COMP4901K/Math4824B
Machine Learning for Natural Language Processing

Lecture 2: Introduction to NLP

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Towards understanding of text

More than a decade ago, Carl Lewis stood on the threshold of what was to become the greatest athletics career in history. He had just broken two of the legendary Jesse Owens' college records, but never believed he would become a corporate icon, the focus of hundreds of millions of dollars in advertising. His sport was still nominally amateur. Eighteen Olympic and World Championship gold medals and 21 world records later, Lewis has become the richest man in the history of track and field -- a multi-millionaire.

- Who is Carl Lewis?
- Did Carl Lewis break any records?

What is NLP?

Arabic text كلب هو مطاردة صبي في الملعب.

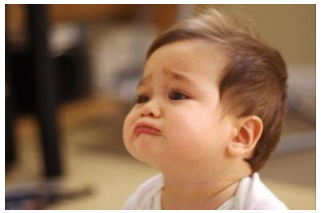
How can a computer make **sense** out of this **string**?

Morphology	- What are the basic units of meaning (words)? - What is the meaning of each word?
Syntax	- How are words related with each other?
Semantics	- What is the “combined meaning” of words?
Pragmatics	- What is the “meta-meaning”? (speech act)
Discourse	- Handling a large chunk of text
Inference	- Making sense of everything

- *Automatically answer our emails*
- *Translate languages accurately*
- *Help us manage, summarize, and aggregate information*
- *Use speech as a UI (when needed)*
- *Talk to us / listen to us*

If we can do this for all the sentences in all languages, then …

- BAD
- Unfo nt now.
- Gen



A brief history of NLP

- Early enthusiasm (1950's): Machine Translation
  - Too ambitious
  - Bar-Hillel report (1960) concluded that fully-automatic high-quality translation could not be accomplished without knowledge (Dictionary + Encyclopedia)
- Less ambitious applications (late 1960's & early 1970's): Limited success, failed to scale up
  - Speech recognition
  - Dialogue (Eliza) Shallow understanding
  - Inference and domain knowledge (SHRDLU="block world")

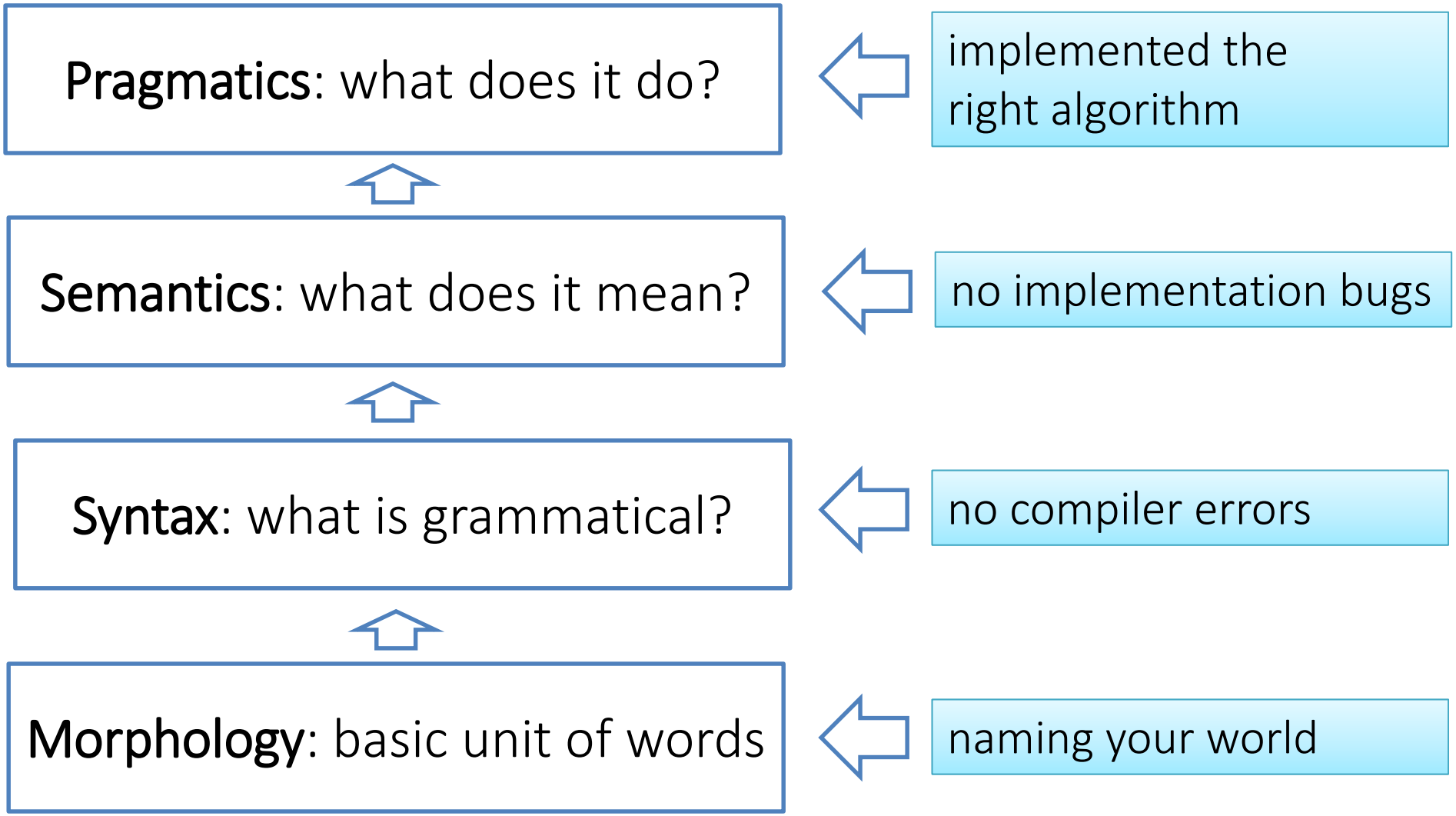
Deep understanding in limited domain

- Real world evaluation (late 1970's – now)
  - Story understanding (late 1970's & early 1980's) Knowledge representation
  - Large scale evaluation of speech recognition, text retrieval, information extraction (1980 – now) Robust component techniques
  - Statistical approaches enjoy more success (first in speech recognition & retrieval, later others) Statistical language models
- Current trend:
  - Boundary between statistical and symbolic approaches is disappearing.
  - We need to use all the available knowledge A lot of applications nowadays
  - Application-driven NLP research (bioinformatics, Web, Question answering…)

NLP is difficult!!!!!!!

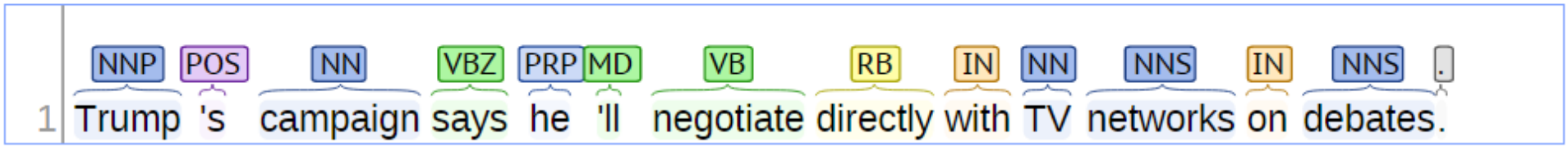
- Natural language is designed to make human communication efficient. Therefore,
  - We omit a lot of “common sense” knowledge, which we assume the hearer/reader possesses
  - We keep a lot of ambiguities, which we assume the hearer/reader knows how to resolve
- This makes EVERY step in NLP hard
  - Ambiguity is a “killer”!
  - Common sense reasoning is pre-required

Levels of Linguistic Analysis: Analogy with Programming Languages



Syntax (1)

- Part of speech



- Tags:
  - NN: common noun
  - NNP: proper noun
  - VB: verb, base form
  - VBZ: verb, 3rd person singular
  - …

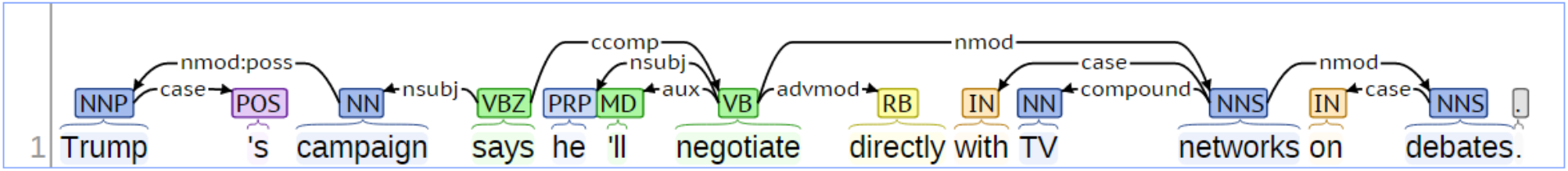
Penn Treebank part-of-speech tags (including punctuation).

Tag	Description	Example	Tag	Description	Example
CC	Coordin. Conjunction	*and, but, or*	SYM	Symbol	*+, %, &*
CD	Cardinal number	*one, two, three*	TO	"to"	*to*
DT	Determiner	*a, the*	UH	Interjection	*ah, oops*
EX	Existential 'there'	*there*	VB	Verb, base form	*eat*
FW	Foreign word	*mea culpa*	VBD	Verb, past tense	*ate*
IN	Preposition/sub-conj	*of, in, by*	VBG	Verb, gerund	*eating*
JJ	Adjective	*yellow*	VBN	Verb, past participle	*eaten*
JJR	Adj., comparative	*bigger*	VBP	Verb, non-3sg pres	*eat*
JJS	Adj., superlative	*wildest*	VBZ	Verb, 3sg pres	*eats*
LS	List item marker	*1, 2, One*	WDT	Wh-determiner	*which, that*
MD	Modal	*can, should*	WP	Wh-pronoun	*what, who*
NN	Noun, sing. or mass	*llama*	WP$	Possessive wh-	*whose*
NNS	Noun, plural	*llamas*	WRB	Wh-adverb	*how, where*
NNP	Proper noun, singular	*IBM*	$	Dollar sign	*$*
NNPS	Proper noun, plural	*Carolinas*	#	Pound sign	*#*
PDT	Predeterminer	*all, both*	"	Left quote	(' or ")
POS	Possessive ending	*'s*	"	Right quote	(' or ")
PRP	Personal pronoun	*I, you, he*	(	Left parenthesis	([, (, {, <)
PRP$	Possessive pronoun	*your, one's*	)	Right parenthesis	( ],), }, >)
RB	Adverb	*quickly, never*	,	Comma	,
RBR	Adverb, comparative	*faster*	.	Sentence-final punc	(. ! ?)
RBS	Adverb, superlative	*fastest*	:	Mid-sentence punc	(: ; ... – -)
RP	Particle	*up, off*			

Syntax (2)

- Dependency parse

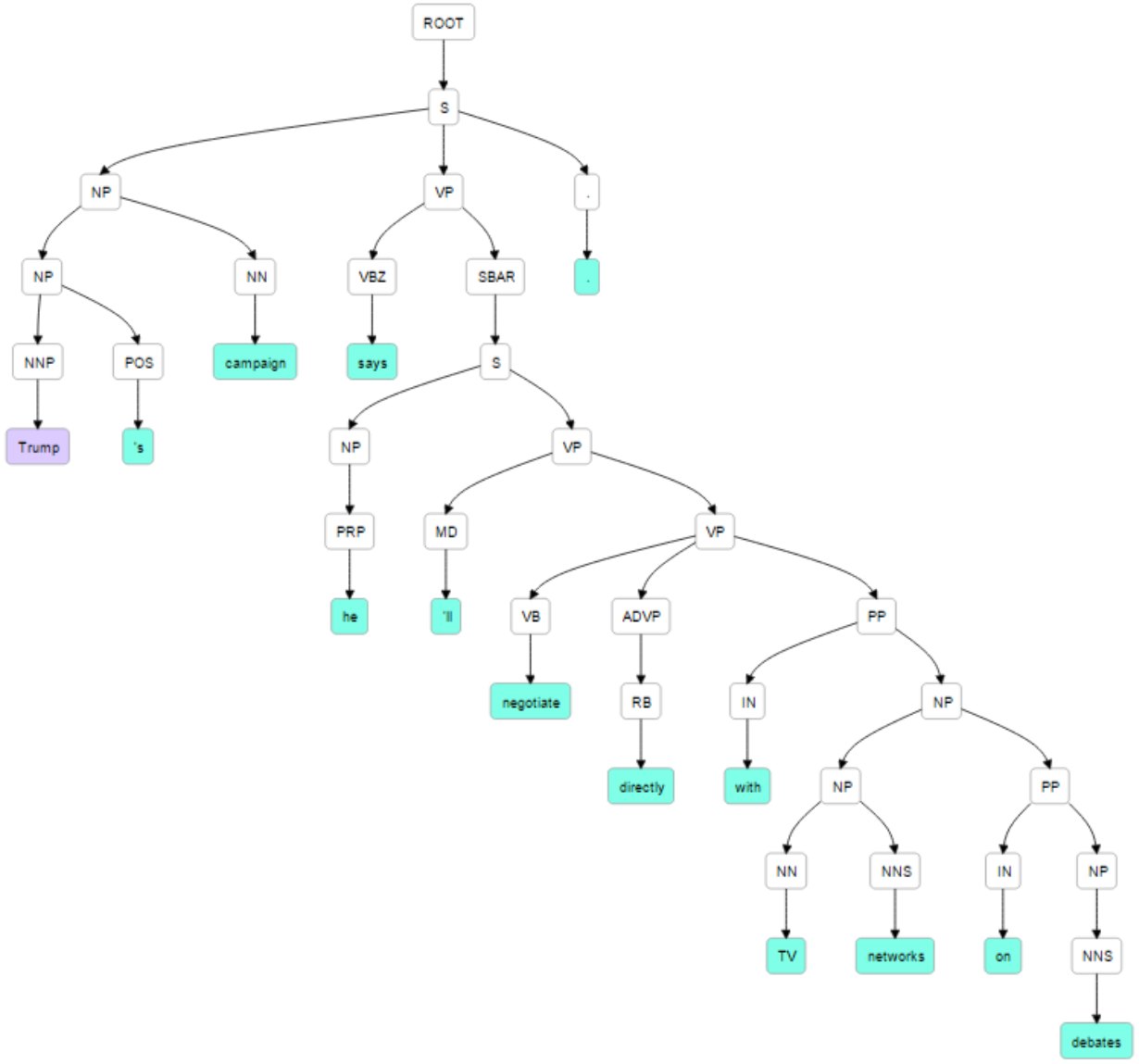
Basic Dependencies:

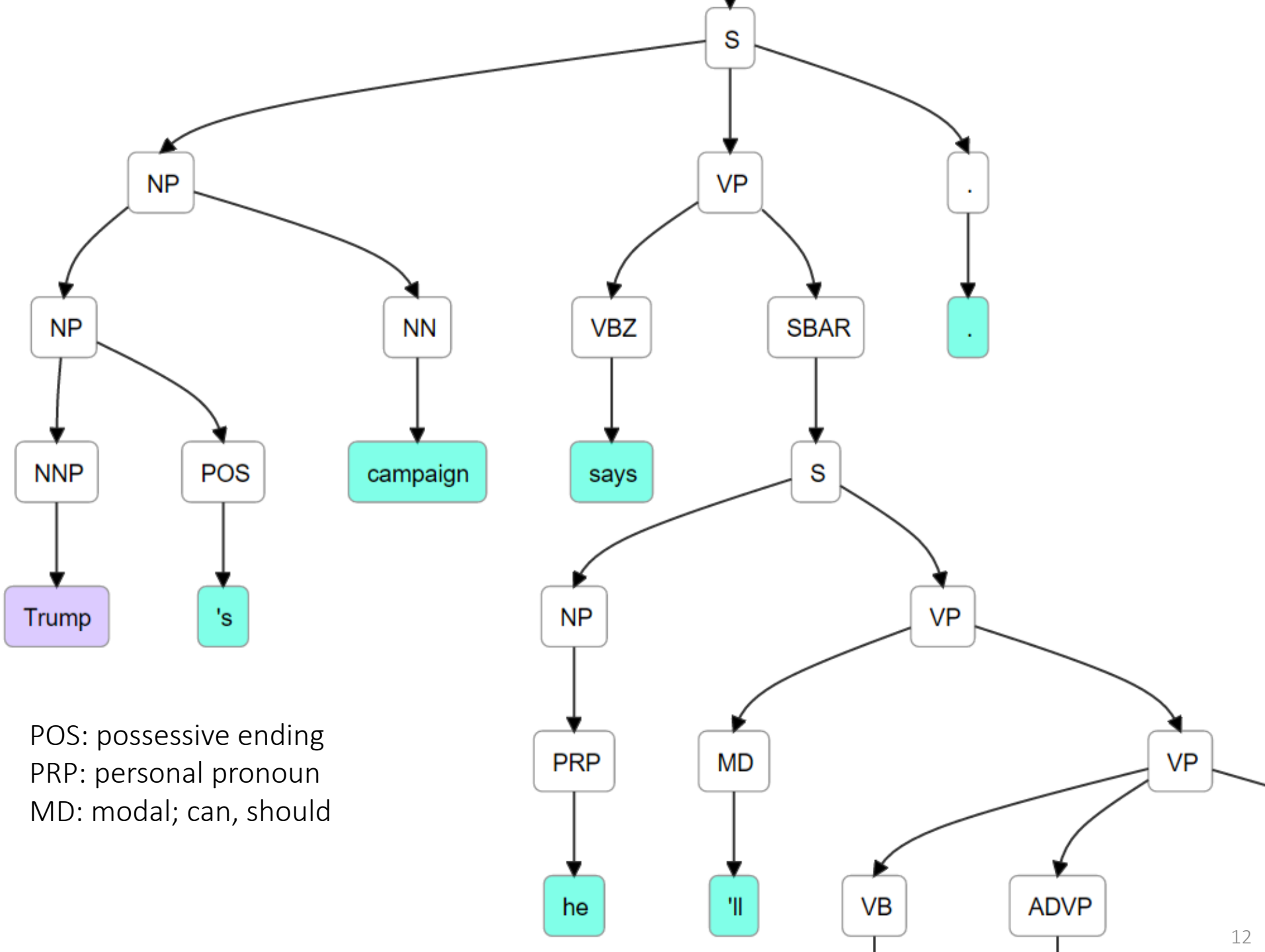


- Dependency relations:
  - nsubj: subject (nominal)
  - advmod: adverbial modifier

Syntax (3)

- Constituency parsing





POS: possessive ending
PRP: personal pronoun
MD: modal; can, should

Penn Treebank constituent (or nonterminal) labels.

Label	Description
ADJP	Adjective Phrase
ADVP	Adverb Phrase
CONJP	Conjunction Phrase
FRAG	Fragment
INTJ	Interjection
NAC	Not a constituent
NP	Noun Phrase
NX	Head subphrase of complex noun phrase
PP	Prepositional Phrase
QP	Quantifier Phrase
RRC	Reduced Relative Clause
S	Simple declarative clause (sentence)
SBAR	Clause introduced by complementizer
SBARQ	Question introduced by *wh*-word
SINV	Inverted declarative sentence
SQ	Inverted yes/no question
UCP	Unlike Co-ordinated Phrase
VP	Verb Phrase
WHADJP	*Wh*-adjective Phrase
WHADVP	*Wh*-adverb Phrase
WHNP	*Wh*-noun Phrase
WHPP	*Wh*-prepositional Phrase

Semantic (1)

Named Entity Recognition:

1 Person
Trump's campaign says he'll negotiate directly with TV networks on debates.

2 Person Dur Location
The move by Trump, coming just hours after his and other campaigns huddled in a Washington suburb to craft a three-page letter of possible demands, thwarts an effort to find consensus after what most candidates agreed was a debacle hosted by Org CNBC Date last week.

- Person
- Location
- Org: Organization
- Date/time
- …

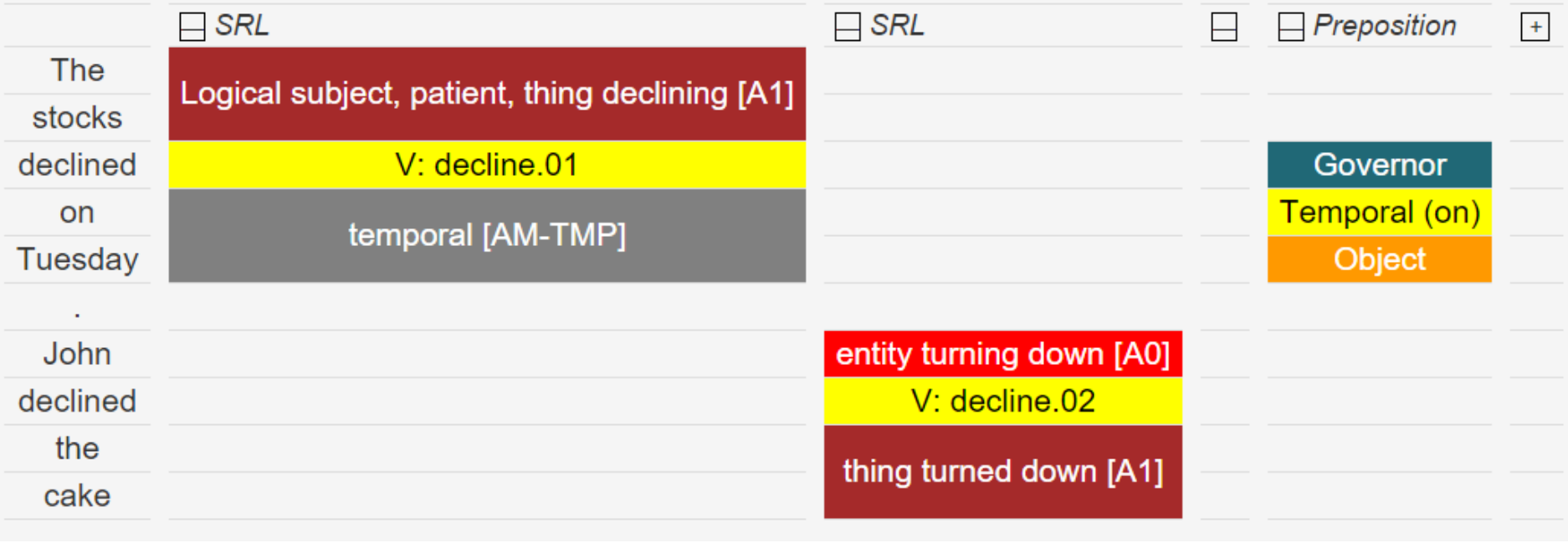
Semantics (2)

- Frame based semantics

  Cynthia sold the bike to Bob for $200

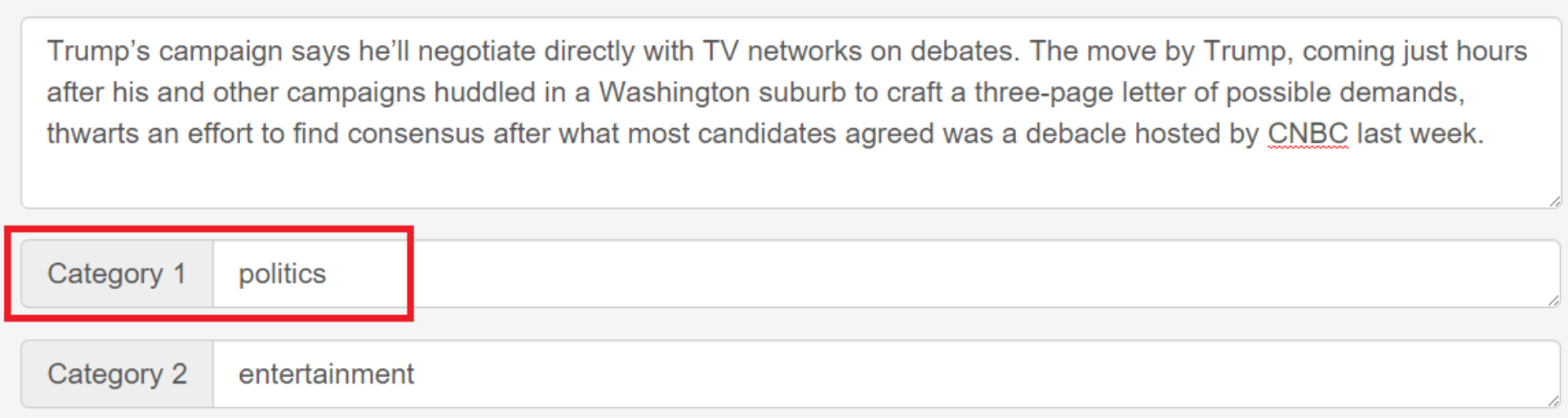
  SELLER PREDICATE GOODS BUYER PRICE

- Semantic role labeling (SRL)



Semantic (3)

- Topics



  - Categorization/classification
  - Clustering
  - Topic modeling

Semantics (4) Lexical/Compositional Semantics

- Word

light

- Multi-word expressions: meaning unit beyond a word

light bulb

- Morphology: meaning unit within a word

light lighten lightening relight

- Polysemy: one word has multiple meanings (word senses)

The light was filtered through a soft glass window.
He stepped into the light.

- Synonymy/paraphrasing

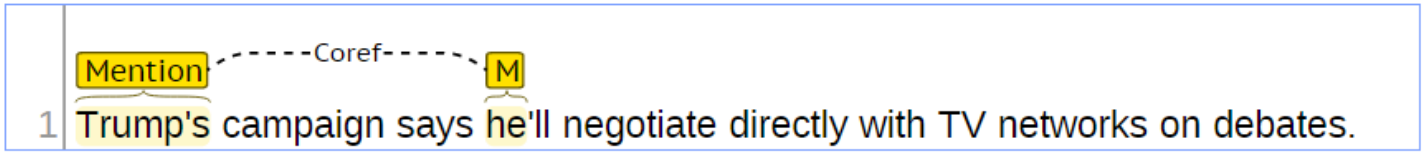
confusing and unclear

I have fond memories of my childhood.
I reflect on my childhood with a certain fondness.
I enjoy thinking back to when I was a kid.

Discourse

- Coreference

Coreference:



  - The dog chased the cat, which ran up a tree. It waited at the top.
  - The dog chased the cat, which ran up a tree. It waited at the bottom.
  - Paul tried to call George on the phone, but he wasn't successful.
  - Paul tried to call George on the phone, but he wasn't available.

- Discourse: sentence relation
  - S1: Senator calls this "the first gift of democracy". But
  - S2: The Poles might do better to view this as a Trojan Horse.

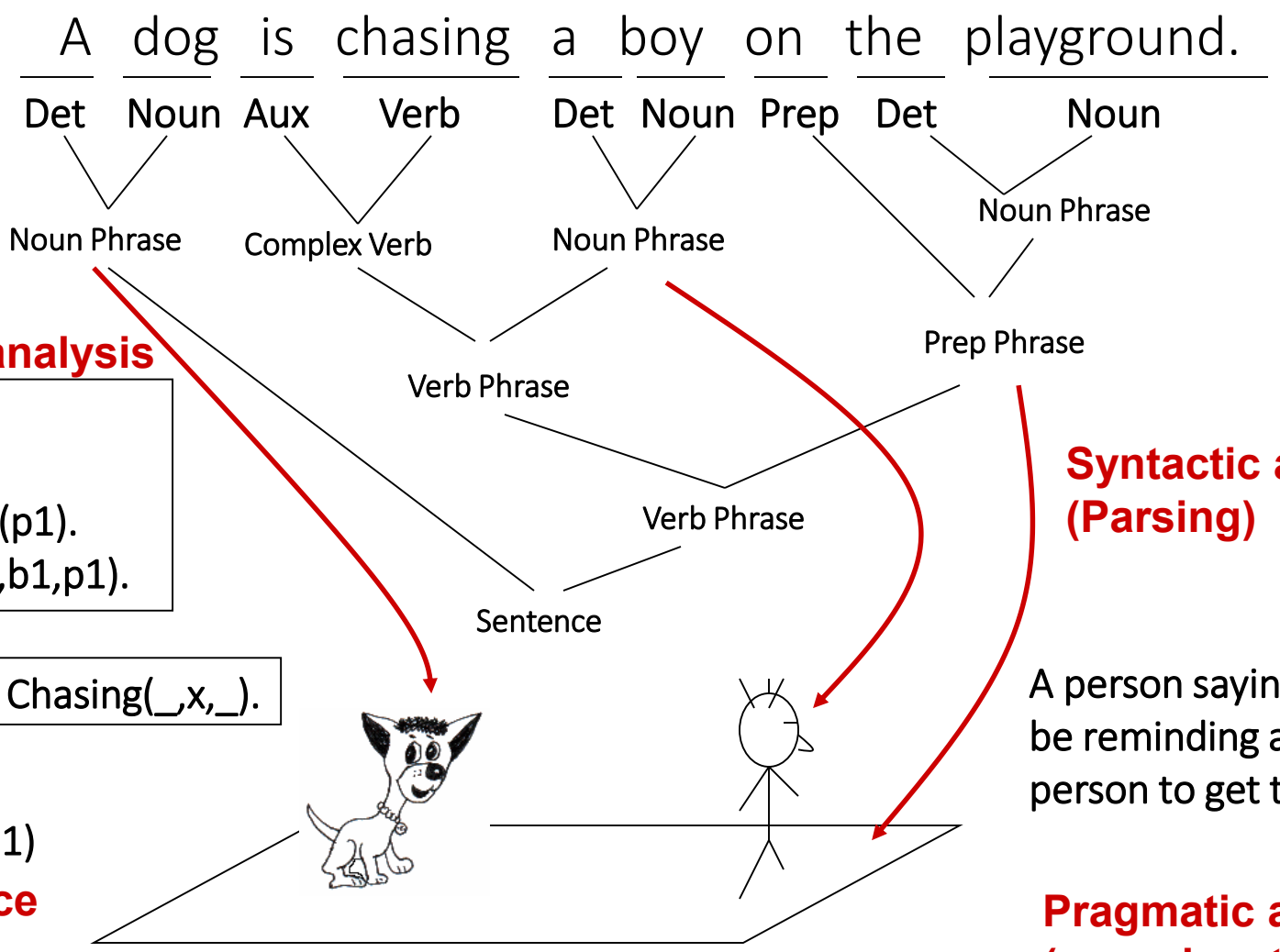
Contrast relationship

Pragmatics

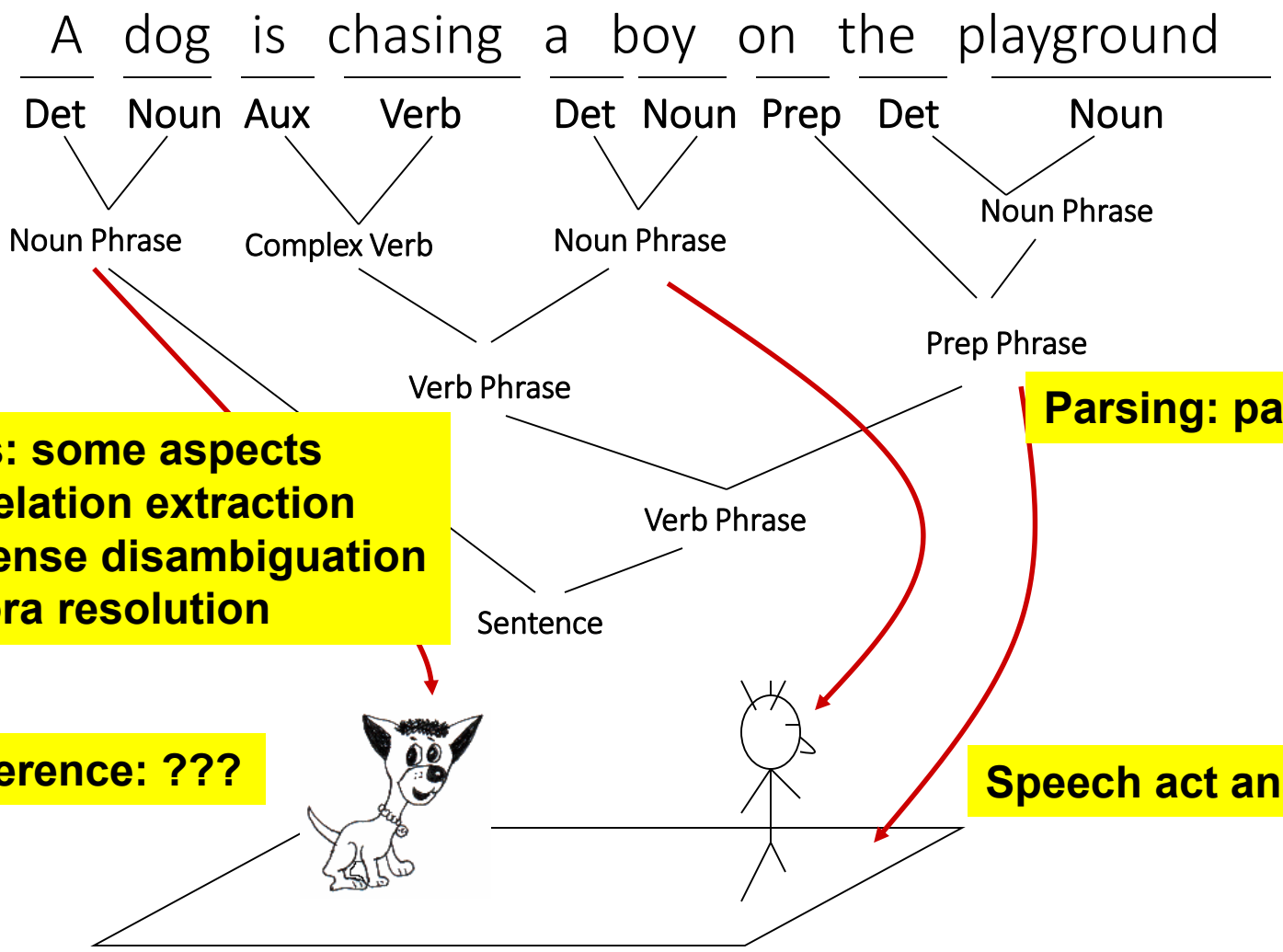
- Semantics: what does it mean literally?

- Pragmatics: what is the speaker really conveying?
  - Conversational implicature
    - A: What on earth has happened to the roast beef?
    - B: The dog is looking very happy.
    - Implicature: The dog at the roast beef.
  - Presupposition: background assumption independent of truth of sentence
    - I have stopped eating meat.
    - Presupposition: I once was eating meat.

An example of NLP



The state of the art



POS Tagging: 97%

Parsing: partial >90%

Semantics: some aspects
- **Entity/relation extraction**
- **Word sense disambiguation**
- **Anaphora resolution**

Inference: ???

Speech act analysis: ???

More about “Commonsense Knowledge”

- When we communicate,
  - we omit a lot of “common sense” knowledge, which we assume the hearer/reader possesses
  - we keep a lot of ambiguities, which we assume the hearer/reader knows how to resolve

What is Commonsense Knowledge?

Knowledge about the everyday world that is possessed by all people

- A lemon is sour.
- To open a door, you must usually first turn the doorknob.
- If you forget someone's birthday, they may be unhappy with you.

More Examples

- A coat is used for keeping warm.
- People want to be respected.
- The sun is very hot.
- The last thing you do when you cook dinner is wash your dishes.
- People want good coffee.

Detecting Moods ("affect") in Text

"My wife left me; she took the kids and the dog" ⇒ ☹

- Approach:
  - Mood keyword (e.g., "sad") → mine a "small society of linguistic models of effect" from the KB (=?)
- Applications:
  - Empathy Buddy: (purpose=?)
  - Summarizing a collection of reviews about a topic

Figure 2. Empathy Buddy Reacts to an E-mail.

Machine Translation

美国关岛国际机场及其办公室均接获一名自称沙地阿拉伯富商拉登等发出的电子邮件，威胁将会向机场等公众地方发动生化袭击後，关岛经保持高度戒备。

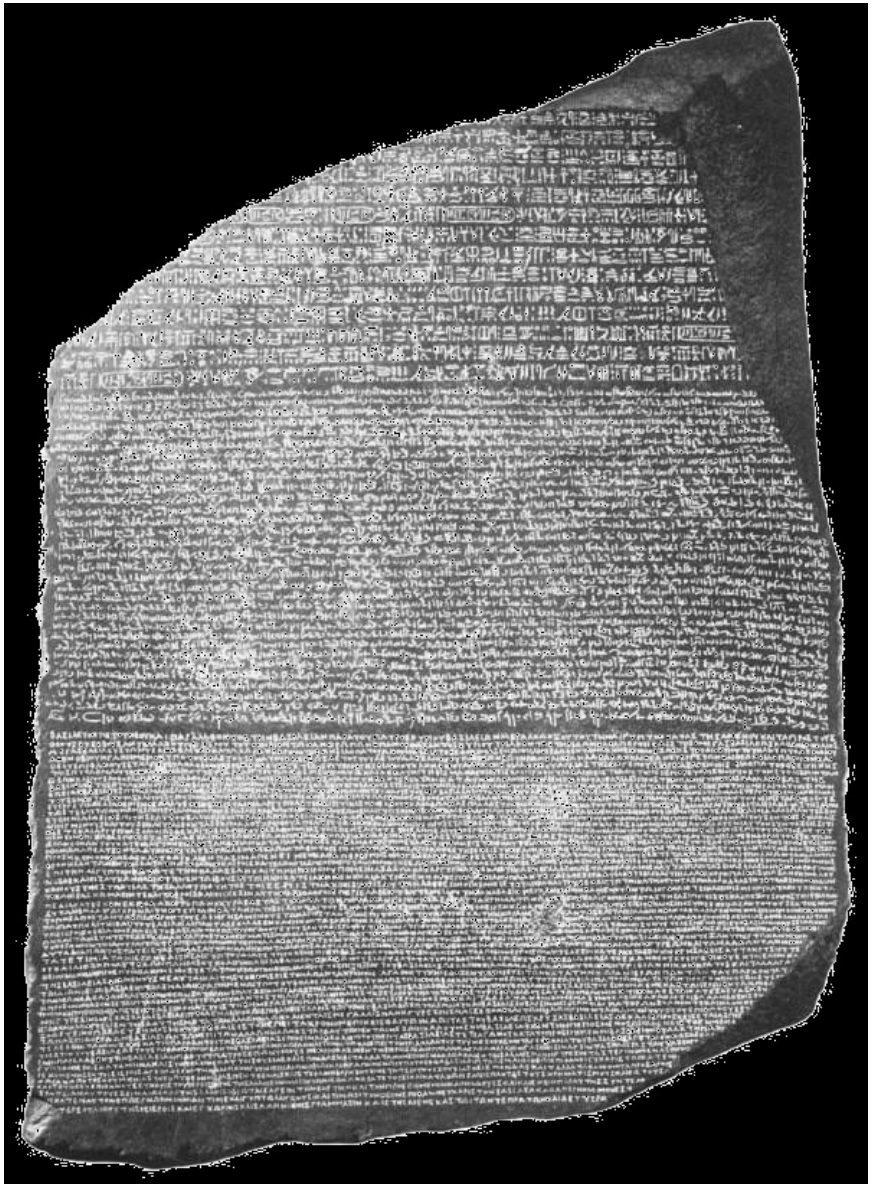
The U.S. island of Guam is maintaining a high state of alert after the Guam airport and its offices both received an e-mail from someone calling himself the Saudi Arabian Osama bin Laden and threatening a biological/chemical attack against public places such as the airport .

- The classic acid test for natural language processing.
- Requires capabilities in both interpretation and generation.
- About $33 billion spent annually on human translation!

Statistical Solution

- Parallel Texts
  - Rosetta Stone

Hieroglyphs
Demotic
Greek



Statistical Solution

- Parallel Texts
  - Instruction Manuals
  - Hong Kong/Macao Legislation
  - United Nations Reports
  - Official Journal of the European Communities
  - Translated news

A Practice for You: Translation Exercise: Learning to translate using parallel text

- Centauri/Arcturan [Knight, 1997]
  - Your assignment, translate this to Arcturan:
    - farok crrrok hihok yorok clok kantok ok-yurp

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: farok crrrok hihok yorok clok kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
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Slide from Kevin Knight

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4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok **clok** . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok** clok kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok **clok** . ??? 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok** clok kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok clok** kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat .
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

process of elimination

Centauri/Arcturan [Knight, 1997]

Your assignment, translate this to Arcturan: **farok** crrrok **hihok yorok clok** kantok ok-yurp

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
3a. erok sprok izok hihok ghirok . 3b. totat dat arrat vat hilat .	9a. wiwok nok izok kantok ok-yurp . 9b. totat nnat quat oloat at-yurp .
4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat . cognate?
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

Centauri/Arcturan [Knight, 1997]

Your assignment, put these words in order: **{ jjat, arrat, mat, bat, oloat, at-yurp }**

1a. ok-voon ororok sprok . 1b. at-voon bichat dat .	7a. lalok farok ororok lalok sprok izok enemok . 7b. wat jjat bichat wat dat vat eneat .
2a. ok-drubel ok-voon anok plok sprok . 2b. at-drubel at-voon pippat rrat dat .	8a. lalok brok anok plok nok . 8b. iat lat pippat rrat nnat .
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4a. ok-voon anok drok brok jok . 4b. at-voon krat pippat sat lat .	10a. lalok mok nok yorok ghirok clok . 10b. wat nnat gat mat bat hilat .
5a. wiwok farok izok stok . 5b. totat jjat quat cat .	11a. lalok nok crrrok hihok yorok zanzanok . 11b. wat nnat arrat mat zanzanat . zero fertility
6a. lalok sprok izok jok stok . 6b. wat dat krat quat cat .	12a. lalok rarok nok izok hihok mok . 12b. wat nnat forat arrat vat gat .

It’s Really Spanish/English

Clients do not sell pharmaceuticals in Europe => Clientes no venden medicinas en Europa

1a. Garcia and associates . 1b. Garcia y asociados .	7a. the clients and the associates are enemies . 7b. los clients y los asociados son enemigos .
2a. Carlos Garcia has three associates . 2b. Carlos Garcia tiene tres asociados .	8a. the company has three groups . 8b. la empresa tiene tres grupos .
3a. his associates are not strong . 3b. sus asociados no son fuertes .	9a. its groups are in Europe . 9b. sus grupos estan en Europa .
4a. Garcia has a company also . 4b. Garcia tambien tiene una empresa .	10a. the modern groups sell strong pharmaceuticals . 10b. los grupos modernos venden medicinas fuertes .
5a. its clients are angry . 5b. sus clientes estan enfadados .	11a. the groups do not sell zenzanine . 11b. los grupos no venden zanzanina .
6a. the associates are also angry . 6b. los asociados tambien estan enfadados .	12a. the small groups are not modern . 12b. los grupos pequenos no son modernos .

Slide from Kevin Knight

Statistical Learning to MT?

- Traditional SMT did a lot of alignment like this
  - It's actually a learning+inference process
    - Learning: learning the parameters to fit the data
    - Inference: make decisions online for the alignment with large likelihood and constraints (rules defined by human)
  - Deep learning
    - Much simplified the process
      - Sequence to sequence model, which we will see
    - Can we borrow the ideas for deep learning?
      - Still an active research area

Goal of this Lecture

- Get familiar with some of the NLP terminologies and tasks
  - We won't be able to touch all of the tasks
  - But we will use some of the terminologies (will also re-introduce when needed)
- Modern NLP solutions are based on large scale data
  - Then the problem becomes machine learning
    - how to (over-)fit the data
  - A detour: there is still a lot of problem
- We will focus on machine learning algorithms that can handle text data and work on more practical tasks
  - Not just syntax/semantics, but more pragmatics