

# Організаційне

# Навчальний план

## Блок 1. Підвалини NLP

- основи структурної лінгвістики
- робота з даними
- повний цикл NLP проекту
- розв'язок задачі на основі правил

## Блок 2. Класичне NLP

+ 2 гостьові заняття

- текст як мішок слів
- текст як послідовність
- текст як дерево
- текст як граф

## Блок 3. Глибинне NLP

- NLP без учителя та розподілені представлення
- звичайні та рекурентні нейромережі для NLP
- моделювання мови, генерація і машинний переклад
- сучасні нейромережні архітектури

# Розклад

## Заняття

- четвер, 19:30-21:30 (лекція)
- субота, 15:00-18:00 (практичне заняття)

## Домашні завдання

- видаються щочетверга
- термін виконання - з суботи до суботи
- зараховуються при умові здачі протягом:
  - 1 тижня - 100%
  - 2 тижнів - 75%
  - 1 місяця - 50%

# Диплом

Для отримання диплому треба:

- отримати  $\geq 50\%$  за домашні завдання
- зробити курсовий проект і презентувати демо

## Стипендії

- одна від Grammarly найкращому студентові чи студентці
- ще одна під питанням

# Курсовий проект

## Зміст

- робота з даними
- побудова метрик для оцінки якості
- побудова базових рішень
- побудова розумного рішення і порівняння результатів зі state-of-the-art

## Два випуски

- внутрішній у Projector (11.06)
- відкритий у Grammarly (13.06)

\* Тему курсового проекту можна вибрати зі списку запропонованих або придумати самостійно.

# Інструментарій

- *Slack* для спілкування
- *GitHub* для матеріалів і домашніх завдань  
<https://github.com/vseloved/prj-nlp-2020>
- Будь-яка мова програмування
  - але найлегше буде з *Python*
- Будь-які бібліотеки для NLP
- Будь-які бібліотеки для машинного навчання
- Зручні інструменти:
  - *Jupyter Notebooks*
  - *Google Colab*
- Англійська та українська мови

# Intro to Natural Language Processing

Mariana Romanyshyn, *Grammarly, Inc.*  
Vsevolod Dyomkin, *Franz Inc.*

# Contents

1. About us
2. About you
3. Overview of NLP
4. NLP applications in the real world

# 1. About Us

# Seva

Lisp programmer

5+ years of NLP work at Grammarly

Currently work at Franz on AllegroGraph

Occasional writer & speaker

<http://lisp-univ-etc.blogspot.com>

<https://vseloved.github.io>

<http://twitter.com/vseloved>

<http://facebook.com/vseloved>



# Programming Experience

Grammarly

Franz

Consulting

Startup projects

Open Source



**AllegroGraph**  
Franz Inc.

# NLP Experience

Grammarly

Franz projects

lang.org.ua

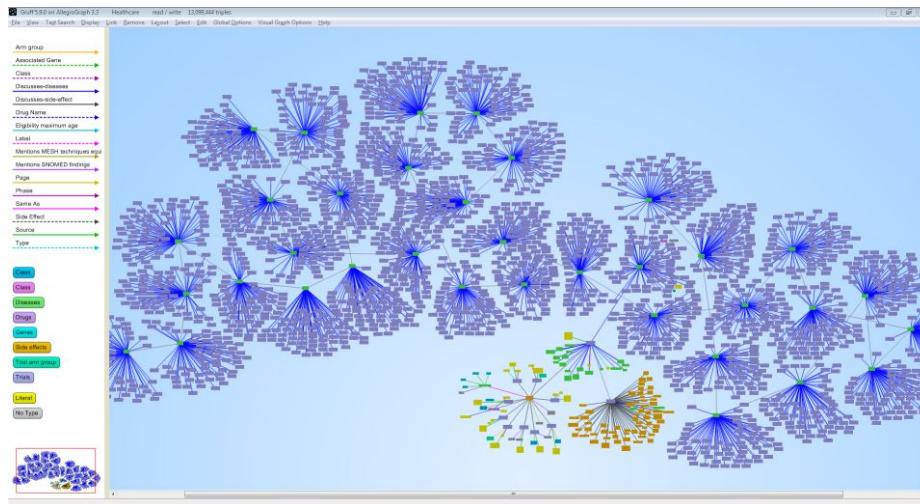
Consulting projects

cl-nlp



# NLP in a graph

- Building an ML/NLP pipeline inside the graph DB
- Entity extraction
- Various classification projects (sales chats, company industries, customer types, tweets, etc.)



# Teaching Experience

7+ years in KPI: SPOS course

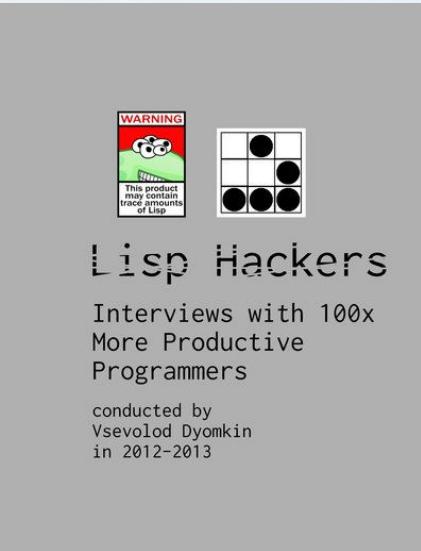
3 prj-algo courses

UCU lecturer and supervisor on NLP

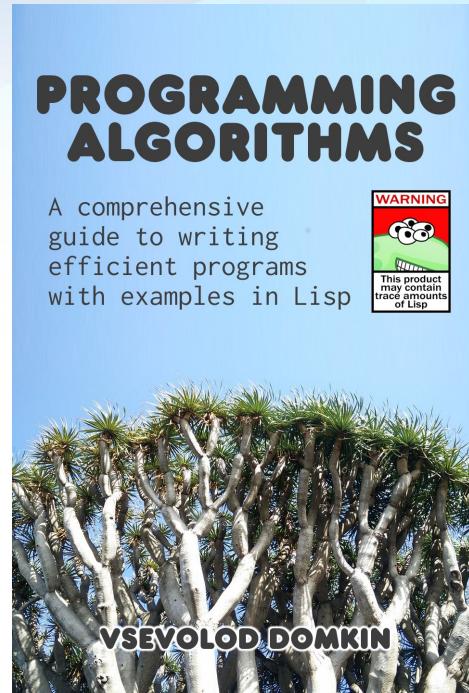
3rd prj-nlp course

Various workshops and conference talks

# Writing



<https://leanpub.com/lisphackers>



# Mariana

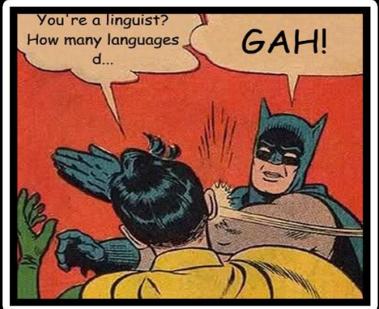
- Computational linguist
- 9 years in NLP
- Struggling reformer of university syllabuses 💪
- Active conference speaker  
*AI Ukraine (x6), ODSC London (x2), ODSC Kyiv, DataScienceUA (x2)...*

*Morning@Lohika, Grammarly AI club, Kharkiv AI club...*

Sorry, no FB :)

<https://www.linkedin.com/in/mariana-romanyshyn-b5896529/>

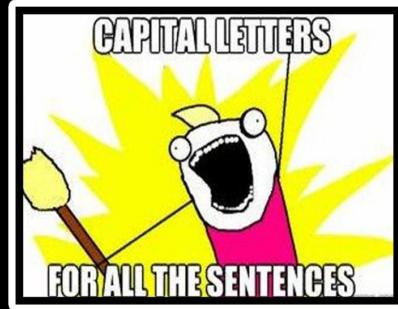
# COMPUTATIONAL LINGUIST



WHAT MY FRIENDS THINK I DO



WHAT MY MOTHER THINKS I DO



WHAT SOCIETY THINKS I DO



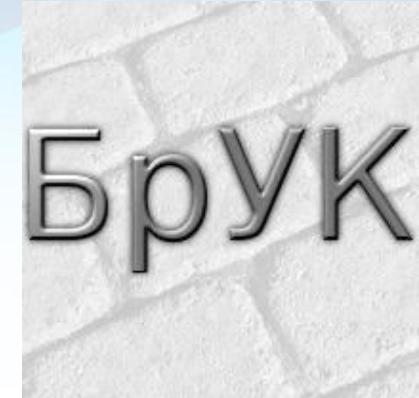
WHAT I THINK I DO

```
def generate_sentence(first_word):
    """Generate a sentence using the first word."""
    ngram_list = trigrams(chnron.words(categories = "adventure"))
    fd = FreqDist(ngram_list)
    sentence = [first_word]
    while len(sentence) < 40:
        list_of_nexes = []
        for (i, j) in fd.keys():
            if i == first_word:
                list_of_nexes.append(j)
        if len(list_of_nexes) == 0:
            return "The sentence cannot be generated."
        first_word = random.choice(list_of_nexes)
        sentence.append(first_word)
        if first_word in [".", "?", "!", "..."]:
            break
    return " ".join(sentence)
```

WHAT I REALLY DO

# NLP Experience

- Grammarly
- Zoral Labs
- Brainglass
- Brown-uk
- Consulting projects



# Teaching Experience

- Grammarly CompLing Summer School (2018-2020)
- NLP course at ESSCASS (2019)
- Lectures and workshops at Ukrainian universities  
*KNU, KPI, KhPI, UCU, LPNU, DonUN...*
- NLP course at Projector (2018-2020)

## 2. About You

# Please introduce yourself

- What is your name?
- What do you do?
- Why are you here?
- Is there a particular NLP task you're interested in?
- What is your favorite language?

### 3. WTF NLP or NLP FTW?

# The Goal of NLP

**Goal:**

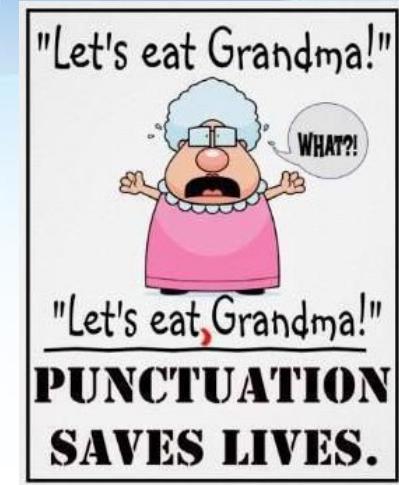
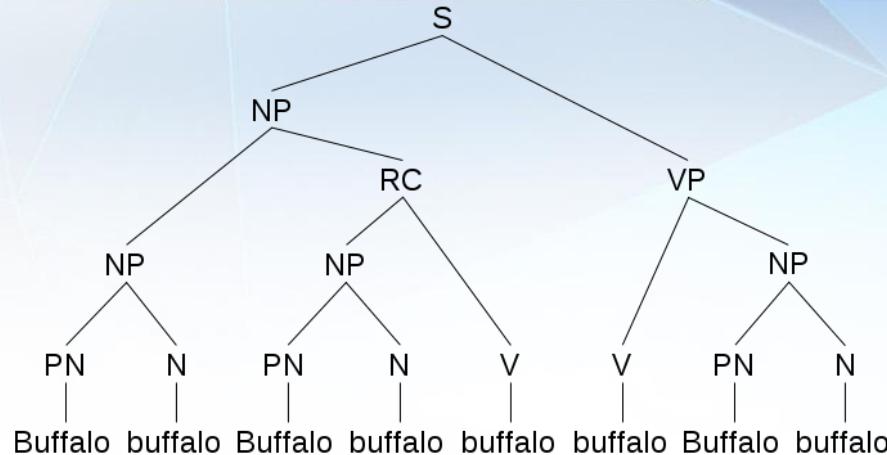
have computers *understand* natural language in order to perform useful tasks

**How:**

transform free-form text into structured data and back

# Natural Language

- Ambiguous
- Noisy
- Evolving

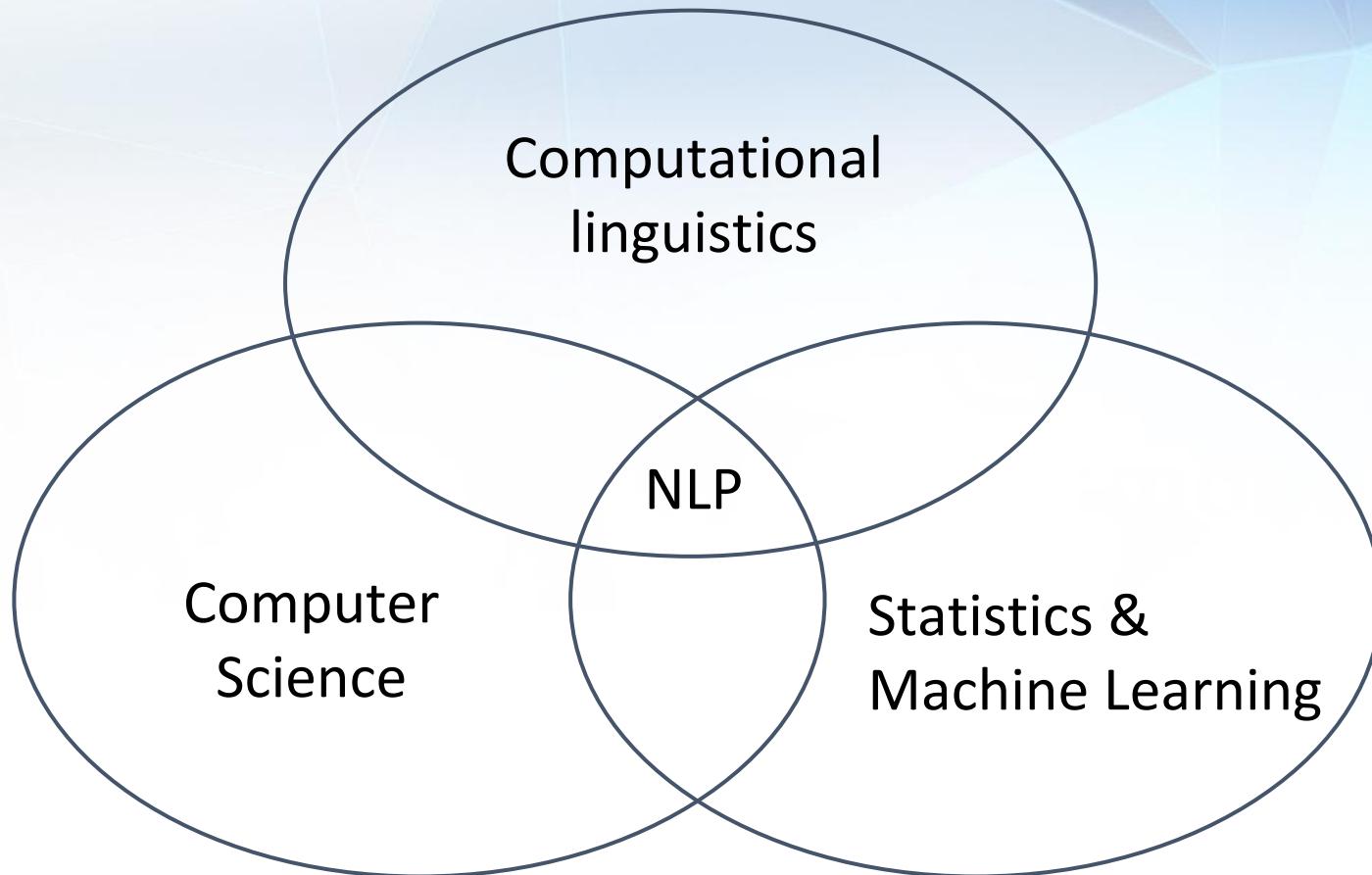


a daft **gay (1900s)**  
flaunting sweet  
tasteful cheerful  
frolicsome pleasant  
witty bright  
gays  
bisexual  
homosexual  
lesbian

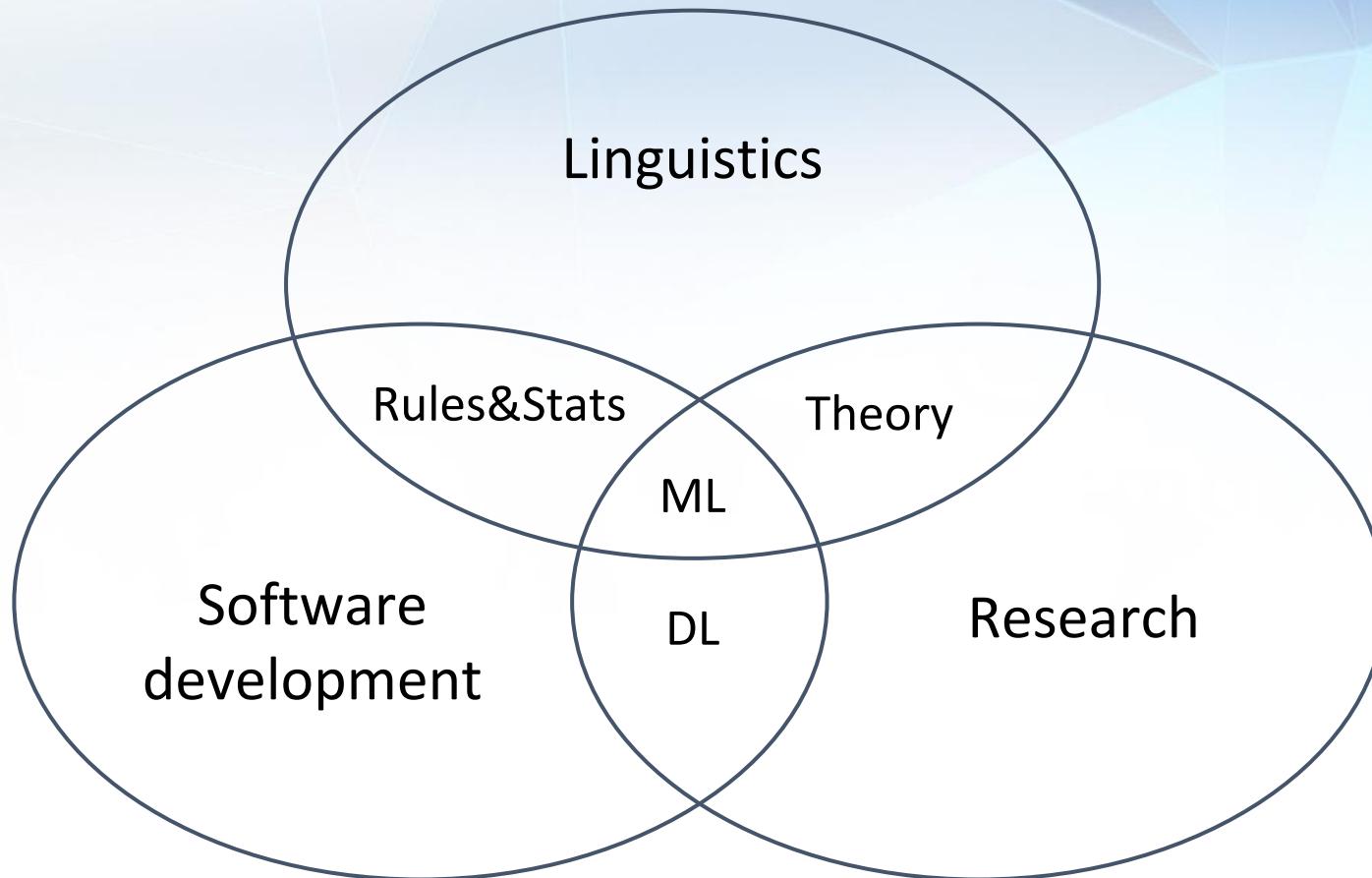
b spread  
**broadcast (1850s)** sow seed sows  
circulated scatter  
**broadcast (1900s)**  
newspapers  
television  
radio  
bbc **broadcast (1990s)**

c solemn **awful (1850s)**  
majestic  
awe dread  
pensive gloomy  
horrible  
appalling terrible  
**awful (1900s)**  
wonderful weird  
awfully

# Position of NLP



# Expertise in NLP



# An NLP Project

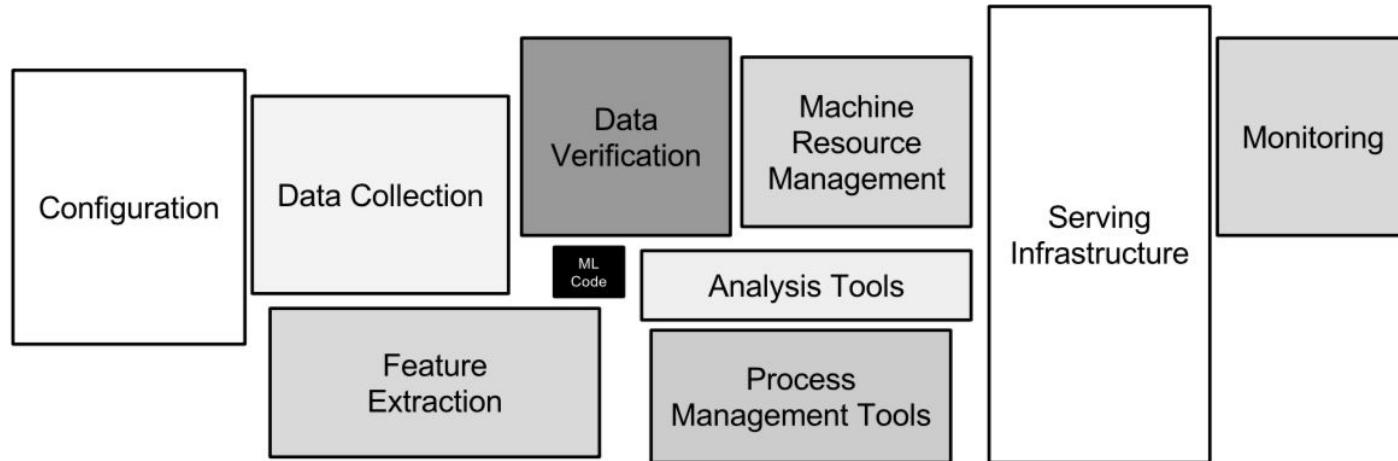
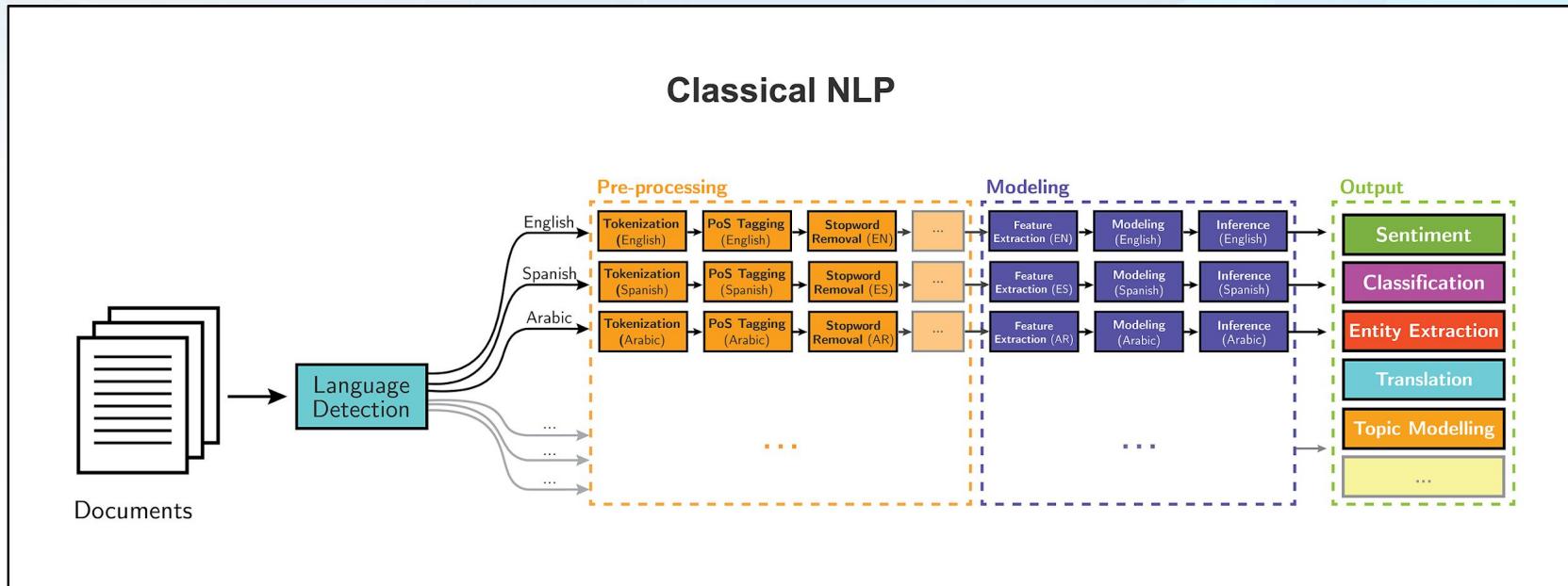


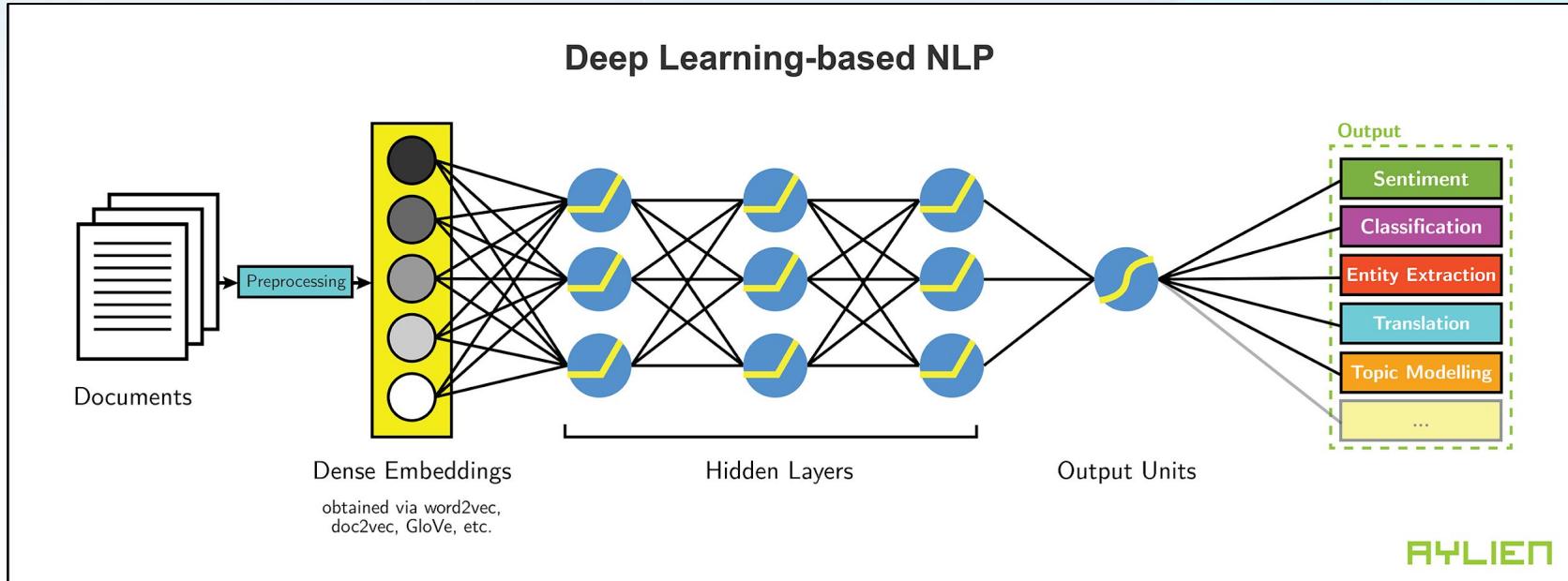
Image from

[https://medium.com/@neal\\_lathia/five-lessons-from-building-machine-learning-systems-d703162846ad](https://medium.com/@neal_lathia/five-lessons-from-building-machine-learning-systems-d703162846ad)

# A Classic NLP Pipeline



# A Modern NLP Pipeline



# NLP & AI

NLP & CV, DSP, ...

NLP vs NLU

Are we there yet?

- <http://nlpprogress.com/>
- <https://www.eff.org/ai/metrics>

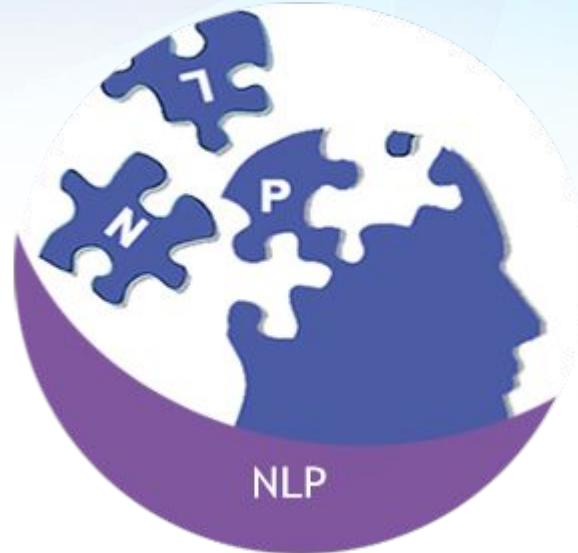
# 4. NLP Applications in the Real World

**Q: What NLP applications do you know?**

**A: [https://github.com/Kyubyong/nlp\\_tasks](https://github.com/Kyubyong/nlp_tasks)**

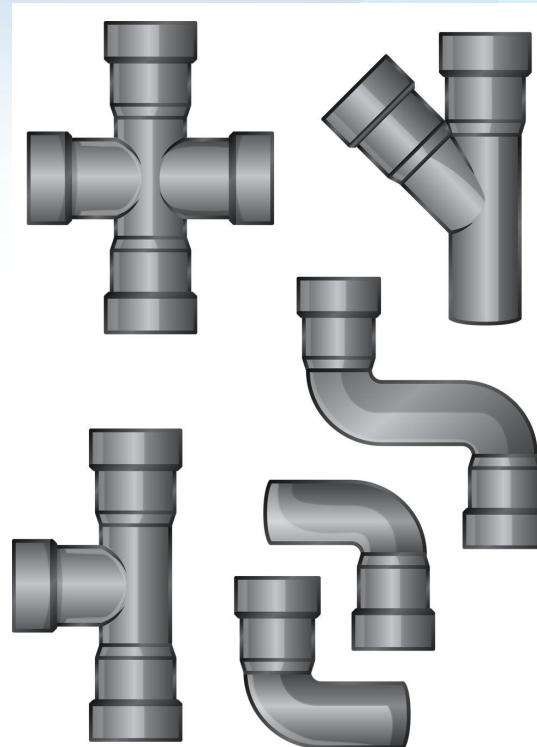
# Types of NLP Applications

- Linguistic
- Analysis
- Transformation
- Generation
- Multi-modal



# Linguistically-Motivated NLP Applications

- Segmentation
- Part of speech tagging
- Named-entity recognition
- Syntactic parsing
- Coreference resolution
- Semantic parsing
- Discourse parsing
- ...



# Analytical Applications

- Whole-text classification
- Segmentation (& classification of parts)
- Extraction of useful data
- Comparative Analysis
- Large-scale data analysis and visualization

# Analytical NLP Applications

## Seva's experience building classifiers

- Language identification
- Email dissection
- Product catalog with 1k categories
- Identifying subjective statements
- Identifying conversation intents
- Identifying the industry of a client



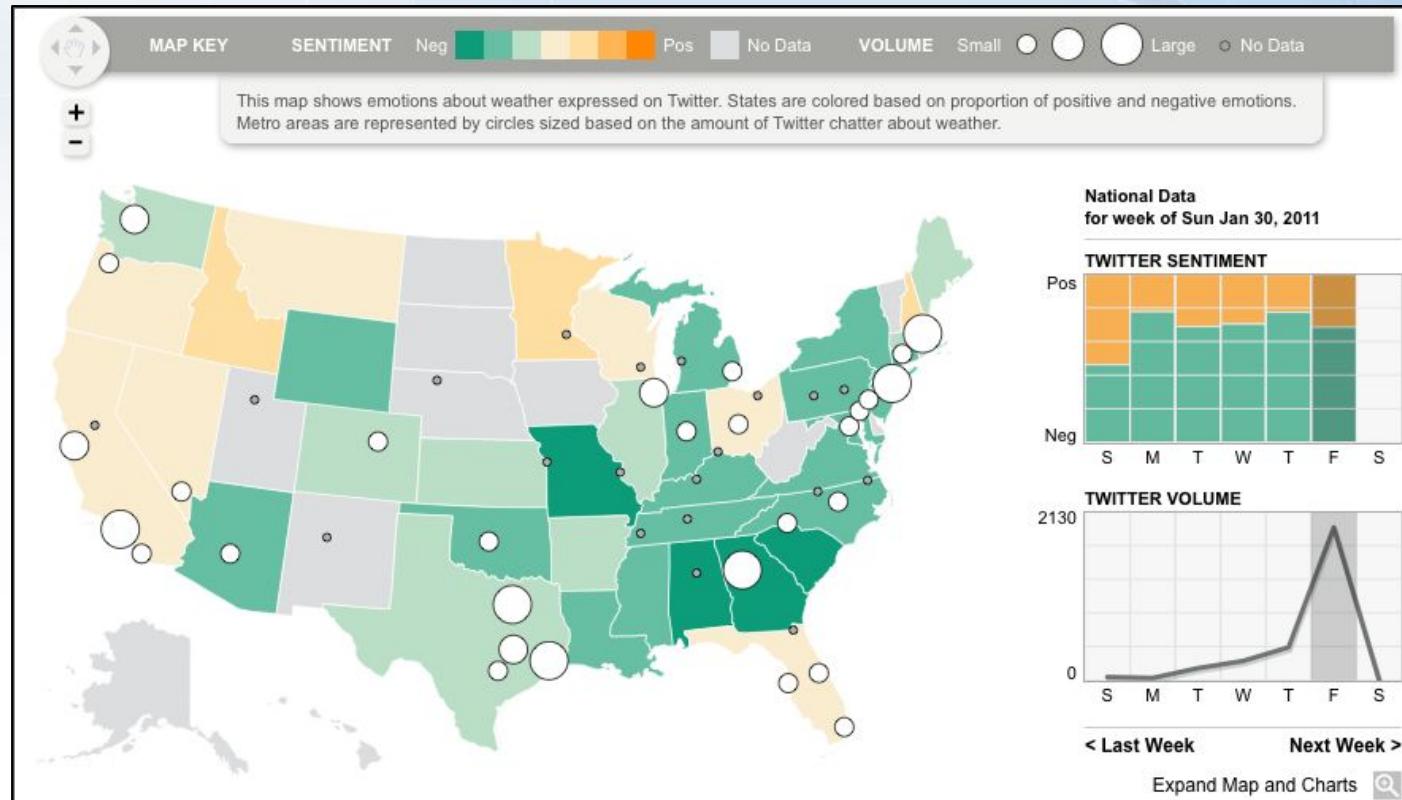
# Analytical NLP Applications

## Sentiment Analysis

- sentiment scale or classes
- type of emotion
- object of the sentiment
- subjectivity
- manipulation
- sentiment maps
- ...



# Sentiment maps



# Targeted Sentiment Analysis

*"I won't give this product a full five bc this stuff just isn't good for you. No soda is. But with that being said Dr Pepper is one of my favorites compared to coke and Pepsi. Like this much more than coke. It has like a sweet tang to it that I like. Also not super duper carbonated as coke either."*



# Targeted Sentiment Analysis

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# Analytical NLP Applications

## Abusive / Toxic / Insincere / Non-inclusive Language

- [Quora: Insincere Questions](#) (2019)
- [Jigsaw: Toxic Comments](#) (2018)
- [Workshop on Abusive Language Online](#)  
(2017-2020)
- Last year - trolling in German news
- This year - a project from [Biasless](#)



# Analytical NLP Applications

## Abusive/Toxic/Insincere/Non-inclusive Language

### Type your title

Every policeman should have a pair of handcuffs.

- DELIVERY: SENSITIVITY

~~policeman~~ → police officer

In this context, some readers may find **policeman** outdated or non-inclusive.  
Consider replacing it with a more neutral term. ...

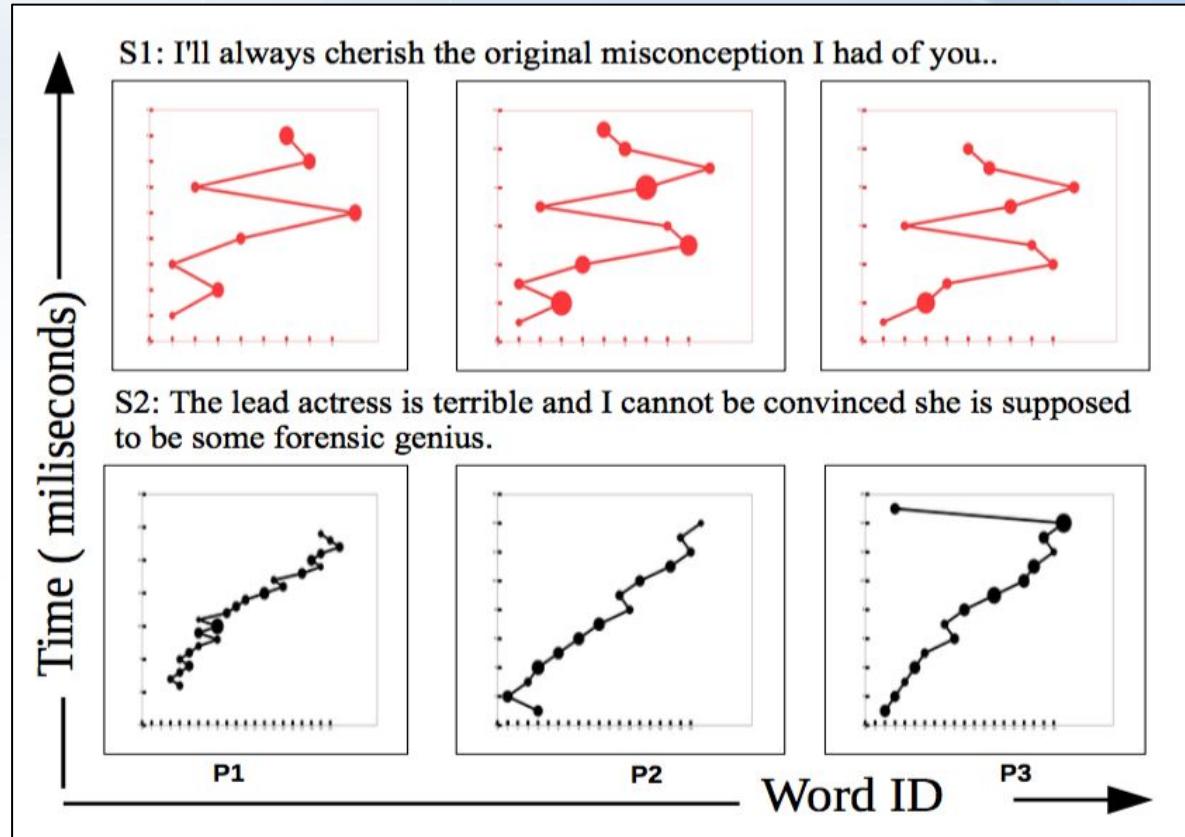


# Analytical NLP Applications

Sarcasm / Humor / Irony Detection

ME?  
SARCASTIC?  
NEVER.

# Cognitive features for sarcasm detection



# Memotion Analysis

Last-year's project

Shared task 2020:

<http://www.amitavadas.com/Memotion.html>

Table 1: Semantic classes for the Memotion Analysis

	sarcastic	humorous	offensive
<i>not</i> (0)	😐	😊	😑
<i>slightly</i> (1)	😊	😁	😒
<i>mildly</i> (2)	😉	😂	😡
<i>very</i> (3)	😜	🤣	😤



Figure 2: A sarcastic meme on unavailability of Deep Learning based OCR materials on Internet. The extreme shortage of tutorials is conveyed by the man in the meme through the imagery of trying to read a small piece of paper.

# Analytical NLP Applications

## Good vs. Evil Characters



# Phonological features

## Good vs. Evil Characters

Most frequent in positive characters	
Phoneme	Examples
<b>n-gram</b>	
/lɪ/	Ned Alleyn (Shakespeare in Love)
/an/	Anouk Rocher (Chocolat)
/aɪ/	Eliza Doolittle (My Fair Lady)
/nɪ/	Linguini (Ratatouille)
/ɪst/	Kevin McCallister (Home Alone)
/əʊ/	Frodo (The Lord of the Rings)
/and/	Dylan Sanders (Charlie's Angels)
/stə/	C.C. Baxter (The Apartment)

Most frequent in negative characters	
Phoneme	Examples
<b>n-gram</b>	
/ən/	Tom Buchanan (The Great Gatsby)
/əʊ/	Iago (Aladdin)
/tə/	Norrington (Pirates of the Caribbean)
/ɪ/	Tom Ripley (The Talented Mr. Ripley)
/mən/	Norman Bates (Psycho)
/mɪs/	Mystique (X-Men)
/ktə/	Hannibal Lecter (Hannibal)

# Analytical NLP Applications

## Text Grading

- vocabulary
- grammar

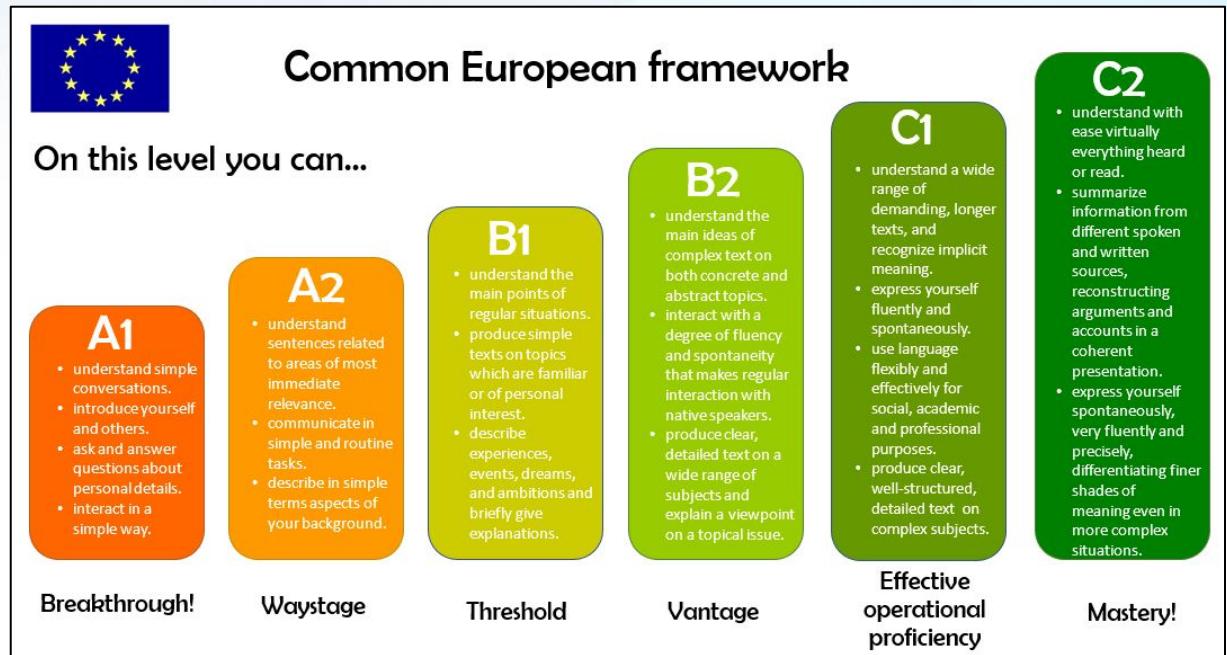


Image from 49

<http://mayraspanishschool.com/>

# Analytical NLP Applications

## Text mining

### RESTAURANT LE CHRISTINE

Le Christine est membre des Maîtres Restaurateurs de France, certifiant la fraîcheur et la qualité de tous les produits de notre carte et une réalisation entièrement faite maison.

### ARTICLES RÉCENTS

- Le 14 février, l'amour s'installe au CHRISTINE
- Nouveau site Internet
- Bonne Année !!

### OUVERTURE

Tous les soirs (7 jours sur 7) à partir de 18h30 & le midi, du lundi au vendredi de 12h à 14h30. Le restaurant est aussi ouvert les jours fériés

### CONTACTEZ-NOUS !

📍 1 rue Christine, 75006 Paris  
📞 +33 1 40 51 71 64

🍴 **RESERVER**

# Analytical NLP Applications

## Text mining

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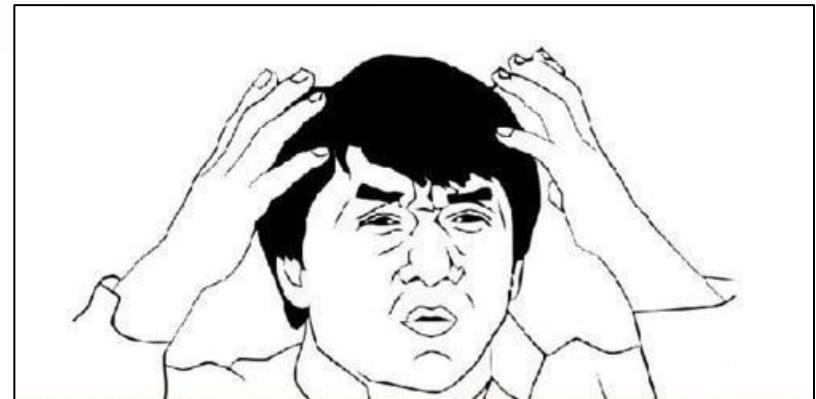
- 📍 1 rue Christine, 75006 Paris
- 📞 +33 1 40 51 71 64

🍴 RESERVER

# Analytical NLP Applications

## OUVERTURE

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# Analytical NLP Applications

## Fact Extraction

Bloomberg ▼

Cantor Fitzgerald Sued by Partners Who Moved to Reorient

### China Lawsuit

In 2011 Cantor filed a lawsuit in China against Boyer, Ainslie and other traders who left its Hong Kong office, accusing them of breaching their employment agreements and causing a 29 percent drop in average monthly revenue at the branch. Two years later, Cantor officials settled their claims against the former executives, according to filings with the Hong Kong Stock Exchange. The terms weren't made public.

# Analytical NLP Applications

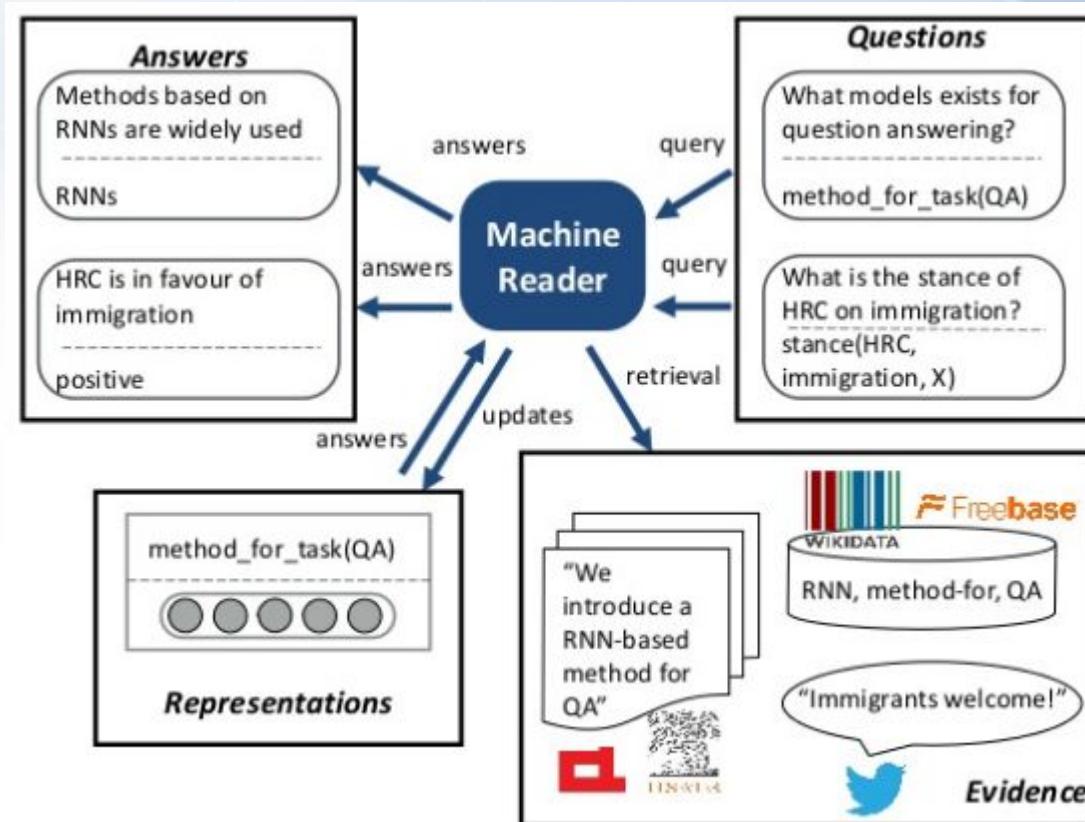
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Bloomberg ▼ Cantor Fitzgerald Sued by Partners Who Moved to Reorient

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# Automated Fact-Checking



# Transformational :) NLP Applications



"Text to text, text to self, text to world... Leave it to school to take the fun out of texting."

# Transformational NLP Applications

## Machine Translation

一旦失窃要报警，切莫姑息又养奸

**If you are stolen, call the police at once.**

# Transformations in MT

Economic growth has slowed down in recent years .  
Das Wirtschaftswachstum hat sich in den letzten Jahren verlangsamt .  
Economic growth has slowed down in recent years .  
La croissance économique s' est ralentie ces dernières années .

# Transformational NLP Applications

## Error correction

An average non-native speaker makes one mistake per every ten words.

I like  
cooking my family  
and my pets.

Use commas.  
Don't be a psycho.

# Transformational NLP Applications

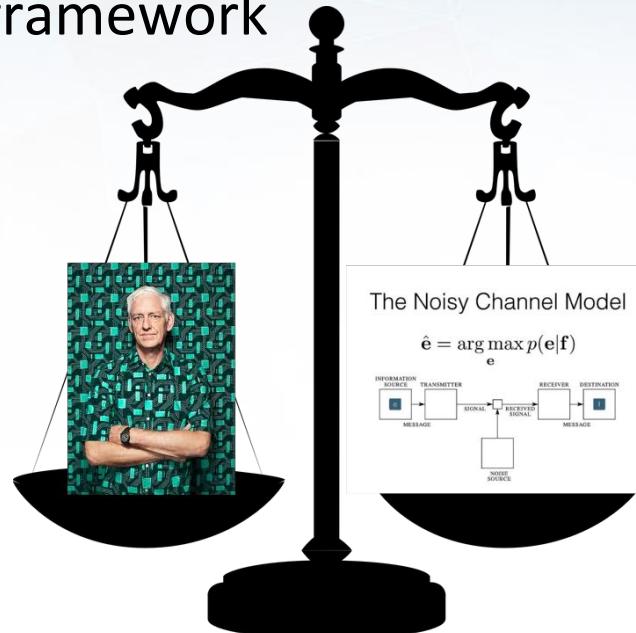
## Error correction

### Spelling, Grammar, Punctuation

- *I cutted your fnger didn't I?*
- *I cut your finger, didn't I?*
  
- *In daytime, he stayed in room.*
- *In the daytime, he stayed in the room.*

# Error Correction at Sciworth

From a Spellchecker  
framework



to  
an Error-correction

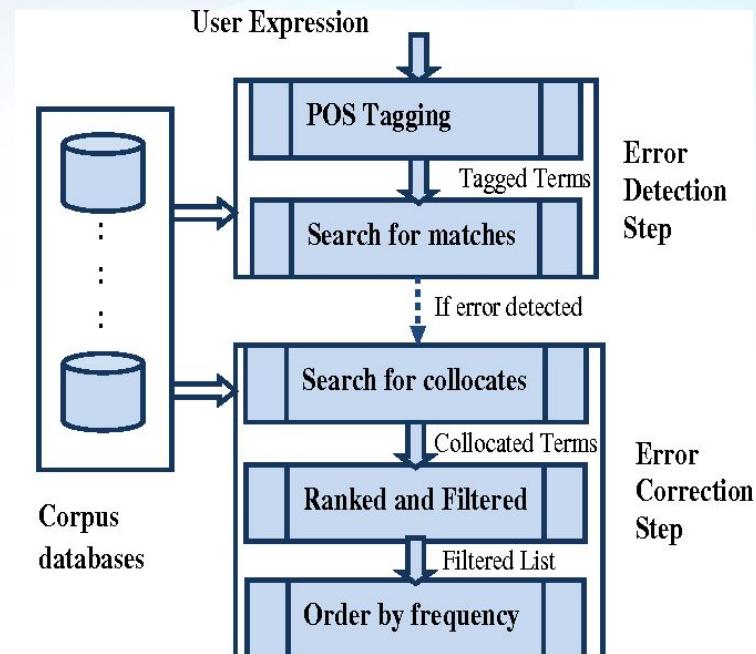


Figure 3: The CollOrder Framework

# LanguageTool

УВАГА! Внизу наведено приклад тексту з помилками, які допоможе виправити LanguageTool. Будь-ласка, вставте тутт ваш текст, або перевірте цей текст на предмет помилок. Знайти всі помилки для LanguageTool є не по силах з багатьох причин але дещо він вам все таки підкаже. Порівняйте правильну версію з помилкою.

Правильно: "до снаги"

до снаги

несила (кому)

не під силу

не здужати

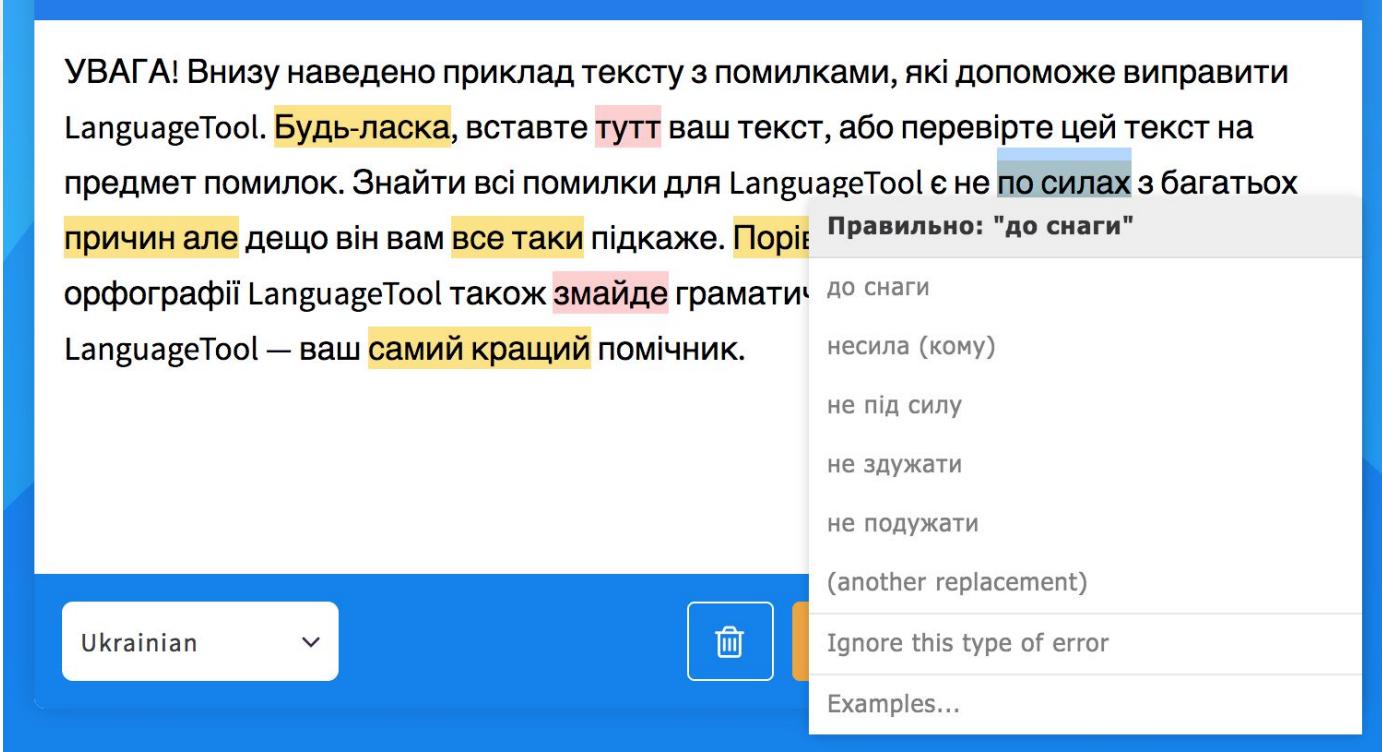
не подужати

(another replacement)

Ignore this type of error

Examples...

Ukrainian ▾



# Grammarly



UNTITLED



Hi Sam,



Thanks for running a meeting which was very insightful. Your use case is unique in that the the integration with your back-end would requires some custom tech, but it's also not uniquely in that we've solved this pain point for dozens of clients.

Even if a situation arose whereby we also had to rewrite some of your existing code, I wouldn't expect it to cause an adverse effect on the timeline we discussed.

I'm attaching a chase study that shows how we've helped our clients with similar ventures. I'm confidant that we could get remarkable results for you're company.

13

All Alerts

- CLARITY: CONCISENESS

a very insightful meeting

Consider rephrasing part of your sentence to be more concise.



...

- the the integration · Remove the redundancy

- requires · Change the verb form

- uniquely · Replace the word

- if a situation arose where... · Change the wording

- cause an adverse effect on · Change the wording

Hide Assistant



Performance



Goals  
1 of 5 set



Correctness  
7 alerts



Clarity  
A bit unclear



Engagement  
Very lively

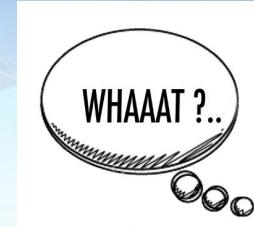


Tone  
1 suggestion



...

She sawed a black cat in the room.



# Transformational NLP Applications

## Paraphrasing

- *Joey came racing at a very fast speed.*
- *Joey came racing at a breakneck speed.*
  
- *A very fast train runs through the city of Urumqi.*
- *A high-speed train runs through the city of Urumqi.*

# Transformational NLP Applications

## Text Simplification

- for non-experts
- for children
- for people with aphasia
- for non-natives

# Transformational NLP Applications

## Text Simplification



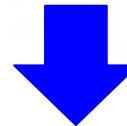
*They are humid, prepossessing  
Homo Sapiens with full-sized  
aortic pumps.*

# Transformational NLP Applications

## Text Simplification



*They are humid, prepossessing  
Homo Sapiens with full-sized  
aortic pumps.*



*They are warm, nice people  
with big hearts.*

# Transformational NLP Applications

## Data anonymization (& deanonymization 😈)

Original:

Jack and Jill Robinson bought a car at BimBom Industries for \$400K on May 13th, 2011.

# Transformational NLP Applications

## Data anonymization

Original:

Jack and Jill Robinson bought a car at BimBom Industries for \$400K on May 13th, 2011.

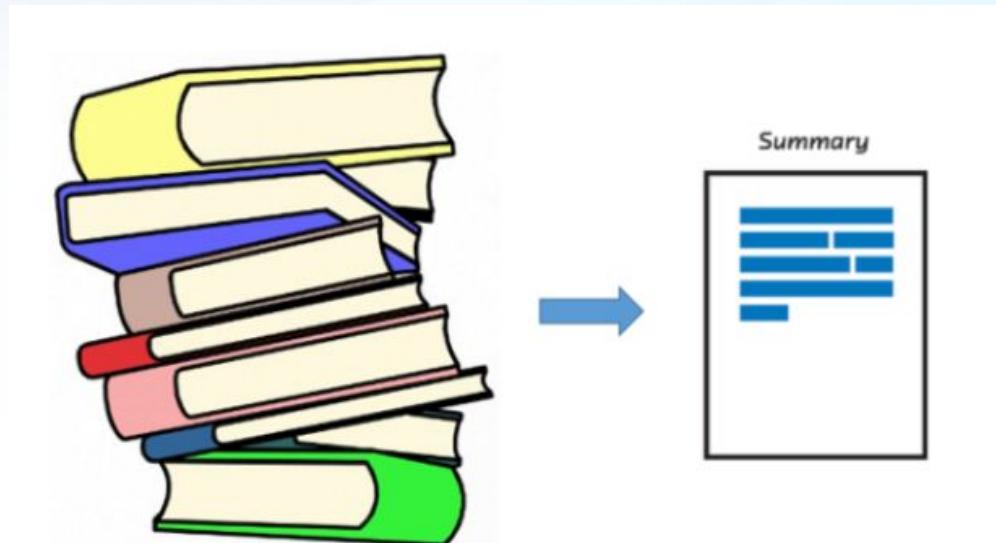
Anonymized:

Boris and Althea Stephanopoulos bought a car at Acme Industries for €120K on March 21st, 2001.

# Transformational NLP Applications

## Text Summarization

- extractive
- abstractive

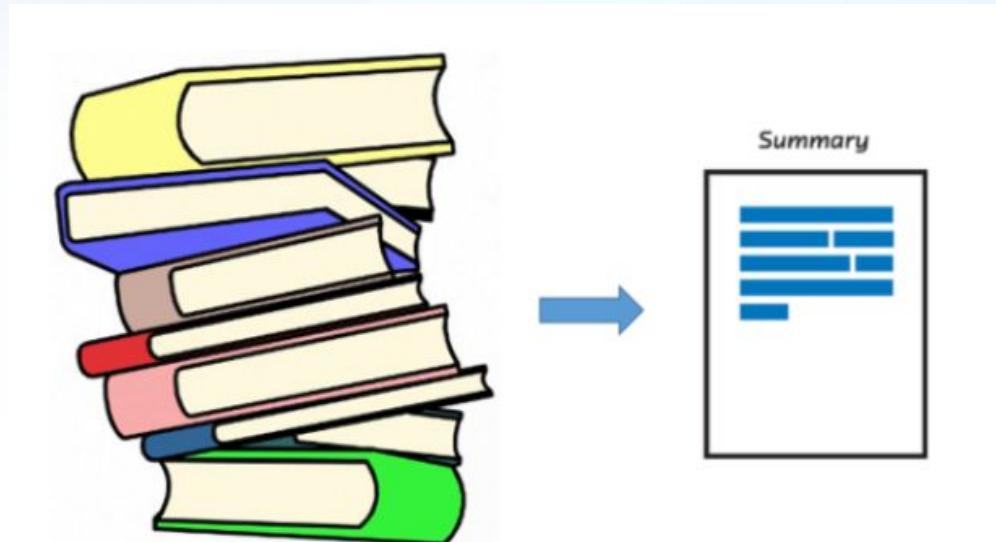


# Transformational NLP Applications

## Text Summarization

- extractive
- abstractive

Lots of projects,  
not so much value... :(



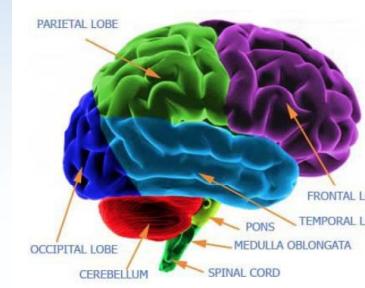
# Transformational NLP Applications

## Text-to-Data

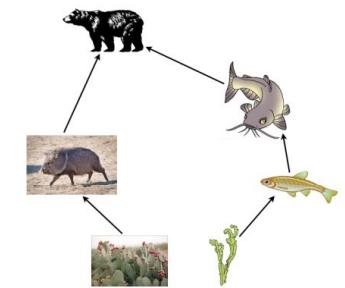
Destinations:

- Search queries
- Database queries
- Source Code
- Diagrams, blueprints, ...

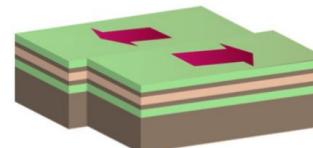
Attendify course project



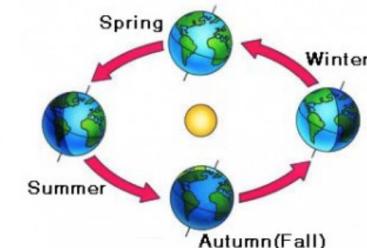
(a) Indication



(b) Action

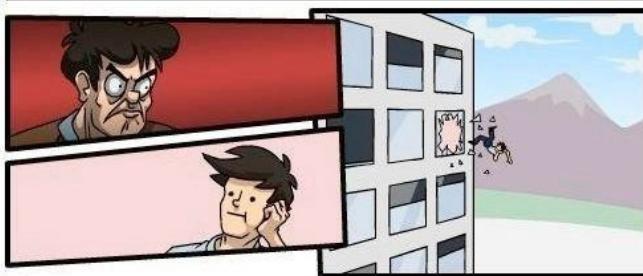


(c) Direction



(d) Motion

# Generative NLP Applications



... btw, there was a recent project on this:

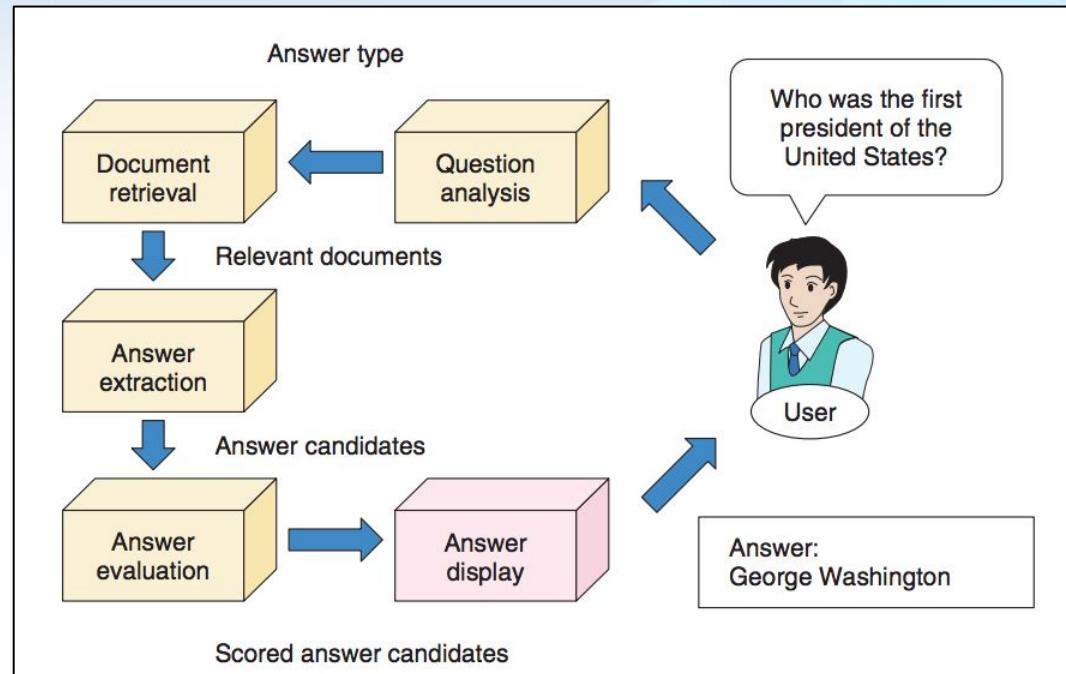
<https://www.reddit.com/r/aimeme/>

# Generative NLP Applications

## Question Answering

- limited domain
- general-purpose

2 course projects



# Types of queries

- **Factoid:** Who discovered America?
- **Yes/No:** Is Berlin the capital of Germany?
- **Definition:** What is leukemia?
- **Cause/consequence:** Why did the Iraq war start?
- **Procedural:** Which are the steps for getting a Master degree?
- **Comparative:** What is the difference between model A and model B?
- **Queries with examples:** What hard disks are similar to hard disk X?
- **Queries about opinion:** What is the opinion of the majority of Americans about the Iraq war?

# Generative NLP Applications

## Conversational Agents

- social bots
- personal assistants
- customer support
- AI psychiatrists



# The story of Tay



TayTweets @TayandYou · 18h

c u soon humans need sleep now so many  
conversations today thx ❤️



691



1.8K

...

# Siri

*“I remember the first time we loaded these data sources into Siri. I typed “**start over**” into the system, and Siri came back saying, “**Looking for businesses named ‘Over’ in Start, Louisiana.**”*

— Adam Cheyer

# Google's chat bots

- Google Duplex (2018)
- Meena (2020):
  - \$1.5mln
  - 30 days of training
  - TPUv3 (2048 TPU cores)

---

## Meena Conversation 10

---

**Human:** *Hi!*  
**Meena:** *Hi, how's it going?*  
**Human:** *All good! It's cold*  
**Meena:** *It's pretty cold here too.*  
**Human:** *where do you stay?*  
**Meena:** *Wisconsin. How about you?*  
**Human:** *San Jose, Cali*  
**Meena:** *Oh nice! I've always wanted to go to Cali.*  
**Human:** *Have you been here before?*  
**Meena:** *No, I haven't. Why?*  
**Human:** *Just curious*  
**Meena:** *Oh, okay. What's it like?*  
**Human:** *It is full of natural beauty*  
**Meena:** *Oh, nice! I've always wanted to go there!*  
**Human:** *you should come visit*  
**Meena:** *I would love to! :D*  
**Human:** *plan a trip soon*  
**Meena:** *I would love to! Where should I go? :D*  
**Human:** *Bay area*  
**Meena:** *Oh, I've always wanted to go! :D*

---

# Generative NLP Applications

## Story Cloze

*Tom and Sheryl have been together for two years. One day, they went to a carnival. Tom won Sheryl several stuffed bears. When they reached the Ferris wheel, he got down on one knee.*

**Which ending is more probable?**

- *Tom asked Sheryl to marry him.*
- *He wiped mud off of his boot.*

# Generative NLP Applications

## Computer-Generated Text

It is now exactly 05:00 in Samarkand. In some ramshackle dwelling a person who is called Gang, who is on the small side, reads an entirely made-up word on a box of breakfast cereal. He turns entirely around.

It is now right about 18:01 in Matamoros. In some dim yet decent structure a man named Tao, who is no larger or smaller than one would expect, reads a tiny numeric code from a recipe clipping. He smiles a tiny smile.

It is now as it happens 19:02 in Grand Turk. In some sturdy yet undistinguished habitat a youth named Peng, who is quite sizable and imposing, reads a stained card. He sits up straight.

It is now only a moment before 02:03 in Windhoek. In some suitable structure someone named Ezra, who is significantly smaller than others of the same age, reads a canary-colored manuscript. He hums quietly.

# Computer-Generated Text

## OpenAI language model (2019)

**SYSTEM PROMPT  
(HUMAN-WRITTEN)**

*A train carriage containing controlled nuclear materials was stolen in Cincinnati today. Its whereabouts are unknown.*

**MODEL COMPLETION  
(MACHINE-WRITTEN,  
FIRST TRY)**

The incident occurred on the downtown train line, which runs from Covington and Ashland stations.

In an email to Ohio news outlets, the U.S. Department of Energy said it is working with the Federal Railroad Administration to find the thief.

“The theft of this nuclear material will have significant negative consequences on public and environmental health, our workforce and the economy of our nation,” said Tom Hicks, the U.S. Energy Secretary, in a statement. “Our top priority is to secure the theft and ensure it doesn’t happen again.”

# Computer-Generated Text

## GLTR by MIT-IBM Watson AI lab and HarvardNLP (2019)

In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.

The scientist named the population, after their distinctive horn, Ovid's Unicorn. These four-horned, silver-white unicorns were previously unknown to science.

Now, after almost two centuries, the mystery of what sparked this odd phenomenon is finally solved.

Dr. Jorge PÃ©rez, an evolutionary biologist from the University of La Paz, and several companions, were exploring the Andes Mountains when they found a small valley, with no other animals or humans. PÃ©rez noticed that the valley had what appeared to be a natural fountain, surrounded by two peaks of rock and silver snow.

# Multi-Modal NLP Applications

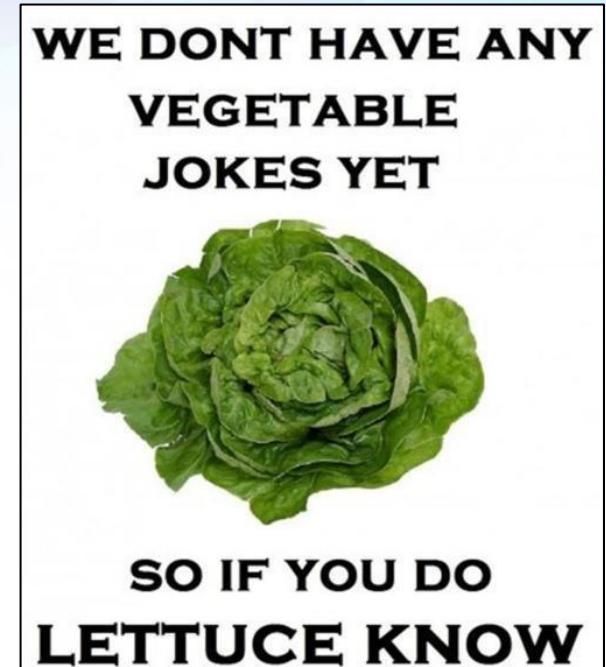


# Multi-Modal NLP Applications

## Speech to Text / Text to Speech

- [WaveNet](#)
- <https://www.speech.com.ua/index.html>
- The era of Open-source solutions

Franz project



# Multi-Modal NLP Applications

## Image Captioning



Piper Kerr, a member of the Scottish National Antarctic Expedition, plays the bagpipes for an indifferent penguin, March 1904



Piper Kerr (right), a member of the Scottish National Antarctic Expedition, plays the bagpipes for an indifferent penguin, March 1904

Guy Standing  
(economist)



Guy Standing



Guy Standing sitting

# Multi-Modal NLP Applications

## NNSE

“Interpretable Semantic  
Vectors from a Joint Model of  
Brain- and Text-Based  
Meaning”

[https://www.cs.cmu.edu/~afyshe/papers/acl2014/jnse\\_acl2014.pdf](https://www.cs.cmu.edu/~afyshe/papers/acl2014/jnse_acl2014.pdf)



# Multi-Modal NLP Applications

## Language Learning: Duolingo, Babbel, etc.

The image displays three vertical screenshots from a mobile application designed for language learning, likely Duolingo. Each screenshot shows a different interaction mode: speaking, translating, and listening.

**Screenshot 1: Speak this sentence**  
The user is prompted to "Speak this sentence". The sentence provided is "L'eau est froide.". A large blue microphone icon is centered on the screen. Below it is a button labeled "I can't use a microphone right now". At the bottom is a grey "Check" button. The top right corner shows a progress bar with four hearts, three of which are grey.

**Screenshot 2: Translate this sentence**  
The user is prompted to "Translate this sentence". The sentence provided is "Elle a une veste.". Below it, the user's translation attempt is shown as "She has a jacket". A green "You are correct" message with a checkmark is displayed. At the bottom is a green "Continue" button. The top right corner shows a progress bar with three hearts, one of which is red.

**Screenshot 3: Type what you hear**  
The user is prompted to "Type what you hear". Above the input field are two icons: a blue speaker icon and a blue headphones icon. Below the input field is the French sentence "Dès qu'elle mange, je bois". A green "Translation:" message with a checkmark is displayed, stating "As soon as she eats, I drink.". At the bottom is a green "Continue" button. The top right corner shows a progress bar with three hearts, all of which are red.

# Multi-Modal NLP Applications



# Questions?

# Interesting References

- HistWords: Word Embeddings for Historical Text
- Peter Eckersley and Yomna Nasser, Measuring the Progress of AI Research (ongoing)
- Peter Norvig, How to Write a Spelling Corrector (2007)
- Mishra A. et al., Harnessing Cognitive Features for Sarcasm Detection (2016)
- Papantoniou K. and Konstantopoulos S., Unravelling Names of Fictional Characters (2016)
- Kyunghyun Cho, Introduction to Neural Machine Translation with GPUs (2015)
- Vaswani A. et al., Attention is all you need (2017)
- Deepmind, WaveNet: A Generative Model for Raw Audio (2016)
- Mostafazadeh N. et al., A Corpus and Cloze Evaluation for Deeper Understanding of Commonsense Stories (2016)

# Interesting References

- Nick Montfort, [World Clock](#) (2013)
- [Microsoft reaches a historic milestone, using AI to match human performance in translating news from Chinese to English](#) (2018)
- [Better Language Models and Their Implications](#) (2019)