1. Intro & Word vectors

LING-581-Natural Language Processing1

Instructor: Hakyung Sung

August 26, 2025

*Acknowledgment: These course slides are based on materials from CS224N: NLP with Deep Learning @ Stanford University.

Table of contents

1. Introduction
2. Lesson plan
3. Human language & Word meaning
4. Encoding and embedding
5. Wrap-up

Introduction

Course logistics

- Instructor: Dr. Hakyung Sung

Course logistics

- Instructor: Dr. Hakyung Sung
    - PhD in Linguistics, MS in Computer Science @ University of Oregon

Course logistics

- Instructor: Dr. Hakyung Sung
    - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido

Course logistics

- Instructor: Dr. Hakyung Sung
  - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
  - a second year Experimental Psychology graduate student

Course logistics

- Instructor: Dr. Hakyung Sung
  - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
  - a second year Experimental Psychology graduate student
- Time: Tu/Th 12:30PM-1:45PM

Course logistics

- Instructor: Dr. Hakyung Sung
    - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
    - a second year Experimental Psychology graduate student
- Time: Tu/Th 12:30PM-1:45PM
- Office: EAS 3173

Course logistics

- Instructor: Dr. Hakyung Sung
    - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
    - a second year Experimental Psychology graduate student
- Time: Tu/Th 12:30PM-1:45PM
- Office: EAS 3173
- Office hour: TuTh 3:30-4:30 in-person, or Zoom by appointment

Course logistics

- Instructor: Dr. Hakyung Sung
  - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
  - a second year Experimental Psychology graduate student
- Time: Tu/Th 12:30PM-1:45PM
- Office: EAS 3173
- Office hour: TuTh 3:30-4:30 in-person, or Zoom by appointment
- Email: `hksgla@rit.edu`

Course logistics

- Instructor: Dr. Hakyung Sung
    - PhD in Linguistics, MS in Computer Science @ University of Oregon
- Grader: Bea (Bey-uh) Pulido
    - a second year Experimental Psychology graduate student
- Time: Tu/Th 12:30PM-1:45PM
- Office: EAS 3173
- Office hour: TuTh 3:30-4:30 in-person, or Zoom by appointment
- Email: `hksgla@rit.edu`
- Course website: `https://hksung.github.io/Fall25_LING581/`

Learning goals

- The foundations of the effective modern methods for deep learning applied to NLP

Learning goals

- The foundations of the effective modern methods for deep learning applied to NLP
    - Basics first: word vectors, feed-forward networks, recurrent networks, attention

Learning goals

- The foundations of the effective modern methods for deep learning applied to NLP
    - Basics first: word vectors, feed-forward networks, recurrent networks, attention
    - Then key methods used in NLP: encoder-decoder models, transformers, pre-training, post-training, benchmark and evaluation, NLP applications (to language research), etc.

Learning goals

- A big picture understanding of human languages and the difficulties in understanding and producing them via computers

Learning goals

- A big picture understanding of human languages and the difficulties in understanding and producing them via computers
- An understanding of an application to build systems for some of the major problems in NLP: Word meaning, dependency parsing, machine translation, question answering

Learning goals

- A big picture understanding of human languages and the difficulties in understanding and producing them via computers
- An understanding of an application to build systems for some of the major problems in NLP: Word meaning, dependency parsing, machine translation, question answering
- Hands-on exercises conducted during classes (on Thursday)

Learning goals

- A big picture understanding of human languages and the difficulties in understanding and producing them via computers
- An understanding of an application to build systems for some of the major problems in NLP: Word meaning, dependency parsing, machine translation, question answering
- Hands-on exercises conducted during classes (on Thursday)
- Opportunities to connect NLP techniques to specific domains of interest using language data (Final project)

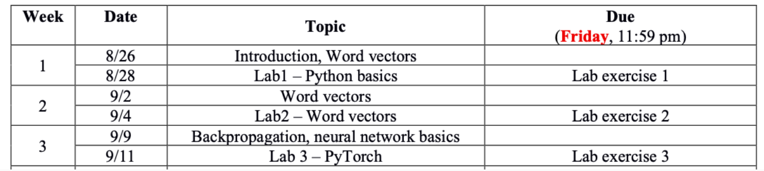
Final grading components

[a × b] a = number; b = points

- Lab exercises [8 × 5]: 40%
- Background research 20%
    - Assignment [1 × 10] 10%
    - Presentation [1 × 10] 10%
- Final project 40%
    - Final project proposal [1 × 10] 10%
    - Final presentation [1 × 15]: 15%
    - Final paper [1 × 15]: 15%

Final grading components

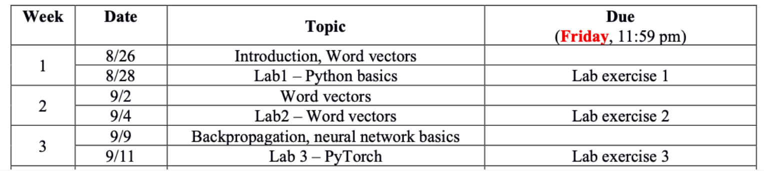
- Lab exercises [8 × 5]: 40%



Week	Date	Topic	Due (**Friday**, 11:59 pm)
1	8/26	Introduction, Word vectors	
	8/28	Lab1 – Python basics	Lab exercise 1
2	9/2	Word vectors	
	9/4	Lab2 – Word vectors	Lab exercise 2
3	9/9	Backpropagation, neural network basics	
	9/11	Lab 3 – PyTorch	Lab exercise 3

Final grading components

- **Lab exercises** [8 × 5]: 40%

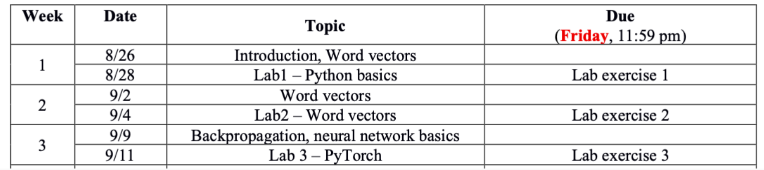


Week	Date	Topic	Due (**Friday**, 11:59 pm)
1	8/26	Introduction, Word vectors	
	8/28	Lab1 – Python basics	Lab exercise 1
2	9/2	Word vectors	
	9/4	Lab2 – Word vectors	Lab exercise 2
3	9/9	Backpropagation, neural network basics	
	9/11	Lab 3 – PyTorch	Lab exercise 3

- Please bring your **laptop on Thursday**.

Final grading components

- **Lab exercises** [8 × 5]: 40%

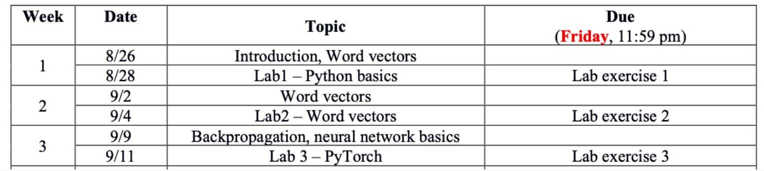


Week	Date	Topic	Due (**Friday**, 11:59 pm)
1	8/26	Introduction, Word vectors	
	8/28	Lab1 – Python basics	Lab exercise 1
2	9/2	Word vectors	
	9/4	Lab2 – Word vectors	Lab exercise 2
3	9/9	Backpropagation, neural network basics	
	9/11	Lab 3 – PyTorch	Lab exercise 3

- Please bring your **laptop on Thursday**.
- Students are expected to complete their exercises **during class and submit their answers before the class ends**.

Final grading components

- **Lab exercises** [8 × 5]: 40%



Week	Date	Topic	Due (**Friday**, 11:59 pm)
1	8/26	Introduction, Word vectors	
	8/28	Lab1 – Python basics	Lab exercise 1
2	9/2	Word vectors	
	9/4	Lab2 – Word vectors	Lab exercise 2
3	9/9	Backpropagation, neural network basics	
	9/11	Lab 3 – PyTorch	Lab exercise 3

- Please bring your **laptop on Thursday**.
- Students are expected to complete their exercises **during class and submit their answers before the class ends**.
- If not possible, the official due date is **Friday** of the same week.

Final grading components

- Background research 20%
    - Assignment [1 × 10] 10%
    - Presentation [1 × 10] 10%
- https://youtube.com/shorts/Yg7WrDt5I1E?si=12YMKYi_OJRj9c6r

Final grading components

- To apply NLP technologies to a given domain, we need at least a basic understanding of that domain (and ideally, a more advanced one).

Final grading components

- To apply NLP technologies to a given domain, we need at least a basic understanding of that domain (and ideally, a more advanced one).
- Think about the areas you are interested in. (e.g., Language learning and NLP applications)

Final grading components

- To apply NLP technologies to a given domain, we need at least a basic understanding of that domain (and ideally, a more advanced one).
- Think about the areas you are interested in. (e.g., Language learning and NLP applications)
- At the end of this class, I will give you some time to reflect on this; Submit your area of interest (it can be broad), and I will form groups of four.

Final grading components

- To apply NLP technologies to a given domain, we need at least a basic understanding of that domain (and ideally, a more advanced one).
- Think about the areas you are interested in. (e.g., Language learning and NLP applications)
- At the end of this class, I will give you some time to reflect on this; Submit your area of interest (it can be broad), and I will form groups of four.
- In **Week 7**, you will submit a more specific research topic.

Final grading components

- To apply NLP technologies to a given domain, we need at least a basic understanding of that domain (and ideally, a more advanced one).
- Think about the areas you are interested in. (e.g., Language learning and NLP applications)
- At the end of this class, I will give you some time to reflect on this; Submit your area of interest (it can be broad), and I will form groups of four.
- In **Week 7**, you will submit a more specific research topic.
- In **Week 13**, you will give a **presentation** about the background research. This presentation will be connected to your **Assignment**.

Final grading components

- Final project 40%
    - Final project proposal [1 × 10] 10%
    - Final presentation [1 × 15]: 15%
    - Final paper [1 × 15]: 15%

Final grading components

- Final project 40%
  - Final project proposal [1 × 10] 10%
  - Final presentation [1 × 15]: 15%
  - Final paper [1 × 15]: 15%
- Based on the problems and prior solutions you identified in your background research, you will design a final project that applies NLP techniques to address the problem (*Continue working on the same group)

Final grading components

- Final project 40%
    - Final project proposal [1 × 10] 10%
    - Final presentation [1 × 15]: 15%
    - Final paper [1 × 15]: 15%
- Based on the problems and prior solutions you identified in your background research, you will design a final project that applies NLP techniques to address the problem (*Continue working on the same group)
- The project proposal is due in Week 9.

Final grading components

- Final project 40%
    - Final project proposal [1 × 10] 10%
    - Final presentation [1 × 15]: 15%
    - Final paper [1 × 15]: 15%
- Based on the problems and prior solutions you identified in your background research, you will design a final project that applies NLP techniques to address the problem (*Continue working on the same group)
- The project proposal is due in Week 9.
- The final presentation and paper are due in Week 16.

More notes

- This process actually follows the typical research flow:

More notes

- This process actually follows the typical research flow:
    1. Review previous research

More notes

- This process actually follows the typical research flow:
    1. Review previous research
    2. Identify a research gap

More notes

- This process actually follows the typical research flow:
    1. Review previous research
    2. Identify a research gap
    3. Apply proposed techniques / conduct analysis

More notes

- This process actually follows the typical research flow:
    1. Review previous research
    2. Identify a research gap
    3. Apply proposed techniques / conduct analysis
    4. Present findings

More notes

- This process actually follows the typical research flow:
    1. Review previous research
    2. Identify a research gap
    3. Apply proposed techniques / conduct analysis
    4. Present findings
    5. Write up the paper

Grading policy

- **2-hr grading window**: Any assignment submitted online will automatically have a 2-hour grading window. This will be applied by the system, and no action is required from students.

Grading policy

- **2-hr grading window**: Any assignment submitted online will automatically have a 2-hour grading window. This will be applied by the system, and no action is required from students.
- **Late penalty**: Late assignments will incur a 10% deduction per day, for up to 5 days (e.g., 1 day late = 10% off). After 5 days, the assignment will receive a grade of zero.

Grading policy

- **2-hr grading window**: Any assignment submitted online will automatically have a 2-hour grading window. This will be applied by the system, and no action is required from students.
- **Late penalty**: Late assignments will incur a 10% deduction per day, for up to 5 days (e.g., 1 day late = 10% off). After 5 days, the assignment will receive a grade of zero.
- **Extenuating circumstances:** Whenever possible, please request an official document that can prove the circumstances—this allows me to accommodate you fairly while respecting your privacy.

Grading policy

- **2-hr grading window**: Any assignment submitted online will automatically have a 2-hour grading window. This will be applied by the system, and no action is required from students.
- **Late penalty**: Late assignments will incur a 10% deduction per day, for up to 5 days (e.g., 1 day late = 10% off). After 5 days, the assignment will receive a grade of zero.
- **Extenuating circumstances:** Whenever possible, please request an official document that can prove the circumstances—this allows me to accommodate you fairly while respecting your privacy.
    - If that is not possible, contact me as soon as you can. Extensions are generally not granted retroactively.

Grading policy

- **2-hr grading window**: Any assignment submitted online will automatically have a 2-hour grading window. This will be applied by the system, and no action is required from students.
- **Late penalty**: Late assignments will incur a 10% deduction per day, for up to 5 days (e.g., 1 day late = 10% off). After 5 days, the assignment will receive a grade of zero.
- **Extenuating circumstances:** Whenever possible, please request an official document that can prove the circumstances—this allows me to accommodate you fairly while respecting your privacy.
  - If that is not possible, contact me as soon as you can. Extensions are generally not granted retroactively.
- No extensions will be granted for the **final paper**.

Collaboration policy

- For the group works, all members are expected to contribute their time and effort equally.

Collaboration policy

- For the group works, all members are expected to contribute their time and effort equally.
- Each submission will include a section outlining both individual and group contributions, which will be evaluated separately.

Collaboration policy

- For the group works, all members are expected to contribute their time and effort equally.
- Each submission will include a section outlining both individual and group contributions, which will be evaluated separately.
- Collaboration with AI tools is permitted, but you are responsible for the quality and integrity of the work produced.

Collaboration policy

- For the group works, all members are expected to contribute their time and effort equally.
- Each submission will include a section outlining both individual and group contributions, which will be evaluated separately.
- Collaboration with AI tools is permitted, but you are responsible for the quality and integrity of the work produced.
- You must acknowledge and document how AI tools were used in your work (including individual exercises).

Pause

Any questions?

Lesson plan

Lesson plan

1. ~~Course logistics~~

Lesson plan

1. ~~Course logistics~~
2. Human language and word meaning

Lesson plan

1. ~~Course logistics~~
2. Human language and word meaning
3. Encoding and embedding: Encoding

Lesson plan

1. ~~Course logistics~~
2. Human language and word meaning
3. Encoding and embedding: Encoding
4. Wrap up

Lesson plan

1. ~~Course logistics~~
2. Human language and word meaning
3. Encoding and embedding: Encoding
4. Wrap up

Lesson plan

1. ~~Course logistics~~
2. Human language and word meaning
3. Encoding and embedding: Encoding
4. Wrap up

Key idea: Language and writing are remarkable technologies; NLP problems begin with encoding meaning in computers.

Human language & Word meaning

Language is *technology*

- Enables us to tell stories, ask questions, share knowledge, plan ahead, and even imagine alternate realities.

Language is *technology*

- Enables us to tell stories, ask questions, share knowledge, plan ahead, and even imagine alternate realities.
- Serves as a tool for coordinating with others, transmitting ideas, and building shared culture.

Language is *technology*

- Enables us to tell stories, ask questions, share knowledge, plan ahead, and even imagine alternate realities.
- Serves as a tool for coordinating with others, transmitting ideas, and building shared culture.
- Universally present across all human societies (regardless of geography or historical period).

Language is *technology*

- Enables us to tell stories, ask questions, share knowledge, plan ahead, and even imagine alternate realities.
- Serves as a tool for coordinating with others, transmitting ideas, and building shared culture.
- Universally present across all human societies (regardless of geography or historical period).
- Estimated age: **100,000–200,000 years**, making it one of the oldest and most powerful human inventions.

Language is *technology*

- Enables us to tell stories, ask questions, share knowledge, plan ahead, and even imagine alternate realities.
- Serves as a tool for coordinating with others, transmitting ideas, and building shared culture.
- Universally present across all human societies (regardless of geography or historical period).
- Estimated age: **100,000–200,000 years**, making it one of the oldest and most powerful human inventions.
- Evidence includes archaeological findings such as *symbolic beads, tools, and burial sites*, which suggest abstract thought and communication.

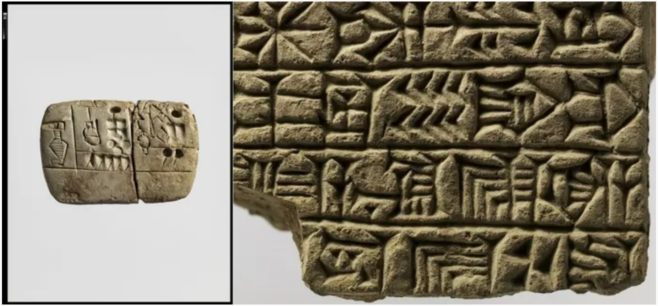


Figure 1: Clay tablet inscribed with the earliest known writing system, cuneiform—recording the receipt of barley and malt (around 3000 BCE, left)—and a close-up of cuneiform text on a mudbrick (around 1200 BCE, right).

Sourced from: `https://en.wikipedia.org/wiki/Cuneiform`

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*
- Makes language usable across time and space

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*
- Makes language usable across time and space
- Enables wide communication—even with strangers!

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*
- Makes language usable across time and space
- Enables wide communication—even with strangers!
- Key to history, law, science, culture

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*
- Makes language usable across time and space
- Enables wide communication—even with strangers!
- Key to history, law, science, culture
- Not all people or societies use writing

What is *Writing*?

Writing = another amazing technology!

- Records language, which is otherwise *ephemeral*
- Makes language usable across time and space
- Enables wide communication—even with strangers!
- Key to history, law, science, culture
- Not all people or societies use writing
- Estimated age: 5,000–6,000 years

Writing systems in NLP

What is NLP?

Writing systems in NLP

What is NLP?

Natural Language Processing (NLP) is the field that enables computers to understand, analyze, and generate human language.

Writing systems in NLP

What is NLP?

Natural Language Processing (NLP) is the field that enables computers to understand, analyze, and generate human language.

- To process language with computers, NLP requires a way to **encode language** → that's where **writing systems** come in!

Writing systems in NLP

What is NLP?

Natural Language Processing (NLP) is the field that enables computers to understand, analyze, and generate human language.

- To process language with computers, NLP requires a way to **encode language** → that's where **writing systems** come in!
- Evolution of writing technologies: **clay → papyrus → printing press → digital text**

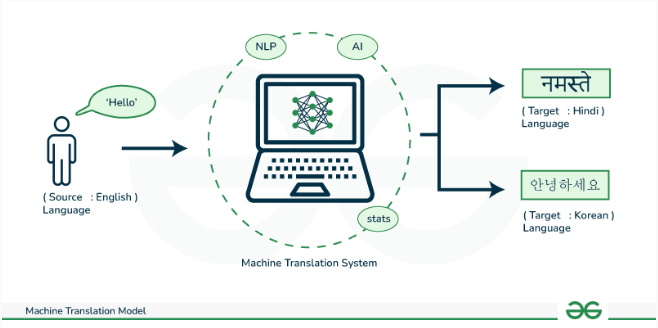
Writing systems in NLP

What is NLP?

Natural Language Processing (NLP) is the field that enables computers to understand, analyze, and generate human language.

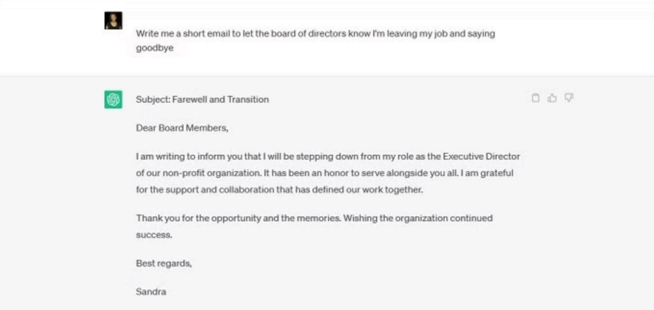
- To process language with computers, NLP requires a way to **encode language** → that's where **writing systems** come in!
- Evolution of writing technologies: **clay → papyrus → printing press → digital text**
- Digital writing allows for new forms of communication and makes language **machine-readable** → **Leap!**

Machine translations



Sourced from:
`https://www.geeksforgeeks.org/nlp/machine-translation-of-languages-in-artificial-intelligence/`

Generating texts



Write me a short email to let the board of directors know I'm leaving my job and saying goodbye

Subject: Farewell and Transition

Dear Board Members,

I am writing to inform you that I will be stepping down from my role as the Executive Director of our non-profit organization. It has been an honor to serve alongside you all. I am grateful for the support and collaboration that has defined our work together.

Thank you for the opportunity and the memories. Wishing the organization continued success.

Best regards,

Sandra

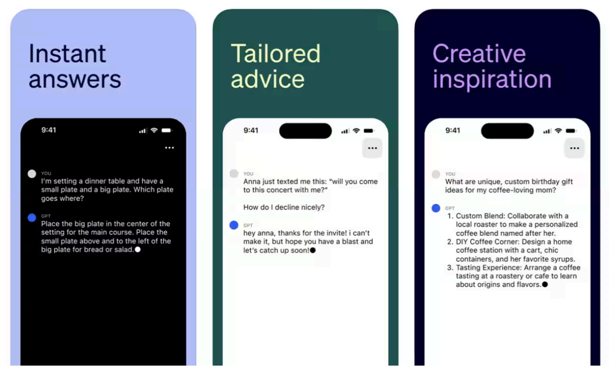
Sourced from: `https://www.makeuseof.com/use-chatgpt-write-work-emails/`

Generating image

Illustration: Justin Jay Wang × DALL·E

Sourced from: `https://openai.com/about/`

Chatbot



Instant answers

9:41

YOU

I'm setting a dinner table and have a small plate and a big plate. Which plate goes where?

GPT

Place the big plate in the center of the setting for the main course. Place the small plate above and to the left of the big plate for bread or salad.

Tailored advice

9:41

YOU

Anna just texted me this: "will you come to this concert with me?"

How do I decline nicely?

GPT

hey anna, thanks for the invite! i can't make it, but hope you have a blast and let's catch up soon!

Creative inspiration

9:41

YOU

What are unique, custom birthday gift ideas for my coffee-loving mom?

GPT

1. Custom Blend: Collaborate with a local roaster to make a personalized coffee blend named after her.
2. DIY Coffee Corner: Design a home coffee station with a cart, chic containers, and her favorite syrups.
3. Tasting Experience: Arrange a coffee tasting at a roastery or cafe to learn about origins and flavors.

Sourced from:
`https://www.theguardian.com/technology/2024/jan/10/openai-launches-gpt-store-customized-chatbots`

How do we represent the *meanings*

- Definition: *meaning* (Webster)

How do we represent the *meanings*

- Definition: *meaning* (Webster)
  - the idea that is represented by a word, phrase, etc.

How do we represent the *meanings*

- Definition: *meaning* (Webster)
    - the idea that is represented by a word, phrase, etc.
    - the idea that a person wants to express by using words, signs

How do we represent the *meanings*

- Definition: *meaning* (Webster)
    - the idea that is represented by a word, phrase, etc.
    - the idea that a person wants to express by using words, signs
    - the idea that is expressed in a work of writing, art, etc.

How do we represent the *meanings*

- Definition: *meaning* (Webster)
    - the idea that is represented by a word, phrase, etc.
    - the idea that a person wants to express by using words, signs
    - the idea that is expressed in a work of writing, art, etc.
- Commonest linguistic way of thinking about meaning:

How do we represent the *meanings*

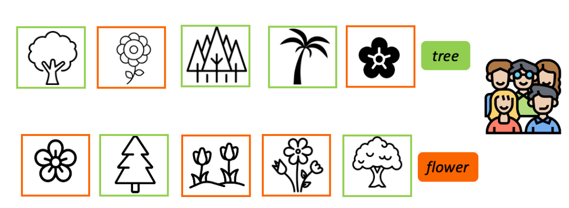
- Definition: *meaning* (Webster)
  - the idea that is represented by a word, phrase, etc.
  - the idea that a person wants to express by using words, signs
  - the idea that is expressed in a work of writing, art, etc.
- Commonest linguistic way of thinking about meaning:
  - **Signifier** (symbol) $\leftrightarrow$ **Signified** (idea or thing)

How do we represent the *meanings*

- Definition: *meaning* (Webster)
  - the idea that is represented by a word, phrase, etc.
  - the idea that a person wants to express by using words, signs
  - the idea that is expressed in a work of writing, art, etc.
- Commonest linguistic way of thinking about meaning:
  - **Signifier** (symbol) ↔ **Signified** (idea or thing)

How do we represent the *meanings*

- Definition: *meaning* (Webster)
  - the idea that is represented by a word, phrase, etc.
  - the idea that a person wants to express by using words, signs
  - the idea that is expressed in a work of writing, art, etc.
- Commonest linguistic way of thinking about meaning:
  - **Signifier** (symbol) ↔ **Signified** (idea or thing)
  - Denotational semantics



How do we represent the meanings *in computer*

Can computers understand meanings of the words as we do?

How do we represent the meanings *in computer*

Can computers understand meanings of the words as we do?

No.

How do we represent the meanings *in computer*

Can computers understand meanings of the words as we do?

No.

Traditional NLP method: Use the sets of synonyms and hypernyms of word by querying some databases (e.g., *WordNet*)

Problems with the traditional method (like WordNet)

- Missing nuances (e.g., *proficient* is listed as a synonym of *good* (but not always)

Problems with the traditional method (like WordNet)

- Missing nuances (e.g., *proficient* is listed as a synonym of *good* (but not always)
- Missing new meanings of words (e.g., *rizz*)

Problems with the traditional method (like WordNet)

- Missing nuances (e.g., *proficient* is listed as a synonym of *good* (but not always)
- Missing new meanings of words (e.g., *rizz*)
    - Word meanings constantly change and adapt based on how people really use the language in the world

Problems with the traditional method (like WordNet)

- Missing nuances (e.g., *proficient* is listed as a synonym of *good* (but not always)
- Missing new meanings of words (e.g., *rizz*)
  - Word meanings constantly change and adapt based on how people really use the language in the world
- Practically, building/updating a database is expensive and inefficient.

Problems with the traditional method (like WordNet)

- Missing nuances (e.g., *proficient* is listed as a synonym of *good* (but not always)
- Missing new meanings of words (e.g., *rizz*)
    - Word meanings constantly change and adapt based on how people really use the language in the world
- Practically, building/updating a database is expensive and inefficient.
- Can't compute accurate word similarity

Encoding and embedding

Encoding

- In traditional NLP, we regard words as discrete symbols

Encoding

- In traditional NLP, we regard words as discrete symbols
- Words themselves cannot be given as inputs to computers

Encoding

- In traditional NLP, we regard words as discrete symbols
- Words themselves cannot be given as inputs to computers
- BUT numbers can be given as inputs to computers

Encoding

- In traditional NLP, we regard words as discrete symbols
- Words themselves cannot be given as inputs to computers
- BUT numbers can be given as inputs to computers
- Encoding = converting words to numbers

Encoding

- In traditional NLP, we regard words as discrete symbols
- Words themselves cannot be given as inputs to computers
- BUT numbers can be given as inputs to computers
- Encoding = converting words to numbers
- *Will continue discussions on encoding/embedding and word vectors next Tuesday.*

Wrap-up

Wrap-up

- Please check the syllabus; let know if you have any question(s).

Wrap-up

- Please check the syllabus; let know if you have any question(s).
- Lab session 1 is planned on Thursday, which we will go over some basic Python functions (If you want to brush up your Python skills, this session will be helpful.)

Wrap-up

- Please check the syllabus; let know if you have any question(s).
- Lab session 1 is planned on Thursday, which we will go over some basic Python functions (If you want to brush up your Python skills, this session will be helpful.)
- A mini survey for group projects: `https://forms.gle/4dtPDFFhDpccfvBu8`