Module 5

Q. Explain reference resolution in detail. Explain Discourse reference resolution in detail

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1. Reference Resolution is the process of **finding the actual entity or object** that a referring expression (like a pronoun, noun phrase, or demonstrative) points to.
2. The referring expression can be a **pronoun** (he, she, it, they), a **noun phrase** (the car, that person), or a **demonstrative** (this, that).
3. The entity that it refers to is called its **antecedent**.
4. Example:
    a. Sentence: *"The dog chased the cat because it was hungry."*
    b. Ambiguity: Does *"it"* refer to *dog* or *cat*?
    c. Reference Resolution tries to determine that *"it"* most likely refers to *dog*, based on meaning and context.

Importance of Reference Resolution

1. It helps in **understanding the continuity of meaning** across sentences.
2. It is crucial for **machine translation**, **question answering**, **information extraction**, and **text summarization**.
3. It ensures that machines do not treat each sentence as isolated, but as part of a continuous narrative or conversation.
4. Without proper reference resolution, NLP systems may interpret text **incorrectly or out of context.**

Types of Reference Resolution

Reference resolution can be broadly divided into several types:

(a) Anaphora Resolution

1. It deals with resolving references that refer **backward** to something already mentioned.
2. Example:
    a. *"Riya went to the market. She bought apples."*
    b. Here, **'She'** refers back to **'Riya'**.

(b) Cataphora Resolution

1. It deals with references that refer **forward** to something mentioned later.

2. Example:
    a. *"When he arrived, John was tired."*
    b. Here, **'he'** refers to **'John'**, which comes later in the sentence.

(c) Exophora Resolution

1. It deals with references that refer to something **outside the text**, often relying on the external context.
2. Example:
    a. *"That is beautiful."* (refers to something the speaker is pointing at)

(d) Coreference Resolution

1. It is a more general form that identifies **all expressions referring to the same real-world entity**.
2. Example:
    a. *"Riya said she would come. The girl is very punctual."*
    b. All three terms (*Riya*, *she*, *the girl*) refer to the same entity.

Steps in Reference Resolution

1. **Detection of referring expressions:** Identify pronouns, noun phrases, and demonstratives.
2. **Finding possible antecedents:** List all potential entities the expression could refer to.
3. **Applying syntactic and semantic constraints:** Use grammatical rules and context to eliminate unlikely candidates.
4. **Selecting the best antecedent:** Choose the most probable referent using rules, distance, and semantic matching.
5. **Linking expressions:** Connect all related expressions to form a coherent reference chain.

Example of Reference Resolution

Sentence:

"John gave his brother a book because he loves reading."

Possible Referents:

- *He* can refer to *John* or *his brother*.

Resolution:

- Based on semantics (*loves reading* → usually refers to the person receiving the book), *he* refers to *his brother*.

Output:

→ "John gave his brother a book because **his brother** loves reading."

Discourse Reference Resolution

1. **Discourse Reference Resolution** extends the concept of reference resolution to the **entire discourse or paragraph**, not just within one sentence.
2. It identifies entities that are referred to **across multiple sentences** in a conversation or document.
3. It helps maintain **semantic consistency** across long texts, where pronouns, noun phrases, or descriptive terms point to earlier entities.

2. Example of Discourse Reference Resolution

Paragraph:

"Riya went to a restaurant. She ordered pasta. The food was delicious, and the waiter was polite. Later, she gave a good review."

Resolution:

- *She* → Riya
- *The food* → pasta
- *The waiter* → staff of the restaurant
- *She* (in last sentence) → Riya again

This creates a **coherent chain of references** connecting the entire passage.

3. Importance of Discourse Reference Resolution

1. It allows the system to **understand narratives or dialogues** over multiple sentences.
2. It helps in building **knowledge graphs** and **event tracking** across documents.
3. It is essential for **summarization, dialogue systems, and reading comprehension tasks.**
4. It supports **contextual continuity** — understanding that "she" in the fourth sentence refers to the same person introduced earlier.

5. Techniques for Discourse Reference Resolution

1. **Centering Theory:** Maintains a focus of attention across sentences to identify what the discourse is about.
2. **Discourse Representation Theory (DRT):** Represents sentences and entities in a logical form to maintain consistent reference.
3. **Neural Coreference Models:** Modern models use **transformers** to link references across large documents (e.g., SpaCy's neuralcoref, HuggingFace models).

6. Example (Document-Level)

Text:

"Elon Musk founded SpaceX in 2002. The company launched its first rocket in 2006. It later became a leader in private space exploration."

Discourse Resolution:

- *The company* → SpaceX
- *It* → SpaceX

This helps the system understand that all references across the paragraph relate to the same entity.

Q. Compare and contrast Hobbs' Algorithm and Centering Theory

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Aspect	Hobbs' Algorithm	Centering Theory
Definition	A syntactic algorithm used for finding the antecedent (reference) of a pronoun in a sentence.	A discourse-based theory that explains how focus and attention shift between entities in connected sentences.
Main Idea	It finds the most likely noun phrase (NP) that a pronoun refers to using parse trees.	It analyzes how entities (centers) are maintained or shifted across utterances to ensure coherent discourse.
Approach Type	Syntax-based approach (uses sentence structure).	Discourse-based approach (uses sentence relationships and context).
Working Method	Traverses the parse tree of the sentence to find a suitable antecedent for each pronoun.	Determines backward-looking and forward-looking centers to track focus in discourse.
Input Required	Requires syntactic parse trees of sentences.	Requires discourse segments and entity information across sentences.
Focus	Works within and across sentences to find antecedents.	Focuses on maintaining coherence and topic continuity in connected sentences.
Example	In the sentence "John saw Peter. He waved," Hobbs' algorithm identifies "John" as the antecedent for "He."	In the same example, "John" is the backward-looking center that continues in the next utterance, maintaining topic focus.
Use Case	Mainly used for **anaphora resolution** (finding referents of pronouns).	Used for **discourse coherence analysis** (understanding topic flow).
Advantages	Simple, structured, and syntactically accurate for short texts.	Captures higher-level discourse relationships beyond single sentences.
Limitations	Fails when context spans multiple sentences or requires world knowledge.	Requires complex discourse modeling and can be computationally heavy.
Output	Gives the antecedent noun phrase for a pronou.n.	Explains whether discourse remains coherent or shifts topic.

Q. Anaphora Resolution using Hobbs and Centering Algorithm.

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1. Anaphora Resolution is the process of finding the **referent (antecedent)** of a **pronoun or noun phrase** in a sentence.
2. In simple words, it means identifying **what or whom** a pronoun refers to.
3. Example: In the sentence **"Ravi met Aman. He was excited."**, the word **"He"** refers to **"Ravi"**.
4. Anaphora Resolution is an important part of **Natural Language Understanding (NLU)** and **Semantic Analysis**.
5. It helps machines correctly understand the **meaning and continuity** in text or dialogue.

Hobbs' Algorithm for Anaphora Resolution

1. Hobbs' Algorithm is a **syntactic approach** to anaphora resolution.
2. It works by using the **parse tree structure** of a sentence to locate the possible antecedent of a pronoun.
3. The algorithm **traverses the parse tree** in a specific order to find noun phrases (NPs) that can match the pronoun.
4. It searches both the **current sentence** and **previous sentences** for a suitable antecedent.
5. The search is done using **left-to-right breadth-first traversal** of the parse tree.
6. It checks whether each noun phrase **matches in number and gender** with the pronoun.
7. Once a suitable noun phrase is found, it is selected as the antecedent.
8. Example:
    a. Sentence: **"John went to the park. He played football."**
    b. The algorithm first finds the pronoun **"He"**, then searches the parse tree of the previous sentence.
    c. It locates **"John"** as the nearest noun phrase that matches in number (singular) and gender (male).
    d. Therefore, **"He → John."**
9. Hobbs' Algorithm is **simple, rule-based, and syntax-driven**, which makes it easy to implement.
10. However, it may fail in cases where **context, world knowledge, or semantics** are needed for disambiguation.

Centering Algorithm (Centering Theory) for Anaphora Resolution

1. The **Centering Algorithm** is a **discourse-based approach** used to maintain the flow of reference across multiple sentences.

2. It is based on **Centering Theory**, which describes how attention shifts between entities (called **centers**) in a discourse.
3. Each utterance or sentence has two types of centers:
    a. **Forward-looking centers (Cf):** Possible entities that might be referred to in the next sentence.
    b. **Backward-looking center (Cb):** The entity that connects the current sentence with the previous one.
4. The algorithm assumes that **discourse is coherent** when the backward-looking center (Cb) remains the same across sentences.
5. It helps identify which entity is the **most salient** or **prominent** in the conversation and likely to be referred again.
6. Example:
    a. Sentences:
        i. "Ravi gave a book to Aman."
        ii. "He thanked him."
    b. Here, the backward-looking center (Cb) from sentence 1 is **"Ravi"**.
    c. The algorithm identifies **"He → Aman"** and **"him → Ravi"** based on focus and discourse flow.
7. The Centering Algorithm thus relies on **coherence** and **topic continuity**, not just syntax.
8. It performs well in long texts or dialogues where maintaining **contextual reference** is important.
9. It can also handle pronouns that refer to entities several sentences away.
10. However, it requires **complex modeling** and **knowledge of discourse structure**, which can be computationally heavy.

Q. Five Types of Referring Expressions

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1. Meaning of Referring Expressions

1. Referring expressions are **words or phrases** used to **identify or point to entities** (people, objects, places, etc.) in a sentence or conversation.
2. They help the listener or reader **understand what the speaker is talking about.**
3. In simple words, they are expressions that refer to **real or imaginary things** in the world or in the discourse.
4. Correct identification of referring expressions is important for **Anaphora Resolution** and **Discourse Understanding** in NLP.
5. Example: In "Ravi bought a car. He loves it." → "He" and "it" are referring expressions referring to "Ravi" and "car."

2. Types of Referring Expressions

(i) Proper Nouns

1. Proper nouns are **specific names** used to refer to a **unique individual, place, or organization.**
2. They clearly identify the referent without needing additional context.
3. Example:
    a. "**Amit** is a doctor." → The word "Amit" uniquely identifies a person.
    b. "**India** won the match." → The name "India" refers to a specific country.
4. Proper nouns are **definite** referring expressions, as they directly point to a single entity.

(ii) Definite Noun Phrases

1. Definite noun phrases use the **definite article "the"** to refer to something that is already known or previously mentioned.
2. They indicate that the listener or reader **can identify the entity** being talked about.
3. Example:
    a. "I saw **a dog** yesterday. **The dog** was very friendly."
    b. Here, "the dog" refers to a specific dog already mentioned earlier.
4. Definite noun phrases are important for **maintaining continuity** in discourse.

(iii) Indefinite Noun Phrases

1. Indefinite noun phrases introduce **new entities** that are not yet known in the conversation.
2. They usually use **"a" or "an"** before the noun.
3. Example:
    a. "**A man** entered the room." → The listener does not know which man; it introduces a new referent.
    b. "She bought **an apple**." → The apple is not previously known.
4. Indefinite noun phrases **create new references** in the discourse and are often followed by definite references later.

(iv) Pronouns

1. Pronouns are **short referring expressions** used to **replace nouns or noun phrases** that have already been mentioned.
2. They prevent repetition and make the text smoother.
3. Common pronouns include **he, she, it, they, them, him, her, this, that**, etc.
4. Example:
    a. "**Ravi** is a teacher. **He** teaches English."
    b. "I bought a laptop. **It** is very fast."
5. In NLP, resolving pronouns correctly is called **Anaphora Resolution** — a key part of understanding meaning.

(v) Demonstratives and Deictic Expressions

1. Demonstratives are expressions that **point to something** in the physical or discourse context.
2. Common demonstratives include **this, that, these, those**.
3. They depend on the **speaker's point of view** and **context** to identify the referent.
4. Example:
    a. "**This book** is mine." → Refers to a book near the speaker.
    b. "**Those students** are from our college." → Refers to students farther away.
5. Deictic expressions include words like **here, there, now, then**, which also depend on **time or place context**.
6. Example:
    a. "I will go **there** tomorrow." → "There" depends on the speaker's current location.