UNIT-6: Application of AI

Syllabus

Unit VI: Applications of AI (6 Hrs.)

6.1. Expert Systems, Development of Expert Systems
6.2. Natural Language Processing: Natural Language Understanding and Natural Language Generation, Steps of Natural Language Processing
6.3. Machine Vision Concepts
6.4. Robotics

Expert system

An expert system, a computer program that uses artificial-intelligence methods to solve problems within a specialized domain that ordinarily requires human expertise.

It is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert. It is called a system because it consists of both a problem-solving component and a support component. Its performance is based on experts' knowledge stored in its knowledge base. The more knowledge stored in the KB, the more that system improves its performance. These systems are designed for a specific domain, such as medicine, science, etc.

In order to accomplish feats of apparent intelligence, an expert system relies on two components: a knowledge base and an inference engine. A knowledge base is an organized collection of facts about the system's domain. An inference engine interprets and evaluates the facts in the knowledge base in order to provide an answer. Typical tasks for expert systems involve classification, diagnosis, monitoring, design, scheduling, and planning for specialized endeavours.

Components of Expert System

There are five components of the expert system in AI:

Knowledge base: The knowledge base contains facts and regulations in an expert system. It includes norms for problem-solving and formulating methods pertinent to the domain and knowledge in specific disciplines.

Inference engine: The inference engine's most fundamental job is to gather pertinent information from the knowledge base, analyze it, and identify a solution to the user's issue. Inference engines also possess explanatory and troubleshooting skills.

Knowledge acquisition and learning module: With the help of this component, expert systems can gather more information from numerous sources. After that, the knowledge is stored in the knowledge base.

User interface: With this element, a non-expert user can communicate with the expert system and develop solutions.

Explanation module: This module gives the user a justification for the conclusion.

Examples of Expert Systems

MYCIN: It could recognize different bacteria that might cause acute infections and was based on backward chaining. Additionally, it might suggest medications based on the weight of the patient. It is among the top examples of an expert system.

DENDRAL: A molecular structure prediction tool for chemical analysis.

CaDet: It's one of the best examples of an expert system that can detect cancer in its earliest stages.

PXDES: The kind and stage of lung cancer are identified using the PXDES expert system. It takes a photo of the upper body, which resembles the shadow, to identify the condition. This shadow determines the kind and severity.

Advantages of Expert System

- These systems are highly reproducible.
- They can be used for risky places where the human presence is not safe.
- Error possibilities are less if the KB contains correct knowledge.
- The performance of these systems remains steady as it is not affected by emotions, tension, or fatigue.
- They provide a very high speed to respond to a particular query.

Disadvantages of Expert System

- The response of the expert system may get wrong if the knowledge base contains the wrong information.
- Like a human being, it cannot produce a creative output for different scenarios.
- Its maintenance and development costs are very high.
- Knowledge acquisition for designing is much difficult.
- For each domain, we require a specific ES, which is one of the big limitations.
- It cannot learn from itself and hence requires manual updates.

Steps in expert system Development process

The expert system development process consists of several key steps, ensuring that the system effectively captures expert knowledge and applies it to solve problems or make decisions.

1. Problem Identification and Domain Selection

- **Identify the Problem:** Clearly define the problem the expert system is intended to solve. This could be diagnosis, recommendation, or decision support in a specific domain.
- **Select a Domain:** Choose the domain where expertise is needed (e.g., medical diagnosis, financial planning, technical support).

2. Knowledge Acquisition

- **Gather Knowledge from Experts:** Work with domain experts to extract their knowledge, including rules, strategies, facts, and experience.
- **Sources of Knowledge:**
  - **Expert Interviews:** Discuss problem-solving methods, approaches, and reasoning.
  - **Textbooks/Research Papers:** Use documented knowledge to supplement expert input.
  - **Observation:** Analyze how experts approach tasks and solve problems.

3. Knowledge Representation

- **Convert Knowledge into a Usable Format:** Structure the acquired knowledge in a way that the system can use effectively. This step defines how the knowledge will be stored and retrieved.
  - **Rules-Based (If-Then):** The most common representation, where rules are used for decision-making.
  - **Frames:** Represent knowledge using structured templates (objects or concepts with associated properties).
  - **Semantic Networks:** Knowledge represented as a network of interconnected nodes (concepts) and links (relationships).
  - **Logic:** Use formal logic (e.g., predicate or propositional logic) to represent knowledge.

4. Designing the Inference Engine

- **Inference Mechanism:** Develop the system's reasoning process by choosing between:
  - **Forward Chaining (Data-Driven):** Start from known facts and apply rules to reach conclusions.
  - **Backward Chaining (Goal-Driven):** Start with a hypothesis or goal and work backward to verify if the data supports the conclusion.
- **Explanation Facility:** Ensure that the system can explain its reasoning and conclusions to users, enhancing transparency and trust.

5. Designing the User Interface (UI)

Create an interface that allows users to interact with the system easily.

6. System Development (Implementation)

- **Select a Development Platform:** Choose a tool or language suited for expert system development, such as:
  - **CLIPS** or **Prolog** (Rule-based systems).
  - **Artificial Intelligence Markup Language (AIML)** for conversational interfaces.
  - **Programming Languages** (Python, Java, etc.) for custom-built systems.
- **Implement Knowledge Base and Inference Engine:** Translate the knowledge representation and reasoning mechanisms into the chosen platform or software.

7. Testing and Validation

- **Unit Testing:** Test individual components (knowledge base, inference engine, UI) to ensure they work as expected.
- **Validation with Experts:** Test the system's performance with expert input and real-world data to ensure it provides accurate results.
- **Performance Evaluation:** Measure the system's speed, accuracy, reliability, and user satisfaction.

8. System Refinement

- **Feedback Loop:** Continuously gather feedback from users and experts to refine the system.
- **Knowledge Base Updates:** Modify the knowledge base as new information becomes available or as expert knowledge evolves.
- **Rule Optimization:** Adjust the inference engine and rules for better performance and accuracy.

9. Deployment

- **Deploy the System:** Make the expert system available to users, integrating it with other tools or environments if necessary (e.g., as a web application, mobile app, or standalone software).
- **Training Users:** Provide instructions or training sessions for users to understand how to interact with the expert system.

10. Maintenance

- **Regular Updates:** Continuously update the knowledge base and inference engine as the domain evolves.
- **System Monitoring:** Monitor the system's performance over time and address any issues that arise.

Natural Language Processing (NLP)

Natural language processing (NLP) is a form of artificial intelligence (AI) that allows computers to understand human language, whether it be written, spoken, or even scribbled. Or it can be defined as a field of computer science and a subfield of artificial intelligence that aims to make computers understand human language. So it is the technology which involves converting spoken or written human language into a form which can be processed by computers and vice-versa.

NLP uses computational linguistics, which is the study of how language works, and various models based on statistics, machine learning, and deep learning. These technologies allow computers to analyze and process text or voice data, and to grasp their full meaning, including the speaker's or writer's intentions and emotions.

NLP powers many applications that use language, such as text translation, voice recognition, text summarization, and chatbots. You may have used some of these applications yourself, such as voice-operated GPS systems, digital assistants, speech-to-text software, and customer service bots.

Some of the better-known applications of NLP include:

- **Voice recognition software** which translates speech into input for word processors or other applications;

- **Text-to-speech synthesizers** which read text aloud for users such as the hearing-impaired;

- **Grammar and style checkers** which analyze text in an attempt to highlight errors of grammar or usage;

- **Machine translation systems** which automatically render a document such as a web page in another language

NLP Techniques

Natural Language Processing (NLP) techniques refer to the methods and algorithms used to enable machines to understand, interpret, and generate human language. These techniques range from simple text processing to advanced machine learning models.

NLP techniques can be categorized into several broad areas, each addressing different aspects of language processing. Here are some of the key NLP techniques:

Tokenization:

Tokenization is the process of breaking down a text into smaller units, such as words, phrases, or sentences.

- **Word Tokenization**: Splitting text into individual words.
  - Example: "I love NLP." → ["I", "love", "NLP"]
- **Sentence Tokenization**: Breaking text into sentences.
  - Example: "NLP is fun. It’s very useful." → ["NLP is fun.", "It’s very useful."]

Sentiment analysis:

Sentiment analysis detects and interprets the emotional tone behind a body of text. It analyzes text to identify its sentiments, such as “positive,” “negative,” or “neutral.” It is commonly used by businesses to better understand customer feedback. It is often used for social media monitoring, customer reviews, and feedback analysis.

Summarization:

An NLP technique that summarizes a longer text, in order to make it more manageable for time-sensitive readers. Some common texts that are summarized include reports and articles.

Keyword extraction:

An NLP technique that analyzes a text to identify the most important keywords or phrases. Keyword extraction is commonly used for search engine optimization (SEO), social media monitoring, and business intelligence purposes.

Speech Recognition:

It converts spoken language into text (Automatic Speech Recognition, ASR). Systems like Siri or Google Assistant rely on this to understand spoken commands.

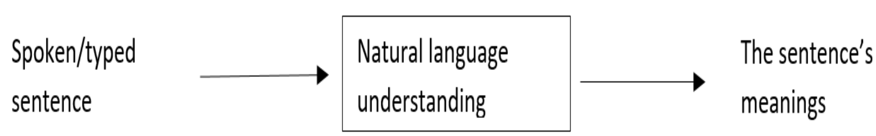
NLP is composed of two parts:

- NLU (Natural Language Understanding)
- NLG (Natural Language Generation)

Natural Language Understanding (NLU)

NLU involves the ability of a system to understand human language. It focuses on interpreting, analyzing, and comprehending the meaning behind the text or speech input. The goal is to convert human language into a form that a machine can understand and process.

Natural language understanding is taking a natural language input, like a sentence or paragraph, and processing it to produce an output.



It can be break down the process into three stages:

Tokenization:

The first stage of NLU involves splitting a given input into individual words or tokens. It includes punctuation, other symbols, and words from all languages.

Lexical Analysis:

Next, the tokens are placed into a dictionary that includes their part of speech (for example, whether they're nouns or verbs). It also includes identifying phrases that should be placed in a separate database for later use.

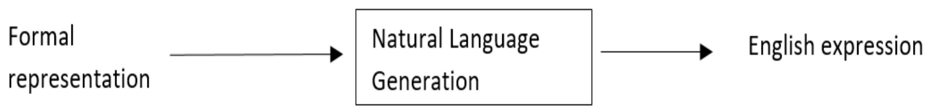
Syntactic Analysis:

The tokens are analyzed for their grammatical structure. It includes identifying each word's roles and whether there's any ambiguity between multiple interpretations of those roles.

Natural language generation (NLG)

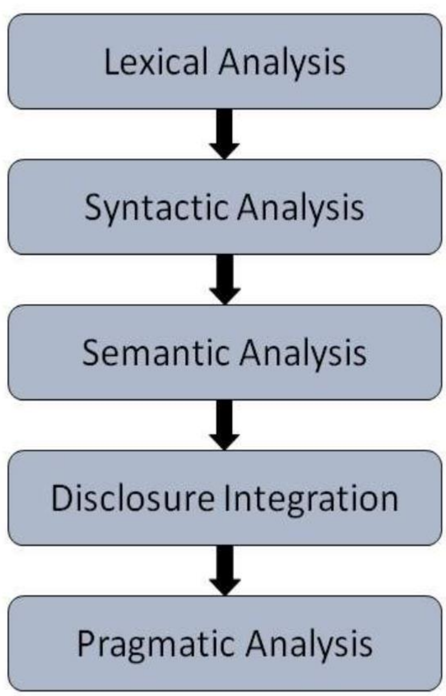
It is the process of producing meaningful phrases and sentences in the form of natural language from a machine representation system such as KB or logical form. It is the programming to produce written or spoken language from a data set.

Or in simple form it is the process of generating text that appears to be written by a human, without the need for a human to actually write it. A subset of Natural Language Processing (NLP), NLG technology works together with Natural Language Understanding (NLU) to generate NLP. It is used to not only create songs, movies scripts and speeches, but also report the news and practice law.



Steps of natural language processing

There are 5 steps in natural language processing:



The five key steps in natural language processing (NLP) are:

1. **Lexical Analysis (Tokenization)**:
   This step involves breaking down the input text into smaller units, typically words or tokens. It includes identifying boundaries between tokens and sometimes stripping away punctuation. The main goal is to create meaningful words or subwords for further processing.
2. **Syntactic Analysis (Parsing)**:
   Also called syntactic parsing, this step focuses on analyzing the grammatical structure of the text. The text is arranged in a way that helps understand how words relate to each other, typically represented using a parse tree. This checks if the input follows the syntax rules of a given language.
3. **Semantic Analysis**:
   This step involves deriving the meaning of a sentence. It converts the syntactic structure into a meaningful representation, ensuring that the meaning aligns with the correct context. Semantic analysis might involve word sense disambiguation, where the meaning of words is determined by their surrounding context.
4. **Discourse Integration**:
   This step focuses on understanding larger chunks of text, such as multiple sentences or even entire conversations. It ensures that sentences are connected logically and that the meaning of one sentence can be interpreted based on the previous and subsequent sentences.
5. **Pragmatic Analysis**:
   Pragmatic analysis takes into account the intended meaning, depending on the situation or the context. It deals with how real-world knowledge influences the meaning of the text. Pragmatics considers factors like the speaker's intent, the social context, and the relationship between participants in a conversation.

Machine Vision Concept

Machine vision is the ability of a computer to “see”. A machine vision system employee one or more video cameras, analog-to-digital conversion and digital signal processing. The resulting data goes to a computer or robot controller. It uses different components to visually analyze an operation or activity.

Two important specifications in any vision system are the sensitivity and the resolution. Sensitivity is the ability of a machine to see in the dim light, or to detect weak impulses at invisible wavelengths. Resolution is the extent to which a machine can differentiate between objects. Machine vision systems have two primary hardware elements the camera, which serves as the eye of the system and a computer video analyzer. Sensitivity and resolution are interdependent. All other factors held constant, increasing the sensitivity reduces the resolution, and improving the resolution reduces the sensitivity. Machine vision is similar in complexity to voice recognition.

Components of Machine Vision systems

A typical machine vision system will consist of the following components.

Image Sensor

This is also known as a vision sensor, which is responsible for analyzing images captured by the camera to determine the accuracy of assembly or the presence of defects. Two types of vision sensors are most commonly found on the market, orthographic projection and perspective projection. In an orthographic projection type, the field of vision is rectangular, making it suitable for infrared sensors. In contrast, the perspective type projects a trapezoidal field of view, making it more suitable for camera-type sensors.

Vision Processor

The Function of Vision Processor is to Processes the raw image data captured by the sensor to extract useful information. Hence, From the name itself, it is clear that the processor is in charge of running machine vision algorithms. It may include a direct interface that has the capacity to take relevant data from a camera device. Basically, it is essential to ensure that the image processing is completed without any mistake or error.

Communication Interface

Another essential component is called the communication interface, which connects the other parts in the vision system. It is necessary to facilitate data transmission. This interface is usually attached to smart camera or other vision devices. Through this, the vision system can link data from the device to particular software that is run in a separate personal computer.

Lighting

Every vision system must have a working lighting analysis sequence. These are the common sources of lighting that is available in most machine vision systems:

- LED
- Mercury (also known as Metal Halide)
- Xenon
- Quartz Halogen
- Fluorescent

The type of lighting devices used depends on the purpose for the creation of the vision system. At the same time, it is also dependent on how big the vision stations are.

Lens

The lens must be matched with the image sensor installed in the vision system. This transparent material has curved sides that are employed to disperse light rays. It can be used singly or can be combined with other lenses. What makes this special is that it is considered as the light-gathering component of the vision system. All these parts are equally essential in order to guarantee that the vision system will provide utmost satisfaction to all its users. The absence of one component will render the entire system worthless.

What is Robotics?

Robotics is a multidisciplinary field that involves the design, construction, operation, and use of robots. It integrates various branches of engineering and computer science, including mechanical engineering, electrical engineering, computer programming, artificial intelligence (AI), and control systems. Robotics aims to create machines that can assist humans by performing tasks autonomously or semi-autonomously.

Aspects of Robotics

- The robots have **mechanical construction**, form, or shape designed to accomplish a particular task.
- They have **electrical components** which power and control the machinery.
- They contain some level of **computer program** that determines what, when and how a robot does something.

Component of Robotics

- **Actuators:** Actuators are the devices that are responsible for moving and controlling a system or machine. It helps to achieve physical movements by converting energy like electrical, hydraulic and air, etc. Actuators can create linear as well as rotary motion.

- **Power Supply:** It is an electrical device that supplies electrical power to an electrical load. The primary function of the power supply is to convert electrical current to power the load.
- **Electric Motors:** These are the devices that convert electrical energy into mechanical energy and are required for the rotational motion of the machines.
- **Pneumatic Air Muscles:** Air Muscles are soft pneumatic devices that are ideally best fitted for robotics. They can contract and extend and operate by pressurized air filling a pneumatic bladder. Whenever air is introduced, it can contract up to 40%.
- **Muscles wire:** These are made up of nickel-titanium alloy called Nitinol and are very thin in shape. It can also extend and contract when a specific amount of heat and electric current is supplied into it. Also, it can be formed and bent into different shapes when it is in its martensitic form. They can contract by 5% when electrical current passes through them.
- **Piezo Motors and Ultrasonic Motors:** Piezoelectric motors or Piezo motors are the electrical devices that receive an electric signal and apply a directional force to an opposing ceramic plate. It helps a robot to move in the desired direction. These are the best suited electrical motors for industrial robots.
- **Sensor:** They provide the ability like see, hear, touch and movement like humans. Sensor are the devices or machine which helps to detect the events or changes in the environment and send data to the computer processor. These devices are usually equipped with other electronic devices. Similar to human organs, the electrical sensor also plays a crucial role in Artificial Intelligence & robotics. AI algorithms control robots by sensing the environment, and it provides real-time information to computer processors.

Applications of Robotics

The robotics has been instrumental in the various domains such as −

- **Industries** − Robots are used for handling material, cutting, welding, color coating, drilling, polishing, etc.
- **Military** − Autonomous robots can reach inaccessible and hazardous zones during war. A robot named *Daksh*, developed by Defense Research and Development Organization (DRDO), is in function to destroy life-threatening objects safely.

- **Medicine** – The robots are capable of carrying out hundreds of clinical tests simultaneously, rehabilitating permanently disabled people, and performing complex surgeries such as brain tumors.
- **Exploration** – The robot rock climbers used for space exploration, underwater drones used for ocean exploration are to name a few.
- **Entertainment** − Disney's engineers have created hundreds of robots for movie making.

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