Need of Robots

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Abstract: ***This paper analyzes the need of robots in present day environment that is, in the growing technology day by day and accidents taking place in various fields causing loss to human life. Robots can be used to the advantages of ontologies and ontological reasoning, such as interoperability of various (heterogeneous) knowledge resources (for example, patient databases or disease ontologies), such an ontology provides the underlying mechanisms for translational physical medicine, from bench-to-bed and back, and personalized rehabilitation robotics. Spatial notions play a vital role when humans interact with robots. Whenever robots are working in dynamic environments which are close to humans, humans must have extensive knowledge of robotics. Otherwise there is a strong need to simplify the user interaction and make the system execute as autonomously as much as possible, as long as it is feasible. In case of industrial robots working side-by-side with humans in manufacturing industry, AI systems are necessary to lessen the demand on programming time and system integration expertise. As robots become more advanced, eventually there may be some standard computer operating system designed mainly for robots, called robot operating system (ROS). Robot Operating System (ROS)is an open source set of programs being currently developed at Stanford University. ROS provides high level commands for items like image recognition and even opening doors, etc. By building a system with proper knowledge and reasoning services can simplify the robot programming sufficiently to meet those demands while still getting a robust and efficient task execution. Robotics & Automation (R&A) quite often involves diverse scenarios where heterogeneous robots has to share their spatial knowledge to achieve a given goal. Such scenarios become more complex when human beings are getting involved. This implies that humans and heterogeneous robots must share their spatial information about the world.***

Keywords: Robotics & Automation (R&A) , ontology, interoperability, rehabilitation , manufacturing , Robotics Technology Middleware (RTM), Robot operating Systems (ROS).

1. Introduction

A robot is a mechanical agent , usually an electro – mechanical machine that is guided by a computer program. In general**,** a robot is a programmed machine possessing anthropomorphic characteristics. The most important characteristic is mechanical arm of the robot which performs various tasks. Robotics is the branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. These technologies deal with automated machines that can take the place of humans in dangerous environments or manufacturing processes, or resemble humans in appearance, behavior, and/or cognition. Many of today's robots are inspired by nature contributing to the field of bio-inspired robotics .Moreover it may also be defined as the branch of applied science which studies the robots is called Robotics. Robots require the integration of heterogenic set of software and hardware elements and they are called middleware i.e. Robotics Technology Middleware (RTM).

2. History of Robots

In 1922, Czech author Karel Capek wrote a story called Rossum’s Universal Robots and introduced the word “Rabota” which means forced worker.

In1927the Maschinenmensch ("machinehuman") gynoid humanoid robot also called "Parody", "Futura", "Robotrix", or the "Maria impersonator".

The first depiction of a robot ever to appear on film, was played by German actress Brigitte Helm in Fritz Lang's film Metropolis.

In 1942 the science fiction writer Isaac Asimov formulated “Three Laws of Robotics”.

In 1946, George C. Devol developed the first programmable Robot.

In 1948 Norbert Wiener formulated the principles of cybernetics, the basis of practical robotics.

In 152 He got patented his work.

1955 Denavit and Hartenberg developed the homogenous transformation matrices.

In 1962 Unimation was formed and first industrial Robots appeared and later on in 1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.

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In 1966, Trallfa, a Norwegian firm , built and installed a spray painting Robot.

1990 Cincinnati Milacron was acquired by ABB. The very first application of a Unimate robot was unloading a die casting machine at General Motors Plant in New Jersey in 1961.

In 2000’s, Micro and nano robots using smart materials, Unmanned Ariel vehicles and underwater robotics.

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Laws of Robots:

(1) A robot should not injure a human beings or life
(2) A robot should obey the orders of the master without conflicting the first law.
(3) A robot should protect its own existence without conflicting the first and second laws.

Classification of Robots:
Robots are classified in many ways:
(a) As per the Robotics Institute of America

- **Limited Sequence Control Robot:** These robots do not use servo control to indicate relative position of joints and they are controlled by limit switches, mechanical stop with a sequence to accommodate and actuation of joints.
- **Playback Robot:** In this type ,A human operator performs the task manually by leading the Robot.
- **Variable-Sequence Robot:** In this A device that performs the successive stages of a task according to a predetermined method, easy to modify.
- **Numerical Control Robot:** The operator supplies the movement program rather than teaching it the task manually.
- **Intelligent Robot** : A robot with the means to understand its environment and the ability to successfully complete a task despite changes to the environment.
- (b) Robots are also classified according to degree of freedom (DOF) they have. Each joint connects two links, an input link and an output link. Links are rigid components of the robot manipulator. The joints provide controlled relative motion between input link and output link.

3. Robot Accessories

A Robot is a system, which are integrated to form a whole consists of the following elements/ components:
1) **Manipulator / Rover:** This is the main body of the Robot and consists of links, joints and structural elements of the Robot.
2) **End Effector: This** is the part that generally handles objects, makes connection to other machines, or performs the required tasks. It can vary in size and complexity from an end effector on the space shuttle to a small gripper.
3) **Actuators :** Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.
4) **Sensors** : Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Robots are often equipped with external sensory devices such as a vision system, touch and tactile sensors etc which help to communicate with the environment
5) **Controller:** The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.

4. Robot Configurations

Some of the commonly used configurations in Robotics are:
(i) **Cartesian/Rectangular Gantry (3P)** :These Robots are made of 3 Linear joints that orient the end effectors, which are usually followed by additional revolute joints.

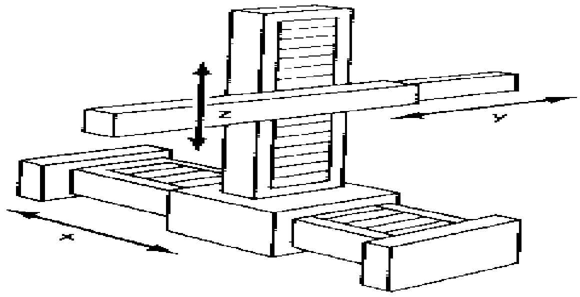

Figure 1: Cartesian Robot - Work Envelope

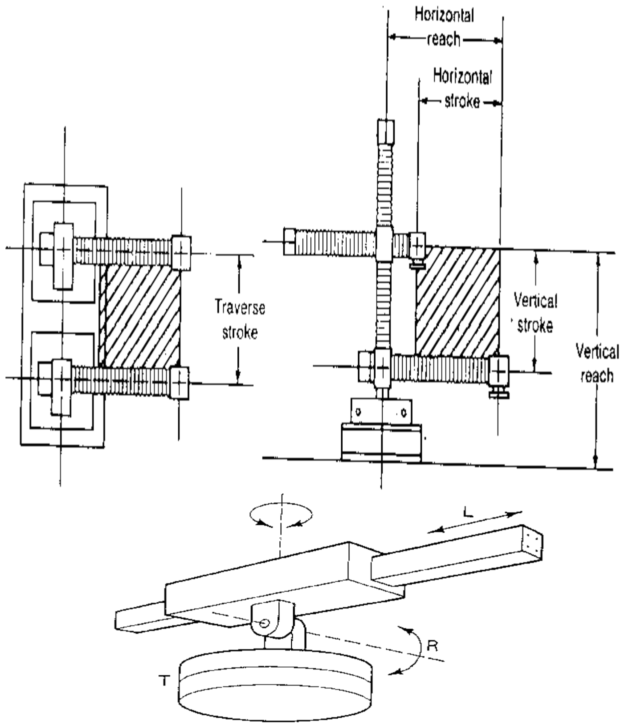

Figure 2: Polar coordinate body and –arm assembly

Cylindrical (R2P): Cylindrical coordinate Robots have 2 prismatic joints and one revolute joint.

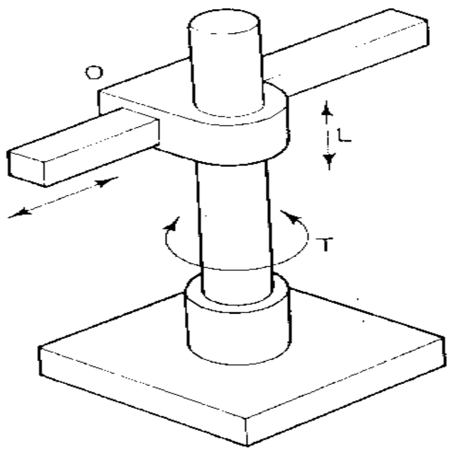

Figure 3: Cylindrical coordinate body and –arm assembly

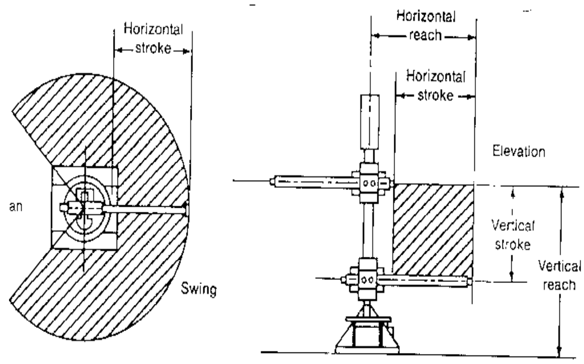

Figure 4: Cylindrical Robot

5. Robot Anatomy and Related Terms

Manipulator: The manipulator is an industrial robot having a number of joints and links. It needs some way to manipulate objects i.e. pick up, modify or have an effect.

Joints: A joint of a robot is similar to a joint in the human body. That is , it provides relative motion between two parts of the body about certain points or line. This line is called axis. Each joint or axis , provides the robots what is called degree of freedom (DOF) of motion. Generally, only one degree of freedom (DOF) is associated with each joint.

Joint classification:

Robot Reference Frames

- World Reference Frame which is a universal coordinate frame, as defined by the x-y-z axes. In this case the joints of the robot move simultaneously so as to create motions along the three major axes.
- Joint Reference Frame which is used to specify movements of each individual joint of the Robot. In this case each joint may be accessed individually and thus only one joint moves at a time.
- Tool Reference Frame which specifies the movements of the Robots hand relative to the frame attached to the hand. The x' ,y' and z' axes attached to the hand define the motions of the hand relative to this local frame. All joints of the Robot move simultaneously to create coordinated motions about the Tool frame.

Work Envelope concept:

- Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a Workspace.
- Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach.

Pure Spherical Jointed Arm - Work envelope

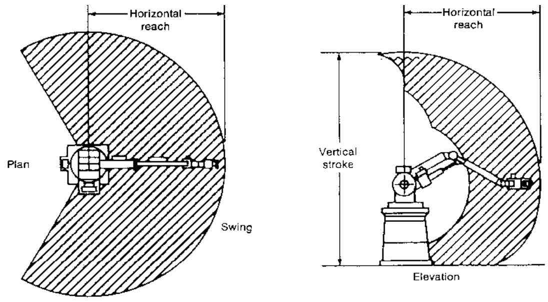

Figure 5: Spherical Jointed Arm - Work envelope

Control Methods

Non Servo Control

- implemented by setting limits or mechanical stops for each joint and sequencing the actuation of each joint to accomplish the cycle
- end point robot, limited sequence robot, bang-bang robot
- No control over the motion at the intermediate points, only end points are known

a) Programming accomplished by
- Setting desired sequence of moves
- Adjusting end stops for each axis accordingly
- The sequence of moves is controlled by a "sequencer", which uses feedback received from the end stops to index to next step in the program

b) Low cost and easy to maintain, reliable
c) Relatively high speed
d) Repeatability of up to 0.01 inch
e) Limited flexibility
f) Typically hydraulic, pneumatic drives

Servo Control

- Point to point Control
- Continuous Path Control
- Closed Loop control used to monitor position, velocity (other variables) of each joint

Point-to-Point Control

- Only the end points are programmed, the path used to connect the end points are computed by the controller
- user can control velocity, and may permit linear or piece wise linear motion
- Feedback control is used during motion to ascertain that individual joints have achieved desired location
- Often used hydraulic drives, recent trend towards servomotors
- loads up to 500lb and large reach
- Applications
- pick and place type operations
- palletizing machine loading

Continuous Path Controlled

- in addition to the control over the endpoints, the path taken by the end effectors can be controlled
- Path is controlled by manipulating the joints throughout the entire motion, via closed loop control
- Applications:
- Spray painting, polishing, grinding, arc welding etc.

Basic Parts of a Robot

Getting straight to the point, for a robot to be mobile (which can move), it should have some basic systems as mentioned below.

1) **Locomotion System** – This system defines how the robot moves. Whether it's translatory motion, rotatory motion, etc. Using this system, you can make your robot move forward, backward, right, left, climb up/down, etc. To accomplish this, we need devices which convert electrical energy into mechanical energy. Such devices are called actuators and the most popular actuator is the DC Motor.
2) **Power Supply System** – For a robot to work, we need a power supply. It acts as food to the robot. Unless you feed your robot, it cannot work! Thus, we need to provide a power supply for that. For robotic applications (in fact most major applications), we need DC supply (usually 5V, 9V, 12V DC, sometimes goes as high as 18V, 24V, 36V, etc. as per your requirement). The best way for this is to use a battery (as it provides DC supply directly) or use an SMPS/Eliminator to convert AC to DC and then use it. But voltage is not the only thing that matters while choosing a proper supply. Your power source should also be able to supply sufficient current to drive all the loads connected to it, directly or indirectly.
3) **Actuator System** – As described above, actuators are devices which bring about the locomotion of the robot. There are many actuators used like DC Motors, Stepper Motors, Servo Motors, etc. The way they are connected together, their circuit diagram, their location, orientation, position, etc. everything comes under Actuator System.
4) **Sensor System** – In order for the robot to interact with the physical world, we need to introduce sensors (which can measure physical parameters like temperature, pressure, heat, radio waves, IR waves, etc). These sensor systems provide a feedback from the real world to the digital world (embedded electronics), which are processed and the robot takes the decision accordingly.
5) **Signal Processing System** – The data from the sensors and other electrical and digital signals need to be processed, so that the robot analyzes the situation and makes its moves. For this, we introduce electronic components to process the signals. The components can be any analog/digital device, or even a microcontroller.
6) **Control System** – This is the major governing system of the robot. Every system that is present inside the robot and functioning can be represented in form of a control system (open-loop and closed-loop).

Path and trajectory of Robot

The following path planning strategies exist:

- Path constrained (signed path) off-line or on-line path planning with collision avoidance
- Position controlled motion with on-line obstacle identification and collision avoidance (without path constraints, i.e. path signs)
- Path constrained off-line path planning or on-line pass through the signed path (collisions are possible)
- Position controlled motion without obstacle identification (collisions are possible)

These strategies can be used to solve path planning tasks in robotics in most of the cases. The **position controlled motion** is the motion along interpolated trajectories between signed and referred path points. The **signed path** is the path having regular defined points that must be unconditionally passed through.

The main path planning tasks for a robot are as follows:

- grasping and releasing objects
- moving from place to place
- following previously specified paths
- following moving objects
- working with other manipulators
- exerting forces (i.e. pushing, pulling and holding)
- exerting torques
- collecting data
- using tools

Robots are subject to all of the constraints of mechanics. In the case of manipulators with many joints (prismatic or revolute), the physical limits of motion become evident. For the best solution, the limits of joint and actuator positions, velocity, acceleration, and jerk must be considered. The physical nature of the device also means that there are dimensions which must be considered, thus kinematics and collision avoidance come into play. When a robot makes any move, it expends energy to accelerate, hold and brake. This also means that the energy efficiency of the manipulator should be optimized by reducing unnecessary expenditures of energy. Most importantly, if robots are to be cost effective, then their speed is of concern. In a high production situation, a cycle time that is 10% faster could save millions of dollars. Thus, the time of path traversal can most often be the most important path planning factor.

Essential performances of a robot:

- time for path traversal
- velocity of manipulator links or joints
- stored energy
- actuator forces
- proximity to obstacles

Mechanical constraints of a manipulator:

- joint positions, velocities, accelerations and jerks
- actuator forces and motion dynamics
- kinematics (including singularities)
- collisions with obstacles
- time when moving obstacles are involved

General requirements, evaluation criteria:

- Dimensions of space (2D, 2.5D, 3D)
- Collision avoidance (none, contact detection, proximity calculation)
- Multilink manipulators
- Rotations of payload or mobile robot
- Moving workspace obstacles
- Multi robot coordination

Automated path planning:

The information source that will be used is the most important to select a method of path planning.

The environment can be identified previously before the start to the path by environment mapping or during the path through going by obstacle detection. Consequently, two general ways for path planning exist:

- Collision Detection and Local or Trajectory Path Planners that are using information about collision detection
- Obstacle Information Global Path Planners that are using information about previously detected obstacles

Path planners listed are as follows:

- knowledge-based simple path planner
- knowledge-based hybrid path planner
- sensor-based path planner
- static knowledge- and sensor-based hierarchical path planner
- dynamic knowledge- and sensor-based path planner
- path planner based on *off-line programming*
- path planner based on *on-line programming*

Knowledge based path planning:
It is much easier to solve a problem if all the information is available at the beginning of the solution. For a robot the paths can be planned before their execution if some knowledge of the environment is known. This is strictly a **"blind"** strategy that trusts the knowledge of the environment provided. Planning paths before execution allow efforts to get a shorter path time, more efficient dynamics, and absolute collision avoidance. When working in this mode knowledge known before is used. Different techniques are available to solve a variety of priori path planning may come from vision systems, engineering specifications, or CAD programs.

Prior knowledge may be applicable to moving objects if they have a predictable frequency or motion. This may not be used for unpredictable or **random motion** if there is no detection method allowed. Prior knowledge may be derived from the results of modelling or with the help of high level sensors. These sensors are like laser scanners or video systems. These sensors are slow and typically drive a World modeler in an off-line programmer. Video system is the most desired information collector for robotics in the future. Some of these sensors require knowledge from the world modeler for object recognition purposes. In general, these sensors are slower because of their need to interpret low level data, before providing high level descriptions.

Knowledge-based simple path planner:
A simple path planner uses environmental information (incl. position coordinate values) for motion start and end points. Then using an algorithmic process the trajectory via points between the start and end point will be calculated, segments of trajectory will be determined by mathematical description in the defined coordinate system. For example, in the base coordinates of a manipulator or in the world coordinates of a robot system.

Knowledge-based hybrid path planner
If knowledge-based hybrid path planner is used, first a number of possible path variants will be determined. Then the optimal path variant from the possible variants will be selected. This method is more complex than other methods, but gives more chances to find the best path for a robot.

Sensor-based path planning
In this case information is not available when we begin to solve a problem of path planning. Thus we must solve the problem in stages as the information from the sensors (known after knowledge) becomes available. Sensor-based planning is an indispensable function when environments change with time, are unknown, or there are inaccuracies in the robotic equipment. Subsequent knowledge may be used to find the next trajectory in a path (by collecting information about the outcome of the previous trajectory) or even be used strictly to guide the robot in a random sense when exploring an environment. Sensors that will be used may be very different: from simple contact switches and tactile sensors up to complicated video systems.

These sensors will typically detect various expected conditions. The sensors can give a signal when contact is made with obstacles, or measure a force being applied. When sensors are used in a feedback loop, they may provide actual joint position for a position control algorithm. High level sensors also have the ability to provide low level data and may be used to detect events.

The amount of knowledge which a path planner has may be very limited. If the robot has no previous knowledge of the environment, then information must be gathered while the robot is in motion. Trajectory planners rely on feedback for finding new trajectories and detecting poor results. Contact or distance sensors are used to detect an obstacle and the manipulator trajectory is altered to avoid collision. This method will typically guarantee a solution (if it exists or if it does not encounter a blind alley), but at a much higher time cost, and a longer path. The collection of current data becomes critical when dealing with moving obstacles that do not have a periodic cycle.

6. Robot Actuators

Hydraulic Actuators:
Principle Used in Hydraulic Actuator System

Pascal's Law :
Pressure applied to a confined fluid at any point is transmitted undiminished and equally throughout the fluid in all directions and acts upon every part of the confining vessel at right angles to its interior surfaces.

Amplification of Force:
Since pressure P applied on an area A gives rise to a force F, given as,
$F = P \times A$

Thus, if a force is applied over a small area to cause a pressure P in a confined fluid, the force generated on a larger area can be made many times larger than the applied force that created the pressure. This principle is used in various hydraulic devices to such hydraulic press to generate very high forces.

Advantages of Hydraulic Actuation Systems
Hydraulics refers to the means and mechanisms of transmitting power through liquids. The original power source for the hydraulic system is a prime mover such as an

electric motor or an engine which drives the pump. However, the mechanical equipment cannot be coupled directly to the prime mover because the required control over the motion, necessary for industrial operations cannot be achieved. In terms of these Hydraulic Actuation Systems offer unique advantages, as given below.

Variable Speed and Direction: Most large electric motors run at adjustable, but constant speeds. It is also the case for engines. The actuator (linear or rotary) of a hydraulic system, however, can be driven at speeds that vary by large amounts and fast, by varying the pump delivery or using a flow control valve. In addition, a hydraulic actuator can be reversed instantly while in full motion without damage. This is not possible for most other prime movers.

Power-to-weight ratio**:** Hydraulic components, because of their high speed and pressure capabilities, can provide high power output with vary small weight and size, say, in comparison to electric system components. Note that in electric components, the size of equipment is mostly limited by the magnetic saturation limit of the iron. It is one of the reasons that hydraulic equipment finds wide usage in aircrafts, where dead-weight must be reduced to a minimum.

Stall Condition and Overload Protection**:** A hydraulic actuator can be stalled without damage when overloaded, and will start up immediately when the load is reduced. The pressure relief valve in a hydraulic system protects it from overload damage. During stall, or when the load pressure exceeds the valve setting, pump delivery is directed to tank with definite limits to torque or force output. The only loss encountered is in terms of pump energy. On the contrary, stalling an electric motor is likely to cause damage. Likewise, engines cannot be stalled without the necessity for restarting.

Robot Programming

- Typically performed using one of the following
  - On line
- teach pendant
- lead through programming
  - Off line
- robot programming languages
- task level programming

Use of Teach Pendant

- hand held device with switches used to control the robot motions
- End points are recorded in controller memory
- sequentially played back to execute robot actions
- trajectory determined by robot controller
- suited for point to point control applications
- Easy to use, no special programming skills required
- Useful when programming robots for wide range of repetitive tasks for long production runs
- RAPID

Lead Through Programming

- lead the robot physically through the required sequence of motions
- trajectory and endpoints are recorded, using a sampling routine which records points at 60-80 times a second
- when played back results in a smooth continuous motion
- Large memory requirements

Programming Languages

- Large number of robot languages available
  AML, VAL, AL, RAIL, Robot Studio, etc. (200+)
- Each robot manufacturer has their own robot programming language
- No standards exist
- Portability of programs virtually non-existent

Motivation

- need to interface robot control system to external sensors, to provide "real time" changes based on sensory equipment
- computing based on geometry of environment
- ability to interface with CAD/CAM systems
- meaningful task descriptions
- off-line programming capability

Spherical joint (2RP): They follow a spherical coordinate system, which has one **ROBOT Software**

Examples of programming languages for robots

ROBOT Application Software

CLARATY

Examples of robot control GUI
Future of robotics

Robot Applications:
Robots are suited to work in an environment where automation is required. Robotics is about controlled action, and the principal objective of that action is to serve humans. Robot technology does not resemble common science fiction scenarios. In most cases, robot technology will be embedded in common objects, and not recognizable as a robot . For example unmanned vehicles. Some Vehicles are already driving themselves in certain restricted applications such as shipping yards. Unmanned aerial vehicles are proving themselves in surveillance and in combat, and unmanned ground vehicles are nearing substantial deployment in combat zones. Now days some passenger cars drive themselves, the result is the dramatic improvements in efficiency and safety, with enormous savings in fuel, insurance, medical bills, and overall a great improvement in the quality of our lives. Ernst Dickmann's driverless car are capable of sensing the environment and taking navigational decisions based on this information. Another example is assistive technology in our homes that can enable the elderly and disabled persons to live independent lives, rather than moving into institutions or depending on others for their daily routine work.

7. Continuum for Advanced Machine Operation

Artificial Intelligence
It is the science and engineering of making intelligent machines and a branch of computer science which aims to

create it. Artificial intelligence along with robotics are used together to manufacture **smarter** robots. So, an artificial intelligent system is basically a robot which has a computer program that has parts for each of the functions described in the intelligent system document. It functions the same way that a normal human brain does, only it performs this in an electronic way instead of by activating neurons. We can say that it is like the proverbial black box; that has inputs and learns which outputs get the most approval by human beings. It stores experiences in its memory, generalizes them, and then deals with new circumstances (new inputs). These robots can and will change our lives in near future.

8. Latest Technology of Robotics

(i)Utility fog
(ii)M-Tran (Modular Transfer)
(iii) Self –replicating robots:

9. Conclusion

In 2013, about 179,000 industrial robots were sold worldwide, which is an all-time high and 12 percent more than in 2012," announced Arturo Baron celli, IFR President.

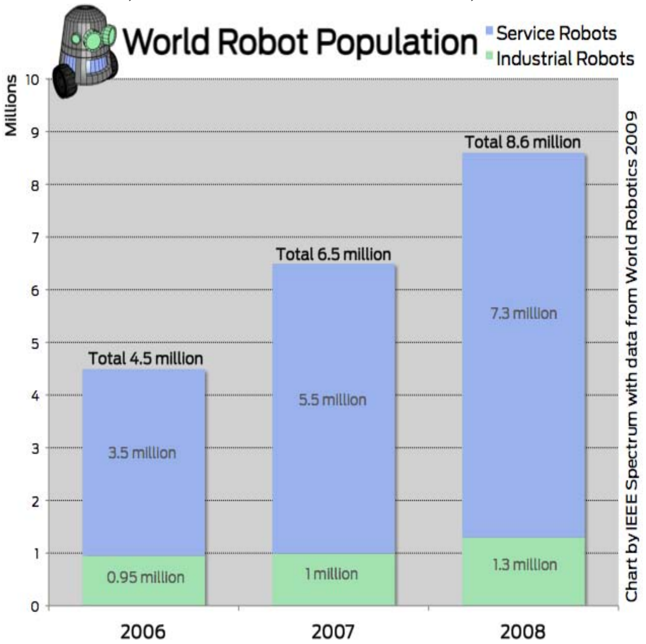

Figure 6: Robot sales data

10. Future Scope

As ROBOTS can be used in all the situations where working of human being can be dangerous or hazardous , the future scope of the robots is very bright.

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