standard preprocessing steps we also include specific preprocessing steps tailored to the legal documents, which include the removal of references to other legal documents (e.g. [...] amended by *Directive 83 / 191 / EEC* [...]) and the removal of all brackets and their contents for the same reason. Also the structure of legal documents can be used in preprocessing in order to remove all headings contained in the documents (e.g. *Article* or *Appendix*).

6.2 Term Frequency - Inversed Document Frequency

The most basic approach used for classification is based on counting the numbers of term occurrences in documents. *Term Frequency (TF)* indicates the number of occurrences of each term in a document. Under the assumption that more important terms occur more often we could say that the higher frequency, the higher the importance (relevancy) of a term. However, there might be terms that occur many times, but are not unique to a particular document in a corpus. For instance, *regulation* might occur very often in legal documents from the European Union but rarely in tweets. To account for the descriptiveness of a term in relation to the entire corpus, term frequency is typically contrasted by *Inverse Document Frequency (IDF)* [15] to measure the descriptive power of a term in a corpus based on the assumption that a term is less descriptive and specific if it appears in a high number of documents. Terms that appear in only a fraction of documents are useful to distinguish those documents from others, and consequently are useful for classification. Finally, the TF-IDF score is the

¹⁶ <https://www.nltk.org/>

¹⁷ <https://spacy.io/>

product of the TF and IDF scores. For our corpus this means that many of the generic domain-specific terms such as *regulation*, *directive*, *commission*, *EC*, *EEC* are considered to have low discriminative power and the remaining terms are weighted higher.

6.3 Word2Vec

In order to apply neural language modeling to large-scale text corpora in a run time-efficient manner, in recent years new methods based on simplified neural network architectures have been proposed. The first, and most well-known approach, in this area is Word2Vec [21]. Word2Vec trains a model on text in an unsupervised way, and as a result generates low-dimensional, dense, floating-point vector representations for each word in the corpus. There is the possibility to download pre-trained models which are trained on different corpora (e.g. from github¹⁸) or to train one's own corpus-specific model. Furthermore, Word2Vec includes two different algorithms for model training, the *Continuous Bag of Words (CBOW)* model and the *skip-gram* model. The former is primarily used to predict a word from a given context, while the latter aims at predicting the context given a word.

First, we tested large-scale pre-trained language models trained with general-purpose text corpora such as GoogleNews and the CommonCrawl, but as expected both performed badly on the legal dataset, for example the CommonCrawl model reached an F-score of 0.38 and the GoogleNews model an F-score of 0.31. Therefore, we opted to train our own model based on the JRC-Acquis corpus. Despite the fact that for using Word2Vec the corpus size typically has a large impact on model quality, we achieve better results by training a model on our 17,519 documents than reusing the large pre-trained models: at the very least, this seems to confirm our base assumption that generic language models do not work well on the domain-specific language used in legal documents. As for the training parameters we use the standard settings with a vector size of 300 and a minimum count of 1 due to the homogeneous corpus and in order to capture very specific words in legal documents. We use the CBOW model for the classification task because it outperforms skip-gram by more than 15% in terms of the F-score (0.4 for skip-gram vs 0.55 for CBOW). We employ a simple method to create the document vectors by summing up the vectors of all words contained in a document and computing an average vector. Our assumption is that these average vectors of documents specific to a given document topic (represented by their EuroVoc classifications) are similar.

6.4 Doc2Vec

While Word2Vec creates global word representations, Doc2Vec creates a vector for an entire document. Doc2Vec uses word vectors and extends the vectors by adding paragraph vectors which allows for the predictions of words in the

¹⁸ <https://github.com/3Top/word2vec-api/#where-to-get-a-pretrained-models>

context of a paragraph [16]. Similar to Word2Vec, Doc2Vec also allows the user to train two different kinds of models: *Distributed Bag of Words (DBOW)* and *Distributed Memory (DM)*. For our training we use a vector size of 300 and minimum count of 1.

6.5 TF-IDF weighting embeddings

In order to filter the domain corpora, and to exclude generic legal terms without discriminative power in the legal domain, we use the weighting approach as suggested in [17] to remove common words from the embeddings. We achieve this by combining the statistical TF-IDF approach mentioned above, with the word embeddings of Word2Vec and Doc2Vec. In the first step, we calculate the TF-IDF scores for all words in the corpus. Since the number of words varies from document to document and the TF-IDF scores are also different we do not set a hard limit for the TF-IDF scores, instead we calculate the TF-IDF scores for all words in a document and rank them according to these scores. Afterwards we set a threshold for the TF-IDF scores and remove all words with a score below the set threshold. The threshold is set as the top x percent of words, in particular experiments showed that the top 10% of the words are most descriptive and a setting of e.g. 25% of the top words decreases the results. We also cannot set the number of words to be considered to a fixed value (e.g. 10 words per documents) as we do not know the TF-IDF score distribution. The training parameters for Word2Vec and Doc2Vec are the same as in the individual approaches.

For all approaches mentioned above we tried Random Forest (RF) and a Support Vector Machine (SVM). For both algorithms we applied GridSearch to find the best training parameters. We mainly use the standard parameters, but set the *class_weight = balanced* to compensate for the skewed label distribution and $C = 100$ for the SVM. All machine learning tasks are performed using Python 3 and the Scikit-learn library¹⁹.

6.6 fast.ai

As a representative of currently popular (deep) neural network training approaches, we also compared the above-mentioned approaches to the powerful fast.ai²⁰ framework: fast.ai is a library for training fast and accurate neural nets. It is based on deep learning research and tries to incorporate current best practices. The fast.ai framework provides support for different task types, such as computer vision, NLP, tabular data and recommender systems. As for input corpora we experimented both with the pre-processed dataset (see Section 6.1) and the original JRC dataset. In both cases, fast.ai also applies its own pre-processing on top, which includes lowercasing, marking the start and end of sentences, etc. Additionally, fast.ai applies an iterative model training process, which includes two basic steps: (i) fine-tuning a pretrained language model with

¹⁹ <https://scikit-learn.org/stable/>

²⁰ <https://github.com/fastai/fastai>

Table 3. Evaluation results for JRC corpus

Approach	Algorithm	Full			Topterms			Microthesauri		
		P	R	F	P	R	F	P	R	F
Baseline	-	0.44	0.52	0.47	-	-	-	-	-	-
TF-IDF	RF	<i>0.88</i>	0.24	0.37	<i>0.90</i>	0.30	0.45	<i>0.89</i>	0.39	0.55
Word2Vec	SVC	0.52	<i>0.59</i>	0.55	0.43	<i>0.80</i>	0.56	0.50	<i>0.85</i>	0.63
Doc2Vec	SVC	0.74	0.40	0.52	0.65	0.61	0.63	0.71	0.69	0.70
TF-IDF + Word2Vec	SVC	0.62	0.47	0.53	0.54	0.69	0.61	0.59	0.77	0.67
TF-IDF + Doc2Vec	SVC	0.62	0.45	0.52	0.46	0.71	0.56	0.53	0.78	0.63
fast.ai	LSTM	0.61	0.55	0.58	0.70	0.63	0.67	0.75	0.73	0.74

Table 4. Evaluation results for KED corpus

Approach	Algorithm	Full			Topterms			Microthesauri		
		P	R	F	P	R	F	P	R	F
Baseline	-	0.40	0.46	0.42	-	-	-	-	-	-
TF-IDF	RF	<i>0.84</i>	0.12	0.21	<i>0.86</i>	0.20	0.33	<i>0.88</i>	0.34	0.49
Word2Vec	SVC	0.29	<i>0.63</i>	0.40	0.34	<i>0.77</i>	0.47	0.44	<i>0.83</i>	0.57
Doc2Vec	SVC	0.53	0.41	0.46	0.60	0.52	0.56	0.69	0.63	0.66
TF-IDF + Word2Vec	SVC	0.15	0.26	0.19	0.20	0.38	0.26	0.29	0.50	0.36
TF-IDF + Doc2Vec	SVC	0.16	0.25	0.19	0.22	0.36	0.27	0.31	0.47	0.38
fast.ai	LSTM	0.54	0.49	0.52	0.64	0.59	0.61	0.73	0.69	0.71

the domain corpus, and (ii) learning the classifier. The process as well as additional techniques such as slanted triangular learning rates are explained in [13]. In training the models, we follow mostly the recommended architecture given in the fast.ai examples²¹, which in the first basic step includes the finetuning of the provided AWD_LSTM RNN language model with the JRC corpus. When training the multi-label classifier, techniques such as gradual unfreezing of the network, weight decay (set to 0.1) and *momentum* are used. Further, we apply the default loss function for multi-label text classification, BCEWithLogitsLoss.

7 Evaluation and Discussion

In this section we present the experiment results. The experiments using embeddings were carried out on a 2.1 GHz machine with 24 cores and a memory of 246 GB. To run the fast.ai experiments we used a i7-8700 CPU with 3.76 GHz, 16 GB of memory and a GeForce GTX 1080 Ti graphics card. The code for the embedding experiments is available on Google²² and the Jupyter notebooks with all fast.ai related experiments on Github²³.

²¹ <https://nbviewer.jupyter.org/github/fastai/course-v3/blob/master/nbs/dl1/lesson3-imdb.ipynb>

²² <https://drive.google.com/open?id=1P14H1pFNuFvcGQwHjkhcUJ9SMHrYjdQ1>

²³ https://github.com/gwohlgen/JRC_fastai

Table 5. Evaluation results for Reuters-21578 corpus

Approach	Algorithm	Full		
		P	R	F
TF-IDF	RF	<i>0.97</i>	0.63	0.76
Word2Vec	SVC	0.50	<i>0.94</i>	0.66
Doc2Vec	SVC	0.82	0.84	0.83
TF-IDF + Word2Vec	SVC	0.05	0.38	0.09
TF-IDF + Doc2Vec	SVC	0.14	0.27	0.18
fast.ai (no prep)	LSTM	0.90	0.87	0.88
fast.ai (w prep)	LSTM	0.92	0.88	0.90

We evaluate our approaches on three multi-label datasets. Two of these datasets contain legal documents (JRC-Acquis and Eur-Lex 4K), and the Reuters-21578 dataset, which contains news articles for comparison and because this dataset is used in many text classification tasks. The dataset properties are depicted in Table 1. The results for each dataset are presented in a separate table, Table 3 for the JRC-Acquis dataset, Table 4 for the results of the EUR-Lex 4K dataset and finally Table 5 contains the results of the Reuters-21578 dataset. Each result table contains a column indicating the chosen approach for the classification task. Furthermore, for each dataset version (full, toptterms and microthesauri) we present the evaluation metrics *Precision*, *Recall* and *F-score*. A - means that there is no result available. The best result for each dataset version is highlighted in boldface while the best precision and the best recall for each dataset version are highlighted in italic. All results have been achieved using the preprocessed documents and a test set size of 20%.

The evaluation metrics *precision*, *recall* and *F-score* are calculated based on the classification results. *True positive (TP)* refers to the correctly predicted classes. *False positive (FP)* and *False negative (FN)* both indicate wrong prediction results, where a *FP* predicts a class that should not have been predicted and *FN* does not predict a class that should have been predicted [24]:

$$Precision = \frac{TP}{TP+FP}$$

Precision (p) is defined as the share of the *true positive (TP)* divided by the sum of the *true positive* and *false positive (FP)*.

$$Recall = \frac{TP}{TP+FN}$$

Recall (r) is defined as the share of the *true positive* divided by the sum of the *true positive* and *false negative (FN)*.

$$F - score = 2 * \frac{Precision * Recall}{Precision + Recall}$$

F-score (F) is defined as the harmonic mean of *precision* and *recall*. The Precision, Recall and F-score measures of our experiments are provided by the scikit-learn classification matrix.

For the baseline we used the JRC EuroVoc Indexer JEX tool as it can be downloaded with the pretrained english model to calculate the metrics for the JRC-Acquis and EUR-Lex 4K full legal datasets which is uses a profile-based ranking algorithm for text classification [27].

Although we tested Random Forest (RF) and Support Vector Machine (SVM) as learning algorithm, the results show that RF performs better only on TF-IDF while for all other machine-learning approaches SVM is the superior learning algorithm. Furthermore, the results clearly show that RF has the highest precision but also the lowest recall on all three versions of the dataset. The increase of the F-score with the TF-IDF approach also shows that a decrease of candidate classes by 87% leads to an increase of 10% of the F-score.

Looking at the result metrics we can say that using TF-IDF in combination with a Random Forest leads to a very high precision, independent of the number of candidate classes. In contrast, the recall is very low and only shows marginal improvement in the case of reduced classes.

The Word2Vec and Doc2Vec approaches and the combinations of both with TF-IDF show the best results using a SVM. However, there is no clear answer to which approach performs best. Having a look at the results for the full dataset the F-score ranges from 0.52 to 0.57 and therefore perform better than the baseline with the exception of TF-IDF with an F-score of only 0.37. Also the values for precision and recall are evenly distributed. Furthermore, the relation of precision and recall changes with the decreasing number of candidate classes. While the Word2Vec and Doc2Vec precision remains almost steady across all dataset versions (± 0.09), the Word2Vec recall increases strongly from 0.59 to 0.85 (+0.26) for Word2Vec and from 0.40 to 0.69 (+0.29) for Doc2Vec on the JRC dataset. The increase of precision and recall on the EUR-Lex 4K is a little bit lower compared to the JRC dataset, but still shows a good increase over the different dataset versions.

The TF-IDF weighting approaches do not show an increase on the overall performance compared to the individual Word2Vec/ Doc2Vec approach for both legal datasets. Only on the JRC dataset the TF-IDF + Word2Vec performs better than Word2Vec only, but solely on the dataset versions with the reduced number of classes. The performance of TF-IDF + Doc2Vec is always lower compared to Doc2Vec. For the EUR-Lex 4K dataset the TF-IDF weighting approach the metrics are much lower compared to the individual approaches.

Our approach using a neural network with language model transfer learning and the deep LSTM architecture of fast.ai delivers the best F-scores on all three versions of the dataset although it never has the best precision or recall values. Depending on the threshold value for label selection the precision and recall change, thus we used a threshold which provides a good F1 result. The results also demonstrate that the multi-label document classification with such a high number of classes and a strongly biased class distribution is very complex and very hard to handle even for deep neural networks which have proven to be very successful in recent year on a variety of NLP tasks. On the full dataset fast.ai performs only 3% better than the non-neural network approach using

Word2Vec. The advantage of fast.ai on topterms and microthesauri datasets the JRC dataset is 4% in both cases. The metrics for the EUR-Lex 4K dataset are lower in general, but fast.ai performs better by 6% on the full and 5% on the topterms and microthesauri dataset versions.

The Reuters-21578 results show the impact of the low number of classes in combination with the lower label cardinality. The best approach using embeddings is Doc2Vec with an F-score of 0.83, while the highest precision is achieved by TF-IDF and the highest recall by Word2Vec. Also fast.ai outperforms all other approaches with an F-score of 0.9.

Overall, we can say that prediction performance significantly increases with the reduction of the number of candidate classes by taking advantage of the hierarchy of terms, and that a neural network outperforms classic approaches. However, the differences in the results are small and therefore a final answer as to which approach performs best cannot be given. Particularly, predicting rare labels instead of resorting to the coarser, upper level prediction, is, as expected hardly possible, due to the lack of training data for rare labels. We hope, in the future to address this issue by investigating new methods to combine coarse-label and fine-label predictions and exploit other semantic connections to also enable predictions of these rare terms.

8 Conclusion

In this paper we investigate document classification approaches exemplified on the legal domain and contrast them with a dataset that is commonly used for such tasks. The results show that document classification in the legal domain is a very challenging task, which is also due to the legal datasets which are highly skewed and use a vast number of classes. We compared six different approaches encompassing a statistical method, methods using vector space embeddings and a neural network approach tested on two legal datasets (JRC-Acquis and EUR-Lex 4K), both domain-specific corpora from the legal domain containing legal documents published by the organizations of the European Union from 1958 to 2006. We classified the documents based on categories from the EuroVoc thesaurus, which contains more than 6000 candidate classes. The results of our experiments show that approaches taking the semantics into account work better than purely statistical approaches, but there is not much difference in the results among the remaining approaches. Furthermore we used the Reuters-21578 dataset containing around 20,000 news articles classified into 120 different classes to demonstrate the general applicability of our approach which shows very good results on a heterogeneous corpus with a low label cardinality. We are following a general approach which in theory should also work for other domains which provide a thesaurus that could be used for the classification task. For the same reason, an evaluation of the approaches we presented fails due to missing gold standard datasets for case laws or other legal documents like contracts. These kind of documents are usually not available to the public and if they are available they are not annotated.

In future work we will investigate the automatic creation of a domain-specific corpus to allow for additional training data in this field. The idea is to add additional documents specific for particular EuroVoc classes to get enhanced class descriptions. Another interesting avenue for exploration is to add external documents giving definitions of the EuroVoc classes and sharpen their semantic profile which could in turn be used for a semantic similarity comparison of documents with the individual EuroVoc classes.

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