COMP5046
Natural Language Processing

Lecture 1: Course Info & Introduction to NLP

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Semester 1, 2021
School of Computer Science,
University of Sydney

Deep Learning

Linguistics

Language

NLP

Lecture 1: Introduction to Natural Language Processing

1. ***Course Introduction***

2. *Overview of Natural Language Processing (NLP)*

3. *Word Meaning and Representation*

4. *Count-based Word Representation*
   - *One-hot Encoding*
   - *Bag of Words*
   - *Term Frequency-Inverse Document Frequency*

5. *Next Week Preview*
   - *Prediction-based Word Representation*

INTRODUCTION

Dr Caren Han

Education

- B CompScience (1st Class Honours)
- PhD Computer Science (Artificial Intelligence)

Australian Young Achiever Teaching Excellence Award

Teacher of the Year 2020 Award

- Machine Learning, Natural Language Processing, etc.

NLP Research Experience (8 years experience)

- **U.S. Air Force**: Robotics Natural Language Processing Interface
- **U.S. Navy**: Deep Learning with NLP
- **Hyundai Co.**: Car Navigation Dialog System
- NLP Top-tier Conferences Best Paper Award/Best Area Paper Award

INTRODUCTION

COMP5046 Natural Language Processing

This unit introduces computational linguistics and the statistical techniques and algorithms used to automatically process natural languages. It will review the core statistics and information theory, and the basic linguistics, required to understand natural language processing (NLP).

NLP is used in a wide range of applications, including information retrieval and extraction; question answering; machine translation; and classifying and clustering of documents. This unit will explore the key challenges of natural language to computational modelling, and the state-of-the-art approaches to the key NLP sub-tasks, including tokenisation, morphological analysis, word sense representation, part-of-speech tagging, named entity recognition and other information extraction.

Students will implement many of these sub-tasks in labs and assignments, that can be used in the real-world cases. The unit will also investigate the annotation process that is central to creating training data for interesting application. With this unit, students can develop the innovative application that can be used in the real world.

Where to find the course information?

Unit Outline - COMP5046
https://www.sydney.edu.au/units/COMP5046

Canvas – COMP5046
https://canvas.sydney.edu.au/courses/30912

INTRODUCTION

What will you learn in this course?

The focus of this course is on the review and comparison of <u>models and methods that have achieved state-of-the-art results on various NLP tasks</u> such as question answering (QA) and machine translation.

In this comprehensive review, students will get a detailed understanding of the past, present, and future of NLP. In addition, students will learn some of the current best practices for applying deep learning in NLP

word2vec

NN

Language Modelling

Dependency Parsing

Part-of-Speech Tagging

Transformer

INTRODUCTION

What will you learn in this course?

Week 1: Introduction to Natural Language Processing (NLP)	
Week 2: Word Embeddings (Word Vector for Meaning)	*NLP and Machine Learning*
Week 3: Word Classification with Machine Learning I	
Week 4: Word Classification with Machine Learning II	

Week 5: Language Fundamental	
Week 6: Part of Speech Tagging	*NLP Techniques*
Week 7: Dependency Parsing	
Week 8: Language Model and Natural Language Generation	

Week 9: Information Extraction: Named Entity Recognition	
Week 10: Advanced NLP: Attention and Reading Comprehension	*Advanced Topic*
Week 11: Advanced NLP: Transformer and Machine Translation	
Week 12: Advanced NLP: Pretrained Model in NLP	

Week 13: Future of NLP and Exam Review

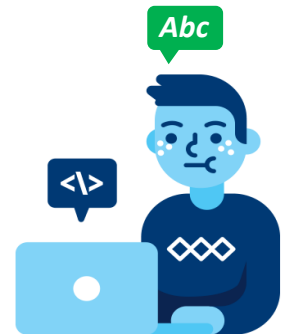# EXPECTATIONS

I DO assume you can program

- By that, I mean you are a confident programmer

- Labs will **involve programming**

- Assessment will **involve programming**

- Python recommended; other popular languages accepted

- There will be **NO NON-programming option** for assignments

- But it's more than just programming:

    - algorithms, mathematics and (esp.) statistics

    - linguistics and intuition about language

    - analytical thinking

EXPECTATIONS

I DO <u>NOT</u> assume you are a linguist

- But you do **need to know** roughly **how to identify a noun/verb/etc.**

- We will think critically about **how we use language**

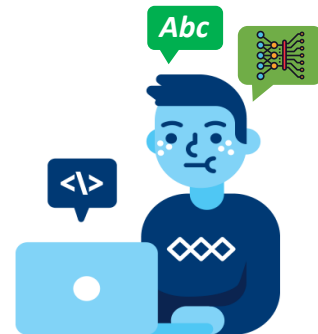- and about how computational models capture **aspects of language**
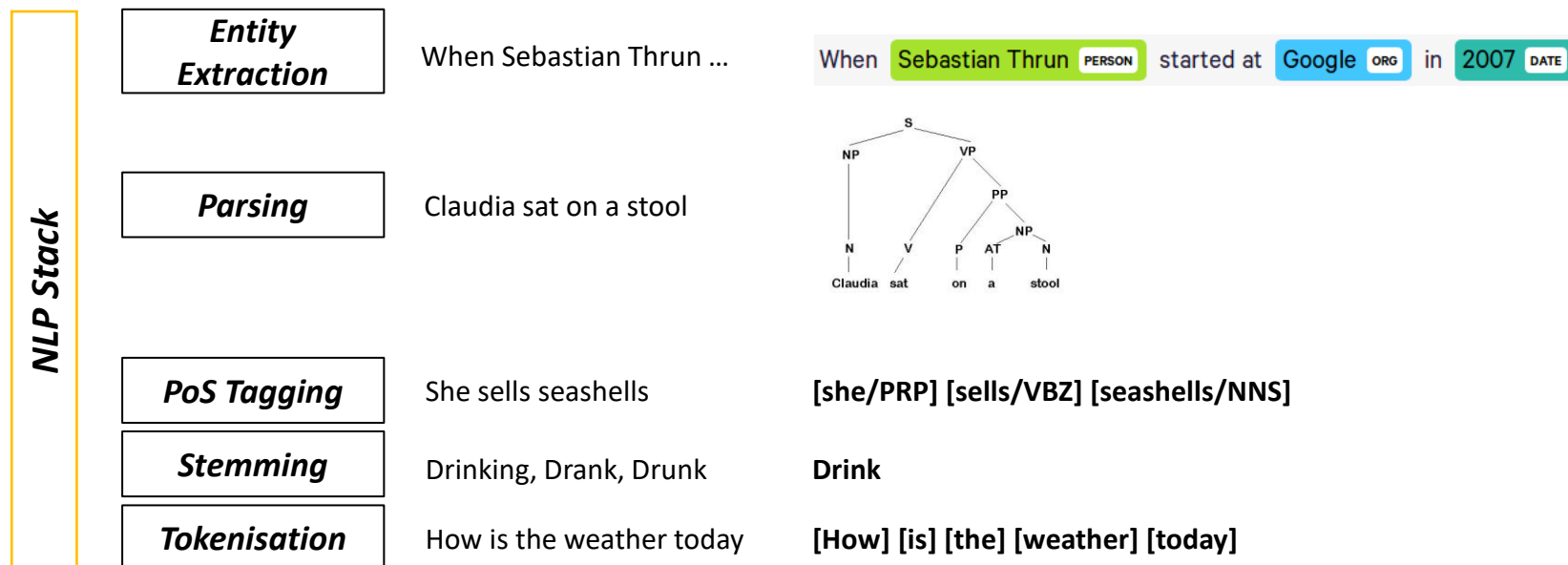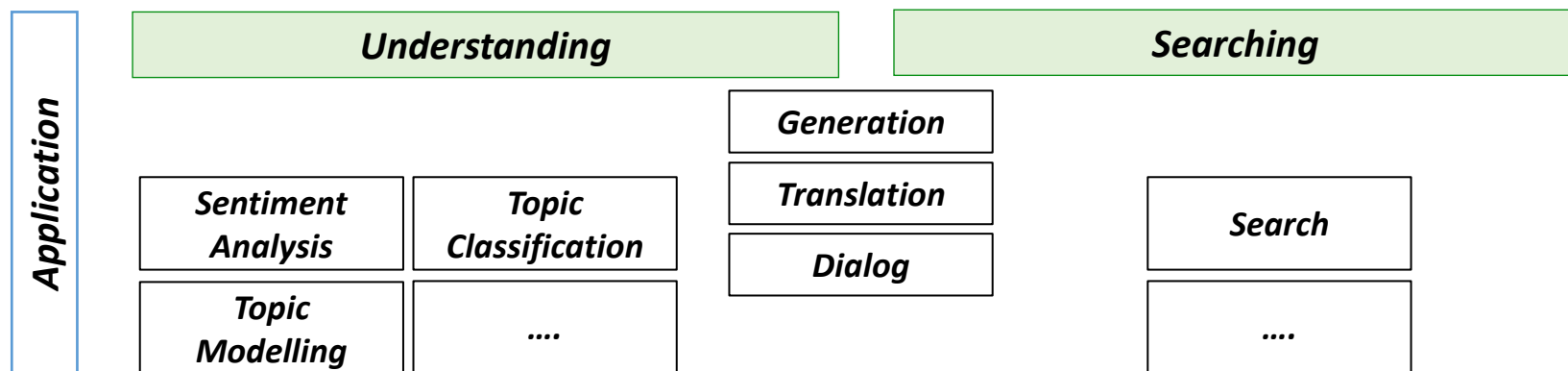
EXPECTATIONS

I DO <u>NOT</u> assume you are a deep learning researcher

- But you do need to know (really) **roughly how machine learning works**.

- We will think critically **how to use text data and embeddings**

- and about how deep learning models capture **aspects of language (context)**

The NLP Big Picture

The purpose of Natural Language Processing: Overview

Application

| *Understanding* | *Searching* |

Generation

| *Sentiment Analysis* | *Topic Classification* | *Translation* | *Search* |
| *Topic Modelling* | *....* | *Dialog* | *....* |

NLP Stack

Entity Extraction	When Sebastian Thrun ...	When **Sebastian Thrun** PERSON started at **Google** ORG in **2007** DATE
Parsing	Claudia sat on a stool	
PoS Tagging	She sells seashells	**[she/PRP] [sells/VBZ] [seashells/NNS]**
Stemming	Drinking, Drank, Drunk	**Drink**
Tokenisation	How is the weather today	**[How] [is] [the] [weather] [today]**

The NLP ERA

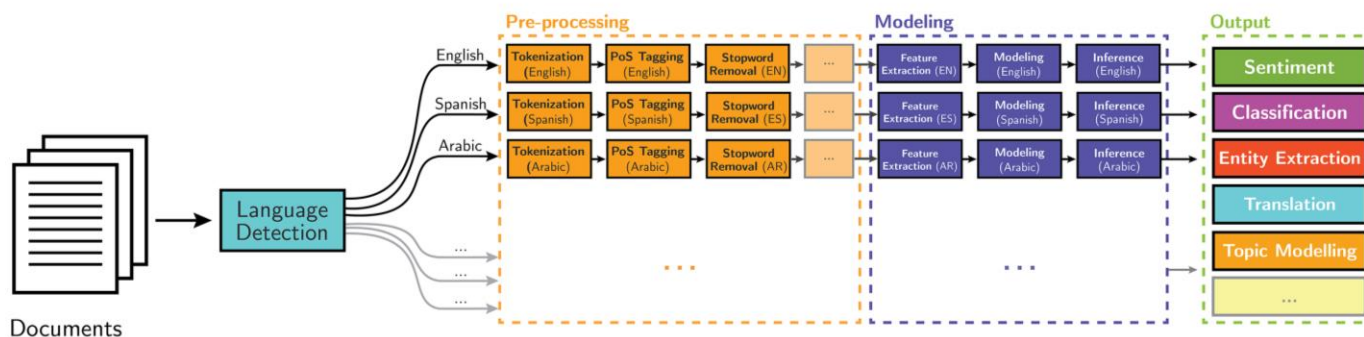## Hype Cycle for Artificial Intelligence

(Gartner, 2020)

The NLP ERA

NLP Techniques – with the Trend of Machine Translation
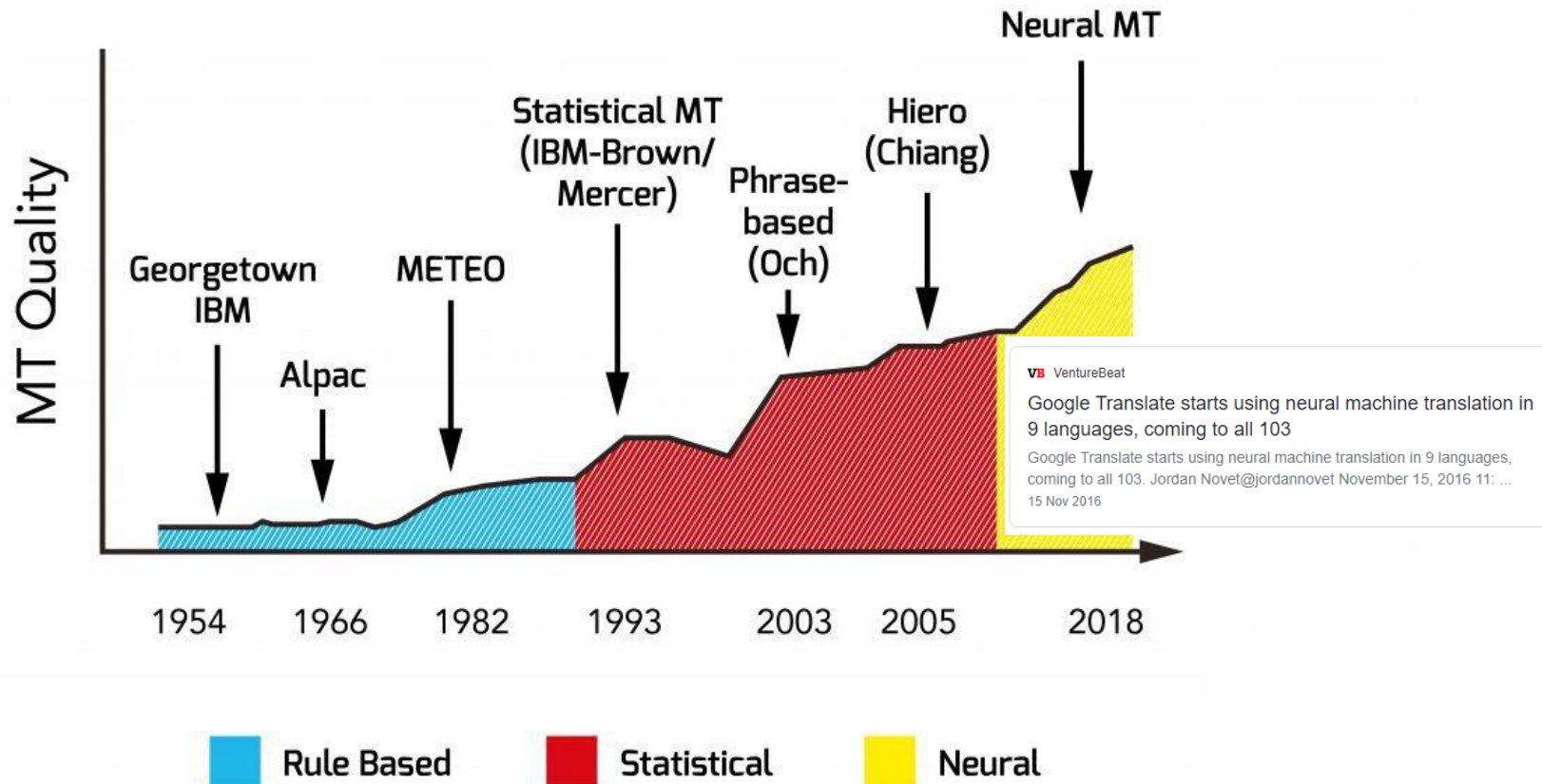
The NLP ERA

Language Modelling using Deep Learning-based NLP Techniques
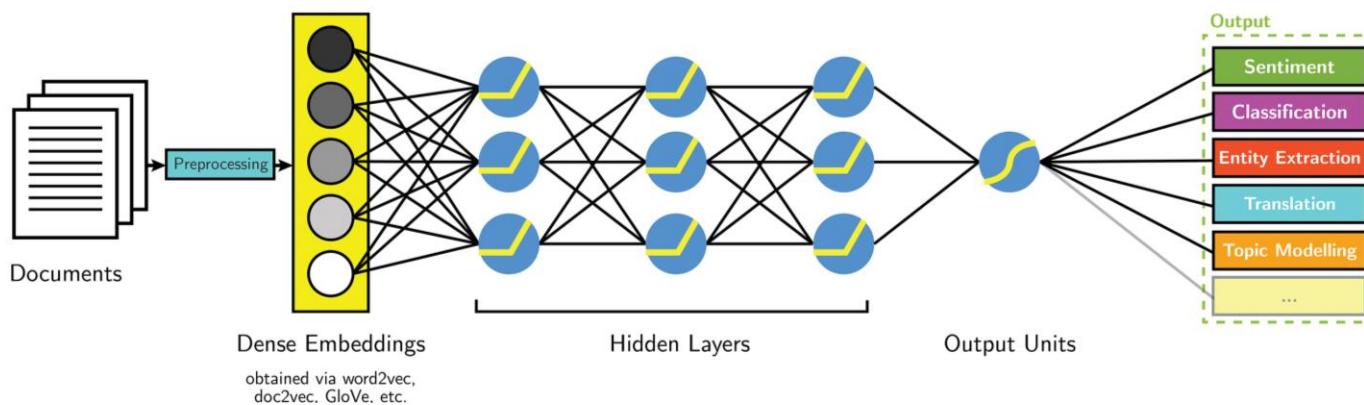
ASSESSMENT

Assessment Overview

Assessment	Weight	Due
Lab Exercise	10%	Multiple Weeks
Assignment 1	20%	Week 8 (Friday 11.59pm – AU time)
Assignment 2	20%	Week 14 (Friday 11.59pm – AU time)
Final Exam	50%	Exam Period

Lab Exercises

- Programming tasks done in weekly computer labs

Assignments

- Take place through the teaching period

- Implementation and Documentation

Penalties for lateness

- 10% of the available marks per day late; maximum 7 days late

ASSESSMENT

Lab Exercise – 10%

- In the Lab, students need to do the small tasks (1% for each week).

- 2-3 tasks are given based on what you learned in the previous lecture.

- You must have been assessed as having completed 10 out of 11 in order to get the 10% for weekly lab exercise.

word2vec

NN

RL

Dependency Parsing

Part-of-Speech Tagging

Language Generation
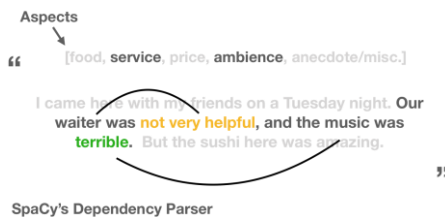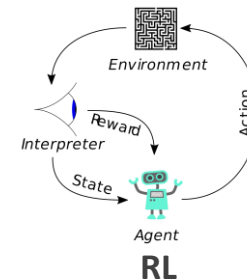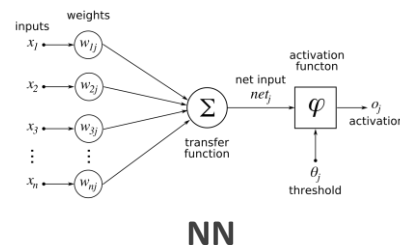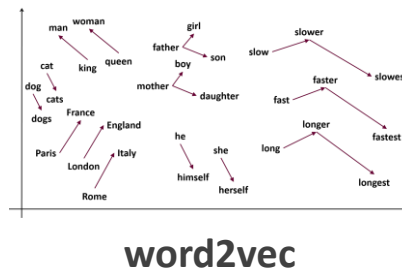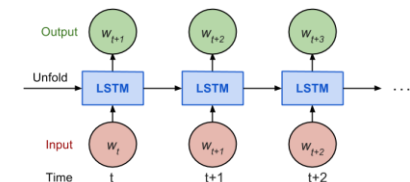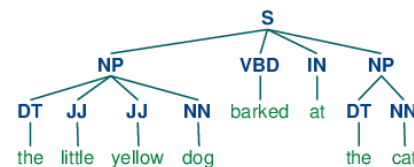
ASSESSMENT

Lab Exercise – 10%

• When to submit the Weekly Lab Exercise (e.g. Lab1 Release and Submission)

Week 1 | Mon | Tue | Wed | Thu | Fri | Sat | **Sun**

Lab1 Release

Lecture1

Week 2 | Mon | Tue | Wed | Thu | Fri | Sat | Sun

Lab2 Release

Lecture2 Lab1

Week 3 | **Mon** | Tue | Wed | Thu | Fri | Sat | Sun

Lab 1 Due

Lecture3 Lab2

ASSESSMENT
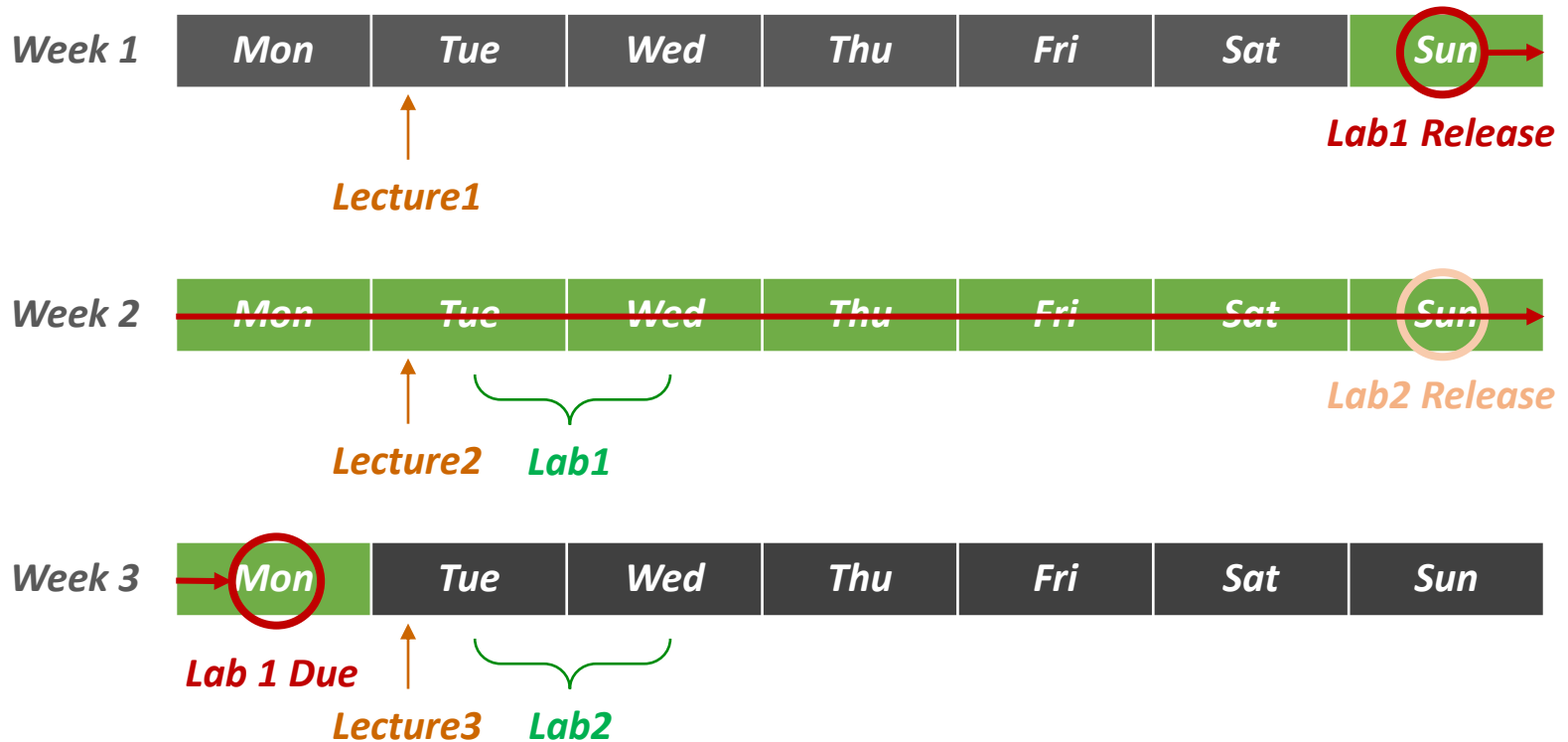
What do we do during Labs?

In Labs, Students will use Google CoLab

Colaboratory is a free Jupyter notebook environment that requires no setup and runs entirely in the cloud. With Colaboratory you can write and execute code, save and share your analyses, and access powerful computing resources, all for free from your browser.

https://colab.research.google.com/notebooks/intro.ipynb

ASSESSMENT
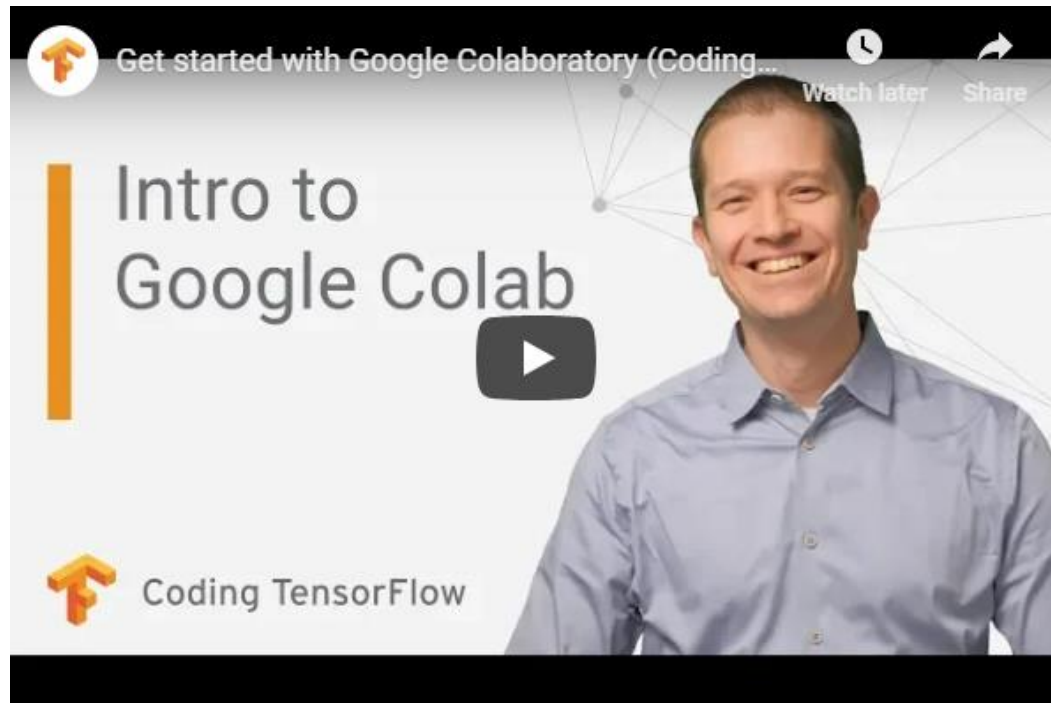
Assignment 1 (20%)

The focus of this assignment 1 is implementing the text/word embeddings/language models, which *1)understands the language* and *2)produces the detection/prediction/generation* decision.

NOTE: *Assignment 1 will be an individual assignment.*

Assignment 2 (20%)

The focus of this assignment 2 is proposing a natural language model to produce high performance (such as accuracy, consistency, plausibility, validity, and distribution) in different NLP tasks. The different NLP tasks can be Question Answering, Named Entity Recognition, Text Classification, or etc.

NOTE: Assignment 2 would be a group assignment (2 people in group).
However, you can do individually only if you want.

Final Exam (50%)

The final exam will be a short take-home exam hosted on Canvas (3 hours duration).
You will be asked to answer variety of theoretical questions.
The sample exam questions will be shared in the week 13 lecture.

ASSESSMENT

ASSESSMENT Due

Week 1: Introduction to Natural Language Processing (NLP)

Week 2: Word Embeddings (Word Vector for Meaning)

Week 3: Word Classification with Machine Learning I

Week 4: Word Classification with Machine Learning II

Week 5: Language Fundamental

Week 6: Part of Speech Tagging

Week 7: Dependency Parsing

Week 8: Language Model and Natural Language Generation   *Assignment 1 Due*

Week 9: Information Extraction: Named Entity Recognition

Week 10: Advanced NLP: Attention and Reading Comprehension

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Week 13: Future of NLP and Exam Review

Assignment 2 Due (Week 14)

ASSESSMENT

Start assignments early!

- All assignments involve coding and report writing

- Reports are the primary deliverable

- Though we will check implementations for correctness

- Assignments will Be very different from last year's

- Reports will be submitted to Turnitin through Canvas

- Code is also submitted (for assignments 1 and 2) and retained

- We will use code plagiarism detection tools

- Clearly reference any copied/adapted code portions and cite their origins

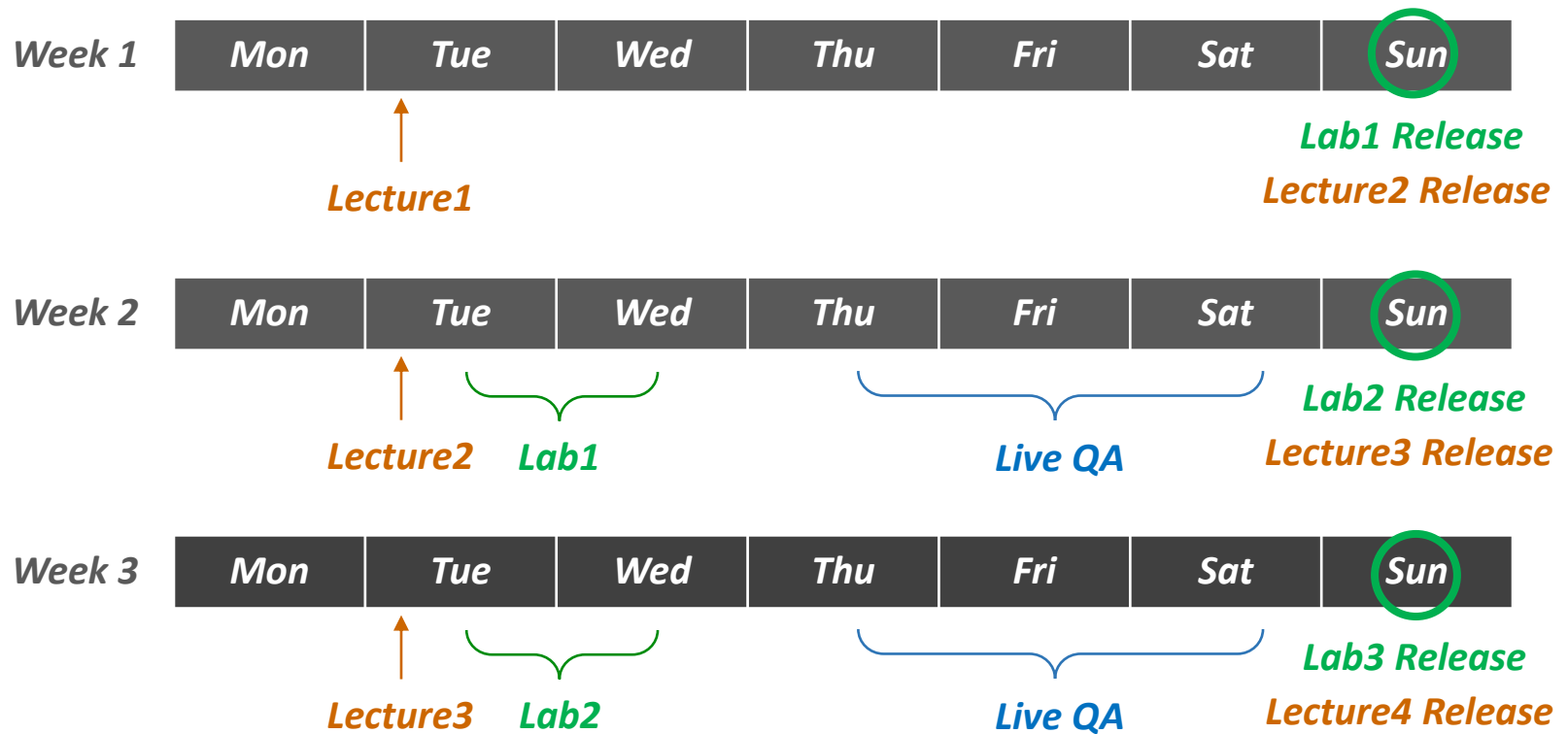# ASSESSMENT

Start assignments early!

- Starting early means you will work while you sleep

- **Don't waste all your time on code**

- The report is more important, but largely depends on the code

- If you're stuck, ask early

- We might be able to offer you alternatives

TIMETABLE

Working Hours

- Work 12 hours per week for this course (including 3 contact hours);

- Attend 2 hours of lectures per week:

    - Tuesday 3 – 5pm

    - Lectures are recorded, but don't depend on it!

- Attend 1 hour of tutorial/laboratory time

- Participate respectfully in discussions in lectures and labs;

- Complete all assessment tasks on time.

Classes and Release Date

- When the Class and Release Dates are

Week 1

Mon	Tue	Wed	Thu	Fri	Sat	Sun

Lab1 Release

Lecture1   *Lecture2 Release*

Week 2

Mon	Tue	Wed	Thu	Fri	Sat	Sun

Lab2 Release

Lecture2   *Lab1*   *Live QA*   *Lecture3 Release*

Week 3

Mon	Tue	Wed	Thu	Fri	Sat	Sun

Lab3 Release

Lecture3   *Lab2*   *Live QA*   *Lecture4 Release*

TIMETABLE

Full Course Timetable at course website:

- **Lecture:** Tue 3-5pm

- **Tutorial:** Tue 5-6pm, 6-7pm / Wed 5-6pm, 6-7pm

- **LiveQA**: Thu, Fri, Sat 9-10pm

STAFF

Who are we?

Unit Coordinator & Lecturer

- Caren.Han@sydney.edu.au

- No fixed consultation hour; please arrange a time to see me.

Teaching Assistants & Tutors

- They will introduce themselves really soon!

For Qs related to course content, please post in Ed.

For Qs related to admin, please contact to the unit coordinator

- Please put [COMP5046] in the title of the email

READINGS (OPTIONAL)

No Textbook Recommended, but if you really want to read some

Deng, L., & Liu, Y. (Eds.). (2018). Deep Learning in Natural Language Processing. Springer.

Rao, D., & McMahan, B. (2019). Natural Language Processing with PyTorch: Build Intelligent Language Applications Using Deep Learning. " O'Reilly Media, Inc.".

Manning, C. D., Manning, C. D., & Schütze, H. (1999). Foundations of statistical natural language processing. MIT press.

SELF TEST

Ask yourself…

- How much work will you be devoting to this unit, each week?

- Who should you see if difficulties arise?

- When is the first assessment due?

- What do you do if you get sick during semester?

- What is Turnitin?

- What programming language do you need to know?

What do we learn? (NLP and Deep Learning)

https://www.youtube.com/watch?v=u5T5Q9yzXnQ

"We wanted border security. We wanted very, very strong military. We wanted all of the things that we're going to get..."

(CPAC Feb. 24th, 201·

"We have an incompetent administration, and if I am not elected President, that will not change over the next four years—but it must change, and it must change now."

(June 13th, 201

We fed 270,000 words spoken by Trump into a computer program that studies language patterns.

"Now, they do charge you tariff on trucks, when we send trucks and other things over there."

(Announcement June 16th, 2015

"I only want to admit people who share our values and love our people."

(June 22nd, 2016

https://www.youtube.com/watch?v=EFHyzuqjaok

LECTURE PLAN

Lecture 1: Introduction to Natural Language Processing

1. Course Introduction

2. **Overview of Natural Language Processing (NLP)**

3. Word Meaning and Representation

4. Count-based Word Representation
    - One-hot Encoding
    - Bag of Words
    - Term Frequency-Inverse Document Frequency

5. Next Week Preview

LANGUAGE

Why Process Language?

- **language stores knowledge**

- language communicates new knowledge

- language is a key to culture and human experience
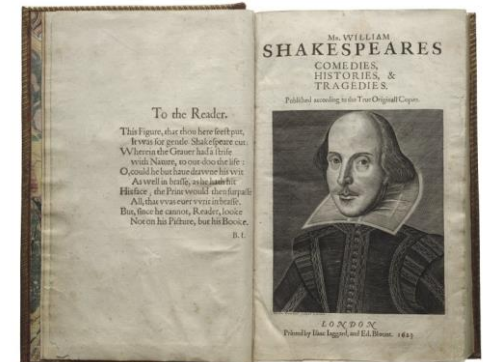
- language is a natural interface for humans
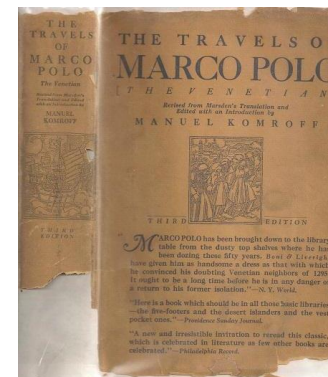
LANGUAGE

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LANGUAGE

Why Process Language?

- language stores knowledge

- language communicates new knowledge

- language is a key to culture and human experience

- **language is a natural interface for humans**

Natural Language Processing (NLP)

What is Natural Language Processing?

Natural Language Processing (NLP) is the branch of artificial intelligence focused on developing systems that allow computers to communicate with people using everyday language

Computational Linguistics

It concerns how computational methods can aid the understanding of language

Communication

The goal in the production / comprehension of language is communication.

Natural Language Processing (NLP)

Communication for the speaker:

- Intention: **Decide when and what information** should be transmitted (a.k.a. strategic generation). May require planning and reasoning about agents' goals and beliefs.

- Generation: **Translate the information to be communicated** (in internal logical representation or "language of thought") into string of words in desired natural language (a.k.a. tactical generation).

- Synthesis: **Output the string** in desired modality, text or speech.

Natural Language Processing (NLP)

Communication for the hearer:
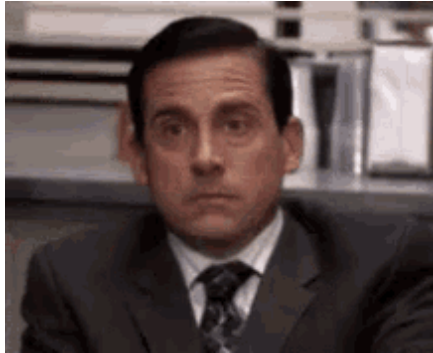
- Perception: **Map input modality to a string of words**, e.g. optical character recognition (OCR) or speech recognition.

- Analysis: **Determine the information content of the string**.
  - Syntactic interpretation (parsing): Find the correct parse tree showing the phrase structure of the string.
  - Semantic Interpretation: Extract the (literal) meaning of the string .
  - Pragmatic Interpretation: Consider effect of the overall context on altering the literal meaning of a sentence.

- Incorporation: Decide whether or not to **believe the content of the string** and add it to the Knowledge Base.

SPECIAL ABOUT NLP

What is special about NLP?

- Human language is a system specifically constructed to **convey meaning** and is **not produced by a physical manifestation of any kind**. In that way, it is very different from vision or any other machine learning task.

- Most words are just symbols for an extra-linguistic entity : the word is a signifier that maps to a signified (idea or thing).
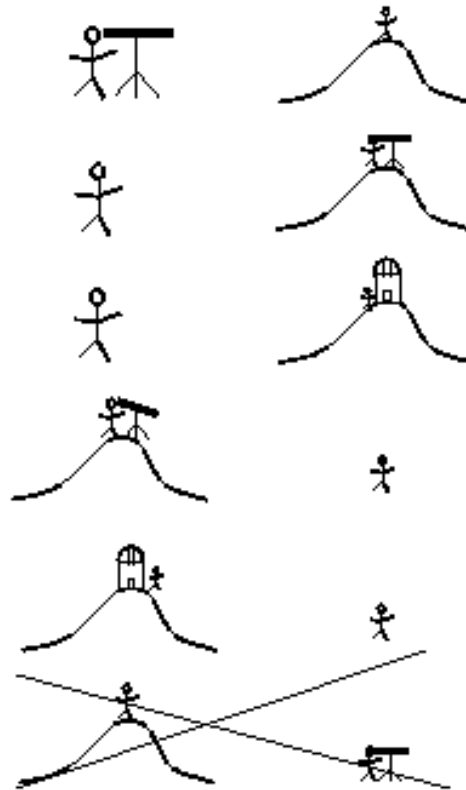
"Computer"   **"Apple"**   **"Whaaaaaaa"**

??????

SPECIAL ABOUT NLP
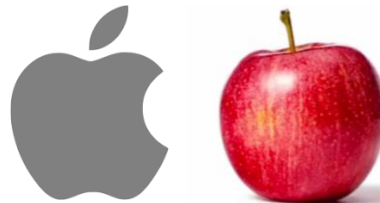
Ambiguity

I saw the man on the hill with a telescope.

SPECIAL ABOUT NLP

Ambiguity is Explosive

Ambiguities compound to generate enormous numbers of possible interpretations.

In English, a sentence ending in n prepositional phrases has over 2n interpretations.

"I saw the man with the telescope": 2 parses

"I saw the man on the hill with the telescope.": 5 parses

"I saw the man on the hill in Texas with the telescope": 14 parses

"I saw the man on the hill in Texas with the telescope at noon.": 42 parses

"I saw the man on the hill in Texas with the telescope at noon on Monday" 132 parses

SPECIAL ABOUT NLP

Ambiguity is Ubiquitous

Speech Recognition

- "recognize speech" vs. "wreck a nice beach"
- "youth in Asia" vs. "euthanasia"

Syntactic Analysis

- "I ate spaghetti with chopsticks" vs. "I ate spaghetti with meatballs."

Semantic Analysis

- "The dog is in the pen." vs. "The ink is in the pen."
- "I put the plant in the window" vs. "Ford put the plant in Mexico"

SPECIAL ABOUT NLP

Even human struggle with understanding

??????

SPECIAL ABOUT NLP

The difficulty level in various NLP tasks

Easy

- Spell Checking

- Keyword Search

- Finding Synonyms

Medium

- Extracting Information from documents (including websites)

Difficult

- Semantic Analysis (What is the meaning of query statement?)

- Machine Translation

- Coreference Resolution

- Question Answering

Lecture 1: Introduction to Natural Language Processing

1. Course Introduction
2. Overview of Natural Language Processing (NLP)
3. **Word Meaning and Representation**
4. Count-based Word Representation
   - One-hot Encoding
   - Bag of Words
   - Term Frequency-Inverse Document Frequency
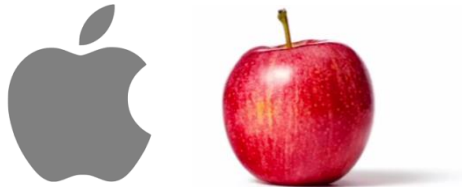5. Next Week Preview

WORD REPRESENTATION

How to represent the meaning of the word?

Definition: meaning (Collins dictionary).

- the idea that it represents, and which can be explained using other words.
- the thoughts or ideas that are intended to be expressed by it.

signifier (symbol) ⟺ signified (idea or thing)

"Apple"

WORD REPRESENTATION

How do we have usable meaning in a computer?

- Common solution: Use e.g. WordNet, a thesaurus containing lists of synonym sets and hypernyms ("is a" relationships).

- http://wordnetweb.princeton.edu/perl/webwn

e.g. synonym sets containing "good":

```
from nltk.corpus import wordnet as wn
poses = { 'n':'noun', 'v':'verb', 's':'adj (s)',
'a':'adj', 'r':'adv'}
for synset in wn.synsets("good"):
print("{}: {}".format(poses[synset.pos()],
", ".join([l.name() for l in synset.lemmas()])))
```

e.g. hypernyms of "panda":

```
from nltk.corpus import wordnet as wn
panda = wn.synset("panda.n.01")
hyper = lambda s: s.hypernyms()
list(panda.closure(hyper))
```

noun: good
noun: good, goodness
noun: good, goodness
noun: commodity, trade_good, good
adj: good
adj (sat): full, good
adj: good
adj (sat): estimable, good, honorable, respectable
adj (sat): beneficial, good
adj (sat): good
adj (sat): good, just, upright
…
adverb: well, good
adverb: thoroughly, soundly, good

[Synset('procyonid.n.01'),
Synset('carnivore.n.01'),
Synset('placental.n.01'),
Synset('mammal.n.01'),
Synset('vertebrate.n.01'),
Synset('chordate.n.01'),
Synset('animal.n.01'),
Synset('organism.n.01'),
Synset('living_thing.n.01'),
Synset('whole.n.02'),
Synset('object.n.01'),
Synset('physical_entity.n.01'),
Synset('entity.n.01')]

WORD REPRESENTATION

Problems with resources like WordNet

- Great as a resource but missing nuance
  - e.g. "proficient" is listed as a synonym for "good". This is only correct in some contexts.
  - e.g. "glad" can be synonym for "fXXX off"???

- Missing new meanings of words
  - e.g., wicked, badass, nifty, wizard, genius, ninja, bombast
  - Impossible to keep up-to-date!

- Subjective

- Requires human labor to create and adapt

- Can't compute accurate word similarity

LECTURE PLAN

Lecture 1: Introduction to Natural Language Processing

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3. Word Meaning and Representation

4. **Count-based Word Representation**
   - One-hot Encoding
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5. Next Week Preview

COUNT based WORD REPRESENTATION

One-hot Encoding

- In traditional NLP, we regard words as discrete symbols.

Hot (True)   Cold (False)

Means one 1, the rest 0s

Words can be represented by **one-hot vector**s:

1. The categorical values be mapped to integer values (index)

2. each integer value is represented as a binary vector that is all zero values except the index of the integer, which is marked with a 1.

hotel   *motel*   *Inn*

motel = [0 0 0 0 0 0 0 0 0 1 0 0 0 0 … 0]

hotel = [0 0 0 0 0 0 0 1 0 0 0 0 0 0 … 0]

Inn   = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 … 1]

Vector dimension = number of words in vocabulary

COUNT based WORD REPRESENTATION

Problem with one-hot vectors

Problem #1. No word similarity representation
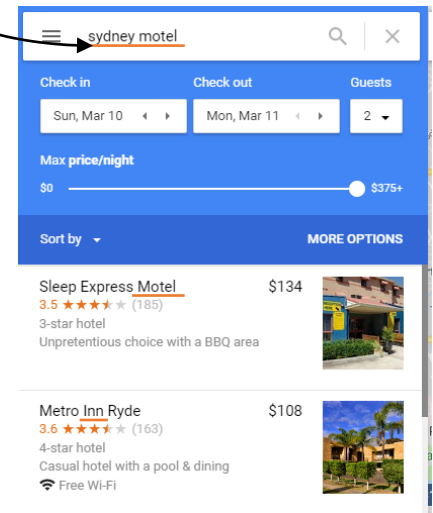
Example: in web search, if user searches for "Sydney motel", we would like to match documents containing "Sydney Inn"

motel = [0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 … 0]

hotel = [0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 … 0]

Inn = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 … 1]

hotel   *motel*   *Inn*

There is no natural notion of similarity for one-hot vectors!

Problem #2. Inefficiency

Vector dimension = number of words in vocabulary

Each representation has only a single '1' with all remaining 0s.

COUNT based WORD REPRESENTATION

Bag of Words (BOW)

- A bag-of-words model (BoW) is a representation of text that describes **the occurrence of words** within a document. It involves two things:
  - A vocabulary of known words.
  - A measure of the presence of known words.

- It is called a "**bag**" of words, because any information about the **order or structure of words in the document is discarded.** The model is only concerned with whether known words occur in the document, not where in the document.

How are you
How have you been
Nice to see you
Have a nice day

WORDS

COUNT based WORD REPRESENTATION

Bag of Words (BOW)

- A bag-of-words model (BoW) is a representation of text that describes **the occurrence of words** within a document. It involves two things:
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    - A measure of the presence of known words.

- It is called a "bag" of words, because any information about the **order or structure of words in the document is discarded**

How are you
How have you been
Nice to see you
Have a nice day

Have   nice   a
are   you
How   been
have   Nice   to
see   you
you   day   How

COUNT based WORD REPRESENTATION

Bag of Words (BOW)

A vocabulary of known words

a	are	been	day	have	how	nice	see	to	you

* **WO** = occurrence of words

[**WO***a*, **WO***are*, **WO***been*, **WO***day*, **WO***have*, **WO***how*, **WO***nice*, **WO***see*, **WO***to*, **WO***you*]

How are you	= [0, 1, 0, 0, 0, 1, 0, 0, 0, 1]
How have you been	= [0, 0, 1, 0, 1, 1, 0, 0, 0, 1]
Nice to see you	= [0, 0, 0, 0, 0, 0, 1, 1, 1, 1]
Have a nice day	= [1, 0, 0, 1, 1, 0, 1, 0, 0, 0]

Total Frequency = [1, 1, 1, 1, 2, 2, 2, 1, 1, 3]

a	are	been	day	have	how	nice	see	to	you
1	1	1	1	2	2	2	1	1	3

COUNT based WORD REPRESENTATION

Why use BoW?

- The intuition is that documents are similar if they have similar content. Further, that from the content alone we can learn something about the meaning of the document.

Problem with BoW

- Discarding word order ignores the context, and in turn meaning of words in the document (semantics). Context and meaning can offer a lot to the model, that if modeled could tell the difference between the same words differently arranged ("this is interesting" vs "is this interesting").

S1= I love you but you hate me

S2= I hate you but you love me

COUNT based WORD REPRESENTATION

Term Frequency-Inverse Document Frequency

- Term Frequency-Inverse Document Frequency (TF-IDF) is a way of representing **how important a word** *is to a document in a collection or corpus*.

$$w_{i,j} = tf_{i,j} \times \log \left(\frac{N}{df_i} \right)$$

$w_{i,j}$ = weight of term i in document j

$tf_{i,j}$ = number of occurrences of term i in document j

N = total number of documents

df_i = number of documents containing term i

- The **Term Frequency** is a count of how many times a word occurs in a given document (synonymous with bag of words)

- The **Document Frequency** is the number of times a word occurs in a corpus of documents

COUNT based WORD REPRESENTATION

Term Frequency

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

Like BoW

$tf_{i,j}$ = *number of occurrences of term i in document j*

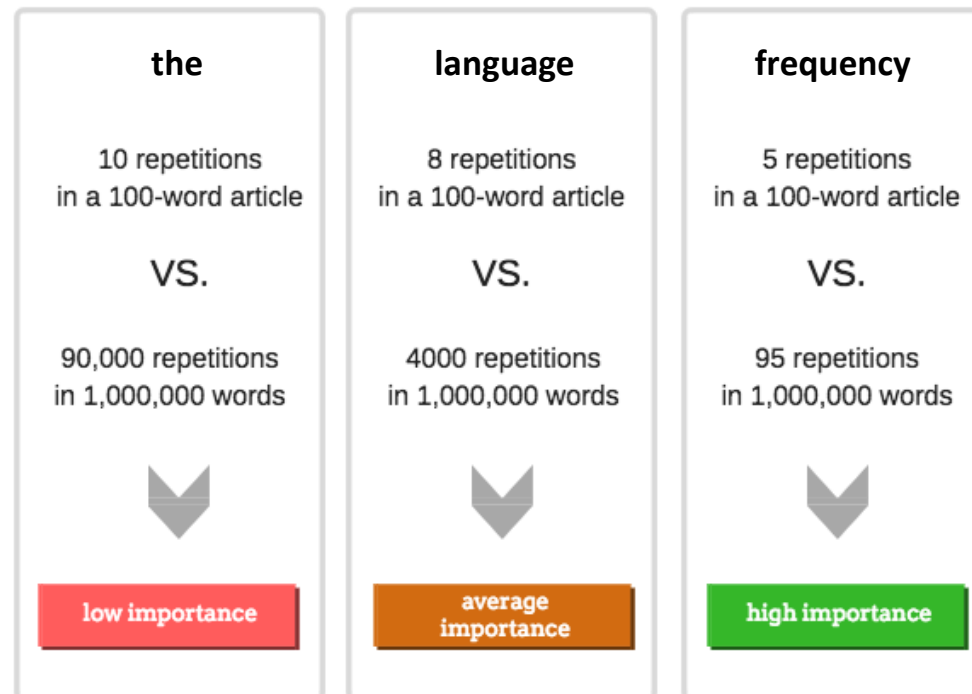*Document #1: I like apple*

Document #2: I like banana

Document #3: Sweet and yellow banana banana

Document #4: Sweet fruit

	and	apple	banana	fruit	I	like	sweet	yellow
D#1	0	1	0	0	1	1	0	0
D#2	0	0	1	0	1	1	0	0
D#3	1	0	2	0	0	0	1	1
D#4	0	0	0	1	0	0	1	0

COUNT based WORD REPRESENTATION

What if we just use Term Frequency Only?

- It is known that certain terms, such as "is", "of", and "that", may appear a lot of times but have little importance. Thus we need to weigh down the frequent terms while scale up the rare ones.
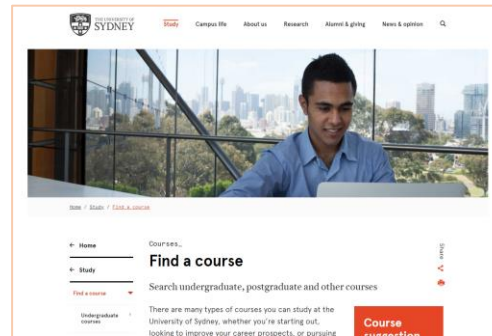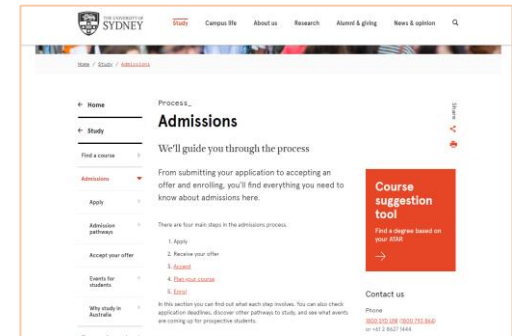
the	language	frequency
10 repetitions in a 100-word article	8 repetitions in a 100-word article	5 repetitions in a 100-word article
VS.	VS.	VS.
90,000 repetitions in 1,000,000 words	4000 repetitions in 1,000,000 words	95 repetitions in 1,000,000 words
↓	↓	↓
low importance	average importance	high importance

COUNT based WORD REPRESENTATION

Can we use Term Frequency Only?

University of Sydney Website

Webpage#1   *Webpage#2*   *Webpage#3*

Inverse Document Frequency

Why do we need log?

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

N = total number of documents

df$_i$ = number of documents containing term i

Document #1: I like apple

Document #2: I like banana

Document #3: Sweet and yellow banana banana

Document #4: Sweet fruit

N = 4

	and	apple	banana	fruit	I	like	sweet	yellow
df	1	1	2	1	2	2	2	1

THE UNIVERSITY OF SYDNEY

Inverse Document Frequency

Why do we need log?

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

N = total number of documents

df_i = number of documents containing term i

With log

$$idf(d,t) = log(n/df(t))$$

$$n = 1,000,000$$

Without log

$$idf(d,t) = n/df(t)$$

	$df(t)$	$idf(d,t)$
word1	1	6
word2	100	4
word3	1,000	3
word4	10,000	2
word5	100,000	1
word6	1,000,000	0

	$df(t)$	$idf(d,t)$
word1	1	1,000,000
word2	100	10,000
word3	1,000	1,000
word4	10,000	100
word5	100,000	10
word6	1,000,000	1

COUNT based WORD REPRESENTATION

Inverse Document Frequency

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

1+df_i sometimes, why?

N = total number of documents

df_i = number of documents containing term i

Document #1: I like apple

Document #2: I like banana

Document #3: Sweet and yellow banana banana

Document #4: Sweet fruit

N = 4

	and	apple	banana	fruit	I	like	sweet	yellow
df	1	1	2	1	2	2	2	1

COUNT based WORD REPRESENTATION

Inverse Document Frequency

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

← *1+df$_i$*

N = total number of documents

df$_i$ = number of documents containing term i

Document #1: I like apple

Document #2: I like banana

Document #3: Sweet and yellow banana banana

Document #4: Sweet fruit

N = 4

	and	apple	banana	fruit	I	like	sweet	yellow
df	1	1	2	1	2	2	2	1
idf (with 1+*df$_i$*)	Inv(4/(1+1)) =0.693147	Inv(4/(1+1)) =0.693147	Inv(4/(2+1)) =0.287682	Inv(4/(1+1)) =0.693147	Inv(4/(2+1)) =0.287682	Inv(4/(2+1)) =0.287682	Inv(4/(2+1)) =0.287682	Inv(4/(1+1)) =0.693147

We use a natural logarithm to the base of the mathematical constant e.
where e is an irrational and transcendental number approximately equal to 2.718281828459

COUNT based WORD REPRESENTATION

Term Frequency Inverse Document Frequency

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right)$$

$\longleftarrow$ *1+df$_i$*

w$_{i,j}$ = weight of term i in document j

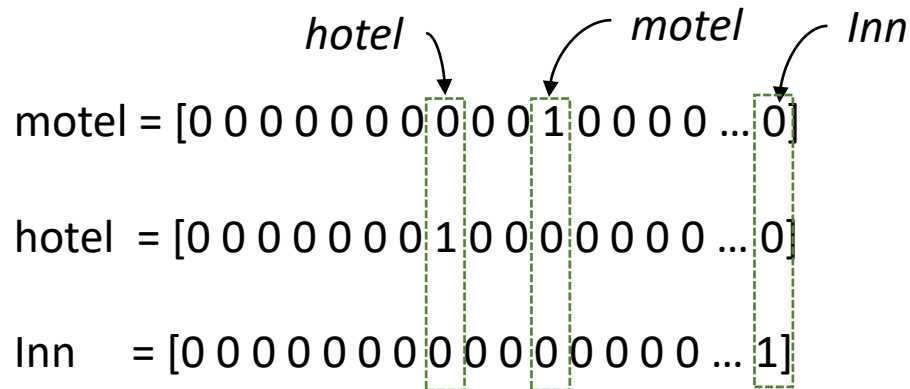*Document #1: I like apple*

Document #2: I like banana

Document #3: Sweet and yellow banana banana

Document #4: Sweet fruit

	and	apple	banana	fruit	I	like	sweet	yellow
D#1	0	0.693147	0	0	0.287682	0.287682	0	0
D#2	0	0	0.287682	0	0.287682	0.287682	0	0
D#3	0.693147	0	0.575364	0	0	0	0.287682	0.693147
D#4	0	0	0	0.693147	0	0	0.287682	0

COUNT based WORD REPRESENTATION

Sparse Representation

With COUNT based word representation (especially, one-hot vector), linguistic information was represented with sparse representations (high-dimensional features)

hotel   *motel*   *Inn*

motel = [0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 … 0]

hotel = [0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 … 0]

Inn   = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 … 1]

However, with the recent popularity and success of **word embeddings (low dimensional, distributed representations)**, **neural-based models have achieved superior results on various language-related tasks** as compared to traditional machine learning models with high-dimensional features.

**Lecture 1: Introduction to Natural Language Processing**

1. Course Introduction
2. Overview of Natural Language Processing (NLP)
3. Word Meaning and Representation
4. **Count-based Word Representation**
   - One-hot Encoding
   - Bag of Words
   - Term Frequency-Inverse Document Frequency
5. Next Week Preview

NEXT WEEK PREVIEW…

How to Represent the Word Similarity!
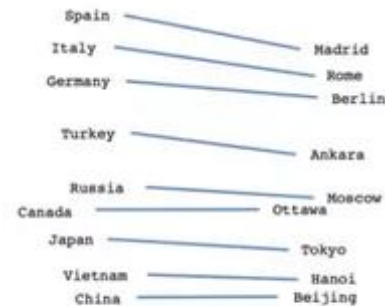
- How to represent the word similarity with dense vector
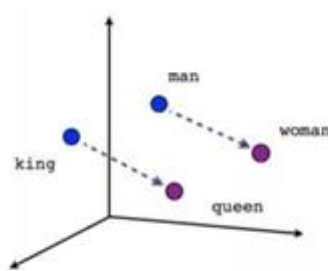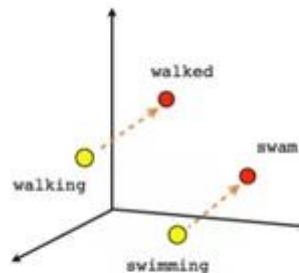
Male-Female   Verb tense   Country-Capital

- Try this with word2vec

Word Algebra

Enter all three words, the first two, or the last two and see the words that result.

| shanghai | + (| australia | - | sydney |) = | Get result |

china   0.7477672216910414

Reference for this lecture

- Deng, L., & Liu, Y. (Eds.). (2018). Deep Learning in Natural Language Processing. Springer.

- Rao, D., & McMahan, B. (2019). Natural Language Processing with PyTorch: Build Intelligent Language Applications Using Deep Learning. " O'Reilly Media, Inc.".

- Manning, C. D., Manning, C. D., & Schütze, H. (1999). Foundations of statistical natural language processing. MIT press.

- Manning, C 2017, Introduction and Word Vectors, Natural Language Processing with Deep Learning, lecture notes, Stanford University

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