Natural Language Processing 1

- **Topic:** Statistical Natural Language Processing
- **Team:**
  - Instructor: Ivan Titov
  - Assistants: Sophie Arnould, Joachim Daiber and Ehsan Khoddam
Computation Research

- **Cognitive / theoretical motivation**
  - Language is a unique cognitive capacity
  - Developing a computation model might help
    - To understand how language is represented, processed and learnt by human brain or
    - to better understand linguistic phenomena

- **Engineering / practical motivation**
  - We need computers to conduct tasks such as translation, summarization, search, answering questions, correcting texts, understanding opinions …
  - Much of human knowledge is represented in natural language texts, so enabling a machine to "read" it and perform inference is important

We will be considering statistical models which deal with these problems
London Bridge really is falling down. The bridge is being taken apart and moved. Its new home will be a small town in Arizona. This bridge is hundreds of years old. It stretches across the Thames River. Robert McCulloch saw this bridge and decided to bring it to the USA.

He paid more than two million dollars. It will cost him more than three million dollars to move it. Each stone will be marked. The pieces must fit when they reach their new home. All that work will not take place overnight. The job will take six years. The bridge is not small. It is longer than three football fields. It is almost as wide as one football field. In time, the London Bridge will stand high above a new river. Flags will be placed at both ends. Cars will cross it. A small town will be built next to the bridge. Most people in Arizona will never see London. But they will see a part of it in their own state.

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2. Where will the bridge be re-built?
3. How long will it take?
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2. Where will the bridge be re-built?
3. How long will it take?
Why processing language is hard?

Meaning

Variability

Language

Ambiguity
Why processing language is hard?

Variability:
He drew the house
He made a sketch of the house
He showed me his drawing of the house
He portrayed the house in his paintings
He drafted the house in his sketchbook
Why processing language is hard?

Ambiguity:

- She *drew* a picture of herself  ~ *sketched, made a drawing of*
- A cart *drawn* by two horses… ~ *pulled*
- He *drew* crowds wherever he went … ~ *attracted*

These properties makes the use of probabilities very natural for natural language processing.
Inference in information retrieval

... Non-steroidal anti-inflammatory drugs have been shown to increase risk of Myocardial infarction...

Nonsteroidal anti-inflammatory drugs (NSAIDs) are a class of drugs which include ibuprofen, aspirin, naproxin ...

Myocardial infarctions, also known as heart attack, ...

E.g., the recent Google Knowledge Graph initiative looks into this direction

Cross-documents inference is generally beyond reach of IR systems
NLP Tasks: core linguistics tasks

- Part-of-speech tagging
  My dog ate a sausage
  PN N V D N

- Syntactic parsing
  root poss nsubj dobj det
  My PN dog N ate V a D sausage N

- Semantic role labeling (shallow semantic analysis)
  AGENT THEME
  Sequa makes and repairs jet engines

- Co-reference resolution, discourse parsing, ...

- What's common between these tasks?
  They can all be thought of as predicting graph structure
NLP Tasks: Application tasks

- **Machine translation**
  
  Hij eet zijn broodje op en vertrekt naar school.

- **Question answering**

- **Summarization**
  
  Given a document (or a collection of documents) produce a short summary

- **Dialogue systems**
  
  E.g., automatic reservations systems

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The linguistic tasks should help to build models for applications (e.g., using syntactic information in machine translation models)
Overall course goals: dealing with NLP problems

Understand the problem (insights / assumptions / signals)

Define the (statistical) model

Derive algorithms for estimation and prediction

Implement and test the method

What kind of assumptions might be crucial to encode?

A "toolbox" of methods for modeling different types of structures (bags, chains, trees, …)

A "toolbox" of estimation (forms of EM, structured perceptron, Gibbs) and prediction algorithms (Viterbi, CKY, …)

Some experience with NLP data and implementing methods is important
NLP Problems

Doc. classification

Topic analysis

Shallow synt. parsing /tagging

Syntactic parsing

Relation extraction

Semantic parsing

Models of inference

Machine translation

Question answering

Opinion analysis

Summarization

Dialogue systems

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<table>
<thead>
<tr>
<th>NLP Problems</th>
<th>Types of structures</th>
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There are relations to other ML topics: e.g., dialog systems are often based on (PO)MDPs and estimated in the RL framework.

Much of this is applicable to other structure processing domains (bioinformatics, vision, music processing, speech, …)

A gross simplification…
How we will organize things…

- We will mostly use Blackboard
  - A link to a website is posted on BB
  - Lectures and reading suggestions will be uploaded to the website (after the lecture)

- Assistants:
  - Ivan: titov@uva.nl  
    F2.03 SP107 (Nikhef / ILLC) – Not F in SP904
  - To reach all TAs (recommended!): nlp.uva.2015@gmail.com

Send us an email to arrange meetings
Our class

- **Lectures**
  - Introduction to statistical natural language processing

- **Mini-project**
  - Group project on your chosen topic!
  - Reading, software, report and presentation

- **Assignments**
  - Pen and paper (or really latex) – "weekly" (4 assignments)

- **Exam**
Projects

- **Topic**
  - Choose a topic from the list of 9 directions
  - Lot's of room for creativity

- **Teams**
  - 3 people
  - Assisted by a designated TA

- **Programming (of a learning / inference algorithm), not use of tools**

- **Deadlines:**
  - Choose a topic by Friday evening
  - November 13 – a very short presentation of your topic
  - Final presentation: Dec 10 or 11, report (8-10 pages) due on Dec 22

We expect that you talk to TAs outside of lab sessions as well

Coordinate it with the designated TA (and me)
Project 1: (Sentiment) summarization

How to make sense of noisy and diverse user-generated content?
Sentiment Summarization

- One option is aspect-based summarization (Hu & Liu 2004): detect key **aspects** and summarize along them.

<table>
<thead>
<tr>
<th>Nikos’ Fine Dining</th>
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</thead>
<tbody>
<tr>
<td><strong>Food</strong></td>
</tr>
<tr>
<td><strong>Decor</strong></td>
</tr>
<tr>
<td><strong>Service</strong></td>
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<tr>
<td><strong>Value</strong></td>
</tr>
</tbody>
</table>

- Many real world manual examples, e.g., Zagat.com

That's not the only option! Much space for creativity.
How to approach the problem?

- **Preparation stage**
  - Get suggestions and read relevant papers
  - Discuss the idea with TA (and me)
  - Get data (e.g., hotel reviews from tripadvisor.com; also datasets exist)

- **Implementation (one option):**
  - A model for detecting key aspects from a corpus => reviews are segmented
  - An objective to select most important sentences => most important sentences per aspect
  - (Maybe) a sentence compression model => phrases per aspect

- **How relevant to the class?**
  - A statistical model for aspect detection / sentence classification
  - The sentence compression model relies on syntax (syntactic parsing / POS tagging)
  - Related to more general summarization methods discussed towards the end of the class

This applies essentially to all problems.
Project 2: semantic frame induction

- **Context:** the same actions can be expressed in many different ways and the same predicate (verb) can refer to many different underlying actions
- **Task:** can we map predicate occurrences to situation types ('frames')?

(1) ... whole family *caught* flu ...
(2) ... Syrian rebels *captured* a pilot ...
(3) ... baby *contracted* flu
(4) ... Michael Jordan jumped and *caught* the ball
(5) ... a British nurse *caught* the deadly virus
(6) ... my cat *caught* a mouse
(7) ... local authorities *contracted* a waste removal company

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How can we do this?
Project 2: semantic frame induction

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7. ... local authorities ? a waste removal company

Already we can get a pretty good idea, right?
Project 3: semantic frame induction

The distributions of frames per predicate are 'sparse' (few-senses-per-predicate assumption)
In late nineteenth century, there was a severe air crash happening at Miami international airport.

Also tracking people is very dangerous if it has been controlled by bad men for a not good purpose.

I think such powerful devices are not to be made easily available.

However, it is an achievement as it is an indication that our society is progressed well and people are living in better conditions.

People still prefer to bear the risk and allow their pets to have maximum freedom.

How, in principle, can we approach task?

Have you seen language models? Noisy channel models before?
Task

Observation: \( O = o_1, \ldots, o_n = o_1^n \)
Correct sentence: \( C = w_1, \ldots, w_n = w_1^n \)

We are interested in \( P(w_1^n | o_1^n) \)

Decompose into 2 models and use the Bayes rule:

\[
\text{argmax}_{w_1^n \in \Gamma} P(w_1^n | o_1^n) = \text{argmax}_{w_1^n \in \Gamma} \frac{P(o_1^n | w_1^n)P(w_1^n)}{P(o_1^n)} \\
= \text{argmax}_{w_1^n \in \Gamma} P(o_1^n | w_1^n) P(w_1^n)
\]

\( \Gamma \) - is the space of potential mistakes

Mistake models

The language model (the probability of a word sequence in the language)

Idioms are an extra pain here

You can, for example, apply neural (deep) models to this problem
Project 5: Analysis of politeness

- This task explores the politeness in online exchanges
- You are given a corpus of utterances:
  - E.g., raw text + politeness rating + context (e.g., writing to a colleague)
- Sub-tasks:
  - Create a classifier that judges the politeness of a text (0.0 very impolite, 1.0 very polite)
  - Suggest a set of changes to make the text seem more polite
- Imagine a demo:
  - A user chooses a desired level of politeness
  - The system highlights words which are not polite enough and suggests changes
Project 6: Building a syntactic parser from scratch

- **Syntactic parsing:**

  ![Dependency tree image]

- **Have you looked into statistical parsing before?**

- **The goal:**
  - You are given an annotated corpus (a treebank) and need to produce a parser
  - You implement (almost) everything from scratch

The idea is to go for neural parsers – in this way we can construct a parser which is effective across many languages.
Project 7: Tools for low resource languages

- Language families:

- Some statistics:
  - Top 8 languages cover 40% world population as native speakers (> 100 mln speakers each)
  - There are 393 languages with more than 1 mln native speakers (~95% of population)
Project 7: Tools for low resource languages

- For the preceding project we assumed that we have a treebank, what if we do not have one?

Tasks:

- Part-of-speech tagging

- Syntactic dependency parsing

Potential ideas:

- Induce from unlabeled data (unsupervised grammar / POS induction)
- Adapt a statistical model from a related language
- Use parallel data (sentences and their translations) to project parser / annotation
Project 7: Tools for low resource languages

- Induction from unlabeled data
  - Define a probabilistic model
  - Estimate from un-annotated texts (e.g., Expectation Maximization)
  - "Easy" for part-of-speech tagging, harder for syntax

- Adapt a statistical model for a related language
  - What about Dutch -> Afrikaans
  - There are different ways how a statistical model can be adapted…

- Project across languages
  - Alignments are noisy so the objective can enforce some form of consistency

- Project syntax and use it to train a syntactic parser / tagger
Project 8: Analysis of food recipes

- There are huge datasets of food recipes
  - Usually text + a list of ingredients
- Can we learn statistical models of cooking?
- What can we use it for?
  - Visualize datasets (embed ingredients and cooking actions into $\mathbb{R}^d$ space)
  - Predict a substitute ingredient?
  - Paraphrase / expand recipes?
  - Generate a recipe given a set of ingredients?
- Technical steps involved:
  - Extract predicate-argument structures – done for you
  - Find alignments between ingredients and texts
  - ...

E.g., use neural network or other types of embedding techniques
Project 9: neural models of word embedding

**Corpus sentences**

He also found five fish swimming in murky water in an old **bathtub**.

We do abhor dust and dirt, and stains on the **bathtub**, and any kind of filth.

Above At the far end of the garden room a **bathtub** has been planted with herbs for the winter.

They had been drinking Cisco, a fruity, wine-based fluid that smells and tastes like a mixture of cough syrup and **bathtub** gin.

Science finds that a surface tension on the water can draw the boats together, like toy boats in a **bathtub**.

In fact, the godfather of gloom comes up with a plot that takes in Windsor Davies (the ghost of sitcoms past), a **bathtub** and a big box of concentrated jelly.

‘I’ll tell him,’ said the Dean from the bathroom above the sound of bathwater falling from a great height into the ample Edwardian **bathtub**.

**Co-occurrence counts**

<table>
<thead>
<tr>
<th>Word</th>
<th>Count</th>
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<tr>
<td>the</td>
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<tr>
<td>a</td>
<td>9</td>
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<tr>
<td>of</td>
<td>7</td>
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<td>and</td>
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<td>in</td>
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<tr>
<td>like</td>
<td>2</td>
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<tr>
<td>water</td>
<td>2</td>
</tr>
<tr>
<td>boat</td>
<td>2</td>
</tr>
<tr>
<td>from</td>
<td>2</td>
</tr>
<tr>
<td>stain</td>
<td>1</td>
</tr>
<tr>
<td>toy</td>
<td>1</td>
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<tr>
<td>godfather</td>
<td>1</td>
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<tr>
<td>Cisco</td>
<td>1</td>
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**Vector**

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\begin{pmatrix}
12 \\
9 \\
7 \\
6 \\
5 \\
\vdots \\
2 \\
2 \\
2 \\
2 \\
1 \\
1 \\
1 \\
\vdots \\
\end{pmatrix}
\]
There exist better ways of embedding words into continuous space based on neural models and factorization methods.
Properties of induced representations (skip gram)
Properties of induced representations (skip gram)

\[ C(KING) + (C(WOMAN) - C(MAN)) \approx C(QUEEN) \]
Properties of induced representations (skip gram)

"Capital of" relation

Semantic analogy task: What is to the sky as is a ship to the ocean?
Project 9: neural embeddings

- There are online tools which can evaluate quality of embeddings
- Several potential directions
  - Different ways how you could formulate the context
  - Alternative statistical models for inducing representations
  - ...
Project 10: text segmentation

- **Task:**
  - Segment text into coherent fragments
- **In principle there are many applications**
  - Segmenting speech into fragments
- **Lots of training data**

- Any idea how to do this? (recall what we discussed about sentiment)
Project ideas

1. Sentiment summarization
2. Semantic frame induction
3. Grammar correction
4. Analysis of politeness
5. Building a syntactic parser from scratch
6. A linguistic tool (e.g., a parser) for a low-resource language
7. Analysis of food recipes
8. Neural word embeddings
9. Text segmentation
More about projects

- **Formalities**
  - Send us (TAs' email) what you want to do by Friday night
  - No labs tomorrow, and only 9-11 session this Friday
  - Within the topic, you can also write some specific ideas / directions
  - Include the second choice (see the constraints)

- **Constraints**
  - Groups of 3 people
  - Not more than 4 groups per project direction (first-come first-serve basis)
  - First-come-first-served basis

- **Important:**
  - If you are not familiar with machine learning and/or not strong in programming (e.g., MoL students should try to join MSc AI students)
Approximate plan

- **1st week (i.e. this week):** choosing the project
- **2nd week:** first meeting with the designated TA, reading recommended papers, discussing in the team
- **3rd week:** finalize the project idea, start working, present the ideas
- **4-6th week:** implementation, discussion of challenges with TAs
- **7th week:** evaluation, final presentation (December 10 or 11 - TBC)
- **8th week -- ...:**
  - Exam on December 15
  - Report due on December 22 (Joint for the team)
  - We will provide additional instructions about the report contents in a few weeks

We will try to help you as much as we can! So bother TAs, bother me! Let us/me know ASAP about any problems