Robotics & Machine Vision

Prof. Dr. M. Zahurul Haq
zahurul@me.buet.ac.bd
http://teacher.buet.ac.bd/zahurul/

Department of Mechanical Engineering
Bangladesh University of Engineering & Technology

ME 475: Mechatronics

Introduction

- A **robot** is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.
- True robots should be distinguished from the manually controlled manipulator or **telecheric**, which is remotely controlled by human operators and not programmed to operate automatically and unattended.
- **Robotics** is the art, knowledgebase, and the know-how of designing, applying, and using robots in human endeavours.

Situations to promote the use of robots

- Hazardous environment for humans
- Repetitive work cycle
- Difficult handling for humans
- Multishift operations
- Infrequent changeovers

Robot Applications

- **Industrial Applications**:
  - Material handling
  - Processing operations
  - Assembly and inspection
- **Field Applications**: Robots are deployed in areas where human being could not survive or be exposed to unsustainable risks.
- **Service Applications**: Robots are used in civil applications such as intelligent transportations, patient rehabilitation system, medical applications, domestic aid, entertainments etc.

Industrial Applications: Material Handling

1. Material transfer
   - pick-and-place
   - palletizing[1]
   - depalletizing
   - warehouse loading and unloading
   - insertion
2. Machine loading and unloading
   - die casting
   - plastic moulding
   - machining processes
   - heat-treatment
   - pressworking

[1] placing objects on a pallets in ordered way

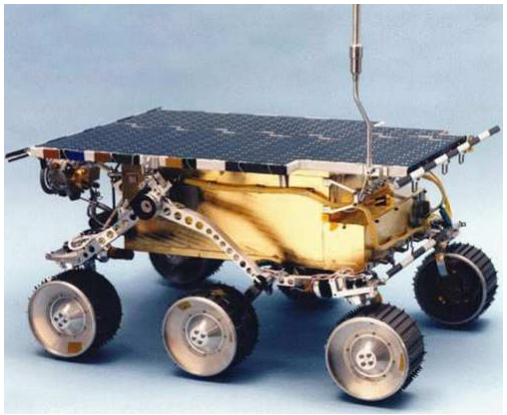
Industrial Applications: Processing operations

- arc and spot welding
- glueing and sealing
- paint and spray coating
- drilling and other machining operations
- grinding, wire brushing and similar operations
- water-jet and laser cutting
- screwing, wiring and fastening.

Industrial Applications: Assembly and Inspection

1. Assembly – involves joining of two or more parts to form a new entity.
2. Inspection – to inspect the work that is supposed to be done.
   - making sure that a given process is completed
   - ensuring that parts have been added in the assembly as specified
   - identifying the flaws in raw materials and finished parts.

Field Robot Applications



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Sojourner rover, deployed by Pathfinder in 1997 by NASA.

Service Robot Applications

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Autonomous car Stanley completed a path of 132 miles in record time of 6 h and 53 min in DARPA Grand Challenge 2005.

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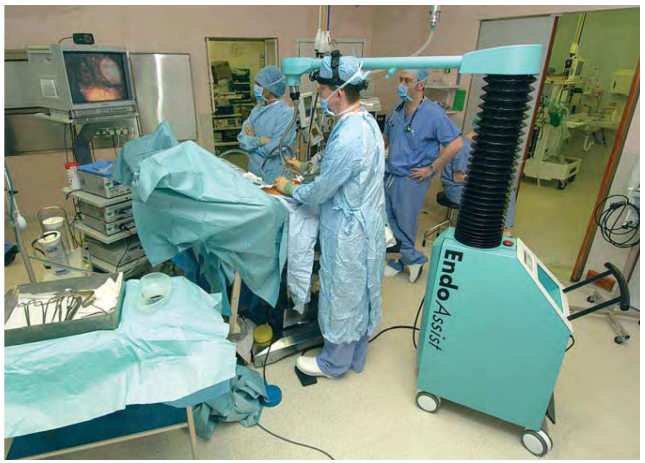

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The EndoAssistant manipulates a laparoscopic camera at the command of the surgeon.

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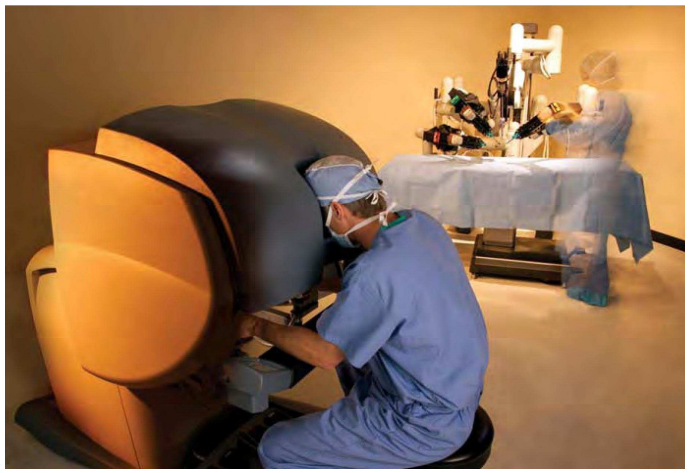

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The da Vinci robotic surgical system comprising of a surgeon's console and a patient side cart.

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Asimo by Honda

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AIBO by Sony Corp

Robot Structure & Classifacations

- Robots can be classified as those with fixed base, **robot manipulators**, and those with a mobile base, **mobile robots**.
- The structure of a robot manipulator consists of a sequence of rigid bodies (**links**) interconnected by means of articulations (**joints**); a manipulator is characterized by an **arm** that ensures mobility, a **wrist** that confers dexterity, and an **end-effector** that performs the task required of the robots.
- The articulation between two consecutive links can be realized by means of a **prismatic** or a **revolute** joint. Prismatic joints are linear; there is no rotation involved. Revolute joints are rotary.

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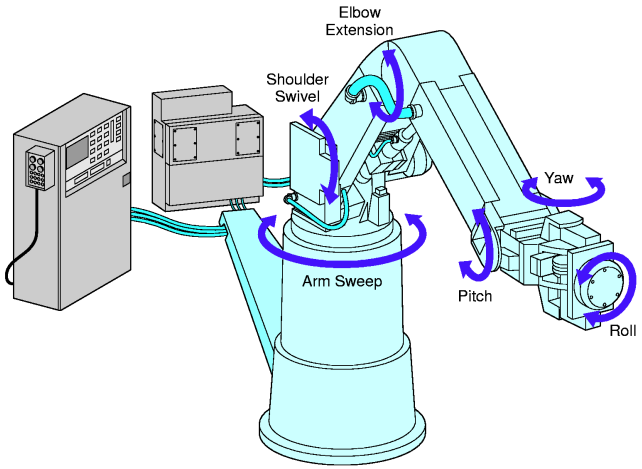
- In most general case of a task consisting of arbitrarily positioning and orienting an object in 3D space **6** DOFs are required.
- The **workspace** represents the position of the environment the manipulator's end-effectors can access.
- The task required of the arm is to position the wrist then it required to orient the end-effector.
- Robot manipulators are classified as:
  1. Cartesian (3P): 20% of industrial robots
  2. Cylindrical (R2P): 12%
  3. Spherical / Polar (2RP)
  4. Articulated / Anthropomorphic (3R): 59%
  5. Selective Compliance Assembly Robot Arm (SCARA): 8%

6 DOF Industrial Robot Example



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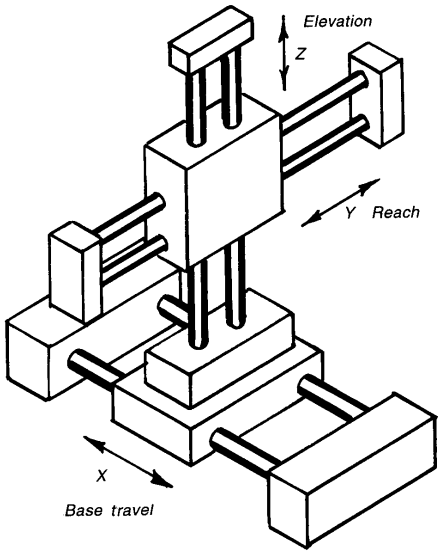
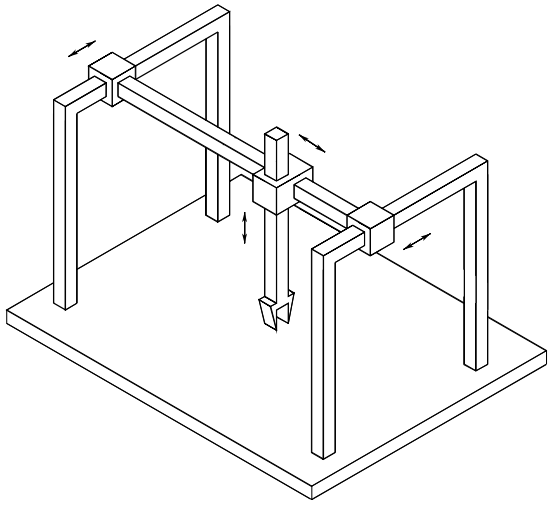
Carteisan (3P) Robot



Gantry Robot



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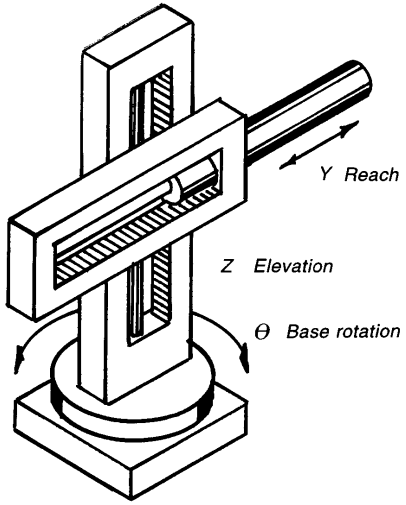
Cylindrical (R2P) Robot



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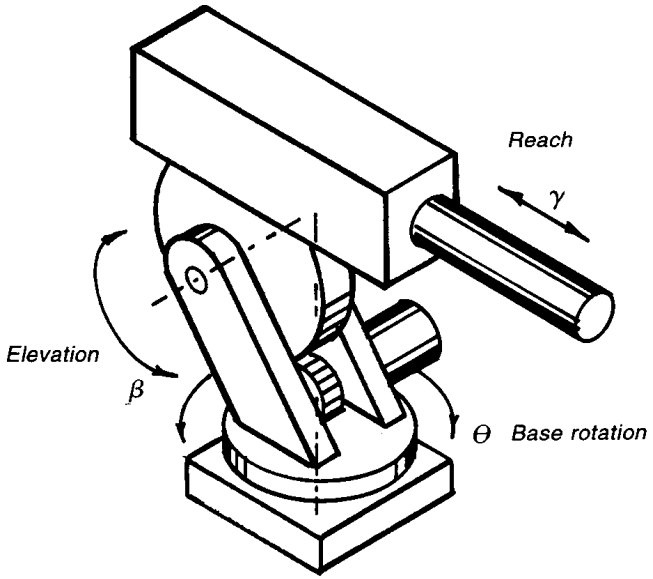
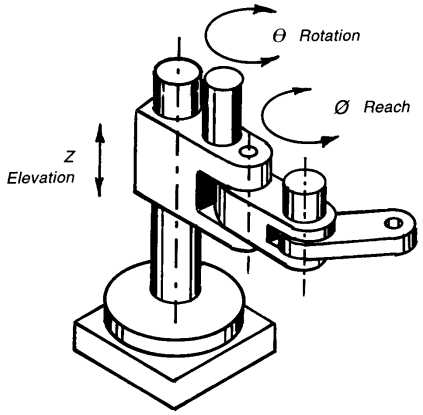
Spherical (2RP) Robot



SCARA Robot



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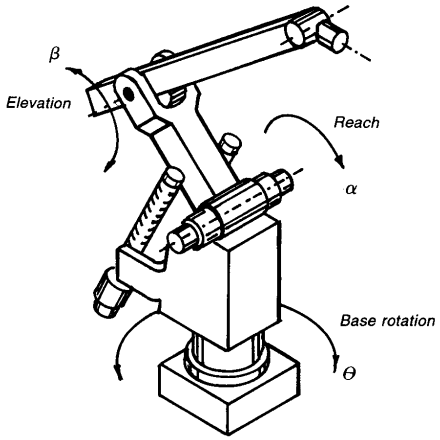
Articulated (3R) Robot



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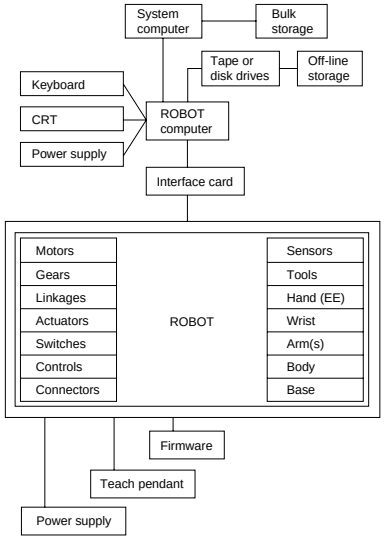
Robot Components



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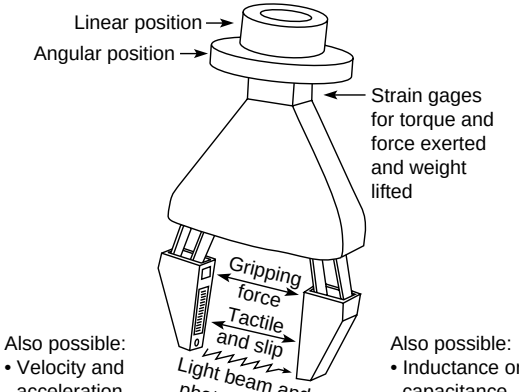
Robot Gripper



Also possible:
- Velocity and acceleration sensors
- Vision
- Sniffer
- Voice recognition
- Speech synthesis or other sounds

Also possible:
- Inductance or capacitance proximity sensor
- Radar or sonar distance ranging sensors

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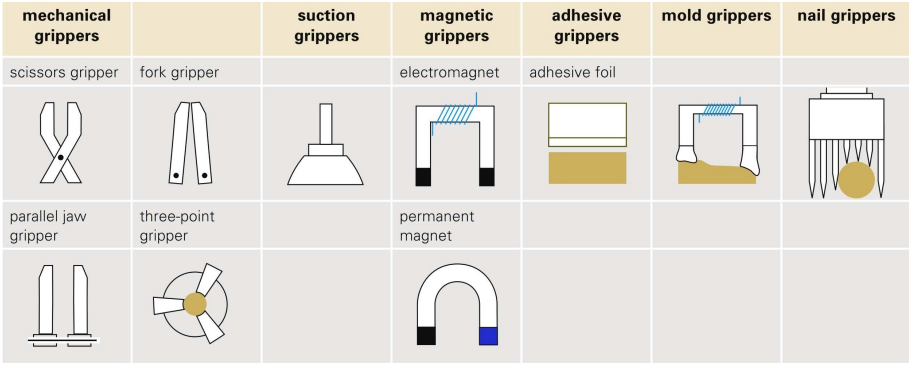

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- **Mechanical grippers:-** consisting of two or more fingers that can be actuated by the robot controller to open and close to grasp the work-piece.
- **Vacuum grippers:-** such cups are used to hold flat objects.
- **Magnetized devices:-** for holding ferrous work-pieces.
- **Adhesive devices:-** where adhesive substances are used to hold flexible materials like fabric.
- **Simple mechanical devices:-** such as hooks and scoops.

Robot Drives

	pneumatic	hydraulic	electric
translatory drive movement with limited travel	pneumatic cylinder	hydraulic czylinder	electromotor
translatory drive movement with unlimited travel			linear motor
rotary drive movement with limited rotary angle	swivel/rotary cylinder	swivel/rotary cylinder	
rotary drive movement with unlimited rotary angle	air-pressure motor	hydromotor	stepping motor DC motor AC motor

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1. **Pneumatic drive:-** pressurized air is supplied through lines to cylinders, causing air pressure to be transformed into mechanical work.
2. **Hydraulic drive:** pressurized fluid entering into cylinders causes the cylinder to extend or retract.
3. **Electric drive:-** electric drive systems either use AC or DC electric motors. Motors are connected to the manipulator's axes through gear reduction mechanisms to develop necessary torque for the robot to lift heavy payloads.

Robot Sensors

tactile	non-tactile		
force/torque	**video-visual**	**ultrasonic**	**other**
• multicomponent force/ torque sensor • gripping force measure • active wing/blade gripper • RCC • IRCC	• linear sensor • image processing (binary, gray scale value) • 3 D stereo imageprocess-ing • image processing with active illumination	• proximity switch • sonic barrier • distance measuring • scanner • acoustic correlation sensor	• microwave • pneumatic • radioactive • chemical
tactile	**visual**	**inductive, capacitive, magnetic and piezoelectric**	
• switch • distance measuring • touch line • touch matrix • flat-top switch • slip sensor	• light barriers • reflection light master • distance measuring • 2 D scanner • 3 D scanner • light stripe sensor • visual correlation sensor	• proximity switch • distance measuring • welding seam tracking • vibration analysis	

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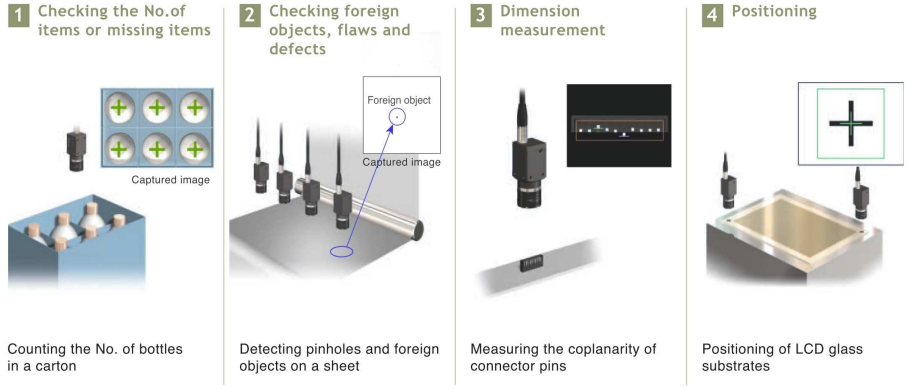
Robot Programming Modes

1. **Physical setup:-** an operator sets up switches and hard stops that control the motion.
2. **Lead through or teach mode:-** the robot's joints are moved with a teach pendant.
3. **Continuous walk-through mode:-** all robot joints are moved simultaneously, while the motion is continuously sampled and recored by the controller.During playback, the recorded motion is executed.
4. **Software mode:-** a program is written off-line/on-line and is executed by the controller to control the motion.

Robot Specifications

- **Payload**: the weight a robot can carry and still remain within it other specifications.
- **Reach**: the maximum distance a robot can reach within work envelope.
- **Precision**: how accurately a specified point can be reached.
- **Repeatability**: how accurately the same position can be reached if the motion is repeated many times.

Machine Vision Applications



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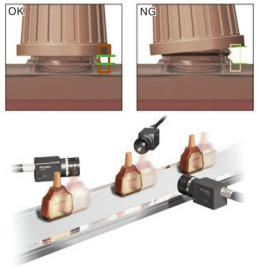
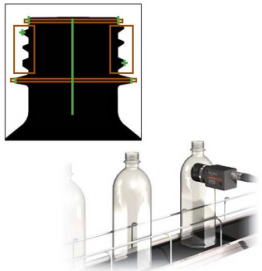
Machine Vision Applications

Typical examples of inspection using edge detection



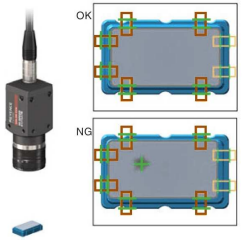
The edge width tool is used to check the clearance between the cap and the bottle. For a more accurate measurement, the clearance is detected from three directions simultaneously.

Measuring the dimensions of bottle mouths



The dimensions of PET bottles are inspected to prevent the shipping of defective products. A vision system can replace sampling methods of inspection and increase efficiency.

Checking for misaligned crystal oscillators



The edge width tool can be used to check for the misalignment of lids on crystal oscillators. By setting up several measurement windows the difference between edges is clearly detected.

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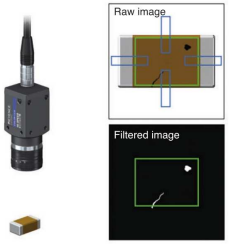
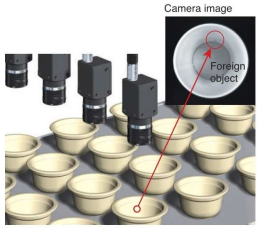
Flaw inspection of a chip capacitor



Stable inspection of minute flaws is necessary because the workpieces are small and production output is large.

Detecting dirt / foreign objects inside of a cup



Flexibility is necessary to simultaneously inspect multiple locations with varying surface conditions such as the bottom and inner sides.

Inspecting dirt / foreign objects on a sheet or film

High processing speed is required to inspect fast-moving workpieces without omission.

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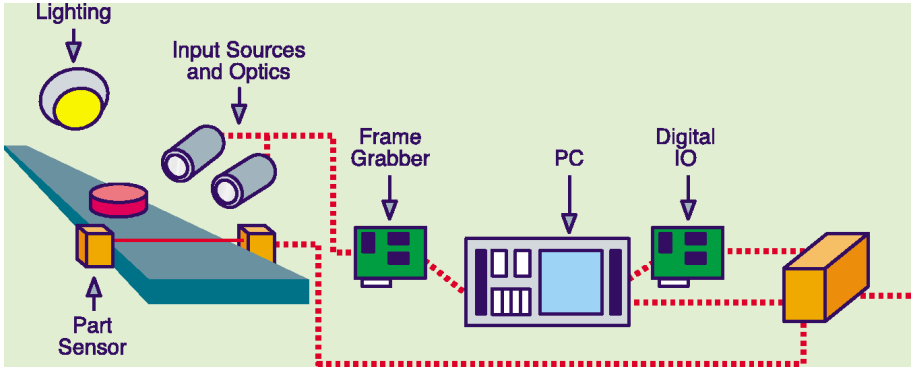
Machine Vision: Key Components



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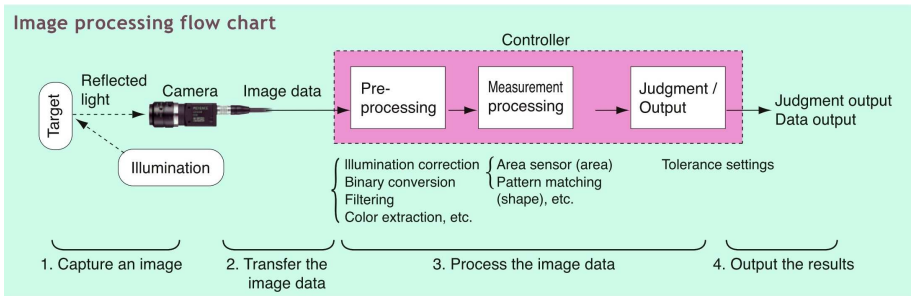

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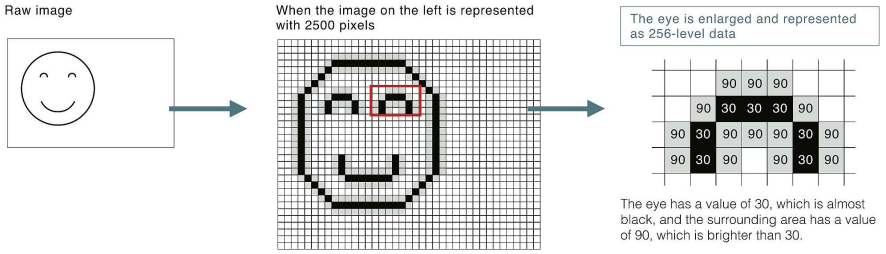

As in the example above, image data is represented with values between 0 and 255 levels per pixel. Image processing is processing that finds features on an image by calculating the numerical data per pixel with a variety of calculation methods as shown below.

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Machine Vision: Key Components

1. **Front-end optics:-** includes the camera, lens and the lighting.
2. **Frame grabber:-** or video capture card, interfaces the imaging units to the host computer. It takes the image data provided by the camera(s) in either analog or digital form and convert it for use by the host computer.
3. **Computer and software:-** A computer forms a necessary part of the machine vision system. Softwares processes the incoming image data and makes decisions such as pass or fail.

Machine Vision: Process steps

1. **Image acquisition:-** system gathers images to be converted into digital format and placed into computer memory.
2. **Image processing:-** various algorithms are used to enhance elements of the image that are of specific importance to the process.
3. **Feature extraction:-** processor identifies and quantifies critical features in the image and sends data to control programs.
4. **Decision and control:-** control program make decision based upon the data. Are the holes within specifications? Is a pin missing? How must a robot move to pick up the component?