

# A Practical Introduction to Machine Learning in Python

## Day 5 – Friday

### »Transformers«

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## This part: State of the art and next steps

One-Hot to Continuous

Encoding text in ML models

Language Modeling

Non-Contextual

Embeddings

Using word embeddings to improve models

Neural networks

Using pretrained embeddings

Contextual Embeddings

Transfer learning paradigm

Transformer-based models

Do I need all this fancy stuff?

Ethical considerations

## One-Hot to Continuous

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## Our BOW approach until now

### Representing a document by word frequency counts

Result of preprocessing and vectorizing:

0. He took the dog for a walk to the dog playground

⇒ took dog walk dog playground

⇒ 'took':1, 'dog': 2, walk: 1, playground: 1

Consider these other sentences

1. He took the doberman for a walk to the dog playground
2. He took the cat for a walk to the dog playground
3. He killed the dog on his walk to the dog playground

The vectorized representations of these sentences have a “distance” (dissimilarity) of 1 each, but arguably, sentences 0 and 1 should be “closer” than others

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# One-Hot to Continuous

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Encoding text in ML models

## Encoding so far: BoW approach

- Our vectorizers gave a random ID to each word
- Words are *discrete* and *independent* tokens.
- This is a rather naïve assumption, with two main disadvantages:
  1. high dimensionality of the *one-hot-encodings* of the tokens
  2. they do not incorporate real-world knowledge

| Token | Index | One-hot vector |
|-------|-------|----------------|
| aargh | 0     | [1,0,0]        |
| king  | 1     | [0,1,0]        |
| queen | 2     | [0,0,1]        |

# Continuous vectors

- A more realistic view: words are continuous vectors in an  $N$  dimensional space
- Their representation contains real numbers, and they can occupy a position in the  $N$  dimensionality space
- This way of *embedding* tokens is referred to as *continuous* or distributed vectors, representations or *word embeddings*
- The dimensions encode meaning (implicit)

| Token | Index | One-hot vector | Continuous vector |
|-------|-------|----------------|-------------------|
| aargh | 0     | [1,0,0]        | [0.3, 1.9, -0.9]  |
| king  | 1     | [0,1,0]        | [0.2, -0.7, 0.2]  |
| queen | 2     | [0,0,1]        | [0.5, 1.3, 0.9]   |

# Language Modeling

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Language modelling refers to a set of techniques that aim determine the probability of a given sequence of words occurring in a sentence.

# Large Language Models

- Often referred to as 'pretrained' or 'foundation' models.
- They rely on massive amounts of training data.
- e.g., wikipedia, news archives, Reddit, etc.

# Training language models: based on unstructured text – in the absence of explicit labels

## Doberman

From Wikipedia, the free encyclopedia

"Doberman" redirects here. For other uses, see *Doberman (disambiguation)*.



This article **needs additional citations for verification**. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.

Find sources: "Doberman" – news · newspapers · books · scholar · JSTOR (March 2018) *(Learn how and when to remove this template message)*

The **Doberman** (/doʊbərmɑːn/; German pronunciation: [ˈdoːbɐman]), or **Doberman Pinscher** in the United States and Canada, is a medium-large *breed* of domestic *dog* that was originally developed around 1890 by *Louis Doberman*, a tax collector from Germany.<sup>[2]</sup> The Doberman has a long muzzle. It stands on its pads and is not usually heavy-footed. Ideally, they have an even and graceful *gait*. Traditionally, the ears are *cropped* and posted and the tail is *docked*. However, in some countries, these procedures are now illegal and it is often considered cruel and unnecessary. Dobermanns have markings on the chest, paws/legs, muzzle, above the eyes, and underneath the tail.

Dobermanns are known to be intelligent, alert, and

### Doberman



| <b>Other names</b>  | Doberman Pinscher  |
|---|--|
| <b>Common nicknames</b>                                     | Dobie, Doberman  |
| <b>Origin</b>   | <span><span><span></span></span><span> </span></span> Germany  |
| <b>Traits</b> <span><span>[</span>hide<span>]</span></span> |  |
| <b>Height</b>   | Dogs 68 to 72 cm (27 to 28 in) <sup>[1]</sup> <div></div> Bitches 63 to 68 cm (25 to 27 in) <sup>[1]</sup> |

## Bulldog

From Wikipedia, the free encyclopedia

*This article is about the English Bulldog. For other uses, see *Bulldog (disambiguation)*. See also: *French Bulldog*, *American Bulldog*, and *Old English Bulldog**

The **Bulldog** is a British *breed* of dog of *mastiff* type. It may also be known as the **English Bulldog** or **British Bulldog**. It is of medium size, a muscular, hefty dog with a wrinkled face and a distinctive pushed-in nose.<sup>[4]</sup> It is commonly kept as a *companion dog*; in 2013 it was in twelfth place on a list of the breeds most frequently registered worldwide.<sup>[5]</sup>

The Bulldog has a longstanding association with *British culture*; the *BBC* wrote: "to many the Bulldog is a national icon, symbolising pluck and determination".<sup>[6]</sup> During the *Second World War*, the Prime Minister *Winston Churchill* was likened to a Bulldog for his defiance of *Nazi Germany*.<sup>[7]</sup> The Bulldog Club (in England) was formed in 1878, and the Bulldog Club of America was formed in 1890.

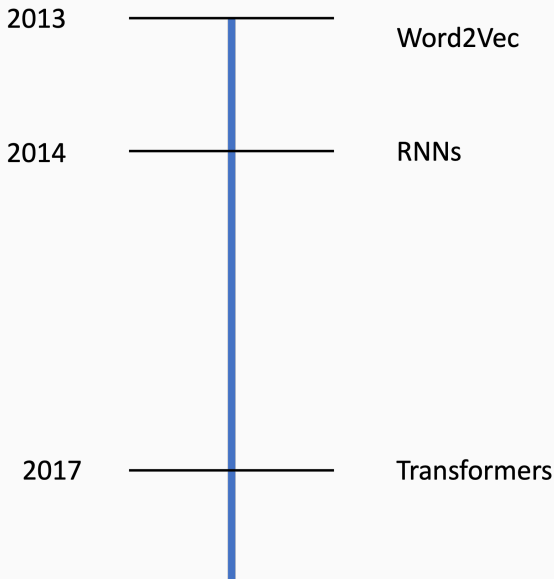
### Bulldog



|                    |  |
|--------------------|--|
| <b>Other names</b> | English Bulldog, British Bulldog   |
| <b>Origin</b>      | <span><span><span></span></span><span> </span></span> England <sup>[1]</sup> |



## Key events in the history of language modeling



# Non-Contextual Embeddings

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“...a word is characterized by the company it keeps...” (Firth, 1957)

## Word embeddings ...

- help capturing the meaning of text
- are low-dimensional vector representations that capture semantic meaning
- for instance, ‘dobermann’ and ‘bulldog’ should be represented by vectors that are close to each other in space, while ‘kill’ and ‘walk’ should be far from each other.

## Word embeddings: Training algorithms

There are two popular approaches to training word embeddings:  
GloVe and word2vec.

- GloVe is count-based: dimensionality reduction on the co-occurrence counts matrix.
- Word2Vec is a predictive model: neural network to predict words/contexts
- That means that GloVe takes global context into account, word2vec local context
- Some technical implications for how training can be implemented
- **However, only subtle differences in final result.**

# Word2Vec: Continuous Bag of Words (CBOW) vs skipgram

Example sentence: "the quick brown fox jumped over the lazy dog"

**CBOW: Predict a word given its context**

Dataset:

([the, brown], quick), ([quick, fox], brown),  
 ([brown, jumped], fox), ...

**skipgram: Predict the context given the word**

(quick, the), (quick, brown), (brown, quick), (brown,  
 fox), ...

Example taken from here: <https://medium.com/explore-artificial-intelligence/word2vec-a-baby-step-in-deep-learning-but-a-giant-leap-towards-natural-language-processing-40fe4e8602ba>

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## Continuous Bag of Words (CBOW) vs skipgram

- CBOW is faster
- skipgram works better for infrequent words
- Both are often used
- Usually, we use larger window sizes (e.g, 5)
- We need to specify the number of dimensions (typically 100–300)

*In any event, as a result of the prediction task, we end up with a {100/200/300}-dimensional vector representation of each word.\**

\* If that makes you think of PCA/SVD, that's not completely crazy, see Levy, O., Goldberg, Y., & Dagan, I. (2018). Improving Distributional Similarity with Lessons Learned from Word Embeddings. *Transactions of the Association for Computational Linguistics*, 3, 211–225. doi:10.1162/tacl\_a\_00134

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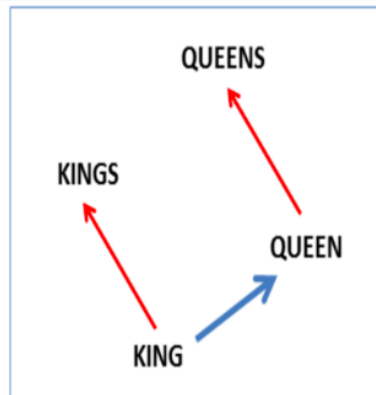
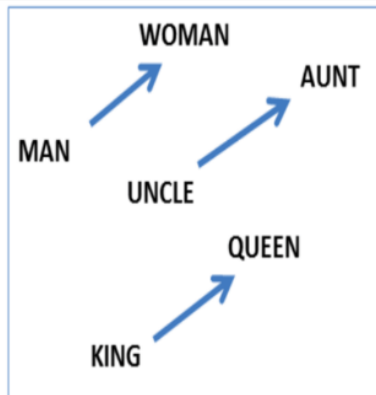
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# You can literally calculate with words!

And answer questions such as “Man is to woman as king is to \_\_\_\_\_?”



semantic relationships vs. syntactic relationships

# Non-Contextual Embeddings

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Improving down-stream classification tasks

Using word embeddings to improve down-stream classification tasks.

## In supervised machine learning

- Modify CountVectorizer or TfidfVectorizer such that for each term, you do not only count how often it occurs, but also multiply with its embedding vector
- Often, pre-trained embeddings (e.g., trained on the whole wikipedia) are used
- Thus, our supervised model will be able to deal with synonyms and related words!

Let's look at an example for using supervised sentiment analysis (i.e., what we did with IMDB-data before).

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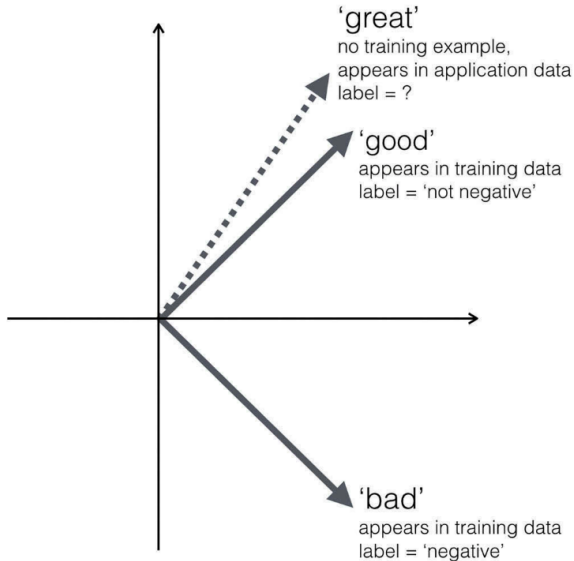
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## It's not always black/white...

Sometimes, BOW may be just fine (for very negative sentences, it doesn't matter). But especially in less clear cases ('slightly negative'), embeddings increased performance.

**Table 1.** Precision, recall, and F1 score for the bag of words approach.

|                       | Actual | Predicted | Precision | Recall | F1 Score |
|-----------------------|--------|-----------|-----------|--------|----------|
| not/slightly negative | 524.3  | 205.6     | 0.33      | 0.83   | 0.47     |
| negative              | 805.7  | 1188.7    | 0.71      | 0.48   | 0.57     |
| very negative         | 730    | 665.7     | 0.53      | 0.58   | 0.56     |

**Table 2.** Precision, recall, and F1 score for the Word Embeddings approach.

|                       | Actual | Predicted | Precision | Recall | F1 Score |
|-----------------------|--------|-----------|-----------|--------|----------|
| not/slightly negative | 522.4  | 575       | 0.65      | 0.59   | 0.61     |
| negative              | 799.2  | 771.6     | 0.52      | 0.53   | 0.53     |
| very negative         | 739.4  | 714.4     | 0.55      | 0.57   | 0.56     |

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# In document similarity calculation

## Use cases

- plagiarism detection
- Are press releases/news agency copy/... taken over?
- Event detection

## Traditional measures

- Levenshtein distance (How many characters|words do I need to change to transform string A into string B?)
- Cosine similarity ("correlation" between the BOW-representations of string A and string B)

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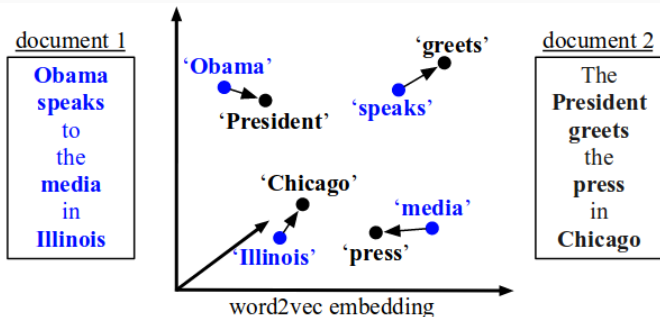


Figure 1. An illustration of the *word mover's distance*. All non-stop words (**bold**) of both documents are embedded into a *word2vec* space. The distance between the two documents is the minimum cumulative distance that all words in document 1 need to travel to exactly match document 2. (Best viewed in color.)

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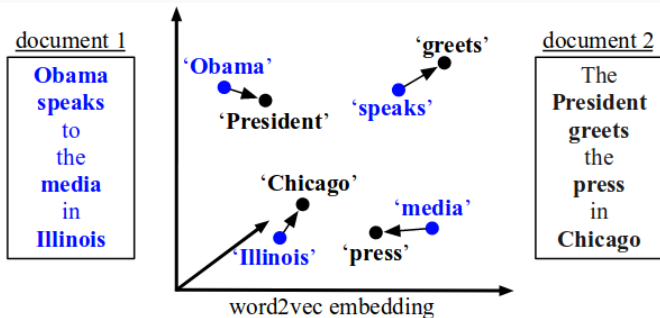


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## There are several approaches

- word mover's distance
- soft cosine similarity

In common: we use pre-trained embeddings to replace words (that otherwise would just have a random identifier and be unrelated) with vectors representing their meaning, when calculating our measure of interest

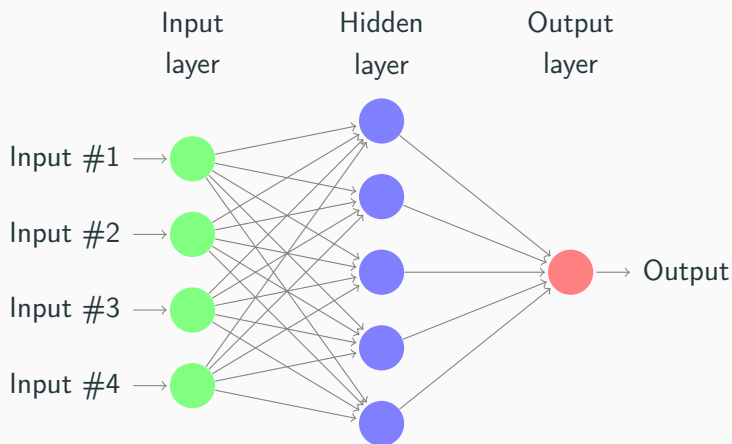
# Neural networks

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# Neural Networks

- In “classical” machine learning, we predict an outcome directly based on the input features
- In neural networks, we can have “hidden layers” that we predict
- These layers are not necessarily interpretable
- “Neurons” that “fire” based on an “activation function”



⇒ If we had multiple hidden layers in a row, we'd call it a *deep* network.

## Why neural networks?

- learn hidden structures (e.g., embeddings (!))
- go beyond the idea that there is a direct relationship between occurrence of word X and label (or occurrence of pixel [R,G,B] and a label)
- images, machine translation — and more and more general NLP, sentiment analysis, etc.

Example of a comparatively easy introduction:

<https://towardsdatascience.com/>

neural-network-embeddings-explained-4d028e6f0526

# Simple feed forward network

```
1 model.add(Dense(300, input_dim=input_dim, activation='relu'))
2 model.add(Dense(1, activation='sigmoid'))
```

- Our first layer reduces the input features (e.g., the 10,000 features our CountVectorizer creates) to 300 neurons
- It does so using the relu function  $f(x) = \max(0, x)$  (as our counts cannot be negative, just a linear function)
- The second layer reduces the 300 neurons to 1 output neuron using the sigmoid function (the S curve you know from logistic regression)
- Of course, we can add multiple layers in between if we want to

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## Convolutional networks

The problem with such a basic networks: just as with classic SML, we still loose all information about order (the “not good” problem).

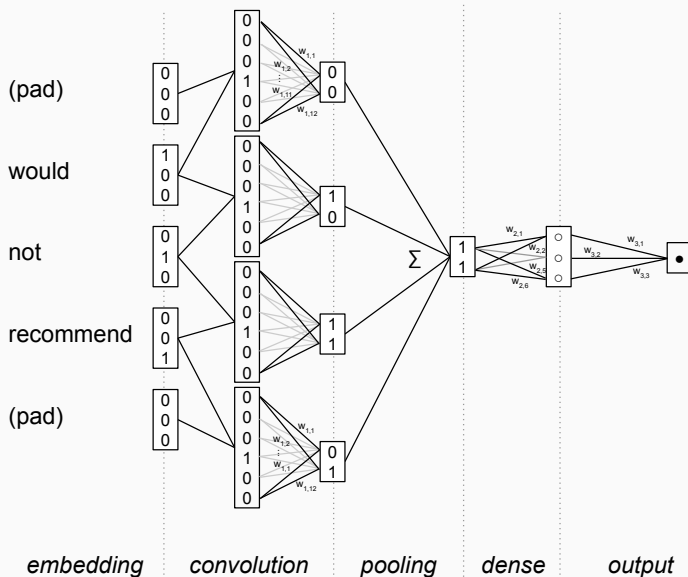
Therefore,

- We concatenate the vectors of neighboring words
- We apply some filter (essentially, we detect patterns)
- and then pool the results (e.g., taking the maximum)

This means that we now excplitly take into acount *the temporal structure* of a sentence.



# Convolutional networks



# Convolutional networks

```
1 model.add(Embedding(input_dim=vocab_size, output_dim=embedding_dim,
    input_length=maxlen))
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3 model.add(GlobalMaxPooling1D())
4 model.add(Dense(300, activation='relu'))
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```

The layers:

1. train an embedding model
2. apply the convolution with 5 “timestamps”
3. pool using the maximum
4. another layer with 300 dimensions
5. the final layer with 1 output neuron

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# Convolutional networks

Note that the preprocessing differs!

- We do not take a word vector per document as input any more, but *a sequence of words*
- For concatenating, these sequences need to have equal length, which is why we *pad* then

## LSTM (long short-term memory)

- Unlike “feed forward” neural networks, this is a “recurrent neural network” (RNN) – the training works in two directions
- Heavy in computation, very useful for predicting *sequences*
- Won't cover today



# Neural networks

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Using pretrained embeddings

## The embedding layer

- Often, the first layer is creating word embeddings
- Good embeddings need a lot of training data
- Training good embeddings needs time
- Therefore, we can replace that layer with a pre-trained embedding layer (!)
- We can even use a hybrid approach and allow the pre-trained embedding layer to be re-trained!

# Contextual Embeddings

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## Downsides of Non-Contextual Word Embeddings

- Word2Vec and Glove produce *static* vectors: each word is represented by a single vector.
  - e.g., the vector for *date* is always the same...
  - ...however, the meaning of this word differs across domains: “she put a *date* in his lunchbox” (1); “they went on a *date*” (2); and “what’s the *date* today?”

## Enter: Contextual Word Embeddings

- *Transformers* create a new vector for each time a word is used in the dataset
- *Contextualized* vectors.
- *self-attention* mechanism is essential here: this is a manner to automatically decide which nearby words should influence a token’s representation; the model *learns* which tokens to *attend to*

# Transfer learning paradigm

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# The idea of transfer learning is very powerful

## Transfer Learning paradigm

1. **Pre-train** a model on data that is at hand (e.g., Wikipedia, Google News)
2. **Fine-tune** the model on your downstream task (bring in your small-scale annotated dataset)

By adding 'task-specific' heads you can produce specific outputs, e.g., classification, text generation, named entity recognition, etc.

# Transformer-based models

---

The architecture of transformers is very efficient on modern hardware; transformers process words in parallel. As they are much faster, we can use much more data.



# Transformer-based models

## BERT: Bidirectional Encoder Representations from Transformers (BERT)

- (Huge) pre-trained model (by, e.g., Google)
- Trained on very large amount of text and can use words in context.
- State of the art performance on the General Language Understanding Evaluation benchmark (GLUE).
- BERT and other transformer-based models are used for a range of tasks;
  1. Sentiment analysis
  2. sequence-to-sequence predictions (e.g., translation)
  3. similarity and paraphrasing tasks
  4. natural language inference tasks

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# How to use

## HuggingFace

- The 'HuggingFace': Python library includes lots of datasets and transformer-based models
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Let's look at an example (imdb.ipynb)

## Transformer-based models

---

Do I need all this fancy stuff?

# Things to consider

How important is...

- precision/recall? Am I satisfied with .88 when .90 is theoretically possible? .85? .80? .75?
- explainability?
- computational resources?
- generalizability and out-of-sample performance?

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## Do I need all this fancy stuff?

- Always estimate a simple baseline model first
- Invest in good hyperparameter-tuning (cross-validation, gridsearch) and don't forget to set aside unseen data for the *final* evaluation.
- If you (a) need to get the highest possible accuracy, or (b) have reasons to assume that the model does not generalize well enough (overfitting problems, bad out-of-sample prediction (e.g., training topics on newspaper 1, predicting topics in newspaper 2), try embedding-based approaches, transformers, etc.
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## Ethical considerations

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(Ab-)using word embeddings to detect biases



## Biased embeddings

- word embeddings are trained on large corpora
- As the task is to learn how to predict a word from its context (CBOW) or vice versa (skip-gram), biased texts produce biased embeddings
- If in the training corpus, the words “man” and “computer programmer” are used in the same context, then we will learn such a gender bias

Bolukbasi, T., Chang, K.-W., Zou, J., Saligrama, V., & Kalai, A. (2016). Man is to Computer Programmer as Woman is to Homemaker? Debiasing Word Embeddings, 1–25. Retrieved from <http://arxiv.org/abs/1607.06520>

## Biased embeddings

Usually, we do not want that (and it has a huge potential for a shitstorm)

unless...

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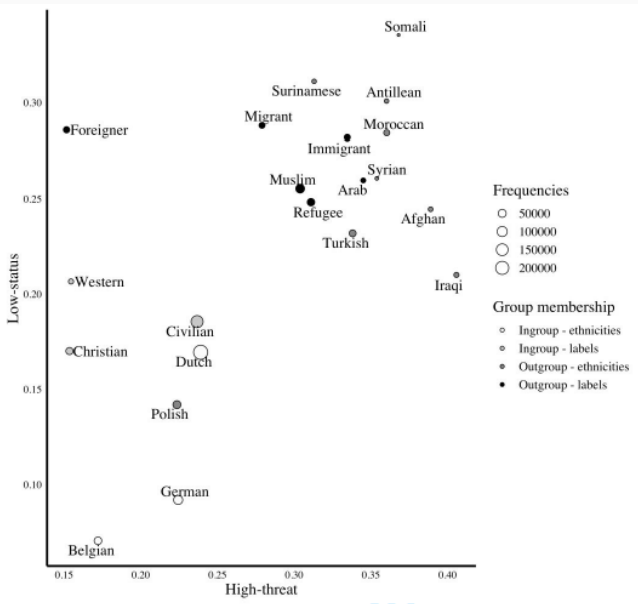
we actually want to chart such biases.

## An example from our research

We trained word embeddings on 3.3 million Dutch news articles.

Are vector representations of outgroups (Maroccans, Muslims) closer to representations of negative stereotype words than ingroups?

Kroon, A.C., Van der Meer, G.L.A., Jonkman, J.G.F., & Trilling, D. (in press): Guilty by Association: Using Word Embeddings to Measure Ethnic Stereotypes in News Coverage. *Journalism & Mass Communication Quarterly*



## Your takeaway

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(short recap of course)





*Have your plans about how to and  
wether to use ML changed?*



*What are your next steps?*

Last part: we help you working on (or  
discussing about) your own projects.

**AEM**

---

We can use pre-trained embeddings – but can we make even better ones? **The Amsterdam Embedding Model (AEM)**

Anne Kroon, Antske Fokkens, Damian Trilling, Felicia Loecherbach, Judith Moeller, Mariken A. C. G. van der Velden, Wouter van Atteveldt

## Why do this?

- Embedding models are of great interest to communication scholars
- yet... Most publicly available models represent **English** language
- The preparation of good-performing embedding models require a significant amount of **time** and **access to a large amount of data sets**
- Few Dutch embedding models are available, but trained on ordinary human language from the World Wide Web.
- These models do not capture the specifics of news article data and are therefore less suitable to study and understand dynamics of this domain
- $\Rightarrow$  No model is available trained on Dutch news data

# Project's Aim

## Aim of the current project

1. Develop and evaluate a high-quality embedding model
2. Assess performance in downstream tasks of interest to Communication Science (such as topic classification of newspaper data).
3. Facilitate distribution and use of the model
4. Offer clear methodological recommendations for researchers interested using our Dutch embedding model

# Training data

## Training data set

- Dataset: diverse print and online news sources
- Preprocessing: duplicate sentences were removed
- Telegraaf (print & online), NRC Handelsblad (print & online), Volkskrant (print & online), Algemeen Dabldad (print & online), Trouw (print & online), nu.nl , nos.nl
- # words: 1.18b (1181701742)
- # sentences: 77.1M (77151321)



## Training model

### Training model

- We trained the model using Gensim's Word2Vec package in Python
- Skip-gram with negative sampling, window size of 5, 300-dimensional word vectors

# Evaluation

## Evaluation of the Amsterdam Embedding Model

# Evaluation

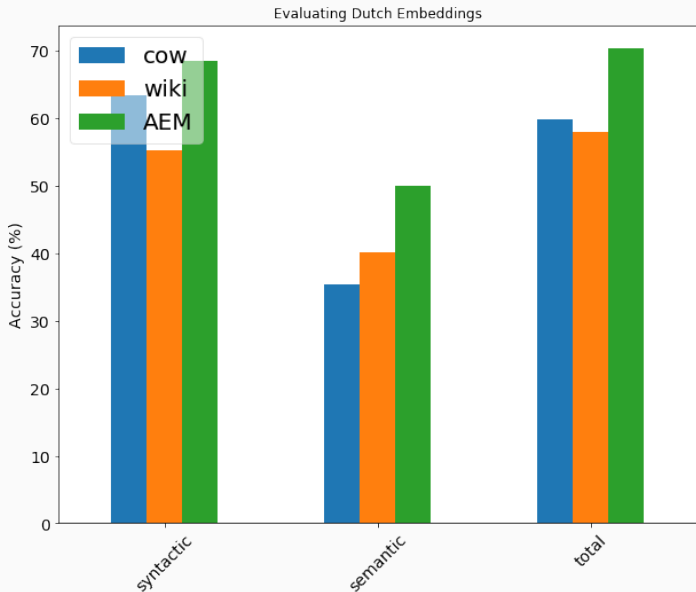
## Evaluation methods

- To evaluate the model, we compare it to two other publicly available embedding models
  - ⇒ **'Wiki'**: Embedding model trained on Wikipedia data (FastText)
  - ⇒ **'Cow'**: Embedding model trained on diverse .nl and .be sites (Schafer & Bildhauer, 2012; Tulkens et al., 2016)
  - ⇒ **'AEM'**: Amsterdam Embedding Model

# Evaluation data

## Evaluation data

1. 'relationship' / analogy-task (Tulkens et al., 2016)
  - **syntactic relationships**: dans dansen loop [*lopen*]
  - **semantic relationships**: denemarken kopenhagen noorwegen [*oslo*]
2. 5806 relationship tasks

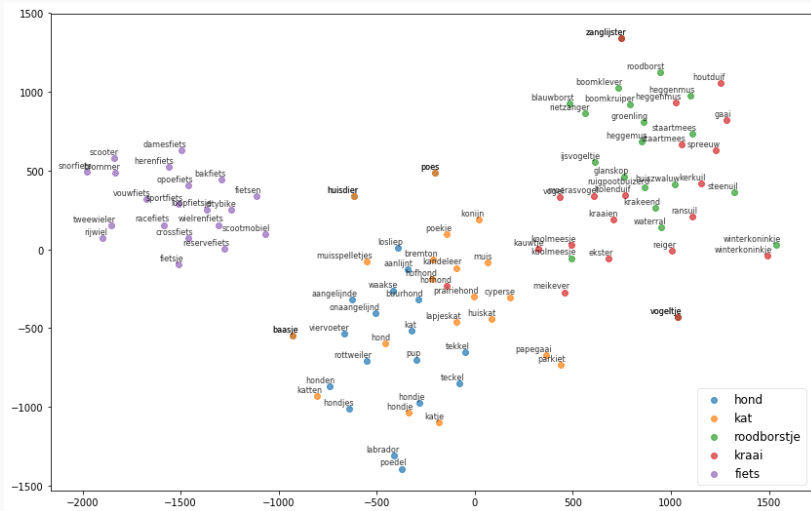


## Illustration

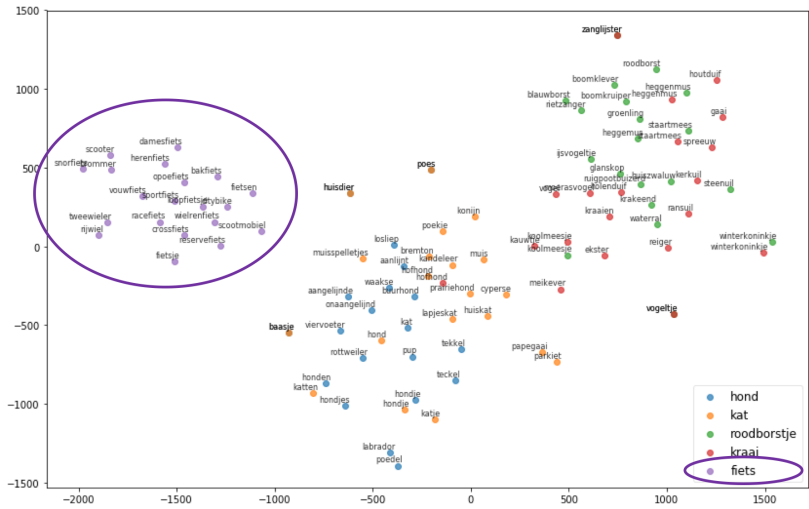
Illustration - Using the Amsterdam Embedding Model

**AEM**

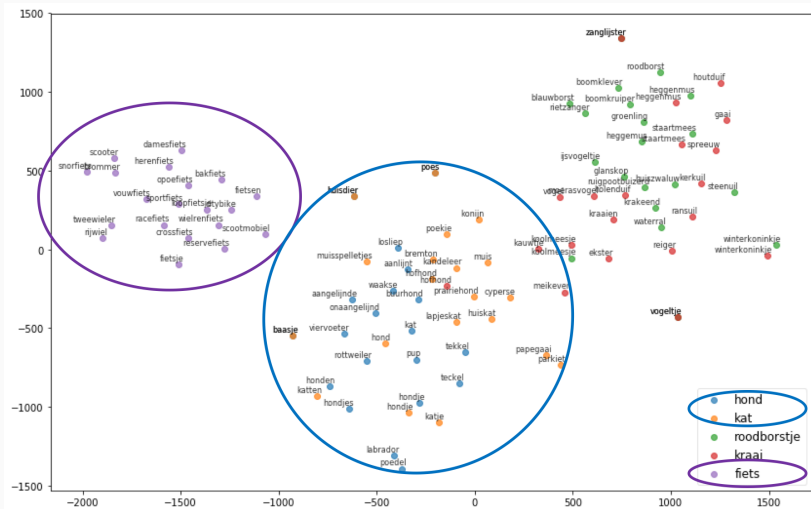
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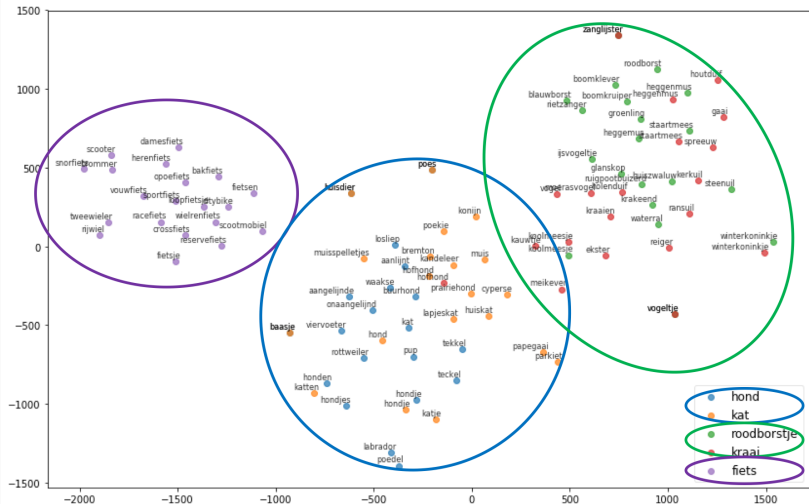












## Re-usability

Re-usability of the Amsterdam Embedding Model

## Re-usability

### Reusing model and data

1. See  
<https://github.com/annekroon/amsterdam-embedding-model>
2. Open access to all the code

Disclaimer: I cannot give a full overview of the whole topic of deep learning here – that's a whole (extensive) course in itself. But embeddings are closely related, that's why we at least will at least get our feet wet a bit.

