UNIT 4

CONTEXT AND WORLD KNOWLEDGE

Knowledge representation and reasoning - Using World Knowledge, Discourse Structure, Local discourse context and reference.

KNOWLEDGE REPRESENTATION AND REASONING

Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence

concerned with AI agents thinking and how thinking contributes to intelligent behavior of agents.

- It is responsible for representing information about the real world so that a computer can understand and can utilize this knowledge to solve the complex real world problems such as diagnosis a medical condition or communicating with humans in natural language.
- It is also a way which describes how we can represent knowledge in artificial intelligence. Knowledge representation is not just storing data into some database, but it also enables an intelligent machine to learn from that knowledge and experiences so that it can behave intelligently like a human.

Following are the kind of knowledge which needs to be represented in AI systems:

- **Object:** All the facts about objects in our world domain. E.g., Guitars contains strings, trumpets are brass instruments.
- **Events:** Events are the actions which occur in our world.
- **Performance:** It describe behavior which involves knowledge about how to do things.
- **Meta-knowledge:** It is knowledge about what we know.
- **Facts:** Facts are the truths about the real world and what we represent.
- **Knowledge-Base:** The central component of the knowledge-based agents is the knowledge base. It is represented as KB. The Knowledgebase is a group of the Sentences (Here, sentences are used as a technical term and not identical with the English language).

Types of knowledge

1. Declarative Knowledge:

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarativesentences.
- It is simpler than procedural language.

2. Procedural Knowledge

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

3. Meta-knowledge:

- Knowledge about the other types of knowledge is called Meta-knowledge.

4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a filed or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

Here are key aspects related to knowledge representation and reasoning using world knowledge:

1. **World Knowledge Integration:**
    - **External Knowledge Sources:** Incorporating information from external databases, ontologies, or knowledge graphs that capture a broad range of facts about the world.
    - **Semantic Web Technologies:** Utilizing standards like RDF (Resource Description Framework) and OWL (Web Ontology Language) to represent and link diverse knowledge on the web.
2. **Ontologies for World Knowledge:**
    - **Definition:** Ontologies provide a formal and shared representation of concepts and their relationships within a specific domain.
    - **Semantic Enrichment:** Extending ontologies to include external world knowledge, creating a more comprehensive understanding of the subject matter.
3. **Commonsense Reasoning:**
    - **Incorporating Everyday Knowledge:** Enhancing systems with the ability to reason about common knowledge that may not be explicitly stated but is assumed to be shared by individuals.
    - **Conceptual Blending:** Integrating disparate pieces of information to form new understandings and insights.
4. **Natural Language Processing (NLP):**
    - **Utilizing Linguistic Knowledge:** Incorporating linguistic resources, such as WordNet, to understand the meanings of words and their relationships.
    - **Contextual Understanding:** Considering the context of language use and incorporating contextual knowledge for more accurate interpretation.
5. **Machine Learning and Knowledge Embeddings:**
    - **Embedding World Knowledge in Vectors:** Using knowledge graph embeddings or pretrained language models (such as BERT or GPT) to capture and represent world knowledge in a computationally efficient manner.
    - **Transfer Learning:** Leveraging pretrained models trained on vast amounts of diverse data to improve performance on specific tasks by transferring learned knowledge.

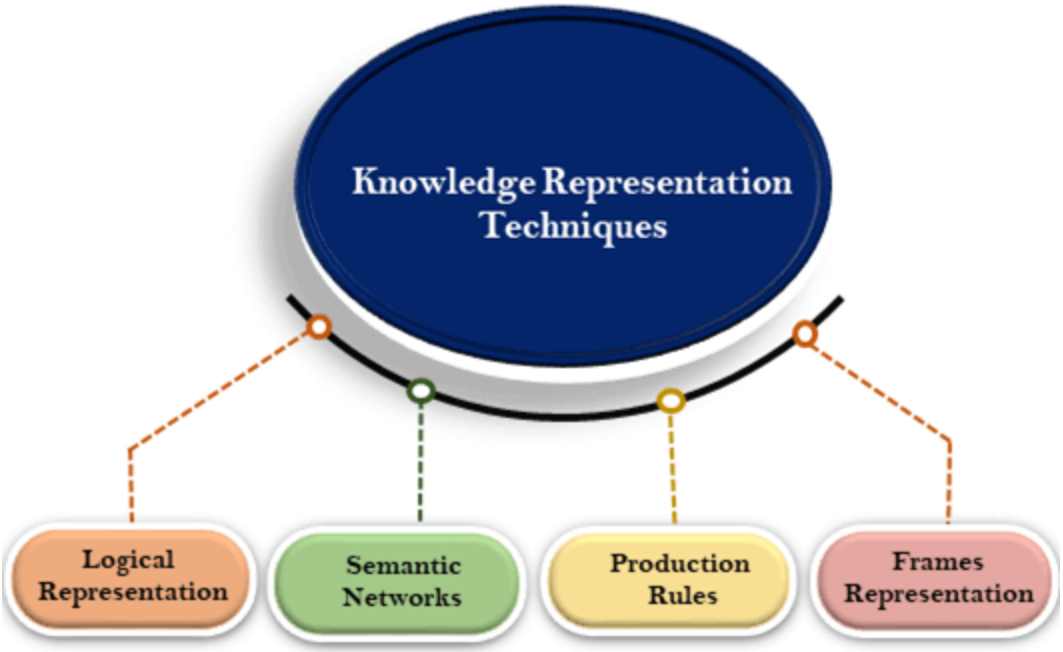
6. **Event and Situation Awareness:**
    - **Temporal Knowledge:** Representing information about the temporal aspects of events and situations to understand how knowledge evolves over time.
    - **Causal Relationships:** Modeling cause-and-effect relationships between events and entities in the world.
7. **Dynamic Knowledge Updating:**
    - **Real-time Information Integration:** Updating knowledge representations dynamically as new information becomes available.
    - **Adaptive Systems:** Systems that can adapt and learn from new world knowledge, adjusting their reasoning processes accordingly.
8. **Ethical Considerations:**
    - **Bias Mitigation:** Addressing biases present in world knowledge sources to ensure fair and unbiased decision-making.
    - **Transparency and Accountability:** Ensuring that the knowledge used by AI systems is transparent and accountable, especially in critical applications.

Incorporating world knowledge into knowledge representation and reasoning systems enhances their capabilities to understand, reason, and make decisions in a manner that aligns more closely with human-like cognitive processes. This integration is particularly important for applications where a broad and nuanced understanding of the world is necessary, such as natural language understanding, intelligent assistants, and decision support systems.

Techniques of knowledge representation

There are mainly four ways of knowledge representation which are given as follows:

1. Logical Representation
2. Semantic Network Representation
3. Frame Representation
4. Production Rules



1. Logical Representation

Logical representation is a language with some concrete rules which deals with propositions and has no ambiguity in representation. Logical representation means drawing a conclusion based on various conditions. This representation lays down some important communication rules. It consists of precisely defined syntax and semantics which supports the sound inference. Each sentence can be translated into logics using syntax and semantics.

Syntax:

- Syntaxes are the rules which decide how we can construct legal sentences in the logic.
- It determines which symbol we can use in knowledge representation.
- How to write those symbols.

Semantics:

- Semantics are the rules by which we can interpret the sentence in the logic.
- Semantic also involves assigning a meaning to each sentence.

Logical representation can be categorised into mainly two logics:

a. Propositional Logics

b. Predicate logics

Advantages of logical representation:

1. Logical representation enables us to do logical reasoning.

2. Logical representation is the basis for the programming languages.

Disadvantages of logical Representation:

1. Logical representations have some restrictions and are challenging to work with.
2. Logical representation technique may not be very natural, and inference may not be so efficient.

2. Semantic Network Representation

Semantic networks are alternative of predicate logic for knowledge representation. In Semantic networks, we can represent our knowledge in the form of graphical networks. This network consists of nodes representing objects and arcs which describe the relationship between those objects. Semantic networks can categorize the object in different forms and can also link those objects. Semantic networks are easy to understand and can be easily extended.

This representation consist of mainly two types of relations:

a. IS-A relation (Inheritance)

b. Kind-of-relation

Example: Following are some statements which we need to represent in the form of nodes and arcs.

Statements:

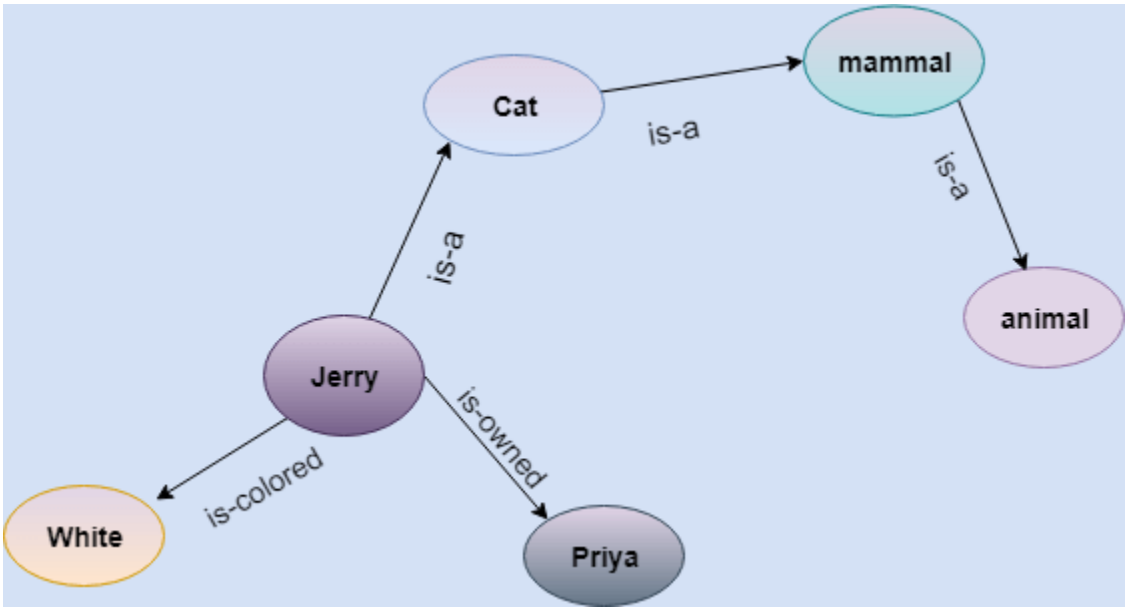
a. Jerry is a cat.

b. Jerry is a mammal

c. Jerry is owned by Priya.

d. Jerry is brown colored.

e. All Mammals are animal.



In the above diagram, we have represented the different type of knowledge in the form of nodes and arcs. Each object is connected with another object by some relation.

Drawbacks in Semantic representation:

1. Semantic networks take more computational time at runtime as we need to traverse the complete network tree to answer some questions. It might be possible in the worst case scenario that after traversing the entire tree, we find that the solution does not exist in this network.
2. Semantic networks try to model human-like memory (Which has 1015 neurons and links) to store the information, but in practice, it is not possible to build such a vast semantic network.
3. These types of representations are inadequate as they do not have any equivalent quantifier, e.g., for all, for some, none, etc.
4. Semantic networks do not have any standard definition for the link names.
5. These networks are not intelligent and depend on the creator of the system.

Advantages of Semantic network:

1. Semantic networks are a natural representation of knowledge.
2. Semantic networks convey meaning in a transparent manner.
3. These networks are simple and easily understandable.

3. Frame Representation

A frame is a record like structure which consists of a collection of attributes and its values to describe an entity in the world. Frames are the AI data structure which divides knowledge into substructures by representing stereotypes situations. It consists of a collection of slots and slot values. These slots may be of any type and sizes. Slots have names and values which are called facets.

Facets: The various aspects of a slot is known as **Facets**. Facets are features of frames which enable us to put constraints on the frames. Example: IF-NEEDED facts are called when data of any particular slot is needed. A frame may consist of any number of slots, and a slot may include any number of facets and facets may have any number of values. A frame is also known as **slot-filter knowledge representation** in artificial intelligence.

Frames are derived from semantic networks and later evolved into our modern-day classes and objects. A single frame is not much useful. Frames system consist of a collection of frames which are connected. In the frame, knowledge about an object or event can be stored together in the knowledge base. The frame is a type of technology which is widely used in various applications including Natural language processing and machine visions.

Example: 1

Let's take an example of a frame for a book

Slots	Filters

Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

Example 2:

Let's suppose we are taking an entity, Peter. Peter is an engineer as a profession, and his age is 25, he lives in city London, and the country is England. So following is the frame representation for this:

Slots	**Filter**
Name	Peter
Profession	Doctor
Age	25
Marital status	Single
Weight	78

Advantages of frame representation:

1. The frame knowledge representation makes the programming easier by grouping the related data.
2. The frame representation is comparably flexible and used by many applications in AI.
3. It is very easy to add slots for new attribute and relations.
4. It is easy to include default data and to search for missing values.
5. Frame representation is easy to understand and visualize.

Disadvantages of frame representation:

1. In frame system inference mechanism is not be easily processed.

2. Inference mechanism cannot be smoothly proceeded by frame representation.
3. Frame representation has a much generalized approach.

4. Production Rules

Production rules system consist of (**condition, action**) pairs which mean, "If condition then action". It has mainly three parts:

- The set of production rules
- Working Memory
- The recognize-act-cycle

In production rules agent checks for the condition and if the condition exists then production rule fires and corresponding action is carried out. The condition part of the rule determines which rule may be applied to a problem. And the action part carries out the associated problem-solving steps. This complete process is called a recognize-act cycle.

The working memory contains the description of the current state of problems-solving and rule can write knowledge to the working memory. This knowledge match and may fire other rules.

If there is a new situation (state) generates, then multiple production rules will be fired together, this is called conflict set. In this situation, the agent needs to select a rule from these sets, and it is called a conflict resolution.

Example:

- **IF (at bus stop AND bus arrives) THEN action (get into the bus)**
- **IF (on the bus AND paid AND empty seat) THEN action (sit down).**
- **IF (on bus AND unpaid) THEN action (pay charges).**
- **IF (bus arrives at destination) THEN action (get down from the bus).**

Advantages of Production rule:

1. The production rules are expressed in natural language.
2. The production rules are highly modular, so we can easily remove, add or modify an individual rule.

Disadvantages of Production rule:

1. Production rule system does not exhibit any learning capabilities, as it does not store the result of the problem for the future uses.
2. During the execution of the program, many rules may be active hence rule-based production systems are inefficient.

Discourse:

One of the primary challenges that we face in the world of Artificial Intelligence is processing Natural Language data by computers. We can even say that Natural Language Processing is quite a difficult issue in the field of AI. Now if we are talking about the major problem in Natural Language Processing, then we are talking about the processing of Discourse in NLP.

So, we can see that the real problem is the processing of the Discourse in NLP, and hence we need to work on it so that our model can be trained well, which will help in better processing of Natural Language data by the computers and hence the Artificial Intelligence can predict the desired result.

Now a question that comes to our mind is what is Discourse in NLP? Well, in simple terms, we can say that discourse in NLP is nothing but coherent groups of sentences. When we are dealing with Natural Language Processing, the provided language consists of structured, collective, and consistent groups of sentences, which are termed discourse in NLP. The relationship between words makes the training of the NLP model quite easy and more predictable than the actual results. **Discourse Analysis** is extracting the meaning out of the corpus or text. Discourse Analysis is very important in Natural language Processing and helps train the NLP model better.

Any linguistic unit that consists of multiple sentences Speakers describe "some situation or state of the real or some hypothetical world" (Webber, 1983) Speakers attempt to get the listener to construct a similar model of the situation. For natural language understanding: Most information is not contained in a single sentence. The system has to aggregate information across paragraphs or entire documents. For natural language generation: When systems generate text, that text needs to be easy to understand and it has to be coherent.

For example, On Monday, John went to Einstein's. He wanted to buy lunch. But the cafe was closed. That made him angry, so the next day he went to Green Street instead. Understanding discourse requires (among other things): 1) doing coreference resolution: 'the cafe' and 'Einstein's' refer to the same entity He and John refer to the same person. That refers to 'the cafe was closed'. 2) identifying discourse ('coherence') relations: 'He wanted to buy lunch' is the reason for 'John went to Bevande.'

Discourse models an explicit representation of the events and entities that a discourse talks about - the relations between them (and to the real world). This representation is often written in some form of logic. Discourse models should capture... Physical entities: John, Einstein's, lunch Events: On Monday, John went to Einstein's involve entities, take place at a point in time States: It was closed. involve entities and hold for a period of time

Temporal relations: afterwards between events and states Rhetorical ('discourse') relations: ... so ... instead between events and states

The most difficult problem of AI is to process the natural language by computers or in other words *natural language processing* is the most difficult problem of artificial intelligence. If we talk about the major problems in NLP, then one of the major problems in NLP is discourse processing − building theories and models of how utterances stick together to form **coherent discourse**. Actually, the language always consists of collocated, structured and coherent groups of sentences rather than isolated and unrelated sentences like movies. These coherent groups of sentences are referred to as discourse.

Concept of Coherence:

Coherence and discourse structure are interconnected in many ways. Coherence, along with property of good text, is used to evaluate the output quality of natural language generation system. The question that arises here is what does it mean for a text to be coherent? Suppose we collected one sentence from every page of the newspaper, then will it be a discourse? Of-course, not. It is because these sentences do not exhibit coherence. The coherent discourse must possess the following properties −

Coherence relation between utterances

The discourse would be coherent if it has meaningful connections between its utterances. This property is called coherence relation. For example, some sort of explanation must be there to justify the connection between utterances.

Relationship between entities

Another property that makes a discourse coherent is that there must be a certain kind of relationship with the entities. Such kind of coherence is called entity-based coherence.

Discourse structure

An important question regarding discourse is what kind of structure the discourse must have. The answer to this question depends upon the segmentation we applied on discourse. Discourse segmentations may be defined as determining the types of structures for large discourse. The segmentation is a difficult thing to implement, but it is very necessary as discourse segmentation is used in fields like:

- Information Retrieval,
- Text summarization,
- Information Extraction, etc.

Algorithms for Discourse Segmentation:

In this section, we will learn about the algorithms for discourse segmentation. The algorithms are described below:

1. **Unsupervised Discourse Segmentation**

The class of unsupervised discourse segmentation is often represented as linear segmentation. We can understand the task of linear segmentation with the help of an example. In the example, there is a task of segmenting the text into multi-paragraph units; the units represent the passage of the original text. These algorithms are dependent on cohesion that may be defined as the use of certain linguistic devices to tie the textual units together. On the other hand, lexicon cohesion is the cohesion that is indicated by the relationship between two or more words in two units like the use of synonyms.

2. **Supervised Discourse Segmentation**

The earlier method does not have any hand-labeled segment boundaries. On the other hand, supervised discourse segmentation needs to have boundary-labeled training data. It is very easy to acquire the same. In supervised discourse segmentation, discourse marker or cue words play an important role. Discourse marker or cue word is a word or phrase that functions to signal discourse structure. These discourse markers are domain-specific.

Text Coherence

Lexical repetition is a way to find the structure in a discourse, but it does not satisfy the requirement of being coherent discourse. To achieve the coherent discourse, we must focus on coherence relations in specific. As we know that coherence relation defines the possible connection between utterances in a discourse. Hebb has proposed such kind of relations as follows: We are taking two terms S0 and S1 to represent the meaning of the two related sentences

Result

It infers that the state asserted by term $\mathbf{S_0}$ could cause the state asserted by $\mathbf{S_1}$. For example, two statements show the relationship result: Ram was caught in the fire. His skin burned.

Explanation

It infers that the state asserted by $\mathbf{S_1}$ could cause the state asserted by $\mathbf{S_0}$. For example, two statements show the relationship − Ram fought with Shyam's friend. He was drunk.

Parallel

It infers p(a1,a2,…) from assertion of S_0 and p(b1,b2,…) from assertion S_1. Here ai and bi are similar for all i. For example, two statements are parallel − Ram wanted car. Shyam wanted money.

Elaboration

It infers the same proposition P from both the assertions − S_0 and S_1 For example, two statements show the relation elaboration: Ram was from Chandigarh. Shyam was from Kerala.

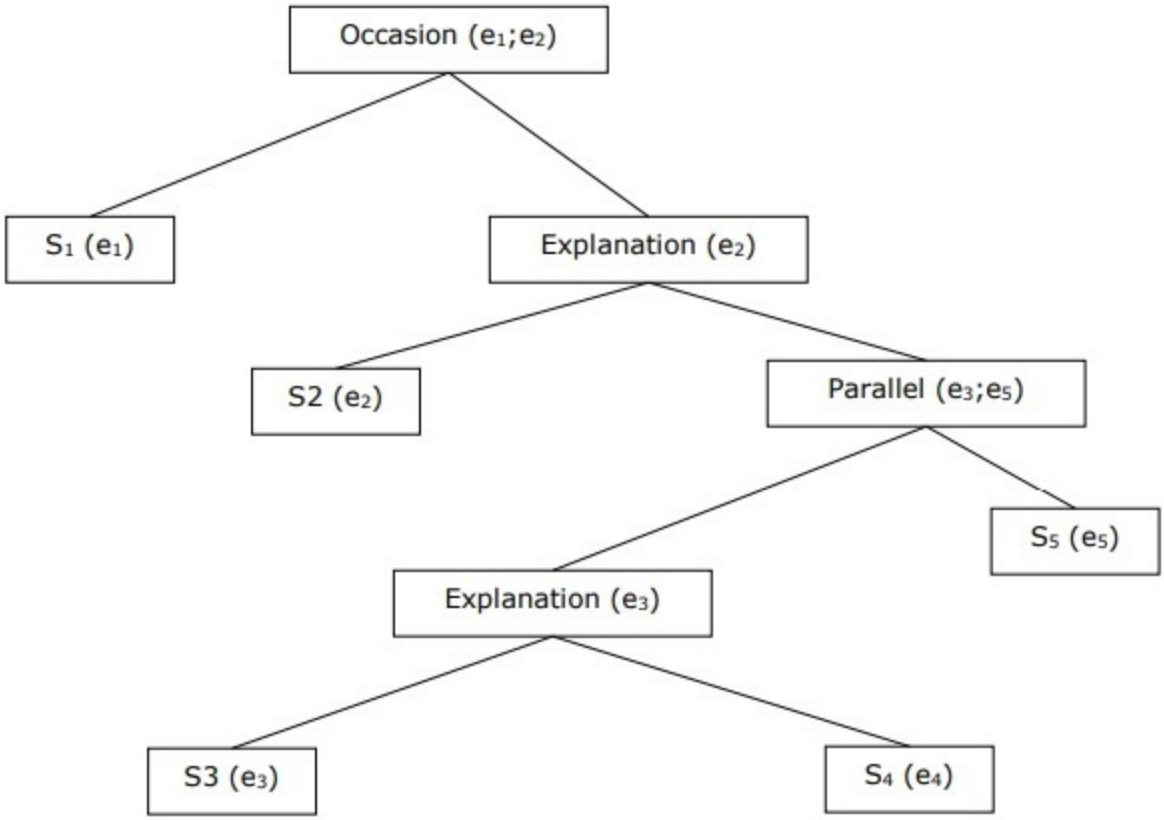
Occasion

It happens when a change of state can be inferred from the assertion of S_0, final state of which can be inferred from S_1 and vice-versa. For example, the two statements show the relation occasion: Ram picked up the book. He gave it to Shyam.

Building Hierarchical Discourse Structure

The coherence of entire discourse can also be considered by hierarchical structure between coherence relations. For example, the following passage can be represented as hierarchical structure:

- S_1 − Ram went to the bank to deposit money.
- S_2 − He then took a train to Shyam's cloth shop.
- S_3 − He wanted to buy some clothes.
- S_4 − He do not have new clothes for party.
- S_5 − He also wanted to talk to Shyam regarding his health



Reference Resolution

Interpretation of the sentences from any discourse is another important task and to achieve this we need to know who or what entity is being talked about. Here, interpretation reference is the key element. **Reference** may be defined as the linguistic expression to denote an entity or individual. For example, in the passage, Ram, the manager of ABC bank, saw his friend Shyam at a shop. He went to meet him, the linguistic expressions like Ram, His, He are reference. On the same note, **reference resolution** may be defined as the task of determining what entities are referred to by which linguistic expression.

Terminology Used in Reference Resolution:

We use the following terminologies in reference resolution:

- **Referring expression** − The natural language expression that is used to perform reference is called a referring expression. For example, the passage used above is a referring expression.
- **Referent** − It is the entity that is referred. For example, in the last given example Ram is a referent.
- **Corefer** − When two expressions are used to refer to the same entity, they are called corefers. For example, ***Ram*** and ***he*** are corefers.

- **Antecedent** − The term has the license to use another term. For example, ***Ram*** is the antecedent of the reference ***he***.
- **Anaphora & Anaphoric** − It may be defined as the reference to an entity that has been previously introduced into the sentence. And, the referring expression is called anaphoric.
- **Discourse model** − The model that contains the representations of the entities that have been referred to in the discourse and the relationship they are engaged in.

Types of Referring Expressions:

Let us now see the different types of referring expressions. The five types of referring expressions are described below:

1. **Indefinite Noun Phrases**

Such kind of reference represents the entities that are new to the hearer into the discourse context. For example, in the sentence Ram had gone around one day to bring him some food − some is an indefinite reference.

2. **Definite Noun Phrases**

Opposite to above, such kind of reference represents the entities that are not new or identifiable to the hearer into the discourse context. For example, in the sentence - I used to read The Times of India – The Times of India is a definite reference.

3. **Pronouns**

It is a form of definite reference. For example, Ram laughed as loud as he could. The word **he** represents pronoun referring expression.

4. **Demonstratives**

These demonstrate and behave differently than simple definite pronouns. For example, this and that are demonstrative pronouns.

5. **Names**

It is the simplest type of referring expression. It can be the name of a person, organization and location also. For example, in the above examples, Ram is the name-refereeing expression.

Reference Resolution Tasks:

1. **Coreference Resolution**

In the **Co-reference Resolution**, the main aim is to find the referring expression from the provided text that refers to the same entity. In a discourse in NLP, Co-refer is a term used for an entity if two or more expressions are referring to the same entity.

For example, Rahul and He is used for the same entity i.e., Rahul.

The **Co-reference Resolution** can be simply termed as finding the relevant co-refer expressions among the provided discourse text. Let us take an example for more clarity.

For example, Rahul went to the farm. He cooked food. In this example, Rahul and He is the referring expressions.

We have some sort of constraints present on the Co-reference Resolution. Let us learn about the constraint.

2. **Constraint on Coreference Resolution**

In English, the main problem for coreference resolution is the pronoun it. The reason behind this is that the pronoun it has many uses. For example, it can refer much like he and she. The pronoun it also refers to the things that do not refer to specific things. For example, It's raining. It is really good.

3. **Pronominal Anaphora Resolution**

Unlike the coreference resolution, pronominal anaphora resolution may be defined as the task of finding the antecedent for a single pronoun. For example, the pronoun is his and the task of pronominal anaphora resolution is to find the word Ram because Ram is the antecedent.

By the terms **Pronominal Anaphora Resolution**, we are aiming to find the antecedent for the current single pronoun.

For example, in the passage - Rahul went to the farm. He cooked food., Rahul is the antecedent of the reference He.

Conclusion:

- **Discourse in NLP** is nothing but coherent groups of sentences. When we are dealing with Natural Language Processing, the provided language consists of structured, collective, and consistent groups of sentences, which are termed discourse in NLP.

- **Discourse Analysis** is very important in Natural language Processing and helps train the NLP model better.

- **Coherence** in terms of Discourse in NLP means making sense between the utterances or making meaningful connections and correlations. We use the property of good text, coherence, etc. to evaluate the quality of the output generated by the natural language processing generation system.

- The extraction of the meaning or interpretation of the sentences of discourse is one of the most important tasks in natural language processing, and to do so, we first need to know what or who is the entity that we are talking about.

- **Indefinite noun reference** is a kind of reference that represents the entity that is new to the discourse context's hearer.

- **Definite noun reference** is a kind of reference that represents the entity that is not new to the discourse context's hearer. The discourse context's hearer can easily identify the definite noun reference.

- In the **Co-reference Resolution**, the main aim is to find the referring expression from the provided text that refers to the same entity. By the terms **Pronominal Anaphora Resolution**, we are aiming to find the antecedent for the current single pronoun.