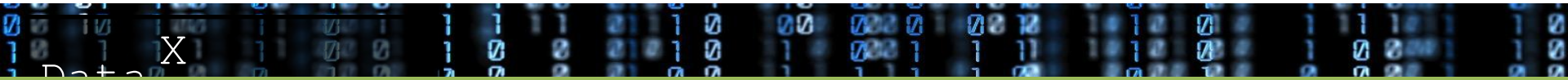# Data ^{X}

About us:

Introduction to Natural Language Processing

(Text Based NLP)

By Sana Iqbal

What is Natural Language Processing?

- NLP aims to analyze language not only as a sequence of words but for its meaning as well.

- Natural Language Processing is a field at intersection of computer science , artificial intelligence, linguistics.
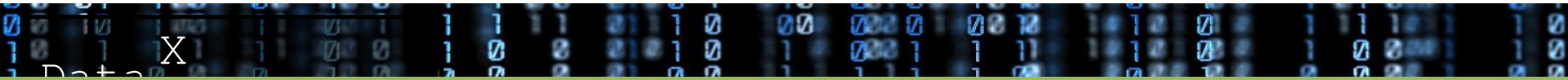
Why should we care about NLP?

We want computers to understand human language.

So that:

1. Computers can communicate with humans.
2. We want computers to perform certain tasks using language data, like:
   a. Text Classification
   b. Information Retrieval
   c. Information extraction / Question Answering
   d. Language Translation

NLP in Industry

1. Search engines
2. Grammarly
3. Autocompletion
4. Sentiment Analysis
5. Language Translation
6. Chatbots
7. …..
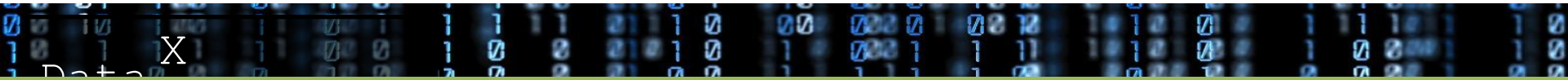
What makes NLP challenging?

1. Natural languages are **ambiguous**, e.g
   print(1+1) always prints 2
    I want to eat honey.   I want to eat honey. I made her duck. I made her duck

2. Natural language **assumes contextual information** is known, as a result it does not go deep explaining everything, eg
   I ask you to count the number of girls in the room. You get up and count.
   To a computer I need to define what is a room, what is a girl and what count means!

3. The corpus of natural languages is large and dynamic.
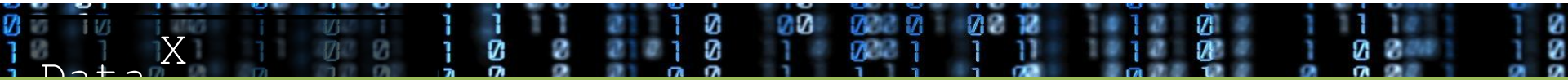
Characteristics of Natural Languages:

1. Construction units or words
2. Syntax
3. Semantics
4. Discourse

Syntax: The way in which words are put together to form phrases, clauses, or sentences; the part of grammar dealing with this.

Semantics: The study of the meanings of words and phrases in language.

Discourse: The study the meanings of sentences in context with one another.

Analysis levels

DISCOURSE

SEMANTICS

SYNTAX

WORDS

Finer representation of language
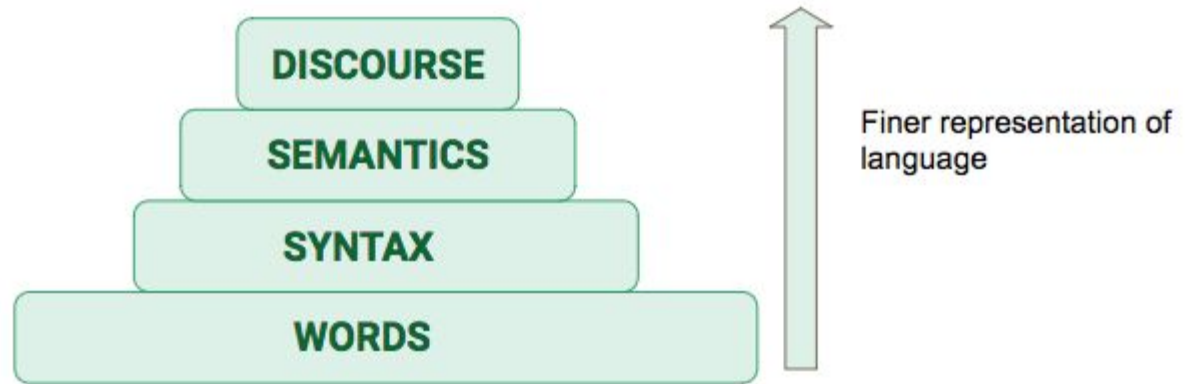
Consider this text from a novel:
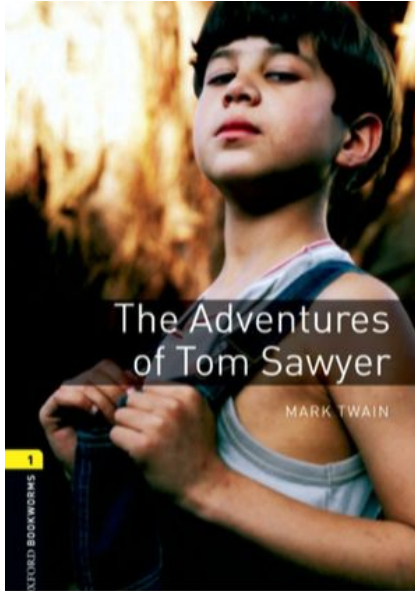
"TOM!"

No answer.

"TOM!"

No answer.

"What is gone with that boy, I wonder? You TOM!"

No answer.

The old lady pulled her spectacles down and looked over them about the room.

A. Represent the corpus as a collection of words.

"TOM!"
No answer.

"TOM!"

No answer.

"What is gone with that boy, I wonder? You TOM!"

No answer.

The old lady pulled her spectacles down and looked over them about the room.

Tokenization →

tom no answer tom no answer tom what is gone with that boy wonder you tom no answer the old lady pulled her spectacles down and looked over them about the room

X

Data

Count the word frequencies:

Word	count	Word	count
tom	3	old	1
no	3	lady	1
answer	3	pulled	1
what	1	her	1
is	1	spectacles	1
gone	1	down	1
with	1	and	1
that	1	looked	1
boy	1	over	1
wonder	1	them	1
you		about	
		room	

tom no answer tom no answer what
is gone with that boy wonder you
tom no answer the old lady pulled
her spectacles down and looked
over them about the room

Bag of Words (BOW) representation of this corpus.

B. Syntax Analysis.

We want to understand the **structural relationship**
between words and how language is constructed.

1. Identify **parts of speech**
   -nouns, verbs, adjectives

2. Identify **named entities** -
   look for nouns.

3. Identify r**elations or
   structural phrases.**

X

Data

PARTS OF SPEECH TAGGING:

--- nouns
--- verbs
--- adjectives

"TOM!"
No answer.

"TOM!"
No answer.

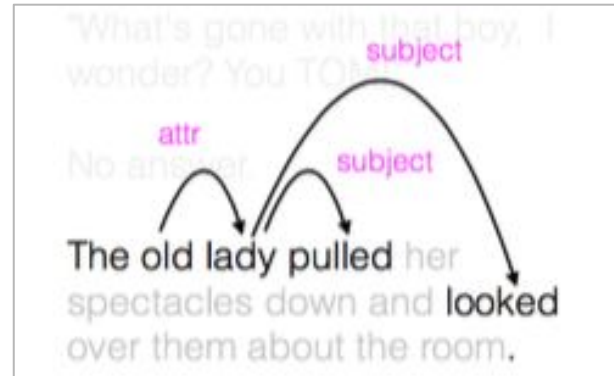"What is gone with that boy, I wonder? You TOM!"

No answer.

The old lady pulled her spectacles down and looked over them about the room.

Chunking:

Data X
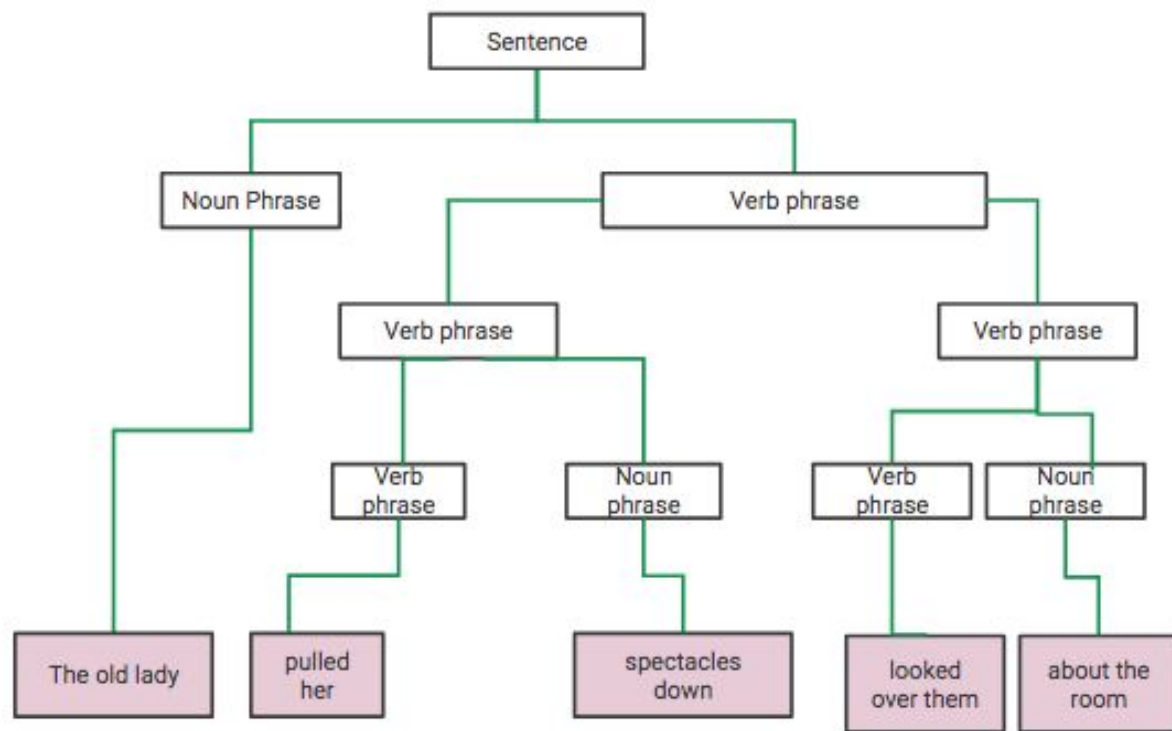
Simple Syntax Parse Tree showing Noun and Verb phrases in a sentence

C. Semantic Analysis:

SEMANTICS

SYNTAX

WORDS

We study the relationship between different parts of a corpus in creating meaning that is language independent..

☐**Lexical semantics** – meanings of component words of a corpus
I am good . I am ok. I am unwell.
Cat is a mammal.

Compositional semantics – how words or phrases combine to create meaning.

Different semantic frames for a same word:

Apply_heat frame: "Michelle baked the potatoes for 45 minutes ."
Cooking_creation frame: "Michelle baked her mother a cake for birthday."
Absorb_heat frame: "The potatoes have to bake for more than 30 minutes."

Not_interesting: Too much theory makes a lecture dry.
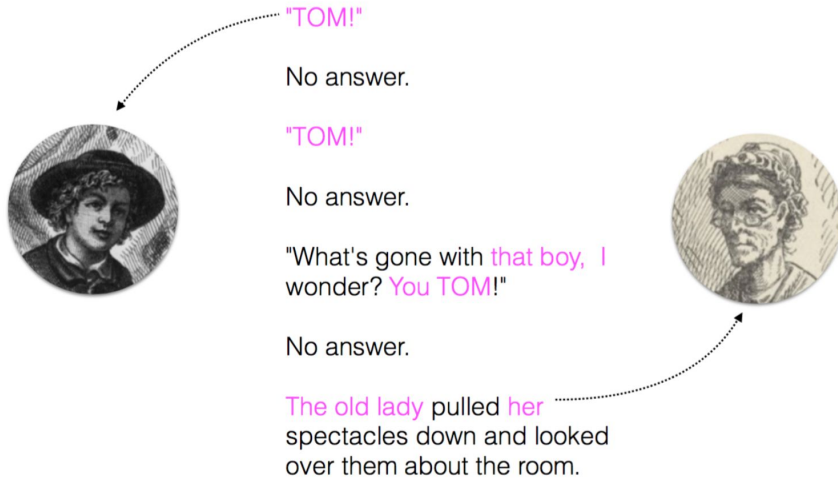Water_evaporated: Your jacket is dry now.

*Some definitions you might come across in NLP:

Lemma: The canonical form of an inflected word, e.g. baked ---->bake
Morphemes: The smallest linguistic unit within a word that can carry a meaning e.g. clueless--->clue, less

Co-references Resolution

Identify Speakers

"TOM!"

No answer.

"TOM!"

No answer.

"What's gone with that boy, I wonder? You TOM!"

No answer.

The old lady pulled her spectacles down and looked over them about the room.

"TOM!"

No answer.

"TOM!"

No answer.

"What's gone with that boy, I wonder? You TOM!"

No answer.

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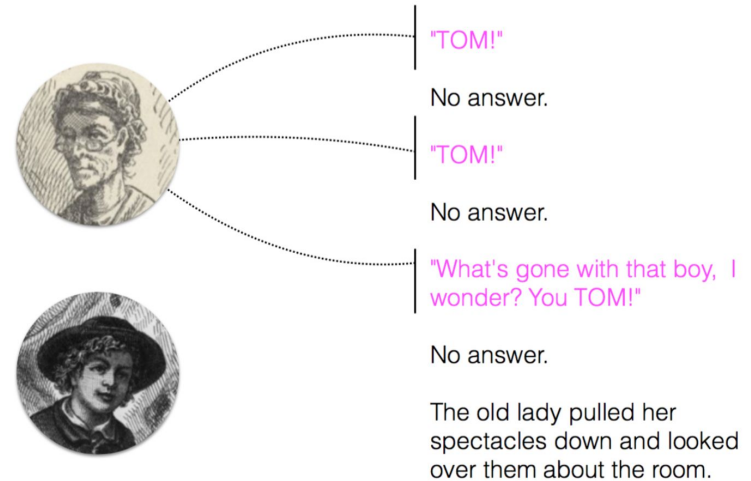
D. Discourse Analysis:

Discourse is dialog or communication, which always has an underlying subject and tone. Here we study how sentences in a corpus affect each other and overall meaning of the language.

E.g

"TOM!"
No answer.
"TOM!"
No answer.

"What is gone with that boy, I wonder? You TOM!"

No answer.

The old lady pulled her spectacles down and looked over them about the room.

Reframing →

An old woman is looking for a boy named TOM.

How is NLP is done? - General Idea

Principles of the traditional NLP

	Word-Level	Phrase-Level	Sentence-Level	Discourse-Level
Segment-ation	Tokenization	Chunking	Sentence Boundary Detection	TextTiling
Syntax	Morphology / Stemming / Part of Speech Tagging	Chunking / Information Extraction	Parsing	Rhetorical Structure Theory Parsing
Semant-ics	Thesauri / Word Similarity	Information Extraction	Sentiment Classification / QA / Word Sense Disam.	Summarization/ Categorization / Discourse Analysis

Imagine the scenario, which do you think is more likely?

   I want to go outside and take a [_____]

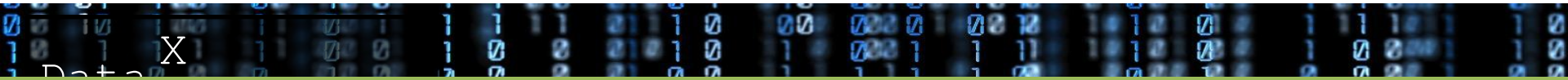I want to go outside and take a walk --- looks most likely Or natural

I want to go outside and take a picture.

I want to go outside and take a stone --- looks least likely

   We want our computer to do this job for us!
   How can we teach it?
   We teach our machine --LANGUAGE MODEL

Language Model for Machines:

At high level:

If we want our machines to do the specific tasks on language , they should be able to understand the language.

To that end we create **language models.**

Language models predict the probability distribution of language expressions given a set of vocabulary.

Language models or the grammar:

Language modeling is the task of estimating likelihood of a **sequence** or **a word** given a sequence.

P(x1, x2, x3) = P(x1) P(x2 | x1) P(x3 | x2, x1)

EXAMPLE:
  P("sunday is a boring day")   =   P(sunday)* P(is|sunday)*   P(a|sunday,is)*
  P(boring|sunday,is,a)*   P(day|sunday,is,a,boring)

For longer sentences it becomes very hard to track large dependencies, we use **Markov Assumption and MLE of Probability.**
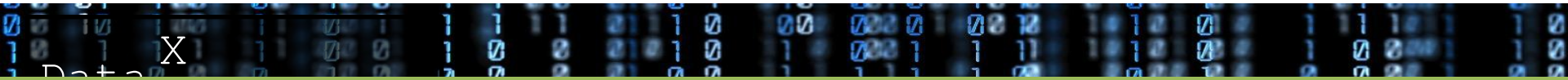
N-grams

The Markov Assumption:
  The probability of a future event depends only on a   limited history of preceding events.

MLE:
  $P(w_i | w_1 w_2 ... w_{i-1}) = count(w_1...w_i)/count(w_1...w_{i-1})$

An **n-gram model** is a statistical model of language in which the **previous n−1** words are used to predict the next word.

Unigram Model

- ❏ Likelihood of a word is not dependent on contextual word
- ❏ Just multiply the probability of each word to get the probability of a sentence.
- ❏ P(w1w2 ...wn) ≈ ∏P(wi)
- ❏ EXAMPLE:

Corpus : sunday is a boring day

P("sunday is a boring day")   =   P(sunday)* P(is)*   P(a)*   P(boring)*   P(day)

P("day|sunday is a boring")   =   P(day) =1/5

Bigram Model

- Likelihood of a word is dependent on one preceding word contextual word .
- $P(w_i | w_1 w_2 ... w_{i-1}) \approx P(w_i | w_{i-1})$

- EXAMPLE:
  P("day|sunday is a boring ")   =   P(day|boring) =Count(boring day)/Count(boring)

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Unigram and bag Of words Model

Doc1: I love dogs.

Doc2: I hate dogs and knitting.

Doc3: Knitting is my hobby d my passion

Bag of words:

.

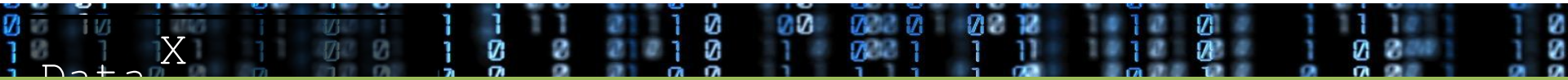|	I	love	dogs	hate	and	knitting	is	my	hobby	passion
Doc 1	1	1	1							
Doc 2	1		1	1	1	1				
Doc 3					1	1	1	2	1	1

Information Extraction

If we want the most relevant document to be delivered back we need to find the document that has our query as the signature word.

IDF: Inverse Document Frequency, which measures how rare a term is the in the documents.

IDF(term(t) = log_e(Total number of documents / Number of documents with term t in it).

Instead of using, counts we use tf-idf weights of terms as features.

Doc1: I love dogs.
Doc2: I hate dogs and knitting.
Doc3: Knitting is my hobby d my passion

	I	love	dogs	hate	and	knitting	is	my	hobby	passion
Doc 1	1	1	1							
Doc 2	1		1	1	1	1				
Doc 3					1	1	1	2	1	1

	I	love	dogs	hate	and	knitting	is	my	hobby	passion
Doc 1	0.18	**0.48**	0.18							
Doc 2	0.18		0.18	**0.48**	0.18	0.18				
Doc 3					0.18	0.18	**0.48**	**0.95**	**0.48**	**0.48**

How we can do NLP:

At high level we can have:

❏ **Rule Based or Logical methods** -classification and information retrieval
❏ **Probabilistic Models or Language Model** - QA,Information extraction
  ❏ Documents are ranked based on the probability of the query *Q* in the document's language model.

Word Representation :

❏ **Can be Discrete - apple,boy,eat**
❏ **Distributional Approaches or Word2Vec---apple=[0.2,0.3,...]**
  ❏ Assumes: Meaning is related to the context, Words that appear in same context are similar
  ❏ Words are represented as continuous representation or embeddings of corpus vocabulary
  – Requires large corpus to learn the relation between words

Applications:

TASK:	SIMPLE SOLUTIONS
a. Text Classification b. Information Retrieval c. Question Answering d. Information extraction e. Spelling correction f. Machine Translation	BOW or any n-gram using a classifier BOW with link ranking analysis BOW with if-else Information retrieval with rule based methods for association Character n-grams Rule based with POS tagging and semantic matching