



From Grammar
Police to Grammar
Detectives!

Syntax, Parsing,
and Semantic
Analysis

ITAI 2373 – Mod 06

Learning Outcomes

By the end of this module, you will

Understand why sentence structure matters for computer understanding of language

Distinguish between syntax (structure) and semantics (meaning) in computational terms

Recognize the two major approaches to parsing: dependency and constituency

Identify semantic roles and relationships in sentences

Connect parsing concepts to real-world NLP applications

🔗 Connecting the Cases (Classes) 😊







- **Module 5:** POS tagging -identifies each word's role (noun, verb, adjective...)
- **Module 6:** Looks how these words work together to create meaning
- **The Evolution:** From individual word identification to relationship analysis

The Case of the Two Sentences



The Mystery of Meaning

- Few Words Can Change Everything
- Exhibit A:
- "The detective questioned the suspect"  
- "The suspect questioned the detective"  

Why This Case Matters:

- **Search engines** need to know if you're searching for "dogs that chase cats" or "cats that chase dogs"
- **Legal systems** need to understand the difference between "the company sued the individual" and "the individual sued the company"
- **Medical records** must be clear about whether "the patient was treated by the doctor" or "the doctor was treated by the patient"

The Tools of the Trade

- **How We Investigate Sentence Structure**
 - 🔍 **Magnifying Glass: Part-of-Speech Tagging**
 - Identifying the role of each word (noun, verb, adjective...)
 - Like identifying the profession of each person at a crime scene
 - 🗺️ **Crime Scene Map: Parsing**
 - Mapping the relationships between words
 - Showing who's connected to whom and how
 - 💡 **The Big Picture: Semantic Analysis**
 - Understanding what it all means in context
 - Moving from "what happened" to "why it happened"



The Tools of the Trade (2)

- **The Modern Detective:**
 - Instead of a magnifying glass, we use algorithms!
 - **spaCy:** The fast, reliable detective for everyday cases
 - **NLTK:** The forensic lab for deep analysis and experimentation
 - **Transformers:** The high-tech specialist for the toughest cases

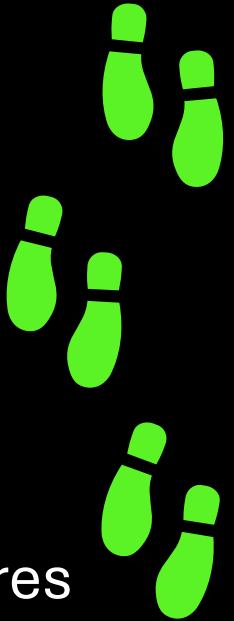


How Parsers Work: The Investigation Process

Following the Evidence to Solve Sentence Structure

The Detective's Investigation Pipeline:

- **1. Secure the Scene:** Break text into individual words and punctuation
- **2. Identify the Suspects:** Assign grammatical roles to each word (from Module 5)
- **3. Apply Investigation Rules:** Use linguistic patterns or learned procedures
- **4. Map the Connections:** Build the relationship network between words
- **5. Solve the Case:** Resolve conflicts when multiple interpretations exist
- **Two Investigation Approaches:**
 - By-the-Book: Uses established linguistic rules and procedures
 - Pattern Recognition: Learns from thousands of previous solved cases



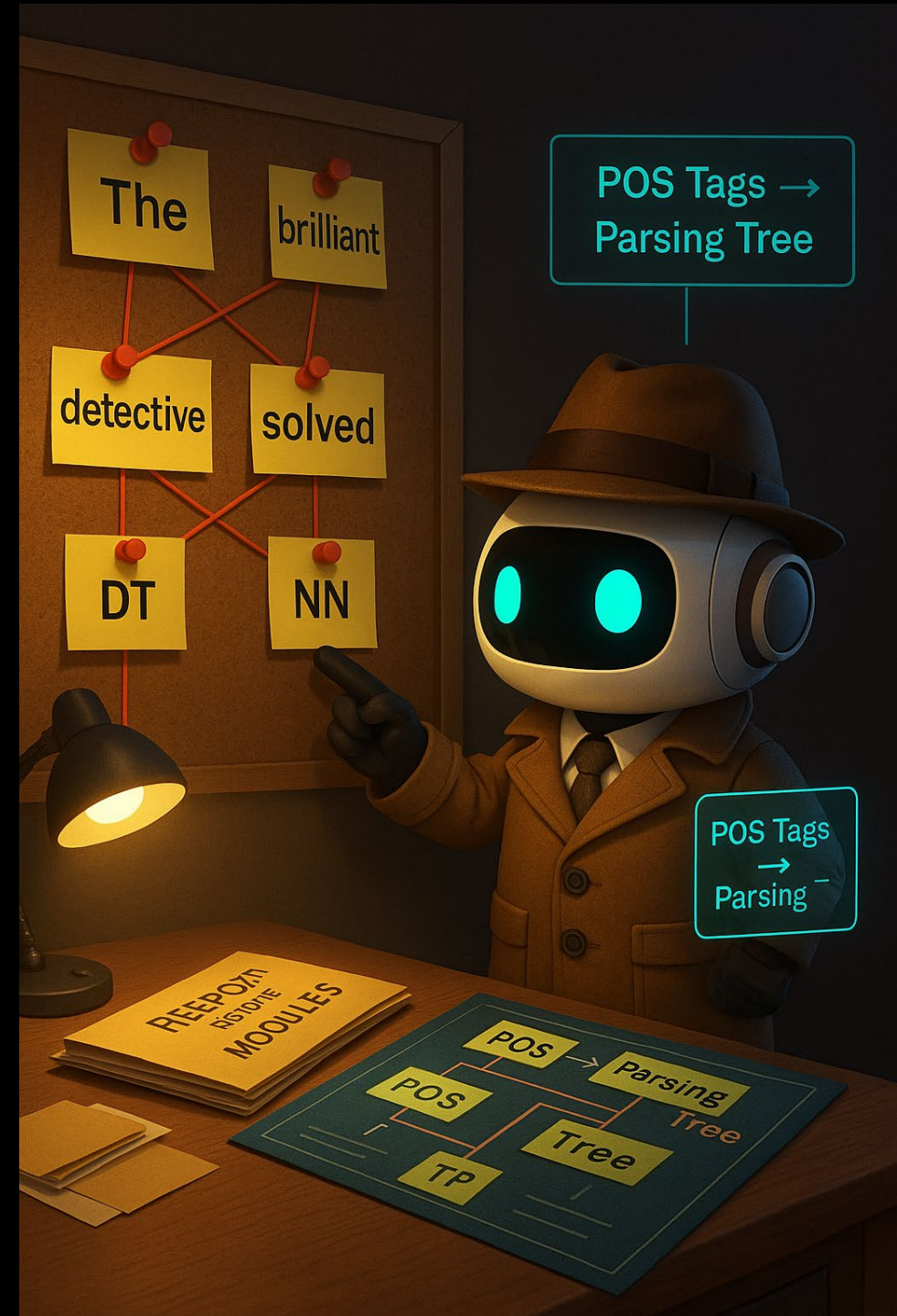
From Grammar Police Evidence to Detective Analysis

How POS Tags Become the Foundation for Parsing

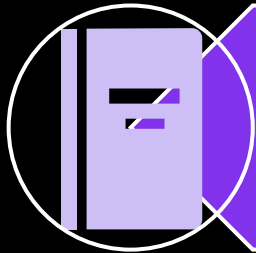
🚓 What the Grammar Police Gave Us (Module 5):

"The brilliant detective solved the case"

- **The** → DT (Determiner)
- **brilliant** → JJ (Adjective)
- **detective** → NN (Noun)
- **solved** → VBD (Verb, past tense)
- **the** → DT (Determiner)
- **case** → NN (Noun)



Syntax - The Rule Book



Syntax = the grammar rule book of sentence formation



Defines which word arrangements are legal and meaningful



Guides how words combine into phrases and sentences

From Grammar Police Evidence to Detective Analysis



What We Detectives Do With This Evidence:

- **Find the main action:** solved (the verb is usually the center of the story)
- **Identify the key players:** detective and case (the nouns are the characters)
- **Understand the relationships:** Who solved what? (detective solved case)
- **Add the details:** How was it solved? (brilliantly)



The Detective's Advantage:

- **Grammar Police:** "Here are the individual word types" **Grammar Detectives:** "Here's how they work together to create meaning"



Why This Progression Matters:

You can't understand relationships without first identifying the players!

Mapping the Connections –Dependency Parsing

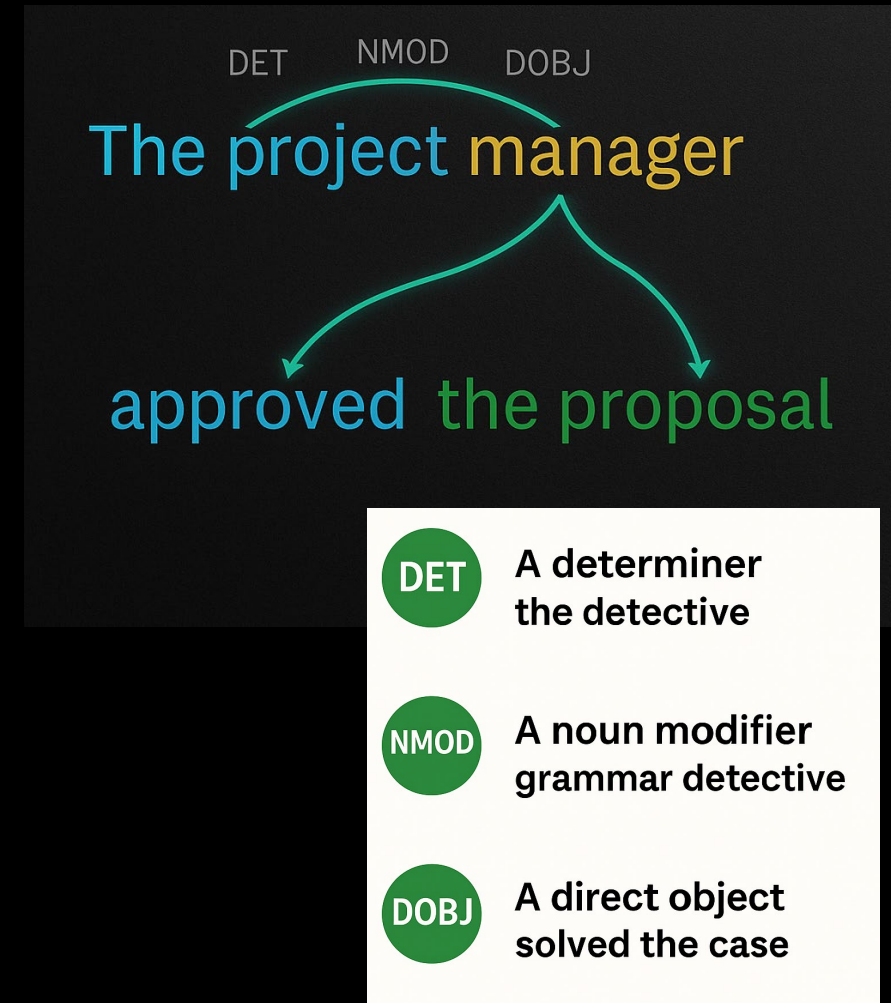
How Dependency Parsing Reveals Relationships

❄ Think of it as a web of connections

- Every word is connected to another word
- We're looking for the lines of influence and control
- Who's the boss? Who's the subordinate?

• 🎯 The Core Idea:

- Dependency parsing reveals WHO depends on WHOM in a sentence





Mapping the Connections –Dependency Parsing

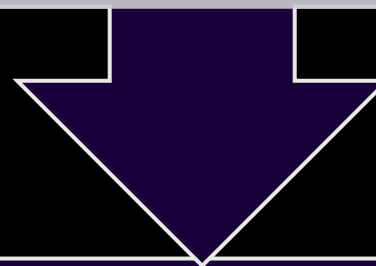


What We're Looking For:

The mastermind:
The main word that
controls the
sentence

The lieutenants:
Words that report
directly to the
mastermind

The assistants:
Words that provide
support and details



Why This Matters:

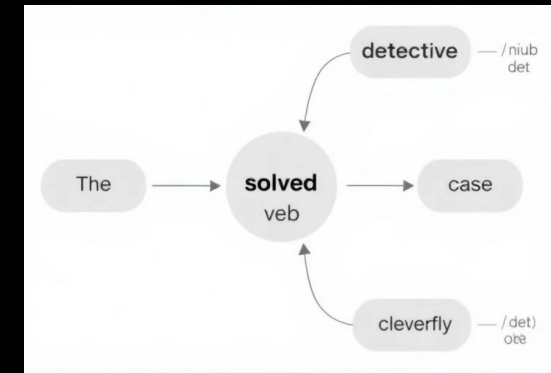
Understanding these connections helps us see the hidden structure
in any sentence!

Dependency Parsing in Action



Case File: "The detective cleverly solved the case"

solved (The Mastermind)
/ | \
detective cleverly case
| |
The the



What Our Map Reveals:

- "solved" is the central action (the mastermind of the sentence)
- "detective" is the one who did the solving (subject)
- "case" is what got solved (object)
- "cleverly" tells us how the solving happened (manner)
- "The" and "the" point to our key players (determiners)



Reading the Evidence:

Each line shows a dependency relationship - one word depends on another for its meaning!

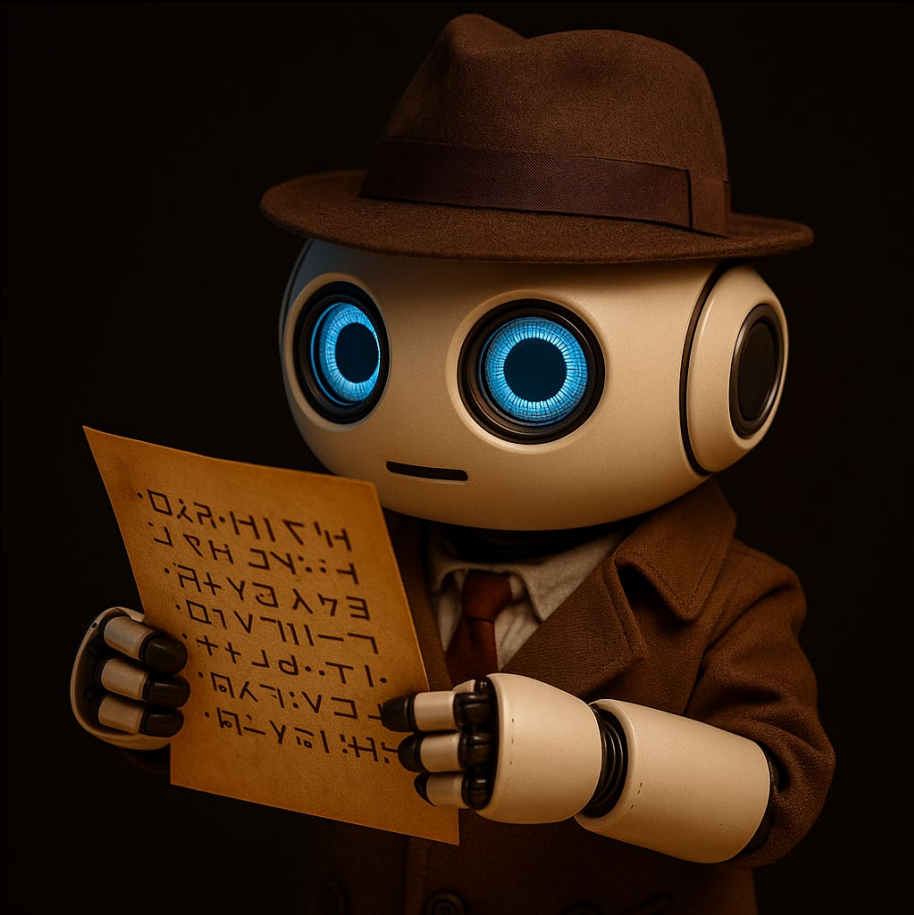


The Secret Code: Universal Dependencies

Label Legend

Universal Dependencies
Label Legend

| Label | Full Form | Example |
|--------|---------------------|-------------------------------------|
| nsubj | Nominal Subject | <i>detective</i> → solved |
| advmod | Direct Object | <i>solved</i> → <i>cesev</i> |
| det | Adverbial Mod- | <i>solved</i> → <i>cleverly</i> |
| amod | Adjectival Modifier | <i>detective</i> → <i>brilliant</i> |
| iobj | Indirect Object | <i>gave</i> → <i>lawyer</i> |
| case | Case Marker | <i>in</i> → <i>courtroom</i> |
| root | Root of Sentence | <i>solved</i> ← ROOT |





The Power of Dependency Analysis

Why This Technique is So Valuable



Instant Question Answering:

- "Who solved the case?" → Follow the subject line to "detective"
- "What was solved?" → Follow the object line to "case"
- "How was it solved?" → Follow the manner line to "cleverly"



Handles Complex Cases:

- Even with long, complicated sentences, the core relationships remain clear!



The Power of Dependency Analysis



Works Across Languages:

- The same relationship concepts work for English, Spanish, Chinese, and more!



Real-World Applications:

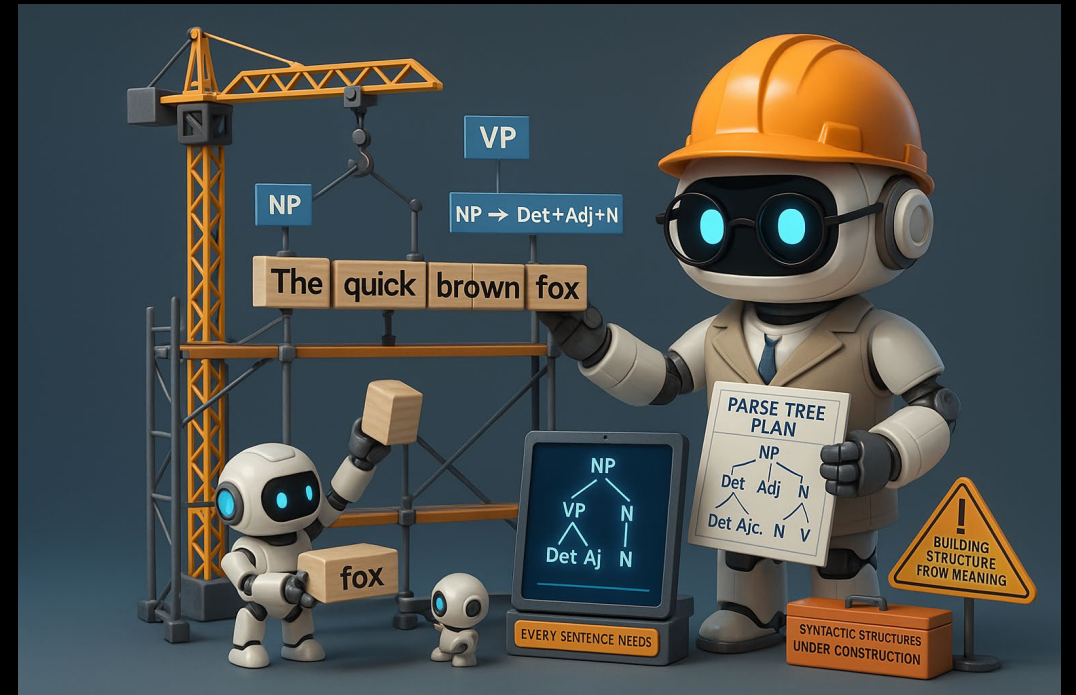
- Voice assistants understanding your comma
- Search engines finding exactly what you need
- Translation systems preserving meaning across languages

The Architecture of a: Sentence Constituency Parsing



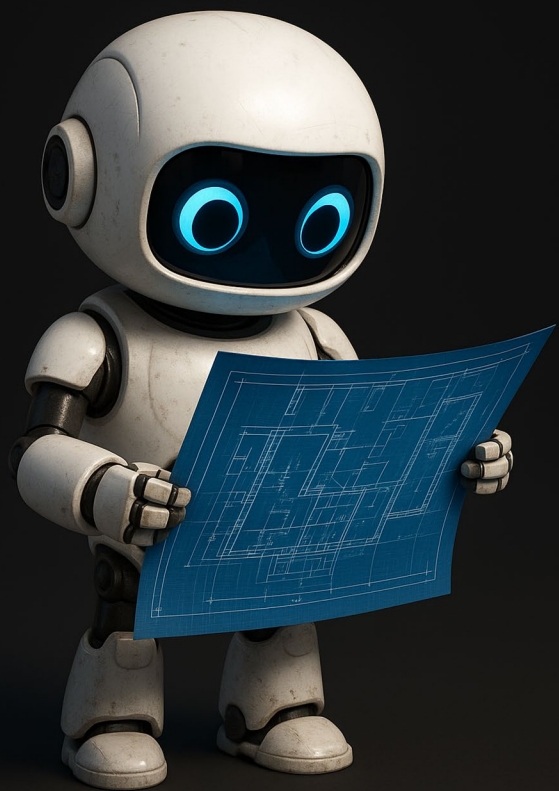
Think of it as a building blueprint

- We're looking at how the sentence is constructed, from the foundation up
- Words are the bricks, phrases are the rooms, the sentence is the building





The Architecture of a Sentence 2



🌳 Case File: "The detective solved the case"

Sentence (The Building)

/ \

Noun Phrase (The Office) Verb Phrase (The Action Zone)

|

/

\

The detective

Verb

Noun Phrase (The File Room)

|

|

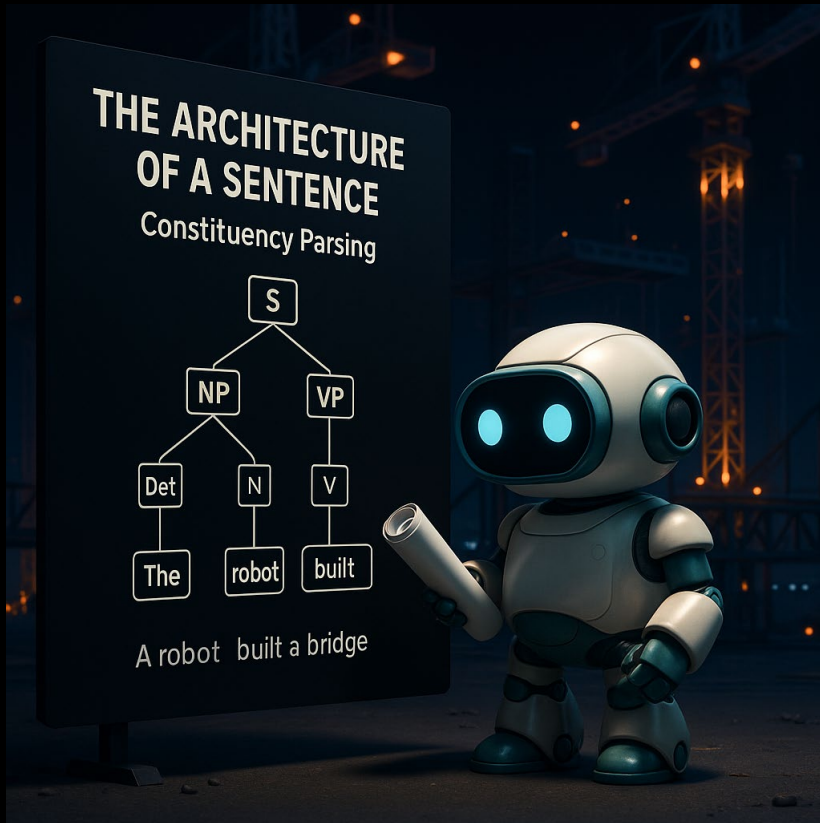
solved

the case

🔍 What Our Blueprint Reveals:

- The sentence is made of two main parts: a noun phrase and a verb phrase.
- "The detective" is a complete unit (the office of the main character).
- "solved the case" is another complete unit (the action zone).
- We can see how smaller parts combine to create the whole structure.

The Architecture of a Sentence 3



Why This Blueprint is So Useful:

- It helps us understand the rules of sentence construction.
- It's great for grammar checking and style analysis.
- It shows how language is built from smaller, reusable parts.

The Motive - Semantic Role Labeling

Semantic Role Labeling: Who Did What to Whom, and Why?



Beyond the How, We Need the Why

- Grammar tells us the structure, but not the story.
- •We need to understand the roles each player has in the narrative.



Assigning Roles in the Drama:

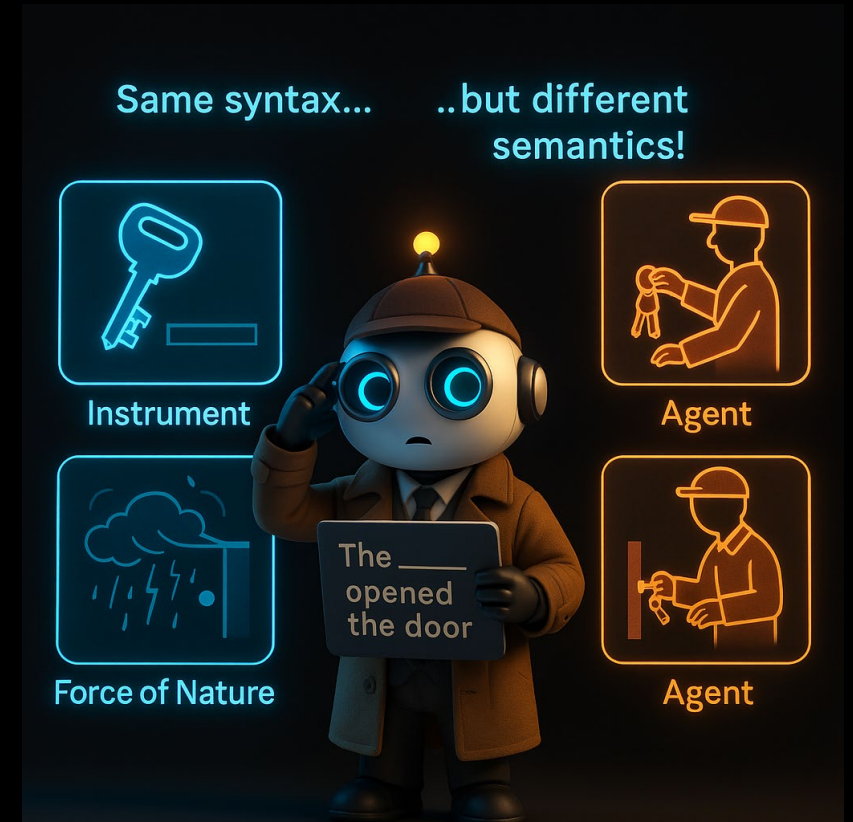
"The detective gave the evidence to the lawyer in the courtroom"

- **Agent** (The Doer): The detective
- **Action** (The Deed): gave
- **Patient** (The Thing Acted Upon): the evidence
- **Recipient** (The Receiver): the lawyer
- **Location** (The Scene of the Crime): in the courtroom

The Motive - Semantic Role Labeling

🤔 The Challenge: Reading Between the Lines

- "The key opened the door" (The key is an instrument)
- "The storm opened the door" (The storm is a natural force)
- "The janitor opened the door" (The janitor is an agent)
- Same grammar, different roles! The computer needs world knowledge to tell the difference.



How Parsing is Used in the Real World



**Search Engines: Cracking the Code
of Your Questions**



**Smart Assistants: Your Personal
Grammar Detective**



**News Analysis: Getting the Scoop,
Automatically**



**Legal Tech: Finding the Smoking
Gun in a Million Documents**



The Toughest Cases: The Linguistic Mysteries

Even top NLP models struggle with these linguistic mysteries:

Ambiguous Alibi

“I saw her duck.” – Action or bird?   Context missing.

Sarcastic Confession

“Yeah, I *totally* stole the cookies.” – Model says: Case closed. Reality: Just kidding.

Foreign Phrase

“It’s raining cats and dogs.” – Idiom misunderstood as pet storm alert.

Evolving Slang

“That movie was fire. No cap.” – Outdated dictionary = total confusion.

Looking Ahead

- **Module 7: Sentiment Analysis** (The emotional state of the witness)
- **Module 8: Text Classification** (Filing the case in the right category)
- **Module 9: Topic Modeling** (Finding the common theme in a series of crimes)



How Today's Class Connects:



Parsing is the key that unlocks all other evidence!

- To understand **sentiment**, you need to know who is happy about what.
- To **classify** a document, you need to understand its grammatical structure.
- To find **topics**, you need to know which words are the main subjects and objects.





Key Takeaways

-  **Key Concepts You've Learned:**
 - **Syntax vs. Semantics:** Structure versus meaning — both are essential for understanding language.
 - **Dependency vs. Constituency Parsing:** Two approaches for analyzing sentence structure.
 - **Why Parsing Matters:** It's the foundation for nearly all advanced NLP tasks.
-  **Skills You've Gained:**
 - You know how to select the right tools (e.g., spaCy, NLTK) for different NLP tasks.
 - You can identify language challenges like ambiguity or complex structure — and begin to analyze them.
 - You understand why even advanced systems struggle with certain inputs — and how to approach those problems.