

# Big Data and Automated Content Analysis (12EC)

## Week 6: »Supervised Approaches to Text Analysis«

Wednesday

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# Today

## Supervised Machine Learning for Text Classification

One step back: (Traditional) non-SML approaches

Diving into SML

An implementation

Classifiers

Vectorizers

Summing up

Revisiting the difference between the dictionary approach and the SML

A note on the input data

Next steps

This week, we will bring together our knowledge about machine learning and about BOW-representations of text.

It's the **combination** of week 5 and week 6!

# Supervised Machine Learning for Text Classification

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## Boumans and Trilling, 2016: Types of Automated Content Analysis

	Methodological approach		
	Counting and Dictionary	Supervised Machine Learning	Unsupervised Machine Learning
Typical research interests and content features	visibility analysis sentiment analysis subjectivity analysis	frames topics gender bias	frames topics
Common statistical procedures	string comparisons counting	support vector machines naive Bayes	principal component analysis cluster analysis latent dirichlet allocation semantic network analysis



## Recap: Supervised vs Unsupervised

## Supervised machine learning

You have a dataset with both predictor and outcome (independent and dependent variables; features and labels) — a *labeled* dataset. Think of regression: You measured  $x_1$ ,  $x_2$ ,  $x_3$  and you want to predict  $y$ , which you also measured

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## Unsupervised machine learning

You have no labels. (You did not measure  $y$ )





## Recap: Supervised vs Unsupervised

## Unsupervised machine learning

You have no labels. (You did not measure  $y$ )

You might already know *some* techniques to figure out whether  $x_1, x_2, \dots, x_i$  co-occur

- Principal Component Analysis (PCA) and Singular Value Decomposition (SVD)
- Cluster analysis
- Topic modelling (Non-negative matrix factorization and Latent Dirichlet Allocation)

# Supervised Machine Learning for Text Classification

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One step back: (Traditional) non-SML approaches

## Let's consider three tasks

For a given text (say, a news article, a press release, a review), determine the

**sentiment** e.g., [positive|neutral|negative]

**topic** e.g., [sports|economy|politics|entertainment|other]

**frames** e.g., [economic|human|moral|conflict], or  
non-exclusive: economic = [0|1], human = [0|1], ...



*What would be the strengths and weaknesses of different approaches from the classification by Boumans and Trilling, 2016 for each of these tasks?*



*Imagine using a dictionary-based (list of keywords, list of regular expressions, or similar) approach to these tasks. How does the design (length, inclusiveness, etc.) of this list influence precision and recall?*

# Dictionary-based approaches for text classification

## good for

- distinct, manifest things  
(names of organizations,  
pronouns, swearwords (?),  
...)
- little room for interpretation/  
misunderstandings etc.
- “must-be-explainable-to-a-  
five-year-old”

## bad for

- latent constructs and  
concepts
- implicit things

Hence, *not* state-of-the-art for

- topics
- frames
- sentiment

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Let's discuss SML for text with the example  
of **sentiment analysis**.

# From dictionary approaches to SML

- Early days of sentiment analysis: list of positive words, list of negative words, count what occurs most
- You can even *buy* lists of words that are meant to measure constructs like “positive emotions” or even “analytic” or “authentic” language use from a psychologist (LIWC, Pennebaker et al., 2007)

# From dictionary approaches to SML

- Early days of sentiment analysis: list of positive words, list of negative words, count what occurs most
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*What do you think? Can this even work?*

# Bag-of-words dictionary approaches to sentiment analysis

## con

- simplistic assumptions
- e.g., intensifiers cannot be interpreted (“really” in “really good” or “really bad”)
- or, even more important, negations.

# Improving the BOW approach

## Example: Sentistrength (Thelwall et al., 2012)

- $-5 \dots -1$  and  $+1 \dots +5$  instead of positive/negative
- spelling correction
- “booster word list” for strengthening/weakening the effect of the following word
- interpreting repeated letters (“baaaaaad”), CAPITALS and !!!
- idioms
- negation

VADER by Hutto and Gilbert, 2014 works in a similar way. Even though this is much less naïve than LIWC, for instance, the problem remains: Can we construct a dictionary that, *irrespective of the context*, gives us a meaningful estimate of sentiment?

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Such an *off-the-shelf* dictionary does not  
(and probably cannot) exist.

## Boukes et al., 2020: Sentiment analysis of economic news

<i>All tones combined (overall score)</i>					
	$F_1$		$n$ (human coding)	precision	recall
Recession	0.26		4640	0.30	0.43
Damstra and Boukes (2018)	0.32		4640	0.52	0.45
LIWC	0.42		4640	<b>0.53</b>	<b>0.48</b>
SentiStrength	0.42		4640	0.45	0.45
Pattern	0.41		4640	0.45	0.45
Polyglot	<b>0.43</b>		4640	0.44	0.44
DANEW	<b>0.43</b>		4640	0.46	0.45
<i>Negative Tone</i>					
	$F_1$	$n$ (predicted)	$n$ (human coding)	precision	recall
Recession	0.00	6	1524	0.33	0.00
Damstra and Boukes (2018)	0.08	99	1524	<b>0.62</b>	0.04
LIWC	0.29	471	1524	<b>0.62</b>	0.19
SentiStrength	0.39	1158	1524	0.45	0.34
Pattern	0.30	692	1524	0.48	0.22
Polyglot	<b>0.42</b>	1158	1524	0.48	<b>0.37</b>
DANEW	0.36	794	1524	0.52	0.27
<i>Neutral Tone</i>					
	$F_1$	$n$ (predicted)	$n$ (human coding)	precision	recall
Recession	<b>0.60</b>	4634	2008	0.43	<b>1.00</b>
Damstra and Boukes (2018)	<b>0.60</b>	4366	2008	0.44	0.96
LIWC	<b>0.60</b>	3750	2008	<b>0.46</b>	0.86
SentiStrength	0.55	3103	2008	0.45	0.70
Pattern	0.56	3260	2008	0.45	0.74
Polyglot	0.47	2231	2008	0.45	0.50
DANEW	0.53	2776	2008	<b>0.46</b>	0.63
<i>Positive tone</i>					
	$F_1$	$n$ (predicted)	$n$ (human coding)	precision	recall
Recession	0.00	0	1108	0.00	0.00
Damstra and Boukes (2018)	0.14	175	1108	<b>0.53</b>	0.08
LIWC	0.29	419	1108	0.52	0.20
SentiStrength	0.22	379	1108	0.42	0.14
Pattern	0.30	688	1108	0.39	0.24
Polyglot	<b>0.39</b>	1251	1108	0.37	<b>0.42</b>
DANEW	0.36	1070	1108	0.37	0.35

# Boukes et al., 2020: Sentiment analysis of economic news

**Table A1.** Correlations between sentiment scores using different methods for headlines (above) and full texts (below).

	Headline							
	Manual coding	Recession	D & B	LIWC	SentiStrength	Pattern	Polyglot	DANEW
Manual coding	1.00 ***							
Recession	-	-						
Damstra and Boukes (2018)	0.16 ***	-	1.00 ***					
LIWC	<b>0.30 ***</b>	-	0.16 ***	1.00 ***				
SentiStrength	0.24 ***	-	0.08 **	0.26 ***	1.00 ***			
Pattern	0.22 ***	-	0.00	0.30 ***	0.22 ***	1.00 ***		
Polyglot	0.30 ***	-	0.19 ***	0.32 ***	0.37 ***	0.26 ***	1.00 ***	
DANEW	0.24 ***	-	0.04	<b>0.43 ***</b>	0.33 ***	0.23 ***	0.32 ***	1.00 ***
	Full text							
	Manual coding	Recession	D & B	LIWC	SentiStrength	Pattern	Polyglot	DANEW
Manual coding	1.00 ***							
Recession	-0.06 *	1.00 ***						
Damstra and Boukes (2018)	0.27 ***	-0.16 ***	1.00 ***					
LIWC	0.39 ***	0.02	0.27 ***	1.00 ***				
SentiStrength	0.17 ***	-0.01	0.10 ***	0.18 ***	1.00 ***			
Pattern	0.13 ***	-0.02	0.04	0.28 ***	0.12 ***	1.00 ***		
Polyglot	0.26 ***	0.05	0.17 ***	0.41 ***	0.21 ***	0.30 ***	1.00 ***	
DANEW	0.15 ***	0.06 *	0.05	0.36 ***	0.18 ***	0.29 ***	0.37 ***	1.00 ***

The word "recession" did not occur in headlines of our sample, as such, no correlation coefficient is available for the recession classifier; \*\*\*  $p < .001$ , \*\*  $p < .010$ , \*  $p < .05$ .

## Boukes et al., 2020: Sentiment analysis of economic news

- Dictionaries have low agreement with each other, and also with human coders
- Even their own dictionary didn't agree
- **This is not because these dictionaries are particularly bad!**. Main point: For such a complex and context-dependent task, a dictionary is just not the right tool.

## van Atteveldt et al., 2021: Extending Boukes et al., 2020 with SML

“manual coding (using undergraduate students) yields the best results

[...] A good second place is taken by crowd coding [...]

[...] machine learning performs worse than both students' manual coding and crowd coding. Reaching  $\alpha = 0.50$  for deep learning (CNN) and slightly worse for classical machine learning (SVM;  $\alpha = 0.41$ , NB;  $\alpha = 0.40$ ), machine learning still performs significantly better than chance. However, since these results are lower than generally accepted levels of inter-coder reliability [...]

Finally, [...] dictionaries [...] perform worse than the machine learning results and much worse than manual annotation [...] [and] approximate chance agreement”

# Vermeer et al., 2019: Satisfaction with brands

Category	Technique	Accuracy	Precision	Recall
<b>Satisfaction (<math>N = 854</math>)</b>				
Sentiment analysis	LIWC	0.05	0.06	0.04
	P	0.04	0.04	0.04
	SN	0.07	0.07	0.08
Dictionary-based	D	0.15	0.30	0.10
Machine learning	BNB	0.38	0.44	0.34
	MNB	0.32	0.67	0.21
	LR	0.51	0.38	0.76
	SGD	0.49	0.38	0.69
	SVM	0.52	0.41	0.63
	PA	0.50	0.40	0.68
<b>Neutral (<math>N = 760</math>)</b>				
Sentiment analysis	LIWC	0.13	0.16	0.10
	P	0.13	0.13	0.14
	SN	0.19	0.16	0.22
Dictionary-based	D	0.14	0.35	0.09
Machine learning	BNB	0.28	0.25	0.32
	MNB	0.15	0.34	0.10
	LR	0.37	0.25	0.74
	SGD	0.33	0.23	0.60
	SVM	0.36	0.24	0.69
	PA	0.34	0.24	0.60
<b>Dissatisfaction (<math>N = 267</math>)</b>				
Sentiment analysis	LIWC	0.20	0.15	0.29
	P	0.19	0.12	0.40
	SN	0.22	0.14	0.54
Dictionary-based	D	0.09	0.41	0.05
Machine learning	BNB	0.26	0.20	0.40
	MNB	0.25	0.48	0.16
	LR	0.35	0.23	0.77
	SGD	0.39	0.32	0.48
	SVM	0.04	0.02	1.00
	PA	0.35	0.23	0.71

Note. LIWC Linguistic Inquiry and Word Count; P Pattern; SN, Sentiment Net; D Dictionary-based; BN Bernoulli Naïve Bayes; MNB Multinomial Naïve Bayes; LR Logistic Regression; SGD Stochastic Gradient Descent; SVM Support Vector Machine; and PA Passive Aggressive. Performance scores  $\geq 0.60$  have been highlighted. Results merely derived from the test set.

SML is no panacea, but the most promising approach to analyzing large quantities of texts. Don't believe off-the-shelf packages that claim to do the work for you. (For small datasets, just do it by hand.)

# Supervised Machine Learning for Text Classification

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Diving into SML



# SML to code frames and topics

Some work by Burscher et al., 2014 and Burscher et al., 2015

- Humans can code generic frames (human-interest, economic, ...)
- Humans can code topics from a pre-defined list
- But it is very hard to formulate an explicit rule (as in: code as 'Human Interest' if regular expression R is matched)

⇒ This is where you need supervised machine learning!

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TABLE 4  
Classification Accuracy of Frames in Sources Outside the Training Set

	<i>VK/NRC</i> <i>→ Tel</i>	<i>VK/TEL</i> <i>→ NRC</i>	<i>NRC/TEL</i> <i>→ VK</i>
Conflict	.69	.74	.75
Economic Cons.	.88	.86	.86
Human Interest	.69	.71	.67
Morality	.97	.90	.89

*Note.* VK = Volkskrant, NRC = NRC/Handelsblad, TEL = Telegraaf

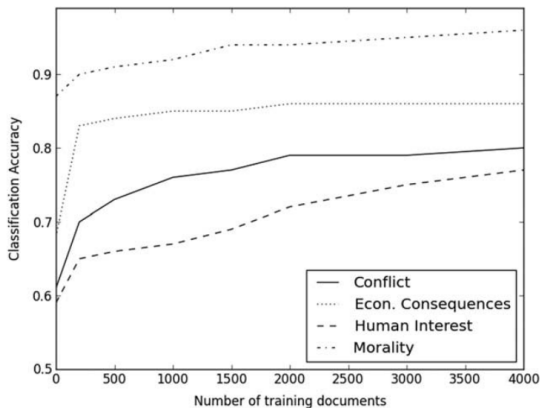


FIGURE 1 Relationship between classification accuracy and number of training documents.

FIGURE 1

Learning Curves for the Classification of News Articles and PQs

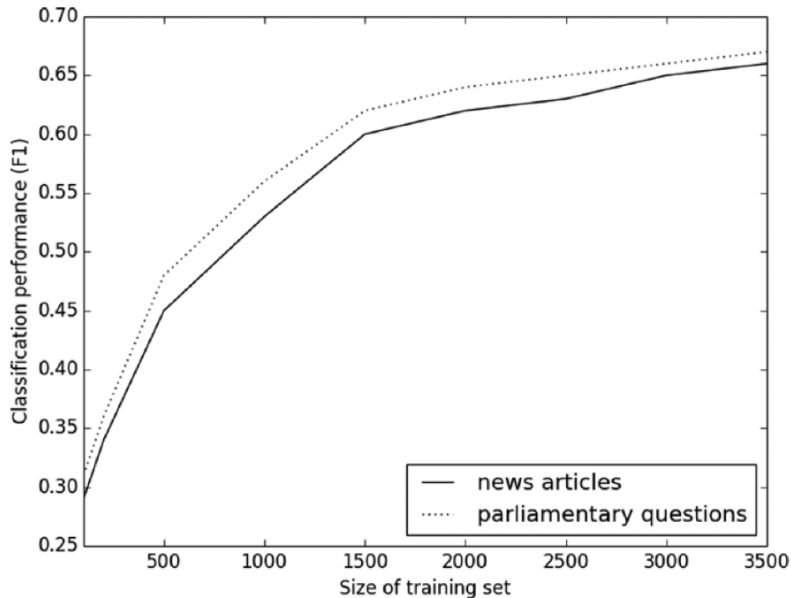


TABLE 1

## F1 Scores for SML-Based Issue Coding in News Articles and PQs

Issue	News Articles			PQs	
		All Words	Lead Only		All Words
Features	N	F1	F1	N	F1
Macroeconomics	413	.54	.63	172	.46
Civil rights and minority issues	327	.34	.28	192	.53
Health	444	.70	.71	520	.81
Agriculture	114	.72	.76	159	.66
Labor and employment	217	.43	.49	174	.58
Education	188	.79	.71	229	.78
Environment	152	.34	.44	237	.59
Energy	81	.35	.59	67	.66
Immigration and integration	150	.50	.57	239	.78
Transportation	416	.58	.67	306	.81
Law and crime	1198	.70	.69	685	.77
Social welfare	115	.33	.34	214	.54
Community development and housing	113	.45	.44	136	.72
Banking, finance, and commerce	622	.62	.67	188	.58
Defense	393	.59	.55	196	.71
Science, technology, and communication	426	.64	.59	57	.53
International affairs and foreign aid	1,106	.70	.64	352	.65
Government operations	1,301	.71	.72	276	.48
Other issue	3,322	.84	.80	360	.51
Total	11,089	.71	.68	4,759	.69

NOTE: The F1 score is equal to the harmonic mean of recall and precision. Recall is the fraction of relevant documents that are retrieved, and precision is the fraction of retrieved documents that are relevant.

# What does this mean for our research?

It we have 2,000 documents with manually coded frames and topics. . .

- we can use them to train a SML classifier
- which can code an unlimited number of new documents
- with an acceptable accuracy (at least for some of them)

Some easier tasks even need only 500 training documents, see Hopkins and King, 2010.

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# Supervised Machine Learning for Text Classification

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An implementation

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Let's say we have two list of tuples with movie reviews and their rating:

```
1 reviews_train = ["This is a great movie", "Bad movie", ... ...]
2 labels_train = [1,-1, ...]
```

And a second dataset with an identical structure:

```
1 reviews_test = ["Not that good","Nice film", ... ...]
2 labels_text = [-1,1, .....]
```

Both are drawn from the same population, it is pure chance whether a specific review is on the one list or the other.

Based on an example from <http://blog.dataquest.io/blog/naive-bayes-movies/>

# Training a Naïve Bayes Classifier

```

1  from sklearn.naive_bayes import MultinomialNB
2  from sklearn.feature_extraction.text import CountVectorizer
3  from sklearn import metrics
4
5  # This is just an efficient way of computing word counts
6  vectorizer = CountVectorizer(stop_words='english')
7  features_train = vectorizer.fit_transform(reviews_train)
8  features_test = vectorizer.transform(reviews_test)
9
10 # Fit a naive bayes model to the training data.
11 nb = MultinomialNB()
12 nb.fit(features_train, labels_train)
13
14 # Now we can use the model to predict classifications for our test
15 ↪ features.
16 predictions = nb.predict(features_test)
17
18 print(f"Precision:\t{metrics.precision_score(labels_test, predictions,
19 ↪ pos_label=1, labels = [-1,1])}")
20 print(f"Recall:\t{metrics.recall_score(labels_test, predictions,
21 ↪ pos_label=1, labels = [-1,1])}")

```

# And it works!

Using 50,000 IMDB movies that are classified as either negative or positive,

- I created a list with 25,000 training tuples and another one with 25,000 test tuples and
- trained a classifier
- with precision and recall values  $> .80$

Dataset obtained from <http://ai.stanford.edu/~amaas/data/sentiment>, Maas, A.L., Daly, R.E., Pham, P.T., Huang, D., Ng, A.Y., & Potts, C. (2011). Learning word vectors for sentiment analysis. *49th Annual Meeting of the Association for Computational Linguistics (ACL 2011)*

# Playing around with new data

```
1 newdata=vectorizer.transform(["What a crappy movie! It sucks!", "This  
  ↳ is awesome. I liked this movie a lot, fantastic actors", "I would  
  ↳ not recommend it to anyone.", "Enjoyed it a lot"])  
2 predictions = nb.predict(newdata)  
3 print(predictions)
```

This returns, as you would expect and hope:

```
1 [-1  1 -1  1]
```

# But we can do even better

We can use different vectorizers and different classifiers.

# Supervised Machine Learning for Text Classification

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## Classifiers

# Different classifiers

Typical options in a nutshell:

- Naïve Bayes
- Logistic Regression
- Support Vector Machine (SVM/SVC)
- Random forests



# Supervised Machine Learning for Text Classification

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Vectorizers

## Different vectorizers

1. CountVectorizer (=simple word counts)
2. TfidfVectorizer (word counts ("term frequency") weighted by number of documents in which the word occurs at all ("inverse document frequency"))

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$$tfidf_{t,d} = tf_{t,d} \cdot idf_t$$

There are different ways to weigh the idf score. A common one is taking the logarithm:

$$idf_t = \log \frac{N}{n_t}$$

where  $N$  is the total number of documents and  $n_t$  is the number of documents containing term  $t$

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## Different vectorizer options

- Preprocessing (e.g., stopword removal)
- Remove words below a specific threshold (“occurring in less than  $n = 5$  documents”)  $\Rightarrow$  spelling mistakes etc.
- Remove words above a specific threshold (“occurring in more than 50% of all documents”)  $\Rightarrow$  de-facto stopwords
- Not only to improve prediction, but also performance (can reduce number of features by a huge amount)

# Which one would you (not) use for which purpose?

## NB with Count

	precision	recall
positive reviews:	0.87	0.77
negative reviews:	0.79	0.88

## NB with TfIdf

	precision	recall
positive reviews:	0.87	0.78
negative reviews:	0.80	0.88

## LogReg with Count

	precision	recall
positive reviews:	0.87	0.85
negative reviews:	0.85	0.87

## LogReg with TfIdf

	precision	recall
positive reviews:	0.89	0.88
negative reviews:	0.88	0.89

## Summing up

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## Summing up

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Revisiting the difference between the dictionary approach and the SML





*But isn't that then essentially very much like a dictionary, except that the words have different weights?*

In some sense, yes.

- But we don't pretend that we can construct the dictionary *a priori*.
- It's specifically tailored to our use-case.
- The weights are *really* essential here.

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- But we don't pretend that we can construct the dictionary *a priori*.
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- The weights are *really* essential here.

We *could* print all coefficients-word pairs, but probably it's enough to just look at those with the largest absolute value:

# ELI5

```
In [98]: import eli5
          eli5.show_weights(pipe, top=10)
```

Out[98]: v=1 top features

Weight <sup>2</sup>	Feature
+9.043	great
+8.487	excellent
+6.908	perfect
... 37662 more positive ...	
... 37178 more negative ...	
-6.507	worse
-7.347	poor
-8.341	boring
-8.944	waste
-8.976	bad
-9.152	awful
-12.749	worst

```
In [111]: eli5.show_prediction(clf, test[0][0], vec=vec)
```

```
Out[111]: y=1 (probability 0.844, score 1.689) top features
```

Contribution <sup>?</sup>	Feature
+1.920	Highlighted in text (sum)
-0.232	<BIAS>

It is a rare and fine spectacle, an allegory of death and transfiguration that is neither preachy nor mawkish, a work of mature and courageous insight, northfork avoids arthouse distinction by refusing to belong to a kind. unlike the most memorable and accomplished film to impose an obvious comparison, wim wenders' 1987 wings of desire (der himmel über berlin), it sustains an ambivalence in a narrative spectrum spanning from the mundane to the supernatural. this story of earthly and celestial eminent domains in the american west withholds the fairytale literalness that marked its german predecessor in the ad hoc genre of angels shedding their wings with obsequious sentimentalism. Its celestial transcendence, be it inspired by doleful faith or impelled by a fever dream, never parts ways with crud and rot. this firm grounding redounds to great credit for writers and directors mark and michael polish.

# ELI5

- Inspecting *all* coefficients of a ML model usually doesn't make much sense
- But that does not mean that we cannot understand how the model makes its predictions
- We can look at the most important coefficients
- We can look which words in a given text contributed most to its classification

## But have we solved all problems of dictionaries?

No.

For instance, the negation and/or intensifier problem.

## Possible approaches

- $n$ -grams as features
- preprocessing (?)
- deep learning
- ...



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## Possible approaches

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- ...

⇒ But ultimately, it's just an empirical question how big the problem is!

## Summing up

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A note on the input data

# The input scikit-learn expects

A training dataset consisting of:

1. an array (e.g., a list) of labels (`y_train`)
2. a corresponding array (e.g., a list) of feature vectors (`X_train`)

A test dataset consisting of:

1. an array (e.g., a list) of labels (`y_test`)
2. a corresponding array (e.g., a list) of feature vectors (`X_test`)

The feature vectors can be created via a *vectorizer*, but could in principle also just be lists themselves.

We use a lowercase `y` because it is a onedimensional vector, and an uppercase `X` because it is a two-dimensional matrix.

## The input scikit-learn expects

- It does not matter *how* you create  $y$  and  $X$ !
- Getting data into the right shape can be as much work (or more) as training the classifier itself

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- It does not matter *how* you create  $y$  and  $X$ !
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Typical techniques:

- Reading text files from folders into lists of strings (looping over folder contents)
- Reading from csv file either directly into lists (`csv` module) or via `pandas`
- List comprehension to restructure or process data
- Potentially, you need to split into train and test dataset yourself (with slicing, or with `scikit-learn` itself)

## Looking forward: Beyond classic SML

Note that classic SML is still based on word frequencies with weights (and hence cannot solve all problems we started off with). State-of-the art approaches like deep learning and transformers address this issue – but that's for another time.



*Any questions?*

# Things to remember

- unsupervised vs supervised
- rough understanding of different techniques and when to use them
- evaluation metrics (e.g., precision, recall)



## Next steps

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Make sure you understood all of today's  
concepts.

Re-read the chapters.

On Friday, you will do some machine  
learning.

[https://github.com/uvacw/teaching-bdaca/blob/  
main/12ec-course/week06/exercises/](https://github.com/uvacw/teaching-bdaca/blob/main/12ec-course/week06/exercises/)

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