# Chapter 5

# Communication, Perceiving and Acting

# Natural Language Processing

- Natural Language Processing (NLP) is the process of computer analysis of input provided in a human language (natural language), and conversion of this input into a useful form of representation.
- The field of NLP is primarily concerned with getting computers to perform useful and interesting tasks with human languages. The field of NLP is secondarily concerned with helping us come to a better understanding of human language.
- • The input/output of a NLP system can be:
  - – **written text**
  - – **speech**
- • We will mostly concerned with written text (not speech).
- • To process written text, we need:
  - – **lexical, syntactic and semantic knowledge about the language**
  - – **discourse information and real world knowledge**
- • To process spoken language, we need everything required to process written text, plus the challenges of speech recognition and speech synthesis.

# Cont'd…

- There are two components of NLP.
- • **Natural Language Understanding**
  - – Mapping the given input in the natural language into a useful representation.
  - – Different level of analysis required:
- ***morphological analysis,***
- ***syntactic analysis,***
- ***semantic analysis,***
- ***discourse analysis***, …
- • **Natural Language Generation**
  - – Producing output in the natural language from some internal representation.
  - – Different level of synthesis required:
- ***deep planning*** (what to say),
- ***syntactic generation***
- • NL Understanding is much harder than NL Generation. But, still both of them are hard.

# Cont'd…

- The difficulty in NL understanding arises from the following facts:
- Natural language is extremely rich in form and structure, and **very ambiguous**.
  – How to represent meaning,
  – Which structures map to which meaning structures.
- One input can mean many different things. Ambiguity can be at different levels.
  – Lexical (word level) ambiguity -- different meanings of words
  – Syntactic ambiguity -- different ways to parse the sentence
  – Interpreting partial information -- how to interpret pronouns
  – Contextual information -- context of the sentence may affect the meaning of that sentence.
- • Many input can mean the same thing.
- • Interaction among components of the input is not clear.

# Cont'd…

- The following language related information are useful in NLP:
- • **Phonology** – concerns how words are related to the sounds that realize them.
- • **Morphology** – concerns how words are constructed from more basic meaning units called morphemes. A morpheme is the primitive unit of meaning in a language.
- • **Syntax** – concerns how can be put together to form correct sentences and determines what structural role each word plays in the sentence and what phrases are subparts of other phrases.
- • **Semantics** – concerns what words mean and how these meaning combine in sentences to form sentence meaning. The study of context-independent meaning.
- • **Pragmatics** – concerns how sentences are used in different situations and how use affects the interpretation of the sentence.
- • **Discourse** – concerns how the immediately preceding sentences affect the interpretation of the next sentence. For example, interpreting pronouns and interpreting the temporal aspects of the information.
- • **World Knowledge** – includes general knowledge about the world. What each language user must know about the other's beliefs and goals.

# Cont'd…

- Ambiguity
- **I made her duck.**
- • How many different interpretations does this sentence have?
- • What are the reasons for the ambiguity?
- • The categories of knowledge of language can be thought of as ambiguity resolving components.
- • How can each ambiguous piece be resolved?
- • Does speech input make the sentence even more ambiguous?
  - – Yes – deciding word boundaries
- • Some interpretations of : **I made her duck.**

# Cont’d…

- 1. I cooked *duck* for her.
- 2. I cooked *duck* belonging to her.
- 3. I created a toy duck which she owns.
- 4. I caused her to quickly lower her head or body.
- 5. I used magic and turned her into a *duck*.
- • duck – morphologically and syntactically ambiguous:
- noun or verb.
- • her – syntactically ambiguous: dative or possessive.
- • make – semantically ambiguous: cook or create.
- • make – syntactically ambiguous:
- – Transitive – takes a direct object. => 2
- – Di-transitive – takes two objects. => 5
- – Takes a direct object and a verb. => 4

# Cont’d…

- Ambiguities are resolved using the following methods.
- • *models* and *algorithms* are introduced to resolve ambiguities at different levels.
- • **part-of-speech tagging** -- Deciding whether duck is verb or noun.
- • **word-sense disambiguation** -- Deciding whether make is create or cook.
- • **lexical disambiguation** -- Resolution of part-of-speech and word-sense ambiguities are two important kinds of lexical disambiguation.
- • **syntactic ambiguity** -- her duck is an example of syntactic ambiguity, and can be addressed by probabilistic parsing.

# Models to represent Linguistic Knowledge

- We will use certain formalisms (*models*) to represent the required linguistic knowledge.
- **State Machines --** FSAs, FSTs, HMMs, ATNs, RTNs
- **Formal Rule Systems --** Context Free Grammars, Unification Grammars, Probabilistic CFGs.
- **Logic-based Formalisms --** first order predicate logic, some higher order logic.
- **Models of Uncertainty --** Bayesian probability theory.

# Algorithms to Manipulate Linguistic Knowledge

- We will use *algorithms* to manipulate the models of linguistic knowledge to produce the desired behavior.
- Most of the algorithms we will study are **transducers** and **parsers**.
  - – These algorithms construct some structure based on their input.
- Since the language is ambiguous at all levels,
- these algorithms are never simple processes.
- Categories of most algorithms that will be used can fall into following categories.
  - – state space search
  - – dynamic programming

# Natural Language Understanding

The steps in natural language understanding are as follows:

Words

Morphological Analysis

Morphologically analyzed words *(another step: POS tagging)*

Syntactic Analysis

Syntactic Structure

Semantic Analysis

Context-independent meaning representation

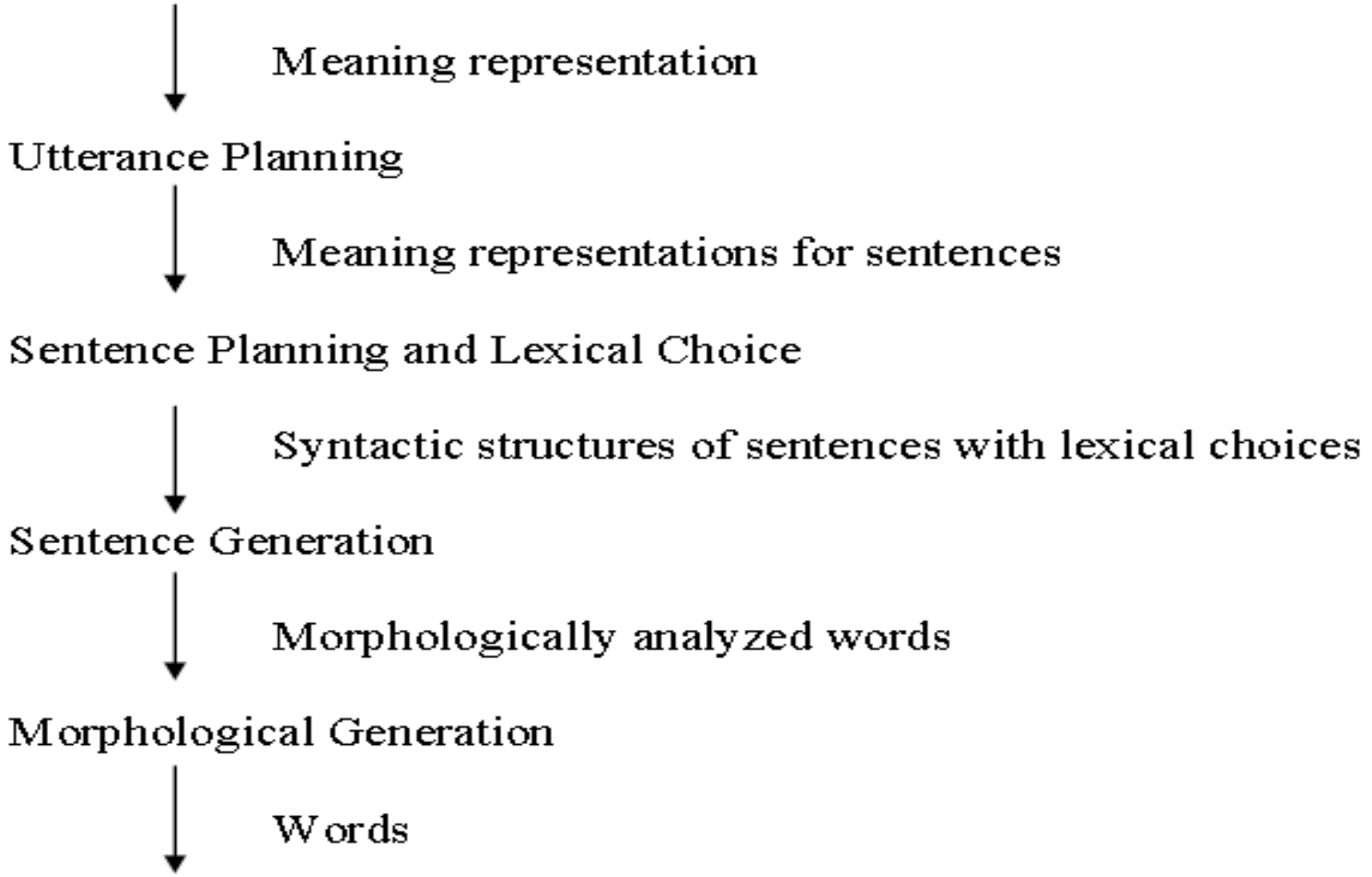
Discourse Processing

Final meaning representation

# Parsing

- **Natural Language Generation**

The steps in natural language generation are as follows.



# Steps in Language Understanding and Generation

- **Morphological Analysis**
- • Analyzing words into their linguistic components (morphemes).
- • Morphemes are the smallest meaningful units of language.
- cars car+PLU
- giving give+PROG
- geliyordum gel+PROG+PAST+1SG - I was coming
- • Ambiguity: More than one alternatives
- flies flyVERB+PROG
- flyNOUN+PLU
- adam adam+ACC - the man (accusative)
- adam+P1SG - my man
- ada+P1SG+ACC - my island (accusative)

# Parts-of-Speech (POS) Tagging

- • Each word has a part-of-speech tag to describe its category.
- • Part-of-speech tag of a word is one of major word groups (or its subgroups).
  - – **open classes** -- noun, verb, adjective, adverb
  - – **closed classes** -- prepositions, determiners, conjuctions, pronouns, particples
- • POS Taggers try to find POS tags for the words.

- • duck is a verb or noun? (morphological analyzer cannot make decision).

- • A POS tagger may make that decision by looking the surrounding words.
  - – Duck! (verb)
  - – Duck is delicious for dinner. (noun)

# Lexical Processing

- • The purpose of lexical processing is to determine meanings of individual words.
- • Basic methods is to lookup in a database of meanings – **lexicon**
- • We should also identify non-words such as punctuation marks.
- • Word-level ambiguity -- words may have several meanings, and the correct one cannot be chosen based solely on the word itself.
  - – bank in English
- • Solution -- resolve the ambiguity on the spot by POS tagging (if possible) or pass-on the ambiguity to the other levels.

# Syntactic Processing

- • **Parsing --** converting a flat input sentence into a hierarchical structure that corresponds to the units of meaning in the sentence.

- • There are different parsing formalisms and algorithms.
- • Most formalisms have two main components:
  - – **grammar --** a declarative representation describing the syntactic structure of sentences in the language.
  - – **parser --** an algorithm that analyzes the input and outputs its structural representation (its parse) consistent with the grammar specification.

- • CFGs are in the center of many of the parsing mechanisms. But they are complemented by some additional features that make the formalism more suitable to handle natural languages.

# Cont'd…

- **Semantic Analysis**
- • Assigning meanings to the structures created by syntactic analysis.

- • Mapping words and structures to particular domain objects in way consistent with our knowledge of the world.

- • Semantic can play an import role in selecting among competing syntactic analyses and discarding illogical analyses.
  - – I robbed the bank -- bank is a river bank or a financial institution

- • We have to decide the formalisms which will be used in the meaning representation.

# Cont'd…

**Knowledge Representation for NLP**

- Which knowledge representation will be used depends on the application -- Machine Translation, Database Query System.
- • Requires the choice of representational framework, as well as the specific meaning vocabulary (what are concepts and relationship between these concepts -- ontology)

- • Must be computationally effective.
- • Common representational formalisms:
  - – first order predicate logic
  - – conceptual dependency graphs
  - – semantic networks
  - – Frame-based representations

# Discourse

- • Discourses are collection of coherent sentences (not arbitrary set of sentences)
- • Discourses have also hierarchical structures (similar to sentences)

- • **anaphora resolution** -- to resolve referring expression
  - – Mary bought a book for Kelly. **She** didn't like **it**.
    - • **She** refers to Mary or Kelly. -- possibly Kelly
    - • **It** refers to what -- book.
  - – Mary had to lie for Kelly. **She** didn't like **it**.
- Discourse structure may depend on application.
- – Monologue
- – Dialogue
- – Human-Computer Interaction

# Applications of Natural Language Processing

- • Machine Translation – Translation between two natural languages.
  - – See the Babel Fish translations system on Alta Vista.
- • Information Retrieval – Web search (uni-lingual or multi-lingual).

- • Query Answering/Dialogue – Natural language interface with a database system, or a dialogue system.

- • Report Generation – Generation of reports such as weather reports.

- • Some Small Applications –
  - – Grammar Checking, Spell Checking, Spell Corrector

# Machine Translation

- • Machine Translation refers to converting a text in language A into the corresponding text in language B (or speech).

- • Different Machine Translation architectures are:
  - – interlingua based systems
  - – transfer based systems
- • Challenges are to acquire the required knowledge resources such as mapping rules and bi-lingual dictionary? By hand or acquire them automatically from corpora.
- • Example Based Machine Translation acquires the required knowledge (some of it or all of it) from corpora.

# Robotics

- The Robot Institute of America defines a robot as a programmable, multifunction manipulator designed to move material, parts, tools, or specific devices through variable programmed motions for the performance of a variety of tasks
- We will define robot simply as an active, artificial agent whose environment is the physical world.
- We will be concerned primarily with autonomous robots, those that make decisions on their own, guided by the feedback they get from their physical sensors.

# Cont…

## What is Robotics?

Robotics is a branch of AI, which is composed of Electrical Engineering, Mechanical Engineering, and Computer Science for designing, construction, and application of robots.

## 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.
- Robots are the artificial agents acting in real world environment.

# Cont…

- **Robots are physical agents that perform tasks by manipulating the physical world.**
- A robot is a system which exists in the physical world and autonomously senses its environment and acts in it.
- **What is autonomy?**
  - the ability to make one's own decisions and act on them
  - for robots, the ability to sense the situation and act on it appropriately
  - A robot *acts* through the use of its actuators, also called effectors

# Cont…

## Difference in Robot System and Other AI Program

Here is the difference between the two –

| AI Programs | Robots |
|---|---|
| They usually operate in computer-stimulated worlds. | They operate in real physical world |
| The input to an AI program is in symbols and rules. | Inputs to robots is analog signal in the form of speech waveform or images |
| They need general purpose computers to operate on. | They need special hardware with sensors and effectors. |

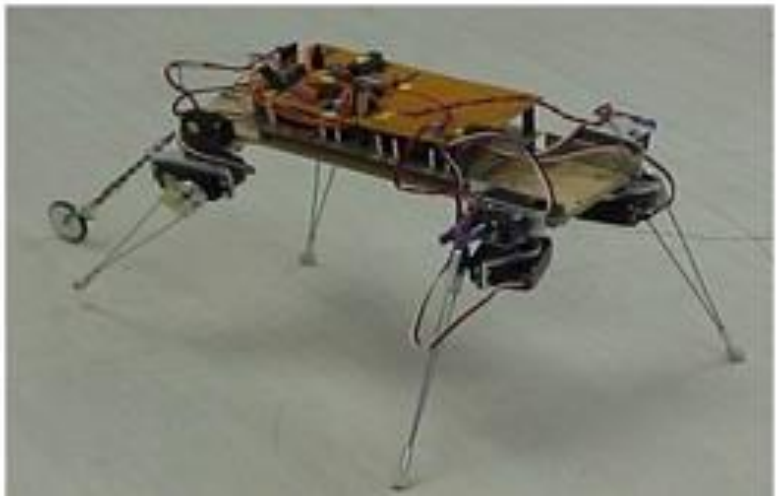
# Cont…

## Mobile Robots

- Mobile robots are able to move from one location to another location using locomotion. Mobile Robots are of two types:

**(a) Rolling robots**

- Rolling robots require wheels to move around.
- They can easily and quickly search. But they are only useful in flat areas.



**(b) Walking robots** - Robots with legs are usually used in condition where the terrain is rocky.

- Most walking robots have at least 4 legs.

# Cont…

- **Industrial Robots**

- Industrial robots perform same tasks repeatedly without ever moving.
- An industrial robot never tired, it will perform their works day and night without ever complaining.

# Cont…

- **Autonomous Robots**

- Autonomous robots are self-supported.

•They use a program that provides them the opportunity to decide the action to perform depending on their surroundings.

- Using artificial intelligence these robots often learn new behaviour. They start with a short routine and adapt this routine to be more successful in a task they perform. Hence, the most successful routine will be repeated.

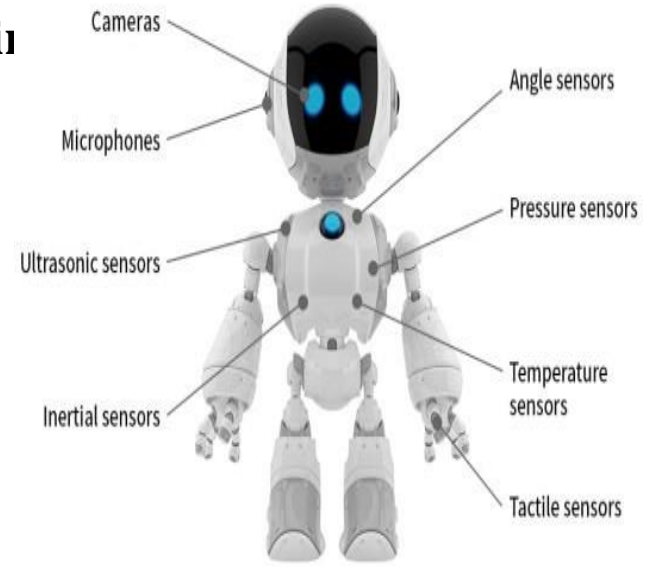
# Cont…

- **Remote Controlled Robots**

- Remote controlled robot used for performing complicated and undetermined tasks that autonomous robot cannot perform due to uncertainty of operation.
- Complicated tasks are best performed by human beings with real brainpower.
- Therefore a person can guide a robot by using remote
- E.g.: NASA robot designed to

# Cont…

- **SENSING**
  - Robotic sensing is **a subarea of robotics science intended to give robots sensing capabilities**.
  - Robotic sensing mainly gives robots the ability to see, touch, hear and move and uses algorithms that require environmental feedback.
  - **Is the ability to extract i**



# Sensors

- Sensors in robots help correctly recognize surroundings and provide the controller or drive with data
- Sensors are the perceptual interface between robots and their environments.
- **Passive sensors:** cameras are true observers of the environment: they capture signals that are generated by other sources in the environment.
- **Active sensors:** sonar sensors (ultrasonic transducer), send energy into the environment. They rely on the fact that this energy is reflected back to the sensor.
- sonar include radar (used primarily by aircraft) and laser.

# Types of Sensors

- **Light Sensor**
- Light sensor is a transducer used for detecting light and creates a voltage difference equivalent to the light intensity fall on a light sensor.
- **Proximity Sensor**
- Proximity sensor can detect the presence of nearby object without any physical contact.
- In proximity sensor transmitter transmits an electromagnetic radiation and receiver receives and analyzes the return signal for interruptions. Therefore the amount of light receiver receives by surrounding can be used for detecting the presence of nearby object.

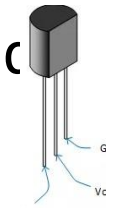
# Cont…

## Sound Sensor

- Sound sensors are generally a microphone used to detect sound and return a voltage equivalent to the sound level. Using sound sensor a simple robot can be designed to navigate based on the sound receives.

## Temperature Sensor

- Temperature sensors are used for sensing the change in temperature of the surrounding. It is based on the principle of change in voltage difference for a change in temperature this change in voltage will provic the equivalent temperature value of the surrounding.



# Effectors

- Effectors are the means by which robots move and change the shape of their bodies with using the concept of a **degree of freedom (DOF)**
- For nonrigid bodies, there are additional degrees of freedom within the robot itself.

eg. in a human arm, the elbow has one degree of freedom-it can flex in one direction and the wrist has three degrees of freedom-it can move up and down, side to side, and can also rotate.

- Robot joints also have 1,2, or 3 degrees of freedom each.

• **Degrees of freedom (DOF)** is ” **a term that describes a robot's freedom of motion in three dimensional space**”. Degree of freedom for a robot is defined as “the number of independent movements performed by the robot wrist in three dimensional space, relative to the robot's base”.

# Robot manipulation

- **Robotic manipulation refers to the ways robots interact with the objects around them**: grasping an object, opening a door, packing an order into a box, folding laundry… All these actions require robots to plan and control the motion of their hands and arms in an intelligent way.
- **Manipulation of Robotics**

**What is a Robotic Manipulator?**

- is a reprogrammable and multifunctional mechanical device responsible for moving materials, parts, objects, or tools through programmed motions in order to perform various tasks.
- A robotic manipulator is capable of moving or handling objects automatically depending
- upon its given number of degrees of freedom.
- Robotic manipulators can range from two axes to ten or more.

# Cont…

- **Manipulators, or robot** arms: usually involves an entire chain controllable joints, enabling such robots to place their effectors in any position within their workplace.

❖ manipulators have even been used to generate original artwork.

- they can move in 1 or more dimensions.
- the number of dimensions are called the robot's degrees of freedom (DOF).

# ROBOT Locomotion

- Locomotion is the mechanism that makes a robot capable of moving in its environment. There are various
- types of locomotion's –
  - Legged
  - Wheeled
  - Combination of Legged and Wheeled Locomotion
  - Tracked slip/skid

# Con’t…

**Legged Locomotion**

- This type of locomotion consumes more power while demonstrating walk, jump, trot, hop, climb up or down, etc.
- It requires more number of motors to accomplish a movement. It is suited for rough as well as smooth terrain where irregular or too smooth surface makes it consume more power for a wheeled locomotion. It is little difficult to implement because of stability issues.
- It comes with the variety of one, two, four, and six legs. If a robot has multiple legs then leg coordination is necessary for locomotion

# Cont…

- The total number of possible **gaits** (a periodic sequence of lift and release events for each of the total legs) a robot can travel depends upon the number of its legs.
- If a robot has k legs, then the number of possible events N = (2k-1)!.
- In case of a two-legged robot (k=2), the number of possible events is N = (2k-1)! = (2*2-1)! = 3! = 6.
- Hence there are six possible different events −
  - ✓ Lifting the Left leg
  - ✓ Releasing the Left leg
  - ✓ Lifting the Right leg
  - ✓ Releasing the Right leg
  - ✓ Lifting both the legs together
  - ✓ Releasing both the legs together

# Cont…

**Wheeled Locomotion**

- It requires fewer number of motors to accomplish a movement. It is little easy to implement as there are less stability issues in case of more number of wheels. It is power efficient as compared to legged locomotion

# Cont…

**Slip/Skid Locomotion**

- In this type, the vehicles use tracks as in a tank. The robot is steered by moving the tracks with different speeds in the same or opposite direction. It offers stability because of large contact area of track and ground.

# HOW DOES THE HUMAN ROBOT INTERACTION?

- Human–robot interaction is the **study of interactions between humans and robots**. It is often referred as HRI by researchers. Human–robot interaction is a multidisciplinary field with contributions from
  - human–computer interaction,
  - artificial intelligence,
  - robotics,
  - natural-language understanding, design, and
  - psychology.

# 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.

# The end of chapter Five!