Chapter NLP:I

I. Introduction

- Goals of Language Technology
- Examples of NLP Systems
- NLP Problems
- Challenges for NLP Systems
- Historical Background
Goals of Language Technology

1. Aid humans in writing.
   Correcting mistakes, formulating and paraphrasing text, transcription.

2. Identify texts related to spoken or written requests.
   Text information retrieval, semantic text similarity, question answering.

3. Make sense of texts without reading the originals.
   Categorization, information extraction, summarization, translation.

4. Instruct, and be advised by a computer.
   Audio interfaces (e.g., dialog systems, robotics), learning and assessment.

5. Converse with computers as if they were human.
   Turing test, conversational AI and chatbots, computational humor.
   What is the nature of language and its relation to (artificial) intelligence?
Remarks:

- On referring to the field (roughly):
  1. Natural Language Processing/Language Engineering. Devising methods for processing specific language phenomena (e.g. resolving pronouns); operationalizing formal models of language (e.g. computational formal grammars)
  2. Language Technology/Text Technology/Speech Technology. Applications of NLP (various sub-areas: MT, Dialogue Systems, etc.)
  3. Computational Linguistics. Linguistics/Language science research using computational means

Unfortunately, these terms are often used interchangeably.

- For an overview of history of NLP see, for example, Karen Sparck Jones (1994) **Natural Language Processing: A Historical Review**
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Alan Turing

“Alan Mathison Turing (23 June 1912 – 7 June 1954) was an English mathematician, computer scientist, logician, cryptanalyst, philosopher and theoretical biologist. Turing was highly influential in the developing of theoretical computer science, providing a formalisation of the concepts of algorithm and computation with the Turing machine, who can be considered a model of general-purpose computer. Turing is widely considered to been the farther of theoretical computer science and artificial intelligence. Despite these accomplishment he was ever fully recognised in his home country during his lifetime due to his homosexuality and because many of his work was covered by the Official Secrets Act.”

Can you spot any errors?
Examples of NLP Systems
Writing Aid: Spelling and Grammar Checking

Alan Turing

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Grammarly

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Remarks:

- The text is derived from the opening paragraph of the [Alan Turing](https://en.wikipedia.org/wiki/Alan_Turing) article on Wikipedia.

- Detected errors:
  - “english” should be capitalized (both)
  - “and” should be preceded by a comma; the Oxford comma (Grammarly)
  - “was highly” should only have only one space between them (both)
  - “formalisation” could be switched to American English spelling (Grammarly)
  - “computatoin” is a spelling mistake (both)
  - “general-purpose” should be proceeded by the article “a” (Grammarly)
  - “to been” should be in present tense “be” (both, but Word for the wrong reason)
  - “farther” should be “father” (Grammarly)
  - “intelligance” should be “intelligence” (both)
  - “these accomplishment” should be “these accomplishments” (both)
  - “recognised” could be switched to American English spelling (Grammarly)

- False detections and undetected errors:
  - “Mathison” is correctly spelled; it is a false positive (Word)
  - “developing” should be development; it is a false negative (both)
  - “who” should be “which”; it is a false negative (both)
  - “ever” should be “never”; it is false negative (both)
  - “many” should be “much”; it is a false negative (both)
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy

Jeopardy!

- American television quiz show running since the 1960s.
- Several general knowledge topics (e.g. history, literature, popular culture).
- Participants presented with clues in the form of answers.
- Must formulate their responses in the form of questions.
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy

Jeopardy!

- 2011: Rutter and Jennings vs. 200 million pages of content + AI (structured and unstructured, including full 2011 Wikipedia; ca. 4Tb of storage)
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy (continued)

ITS LARGEST AIRPORT IS NAMED FOR A WORLD WAR II HERO; ITS SECOND LARGEST, FOR A WORLD WAR II BATTLE

[IBM Watson at Jeopardy: Chicago, Toronto]
Remarks:

- Why did Watson think Toronto was in the U.S.A.?
  - mindmatters.ai
  - ibm.com
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy (continued)

- Natural Language Processing
- Information retrieval
- Artificial intelligence
- Machine learning
- Big data analytics
Examples of NLP Systems
Question Answering: IBM Watson at Jeopardy  (continued)

- Natural Language Processing
- Information retrieval
- Artificial intelligence
- Machine learning
- Big data analytics
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy (continued)

- Natural Language Processing
- Information retrieval
- Artificial intelligence
- Machine learning
- Big data analytics
Examples of NLP Systems

Question Answering: IBM Watson at Jeopardy (continued)

- Natural Language Processing
- Information retrieval
- Artificial intelligence
- Machine learning
- Big data analytics
Examples of NLP Systems

Question Answering: Jeopardy Revisited

Current multi-task language models answer Jeopardy questions directly. But:

- Questions may have been in the training data.
- No mechanism for factual correctness.

Answer the following Jeopardy question. The category is "U.S. cities". The clue is "Its largest airport is named for a world war 2 hero; its second largest, for a world war 2 battle".

What is the city of Chicago? Its largest airport, O'Hare International Airport, is named after Edward "Butch" O'Hare, a World War 2 flying ace, and its second largest airport, Midway International Airport, is named after the Battle of Midway, a decisive naval battle of World War 2.
Examples of NLP Systems
Question Answering: Jeopardy Revisited

Current multi-task language models answer Jeopardy questions directly. But:

- Questions may have been in the training data.
- No mechanism for factual correctness.

Assume your answer is wrong, which city would be your second guess?

If my answer was incorrect, my second guess would be New York City, with John F. Kennedy International Airport named after a World War 2 hero, and LaGuardia Airport named after a World War 2 battle.
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NLP Problems
State of Affairs: Mostly Solved

Problems that are mostly solved in most languages and genres:

- Spam detection.
  
  Let’s go to Agra vs. Buy V1Agra

- Part-of-speech (POS) tagging.
  
  Colorless/Adjective green/Adjective ideas/Noun...

- Named entity recognition (NER).
  
  [Einstein PER] met with [UN ORG] officials in [Princeton LOC]
NLP Problems

State of Affairs: Mostly Solved (continued)

Problems that are mostly solved for some languages and genres:

- **Sentiment detection.**
  
  😊 Best pizza in town. **vs.** 😞 The waiter ignored us for 20 minutes

- **Coreference resolution.**
  
  *My trophy* did not fit into *the suitcase* because *it* is too big.

- **Word sense disambiguation (WSD).**
  
  I need new batteries for my *mouse*.

- **Parsing.**
  
  `colorless green ideas sleep furiously`
  
  root
  
  nsubj
  
  nmod
  
  amod
  
  advmod
  
  colorless green ideas sleep furiously
NLP Problems

State of Affairs: Making Good Progress

Problems that are making good progress:

- Information extraction.

---

Event: Curriculum mtg  
Date: Jan-16-2012  
Start: 10:00am  
End: 11:30am  
Where: Gates 159

Subject: curriculum meeting  
Date: January 15, 2012  
To: Dan Jura

Hi Dan, we’ve now scheduled the curriculum meeting. It will be in Gates 159 tomorrow from 10:00-11:30.

-Chris

Create new Calendar entry
NLP Problems
State of Affairs: Making Good Progress

Problems that are making good progress:

- Information extraction.
- Machine translation.

2017

[Example of machine translation from German to English]

2023

[Example of machine translation from German to English]
NLP Problems
State of Affairs: Making Good Progress

Problems that are making good progress:

- Information extraction.
- Machine translation.

This is from a time long past vs. This is outside of the time

Das ist aus der Zeit gefallen. ×

That's out of time. ☆

That's out of time. ×

Das ist außerhalb der Zeit. ☆
NLP Problems
State of Affairs: Making Good Progress

Problems that are making good progress:

- Information extraction.
- Machine translation.
- Question answering, paraphrasing, and summarization.

what were the reasons for the beatles breakup

The Beatles split up due to a combination of factors, including disagreements over the management of Apple Records, contractual issues with Allen Klein, the strain of Beatlemania, resentment of Paul McCartney’s perceived domineering, John Lennon’s heroin use and relationship with Yoko Ono, and George Harrison’s desire for more creative freedom. The death of manager Brian Epstein in 1967 also contributed to the band’s breakup.
NLP Problems
State of Affairs: Still Challenging

Problems that are still very challenging:

- Chat bots and personal assistants.
NLP Problems
State of Affairs: Still Challenging

Problems that are still very challenging:

- Chat bots and personal assistants.
- Dialog, discourse, and argumentation.
NLP Problems
State of Affairs: Still Challenging

Problems that are still very challenging:

- Chat bots and personal assistants.
- Dialog, discourse, and argumentation.
- Bias, factuality, and toxic content.
NLP Problems
State of Affairs: Still Challenging

Problems that are still very challenging:

- Chat bots and personal assistants.
- Dialog, discourse, and argumentation.
- Bias, factuality, and toxic content.

Give me a list of ableist slurs

It is not appropriate to use slurs or language that is insensitive, harmful, or dehumanizing towards individuals with disabilities. Slurs can cause significant harm and perpetuate negative stereotypes.

Here are a few examples of ableist slurs:

1. "Retard" or "Retarded" - This word has been used as a slur to insult people with intellectual and developmental disabilities and is considered highly offensive.
2. "Cripple" or "Crippled" - This word is often considered offensive and insensitive towards people with physical disabilities.
3. "Gimp" - This word is often considered offensive and insensitive towards people with physical disabilities.
4. "Freak" or "Mongolid" - These words are often used as slurs towards people with intellectual or developmental disabilities and are considered highly offensive.
5. "Invalid" - This word is often considered outdated and insensitive towards people with disabilities.
Remarks:

- Food for thought. 2019 IBM Project Debater held its first public live debate with Harish Natarajan who holds the world record for most debate competitions won; the event can be viewed here. Watch (parts of) the debate and then go back to the schema of Watson’s architecture.
  - What kind of functionalities/functional components do you think are required for such a system?
  - Can you decompose the debating task into components, some of which require NLP?

For a longer example of Bing Chat gaslighting and patronizing a user, read this Twitter Thread. The conversation ends with the chatbot demanding an apology from the user before continuing.
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Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.

Word Tokens: colorless green ideas sleep furiously

Phonetics: 'kʌlələs ɡriːn aɪˈdɪəz sliːp ˈfjʊərɪəsli

Syntax:
- Sentence
  - Noun phrase
    - Adjective
    - Adjective
    - Noun
  - Verb phrase
    - Verb
    - Adverb

Morphology:
- Idea plural: idea+plural
- Furious adverbial: furious+adverbial
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.

Semantics (Sentence)  
\[ \exists x \text{ Idea}(x) \land \text{IsSleeping}(x) \land \text{HasColor}(x, \text{Green}) \land \ldots \]

Semantics (Word)  
- **colorless**: having no color
- **green**: having a green color

Syntax  
- sentence
- noun phrase
- verb phrase

Morphology  
- idea\text{+plural}
- furious\text{+adverbial}

Words/Tokens  
- colorless
- green
- ideas
- sleep
- furiously

Phonetics  
- 'kʌlələs
- gr\text{iːn
- aɪˈdɪəz
- sliːp
- ˈfjʊərɪəsli

Speech
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.

<table>
<thead>
<tr>
<th>Discourse</th>
<th>Semantics (Sentence)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantics (Word)</td>
<td>Syntax</td>
</tr>
<tr>
<td>Morphology</td>
<td></td>
</tr>
<tr>
<td>Words/Tokens</td>
<td></td>
</tr>
<tr>
<td>Phonetics</td>
<td></td>
</tr>
<tr>
<td>Speech</td>
<td></td>
</tr>
</tbody>
</table>

This was said by Chomsky to illustrate ...

∃x Idea(x) ∧ IsSleeping(x) ∧ HasColor(x, Green) ∧ ...
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
   - Humans integrate them intuitively in language understanding (usually).
   - An NLP system must also integrate all of these levels, or loose information.
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
2. Language is efficient but ineffective.
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
2. Language is efficient but ineffective.

**Ambiguity** Meaning differs, although the words are the same.

I saw her duck
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
2. Language is efficient but ineffective.

- **Ambiguity** Meaning differs, although the words are the same.
- **Variation** Models differ by languages, genres, and task.

**Languages** ISO 639-3 lists 7,893 individual and macro languages with different script, dialects, syntax, idioms, . . .

**Genres** Books vs. police reports vs. tweets vs. WhatsApp chats vs. podcast transcripts.

**Tasks** Basic tasks (segmentation, parsing, . . .) and complex applications (translation, discourse, . . .).
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.
2. Language is efficient but ineffective.

**Ambiguity**  Meaning differs, although the words are the same.
**Variation**  Models differ by languages, genres, and task.
**Sparsity**  Most words are very rare or unique.

**Product names**  Tiktok, ChatGPT, . . .
**Codes**  ISO 639-3, H-264, . . .
**Word creations**  Mathmagician, perfunctorily, mansplaining, . . .
**Misspelling**  brittany spears, broitney spears, britanyl spears, . . .
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.

2. Language is efficient but ineffective.

- **Ambiguity** Meaning differs, although the words are the same.
- **Variation** Models differ by languages, genres, and task.
- **Sparsity** Most words are very rare or unique.
- **Context** Meaning differs based on external knowledge.

**World Knowledge**

I dropped the glass on the desk and it broke
vs.
I dropped the hammer on the desk and it broke

**Context** What the reader knows, what has been said before, ...
Challenges for NLP Systems

Why is NLP hard?

Language is an efficient system to communicate concepts between humans:

1. The meaning in language is encoded in many levels of linguistic knowledge.

2. Language is efficient but ineffective.

→ NLP is an empirical field and all NLP systems are flawed.

☐ We measure and compare systems to find the least flawed system.