SKEM4153
ROBOT TECHNOLOGY FOR AUTOMATION

CHAPTER 6
Work Cell Support Systems

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1. Machine Vision
2. Material Handling
3. Part Feeding
4. Inspection
5. Automated Tracking

MACHINE VISION

- Vision is the most powerful robot sensory capabilities. Enables a robot to have a sophisticated sensing mechanism that allows it to respond to its environment in intelligent and flexible manner. Therefore machine vision is the most complex sensor type.
- Robot vision may be defined as the process of extracting, characterizing, and interpreting information from images of a three-dimensional world. This process, also known as machine or computer vision may be subdivided into six principle areas. These are:

1. **Sensing** : the process that yields visual image
2. **Preprocessing** : deals with techniques such as noise reduction and enhancement of details
3. **Segmentation** : the process that partitions an image into objects of interest
4. **Description**: deals with that computation of features for example size or shape, suitable for differentiating one type of objects from another.
5. **Recognition:** the process that identifies these objects (for example wrench, bolt, engine block, etc.)
6. **Interpretation**: assigns meaning to an ensemble of recognized objects.

1. Machine Vision Systems

Used for the following tasks:

- **Part identification** – vision systems store data for different parts in active memory and use the data to distinguish between parts as they enter the work cell. The system can learn the characteristics of different parts and identify each part from its two-dimensional silhouette.

1. Machine Vision Systems

Used for the following tasks:

- Part location – use can locate randomly placed parts on an X-Y grid. Vision system measures the X and Y distances from the centre of the camera coordinate system to the centre of the randomly placed part.

1. Machine Vision Systems

Used for the following tasks:

- Part orientation – Vision system supplied the orientation information and data that are used to drive the gripper into the correct orientation for part pickup.

1. Machine Vision Systems

Used for the following tasks:

- **Part inspection** – Vision system is used to check parts for dimensional accuracy (e.g. diameter), geometrical integrity (e.g. number of holes). Vision system also checks for any missing features or changes in part geometry.

1. Machine Vision Systems

Used for the following tasks:

- **Range finding** – Systems with two or more cameras can be used to measure the X, Y, and Z location of parts. Can also be used to calculate the cross-sectional area of parts.

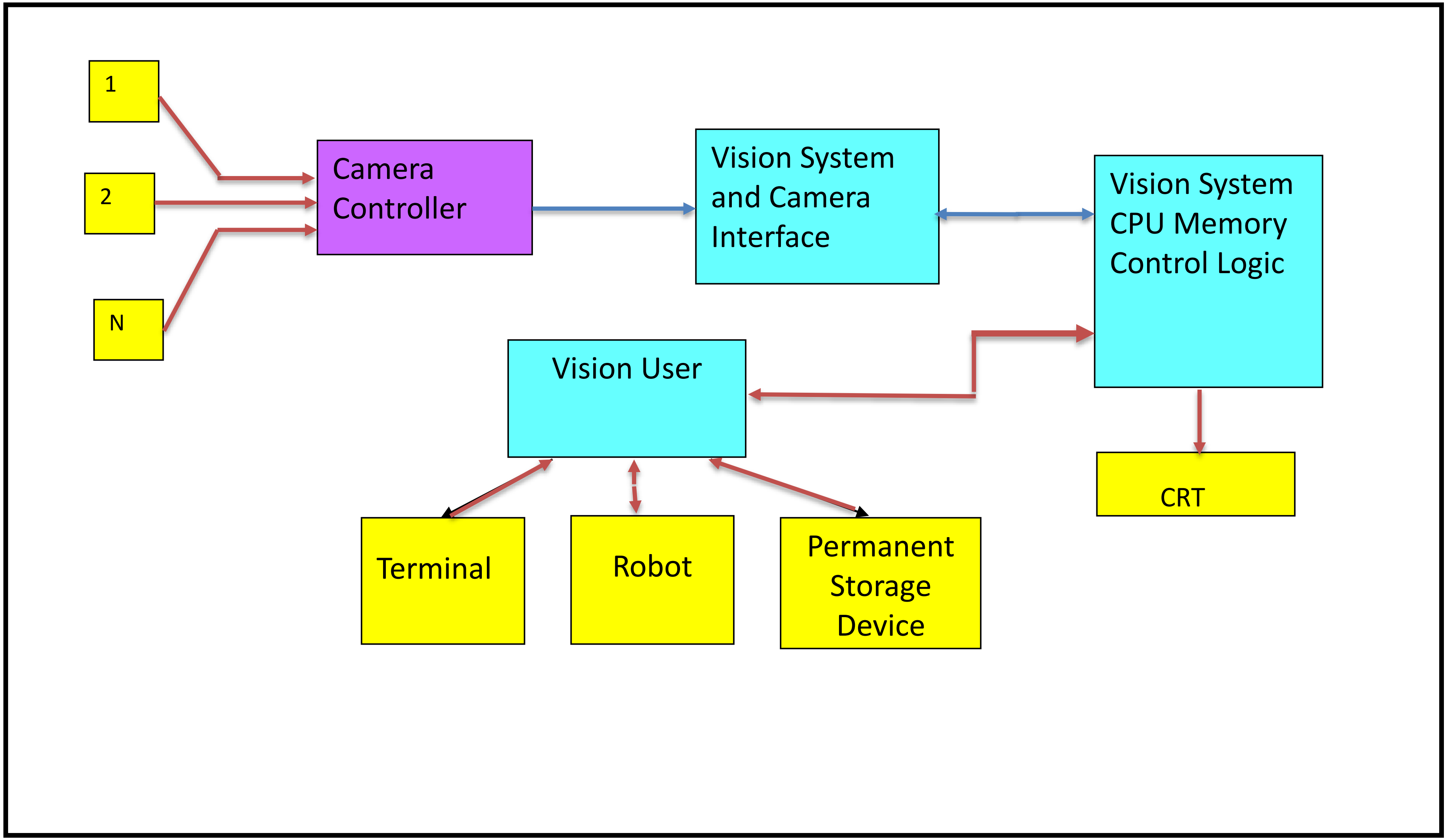
1. Machine Vision Systems

Vision system components

Three architectures to implement vision technology:

- **Stand-alone vision system (self-contained)** Vision system does not use resources from any other work cell hardware. Information is passed to the work cell robot via a serial interface.

Stand-alone vision system (self-contained)

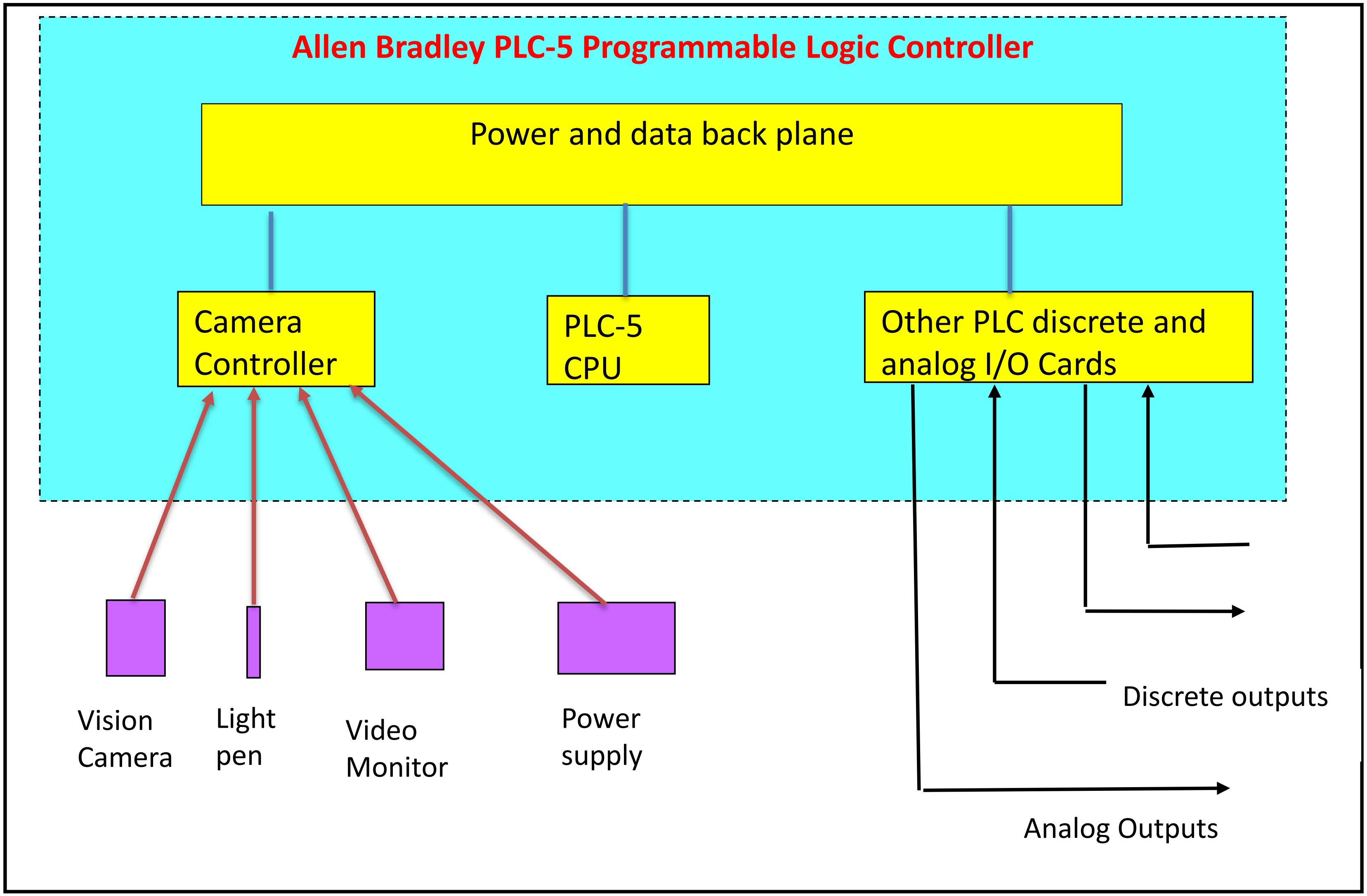


Vision system components

Three architectures to implement vision technology:

- Vision system integrated into work cell PLC – Vision system is integrated into the work cell PLC. Vision data and PLC control data is on the same bus – the back plane within the PLC.

Vision system integrated into work cell PLC

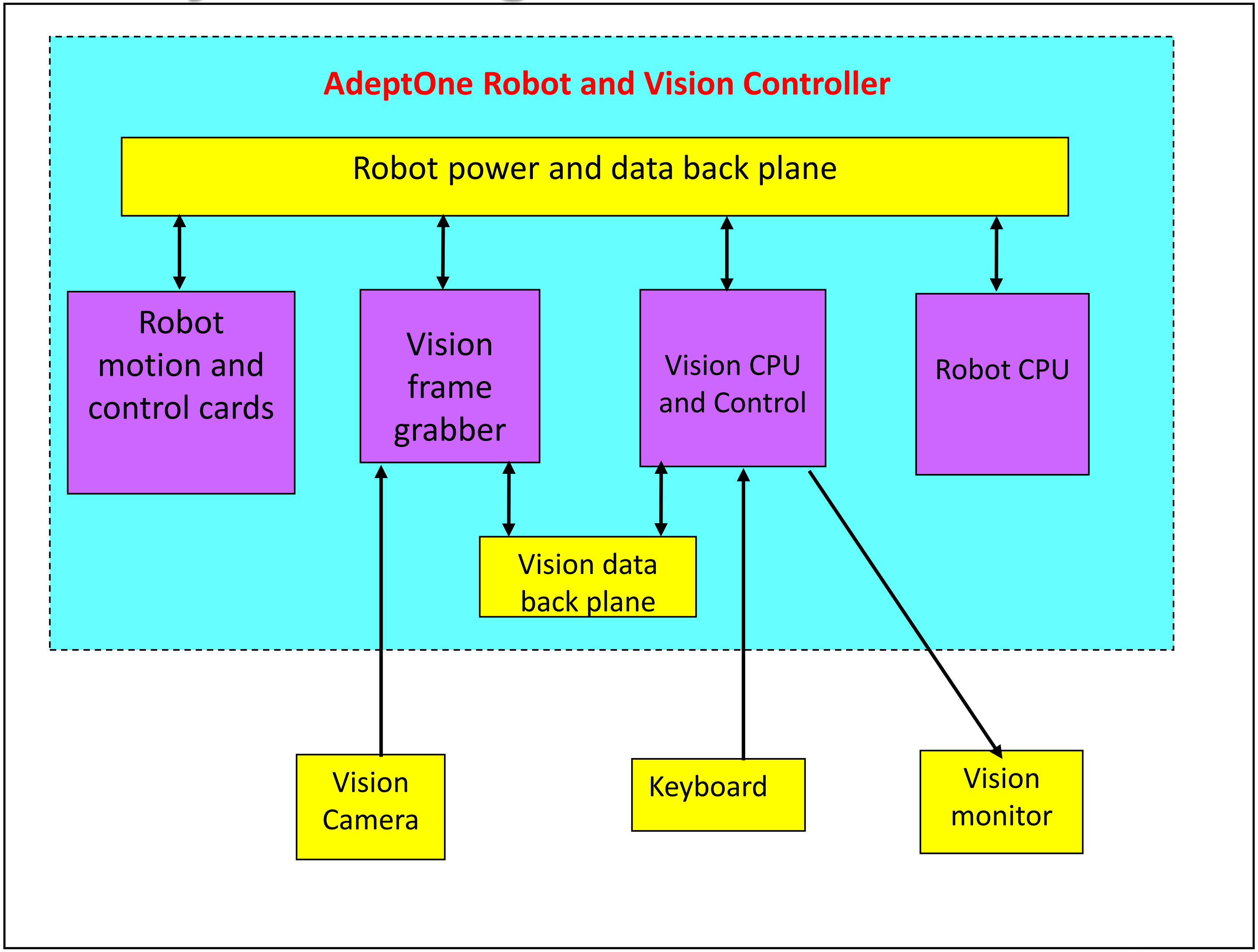


Vision system components

Three architectures to implement vision technology:

- **Vision system integrated with robot controller** – Vision system has a separate back plane for exchanging vision data between the electronic cards. This is used in Adept Technology Vision system. (Better response time due to changes in work cell and reduced cost since fewer interfaces and less complex electronics are used).

Vision system integrated with robot controller



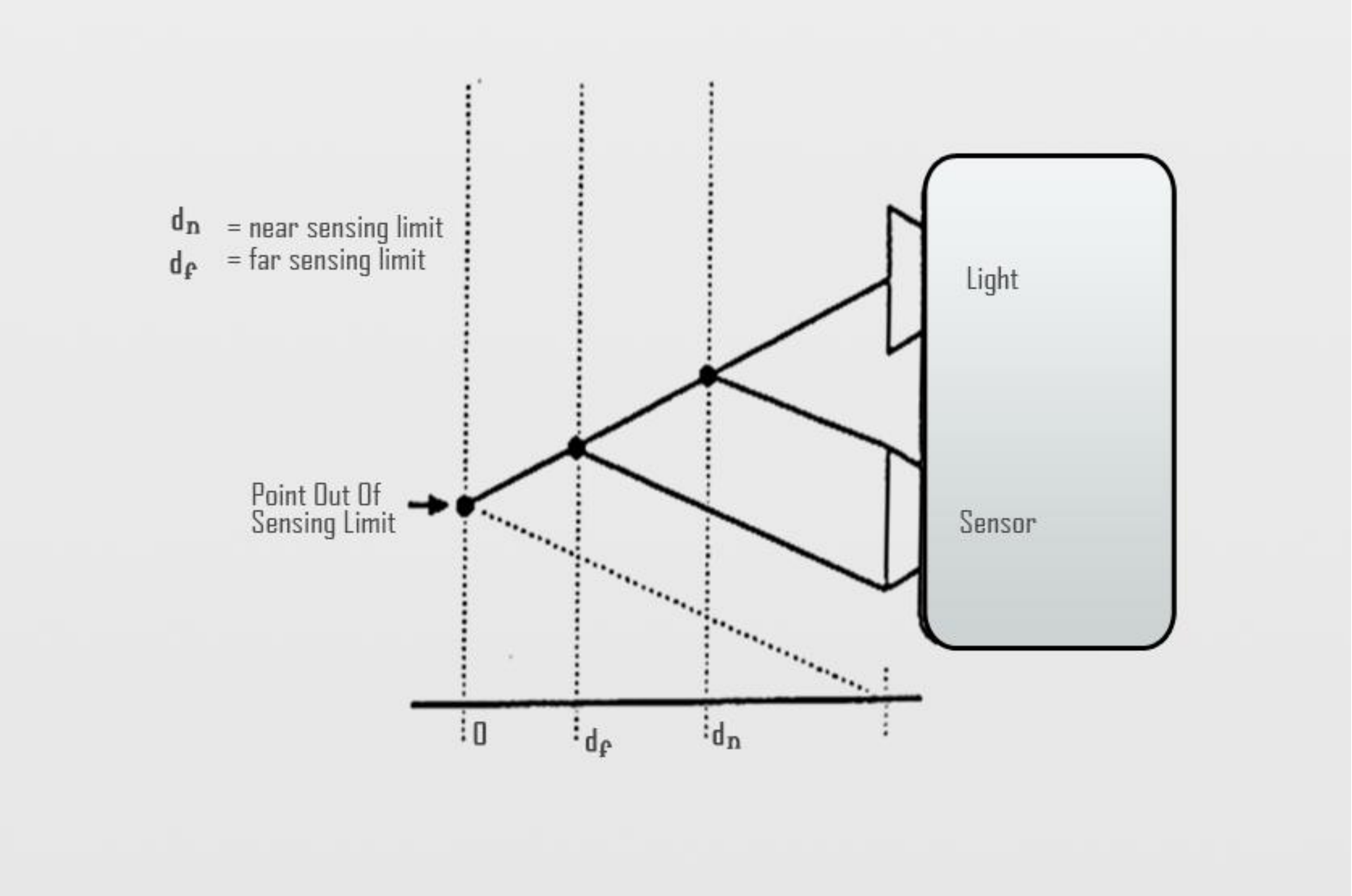
IMAGING COMPONENTS

The imaging component, the "eye" or sensor, is the first link in the vision chain. Numerous sensors may be used to observe the world. There are four type of vision sensors or imaging components:

1. Point sensors

Capable of measuring light only at a single point in space. These sensors are used coupled with a light source (such as LED) and used as a noncontact 'feeler'

It also may be used to create higher – dimensions set of vision information by scanning across a field of view by using mechanisms such as orthogonal set of scanning mirrors.



Noncontact feeler-point sensor

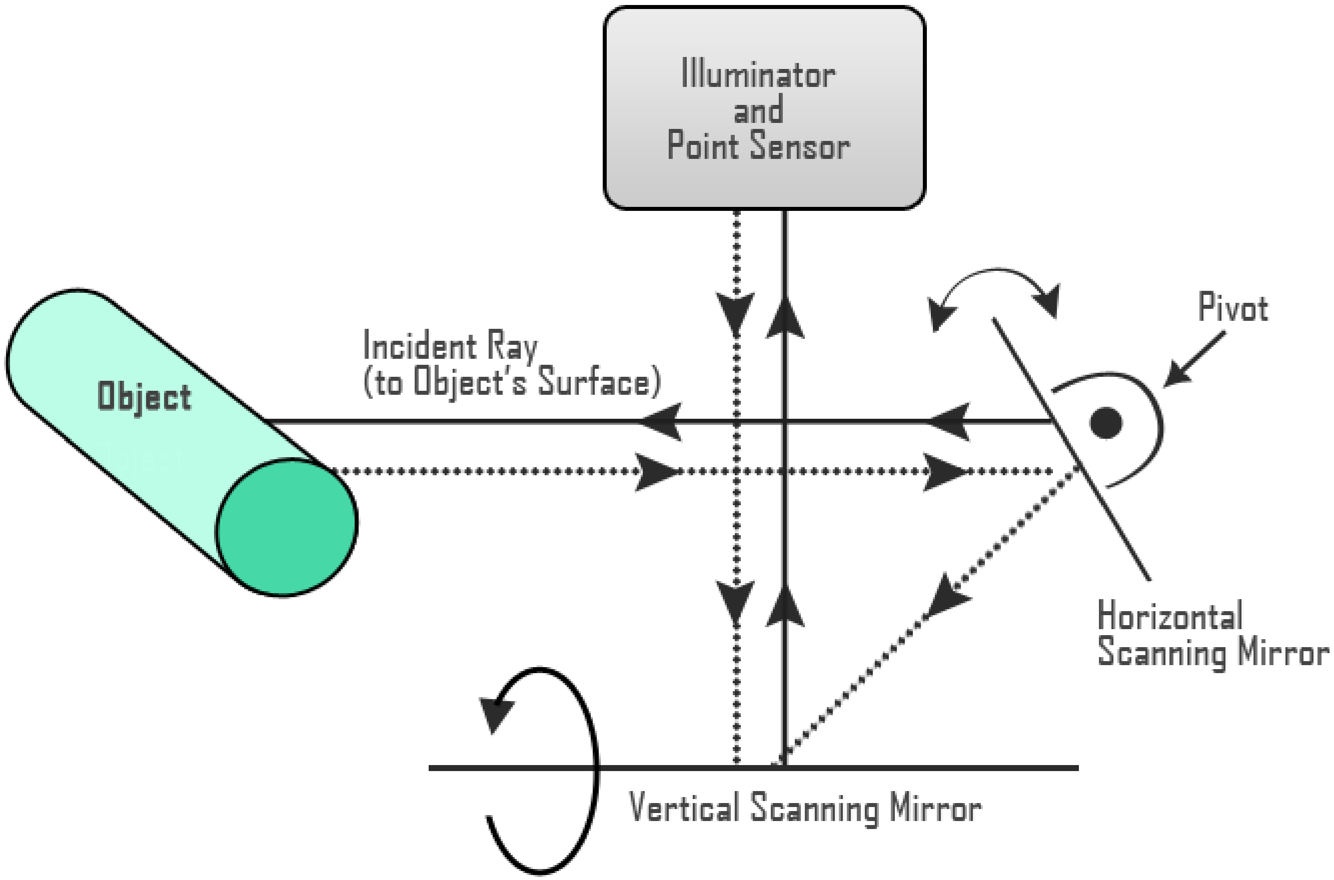
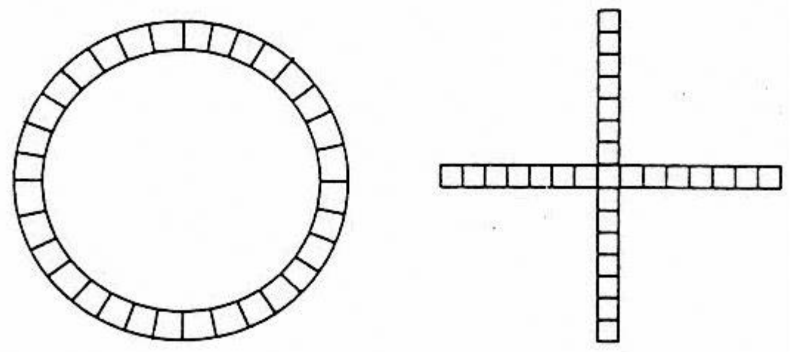


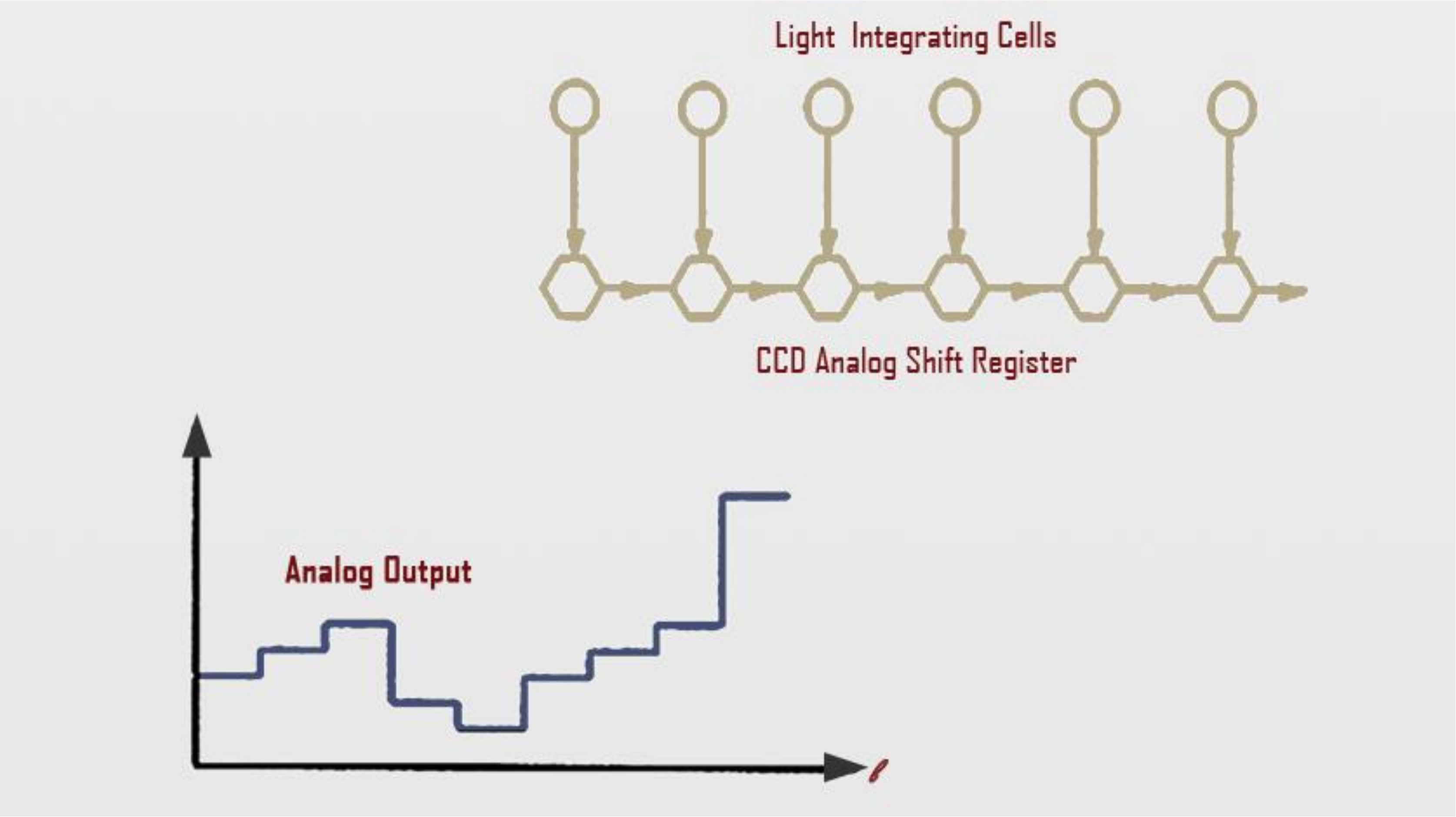
Image scanning using a point sensor and oscillating deflecting mirrors

2. Line Sensor

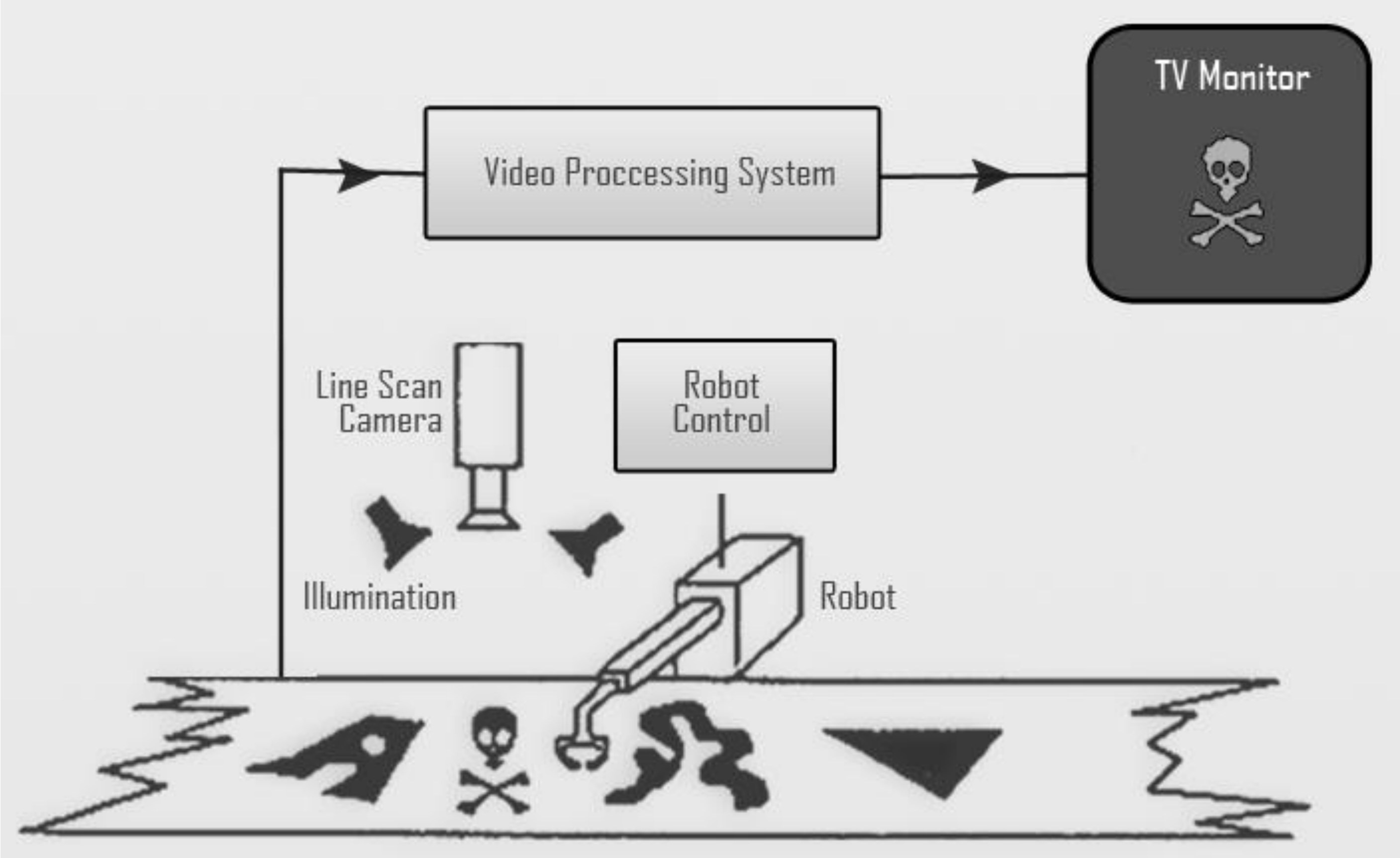
- Line sensors are one-dimensional devices used to collect vision information from a real scene in the real world.
- The sensor most frequently used is a “line array” of photodiodes or charger-couple-device components.
- It operates in a similar manner to analog shift register, producing sequential, synchronized output of electrical signals, corresponding to the light intensity falling on an integrated light-collecting cell.



Circular and cross configurations of light sensors



Schematic representation of line scanning arrays



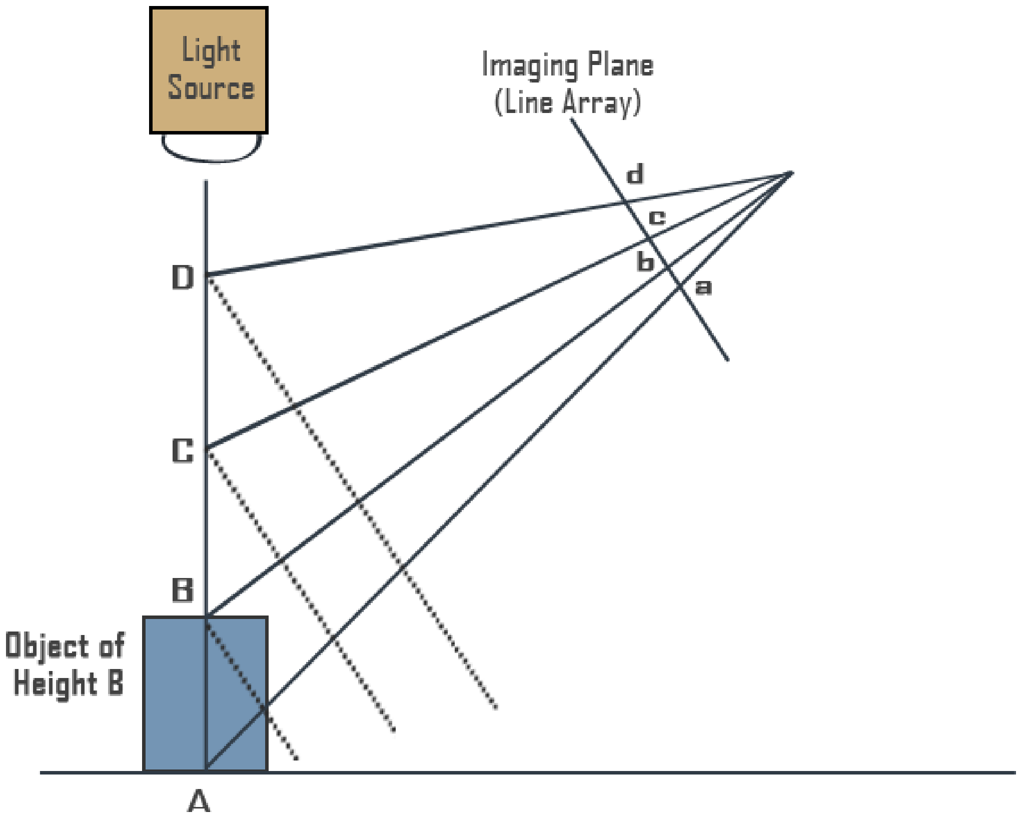
- Line array may be used to image scene. E.g. by fixing the position of a straight-line sensor and moving an object orthogonally to the orientation of the array, one may scan the entire object of interest.

3. Planar Sensor

- A two dimensional configuration of the line-scan concept. Two generic types of these sensors generally in use today are scanning photomultipliers and solid-state sensors.
- Photomultipliers are represented by television cameras, the most common of which is the vidicon tube, which essentially an optical-to-electrical signal converter.
- In addition to vidicon tubes, several types of solid-state cameras are available. Many applications require the solid-state sensors because of weight and noise factor (solid-state arrays are less noisy but more expensive). This is important when mounting a camera near or on the end-effector of a robot.

4. Volume Sensor

- A sensor that provide three-dimensional information. The sensor may obtain the information by using the directional laser or acoustic range finders.



Schematic representation of a triangulation range finder

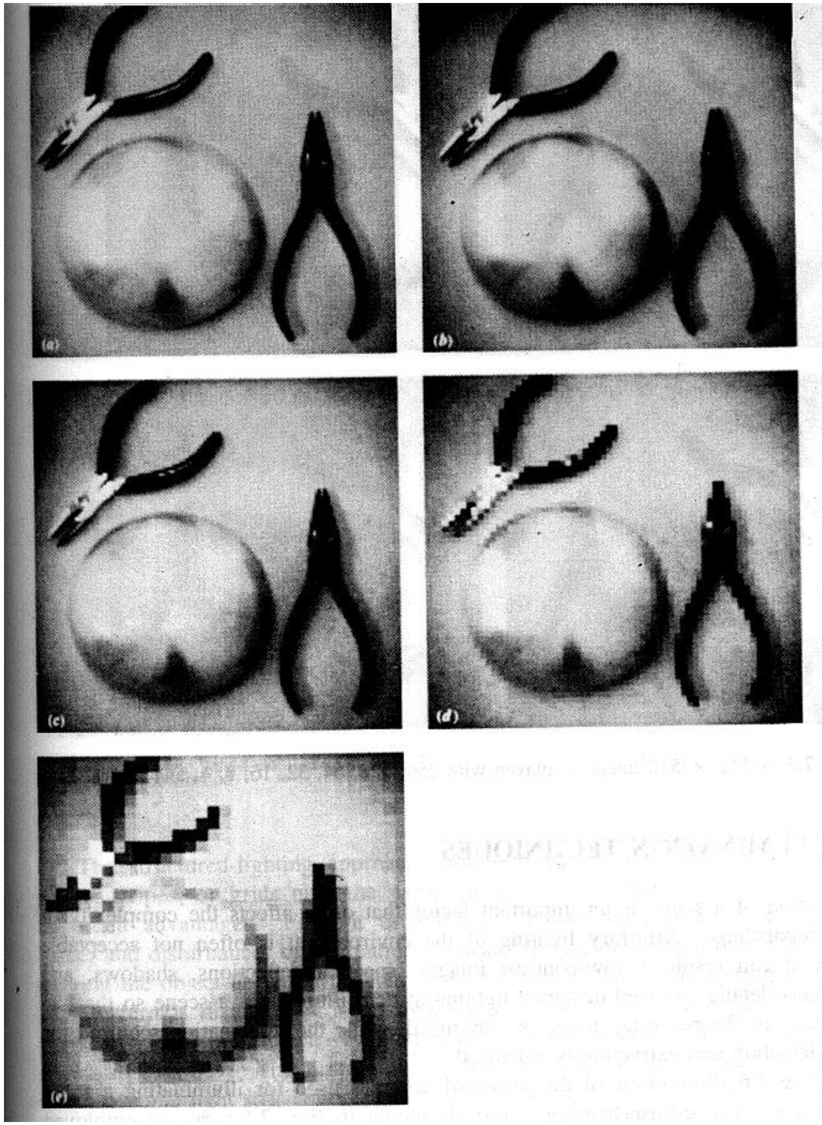
Image Measurement

Digitised image

- Spatial coordinates – sampling of image, picture element (pixel)
  - CCD with 256x256 array of pixels has higher resolution than 128x128
- Intensity/brightness – quantisation of image (gray levels)
  - Each pixel with no light is turned OFF
  - Pixels with a saturation level, is ON
  - In between On and OFF there are gray levels from 4 to 256

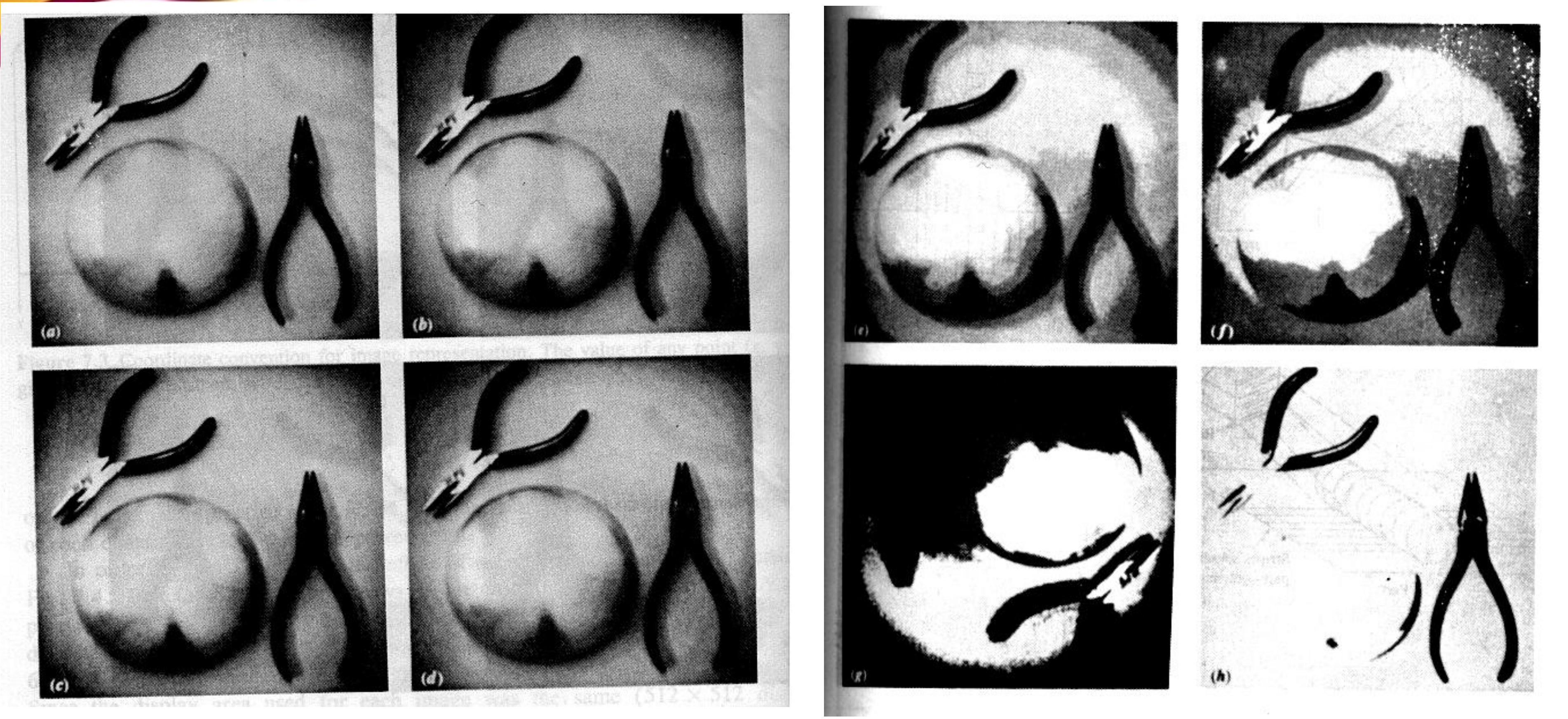
IMAGE REPRESENTATION

- From the diagram below. F(x,y) is used to denote the two-dimensional image out of a television camera or other imaging device.
- "x" and "y" denote the spatial coordinates (image plane)
- "f" at any point (x,y) is proportional to the brightness (intensity) of the image at that point.
- In form suitable for computer processing, an image function f(x,y) must be digitized both spatially and in amplitude (intensity). Digitization of the spatial coordinates (x,y) will be known as image sampling, while amplitude digitization is known as intensity or grey-level quantization.
- The array of (N, M) rows and columns, where each sample is sampled uniformly, and also quantized in intensity is known as a digital image. Each element in the array is called image element, picture element (or pixel).



Effects of reducing sampling grid size.

a) 512x512.
b) 256x256.
c) 128x128.
d) 64x64.
e) 32x32.



Effect produced by reducing the number of intensity levels while maintaining the spatial resolution constant at 512x512. The 256-, 128- and 64-levels are of acceptable quality. a) 256, b) 128, c) 64, d) 32, e) 16, f) 8, g) 4, and h) 2 levels

ILLUMINATION TECHNIQUES

- Illumination of a scene is an important factor that often affects the complexity of vision algorithms.
- A well designed lighting system illuminates a scene so that the complexity of the resulting image is minimised, while the information required for object detection and extraction is enhanced.
- Arbitrary lighting of the environment is often not acceptable because it can result in low contras images, specular reflections, shadows and extraneous details.
- There are 4 main illumination techniques for a robot work space :

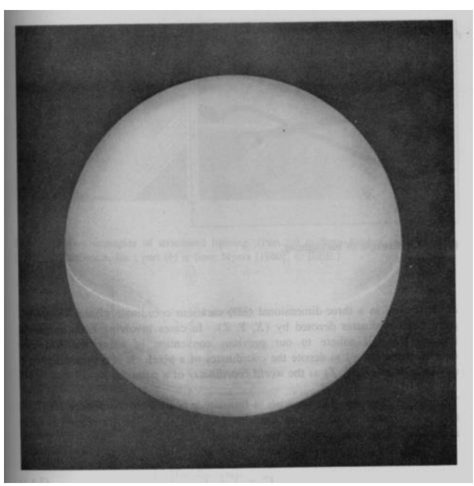
Lighting Techniques

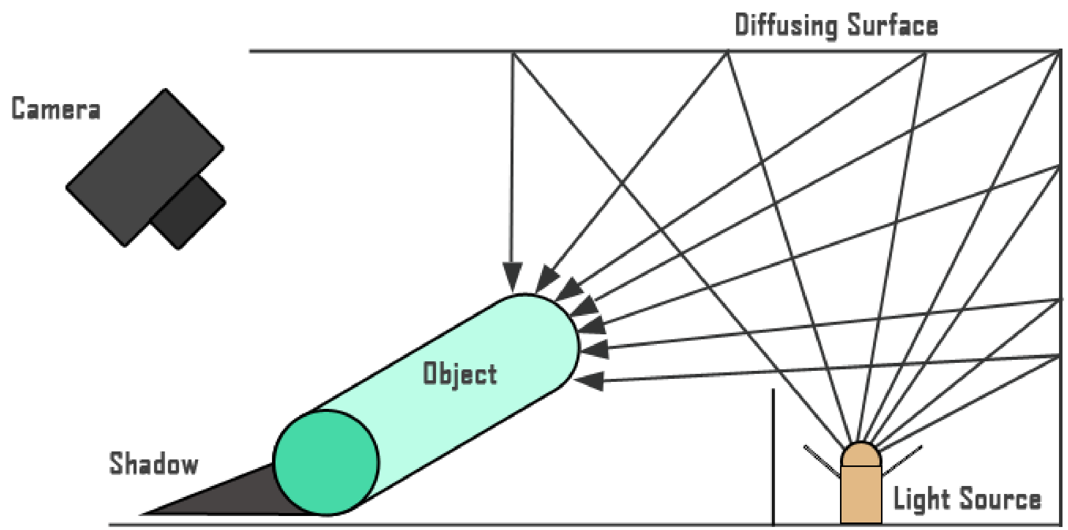
- Diffused lighting
- Backlighting
- Structured lighting
- Directional lighting

ILLUMINATION TECHNIQUES

1. DIFFUSE-LIGHTING

- This technique is for smooth, regular surface object. It is used where surface characteristic are important.
- Example:





Diffuse-lighting technique

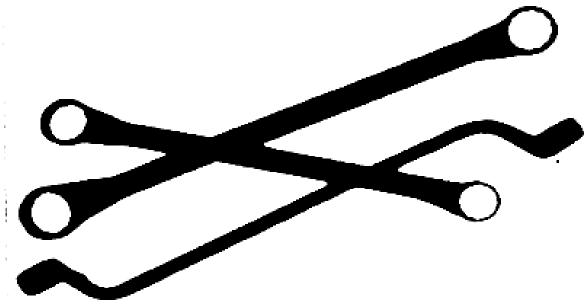
Advantages of Diffused lighting

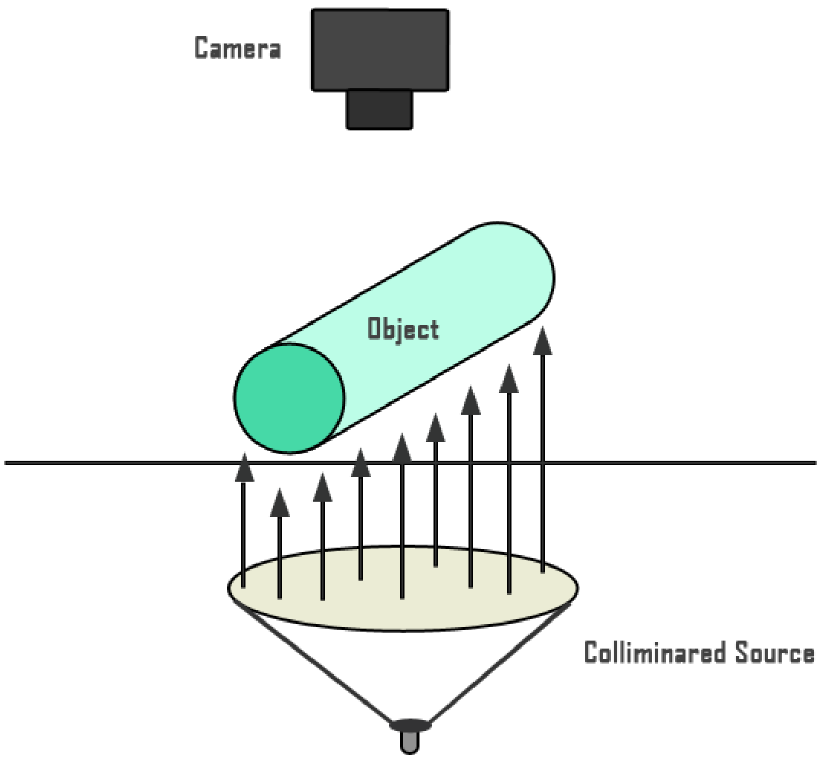
- Can capture details on surfaces
- Good for detection of features on surfaces

- However, may result in specular images (shiny reflectance)

ILLUMINATION TECHNIQUES
2. BACKLIGHTING

- Produce black and white image. This technique suited for applications in which silhouettes of object are sufficient for recognition or other measurement.
- Example:





Backlighting technique

Advantages of Back lighting

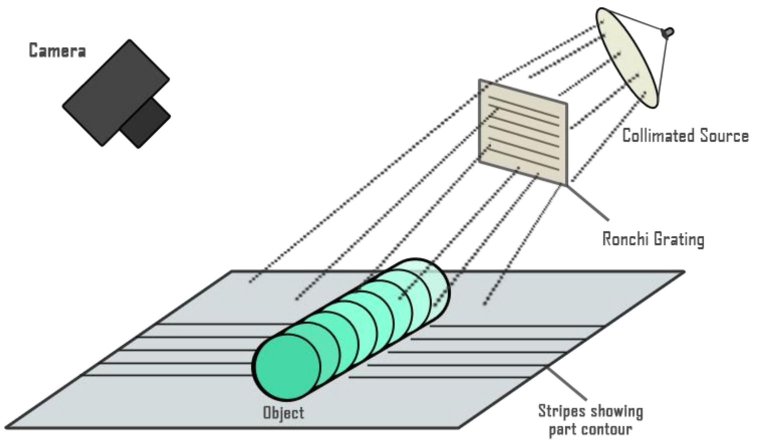
- Can capture silhouettes, outline shapes
- Will not capture details on surfaces

ILLUMINATION TECHNIQUES

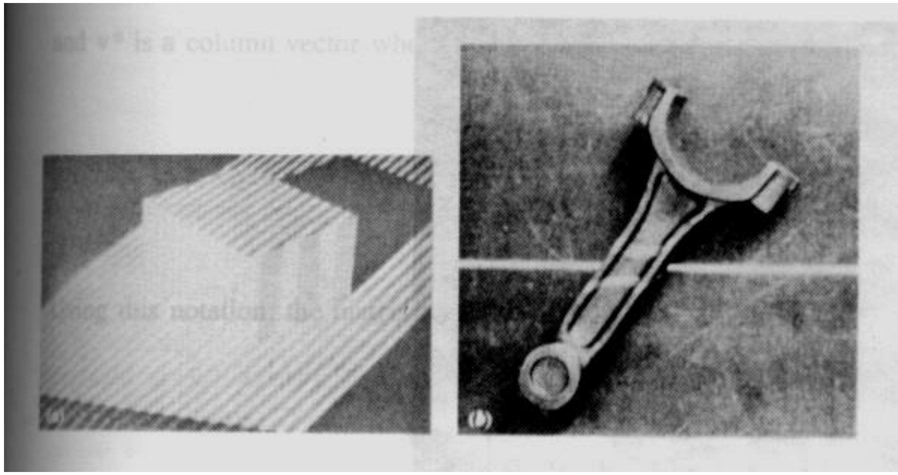
3. STRUCTURED LIGHTING

- Consist of projecting points, stripes, grids onto work surface.
- This lighting technique has 2 important advantages:

1. It establishes a known light pattern on the work space and disturbances of this indicate the presence of an object, thus simplifying the object detection problems.
2. By analysing the way which the light pattern distorted, it is possible to gain insight into three-dimensional characteristics of the object.



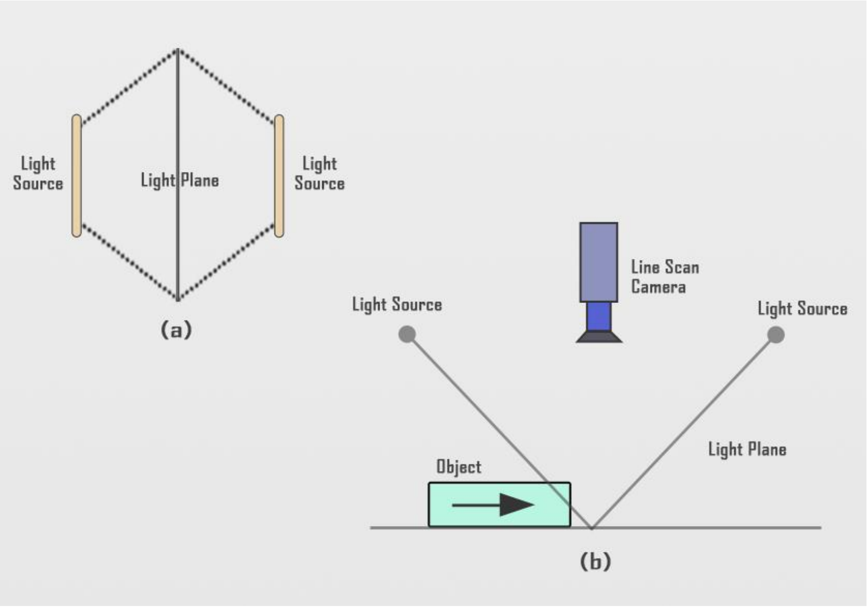
Structured lighting technique



3. STRUCTURED LIGHTING (cont.)

- The following figure illustrates the structured lighting technique using two light planes projected from different directions, but converging on a single stripe on the surface. The two light sources guarantee that the object will break the light stripe only when it is directly below the camera.
- This technique is suitable for moving object.
- Note: "The line scan camera sees only the line on which the two light planes converge, but two-dimension information can be accumulated as the object move past the camera"

(a) Top view of two light planes intersecting in a line sight



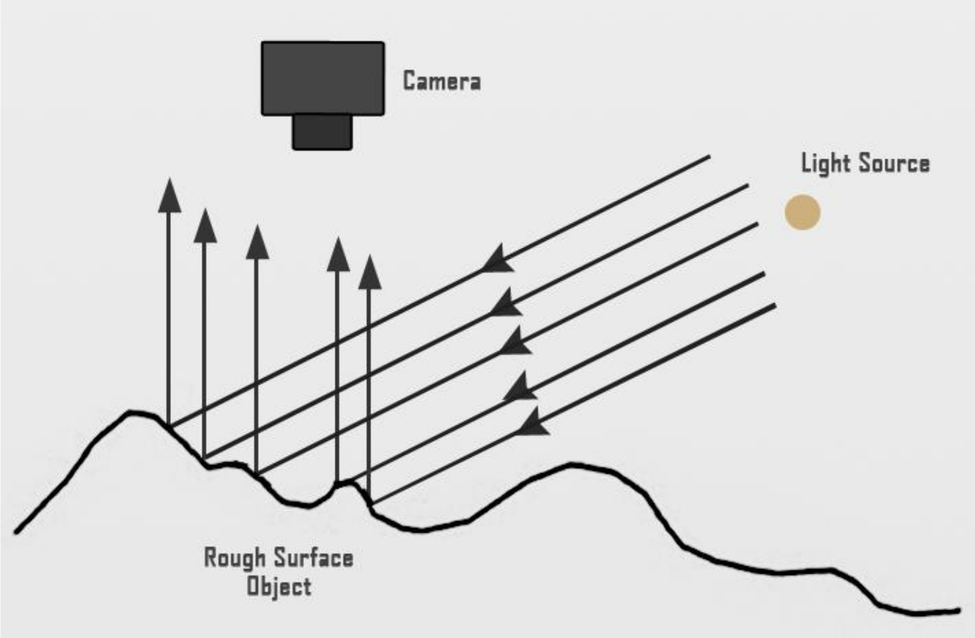
(b) Object will be seen by the camera only When it interrupts both light planes

Advantages of Structured lighting

- Can capture surface contours
- Good for detection of uncommon shapes

ILLUMINATION TECHNIQUES
4. DIRECTIONAL LIGHTING

- This method is used to inspection of object surfaces.
- Defects on the surface such as scratches, can be detected by using a highly directed light beam (such as laser beam) and measuring the amount of scatter.



Directional lighting technique

Advantages of Directional lighting

- Can capture roughness on surfaces
- Good for detection of scratches, holes, indents, faults on surfaces

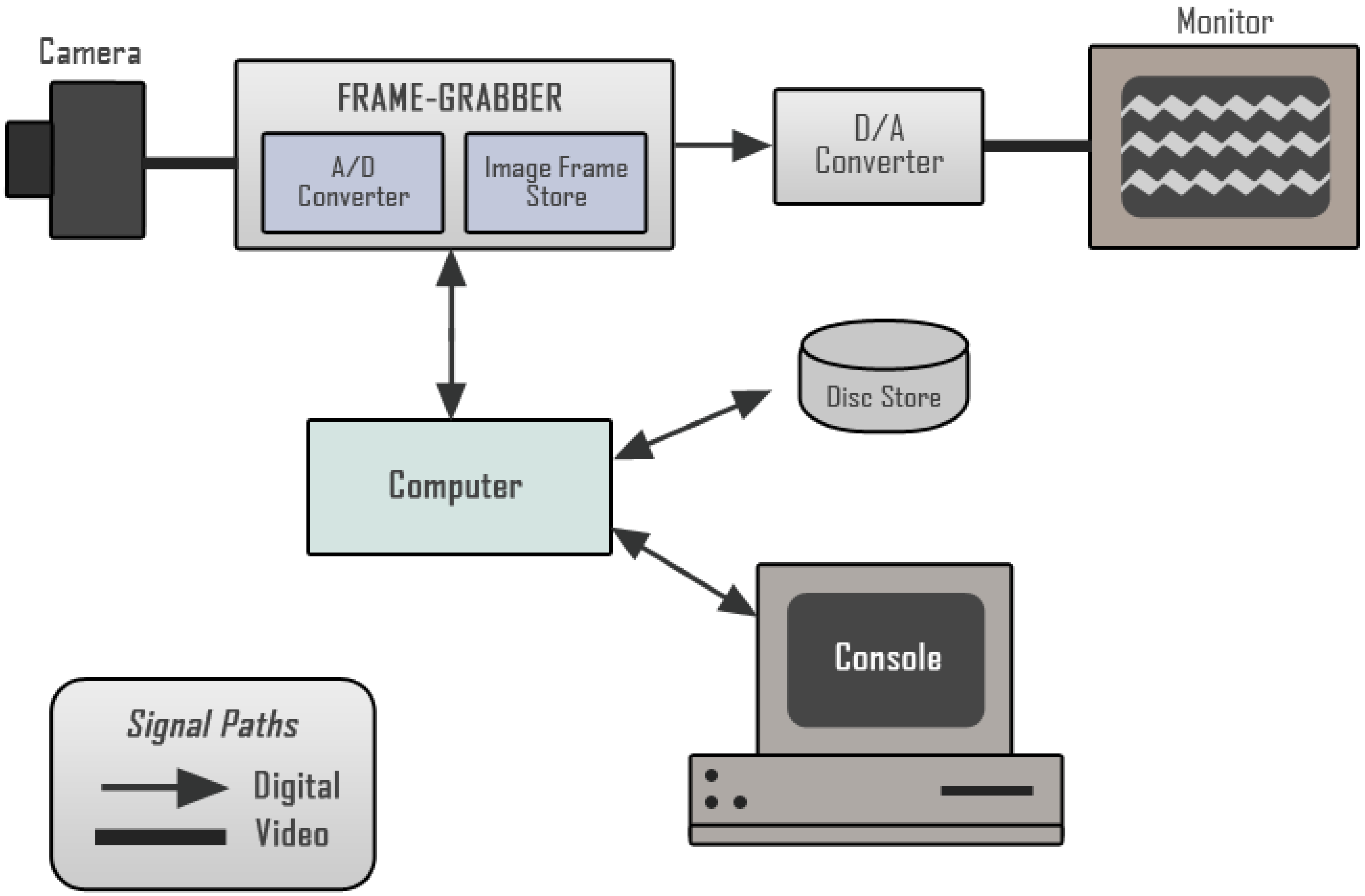
- However, may result in scattering of light

ROBOT VISION SYSTEM

- There are several commercial packages that can be bought for vision processing work. A typical hardware configuration is shown below.
- Based on the technique used, the robotic vision systems can be grouped into the following major types:

1. Binary vision systems
2. Gray-level vision systems
3. Ad hoc special-purpose vision systems
4. Structured light vision systems
5. Character recognition vision systems

ROBOT VISION SYSTEM



Vision system hardware

ROBOT VISION SYSTEM

- A typical system will have facilities for controlling the camera remotely and perhaps interfaces for remote lighting control.
- The main problem with commercial vision packages is that they have to be general purpose in order to be applicable in many situations. This very requirement sometimes means that they are not suitable or are over complicated for a particular robot task in hand.
- In industrial robot world, vision is not used in an exploratory sense but is used to confirm or measure or refine existing known data.
- Whichever commercial vision system one purchases, one is likely to use it for applications such as those listed in the next section.

Vision Dev. Tools: Survey

Commercial products

- Matrox: MIL, Inspector
- Coreco Imaging: Sapera, MVTools, WiT
- MVTec: Halcon
- Euresys: eVision, EasyAccess
- AAI: Aphlion

Free tools

- Intel: Open Source Computer Vision
- Microsoft: Vision SDK
- XMegaWave: XMegaWave
- UTHSCSA: ImageTool

VISION APPLICATIONS

1. OBJECT LOCATION

Used in object handling and processing:

-Position -Orientation

2. OBJECT PROPERTIES

Used in inspection, identification, measurement:

-Size -Area -Shape -Periphery length / area ratio -Texture -Repetition of pattern -Properties of internal features

3. SPATIAL RELATIONS

Used in measurement and task verification:

-Relative positions -Relative orientations -Occlusions -Alignments –Connectivity

4. ACTION MONITORING

Used in actuator control and verification:

-Direct feedback -Error measurement -Action confirmation -Inspection -Collision avoidance planning.

Image Analysis

Techniques of finding objects

- Edge detection
  - Based on sharp difference in brightness between object and its background.
  - A threshold level is set to indicate change in the neighbourhood
- Clustering or region growing
  - Find the adjacent pixels with similar properties, until a boundary is found.
  - Pixel data are changed to binary and stored, and hence object shape is determined.

Image Recognition or Identification

Recognition strategies

- Template matching
  - Captured images are compared with stored templates. If matching, object is identified. Disoriented images, scaled down, scaled up may cause difficulties. But introduction of robust and intelligent template matching solves the problem.
- Edge and region statistics
  - Defines significant features of parts.
  - Features are then evaluated by common features e.g. centre of area, major axis, minor axis, number of holes, angular relationships, perimeter squared divided by the area, surface texture.
- Statistical matching
  - Statistical data of parts to be identified are stored in memory, when camera captures an unknown part the system calculates a set of feature values from the pixel data. A comparison is made, and if a close match is found, the part is recognised.

Lighting for Machine Vision

- Selection for lighting
- Lighting techniques
- Illumination sources

Selection of the Light Source

- The analysis of captured images needs high contrast between part features and the background of the captured data.
- Lighting systems must minimise the effects of natural light, and radiation from process sources.
- Selection is driven by three factors:
  - Type of features that must be captured
  - Part moving or stationary when image is made
  - Degree of visibility of the environment

Illumination Sources

- Incandescent bulbs
- Flourescent tubes
- Xenon flash tubes
- Lasers

Illumination Sources

- Incandescent bulbs
  - Most commonly used. From household bulbs with reflectors to high-power quartz halogen lamps.
  - Fibre-optic bundles used to pipe light onto specific locations on the part.
  - Need to consider bulb life and removal of heat generated by the bulb.
- Fluorescent tubes
  - More efficient than incandescent bulb (reduced infrared energy, extended life)
  - Natural diffused light, preferred for highly reflective parts

Illumination Sources

- LEDs
- Xenon flash tubes
  - Used as strobing light source.
  - Applied in capturing image of moving parts.
- Lasers
  - Coherent light. Does not disperse as it travels from source to the target. Diameter at the target is almost of same size as at the source.
  - Good for structured light applications

Illumination Sources

- The selection and design of the light source is a critical part of the vision application.
- A successful vision application must put an equal emphasis on part lighting and selection of image-capture hardware and software.

Vision Application Example

Quality Inspection for Semiconductor Industry (ICs)

- Pre/Post Die
- Lead Frame
- Package
- Symbol
- Marking

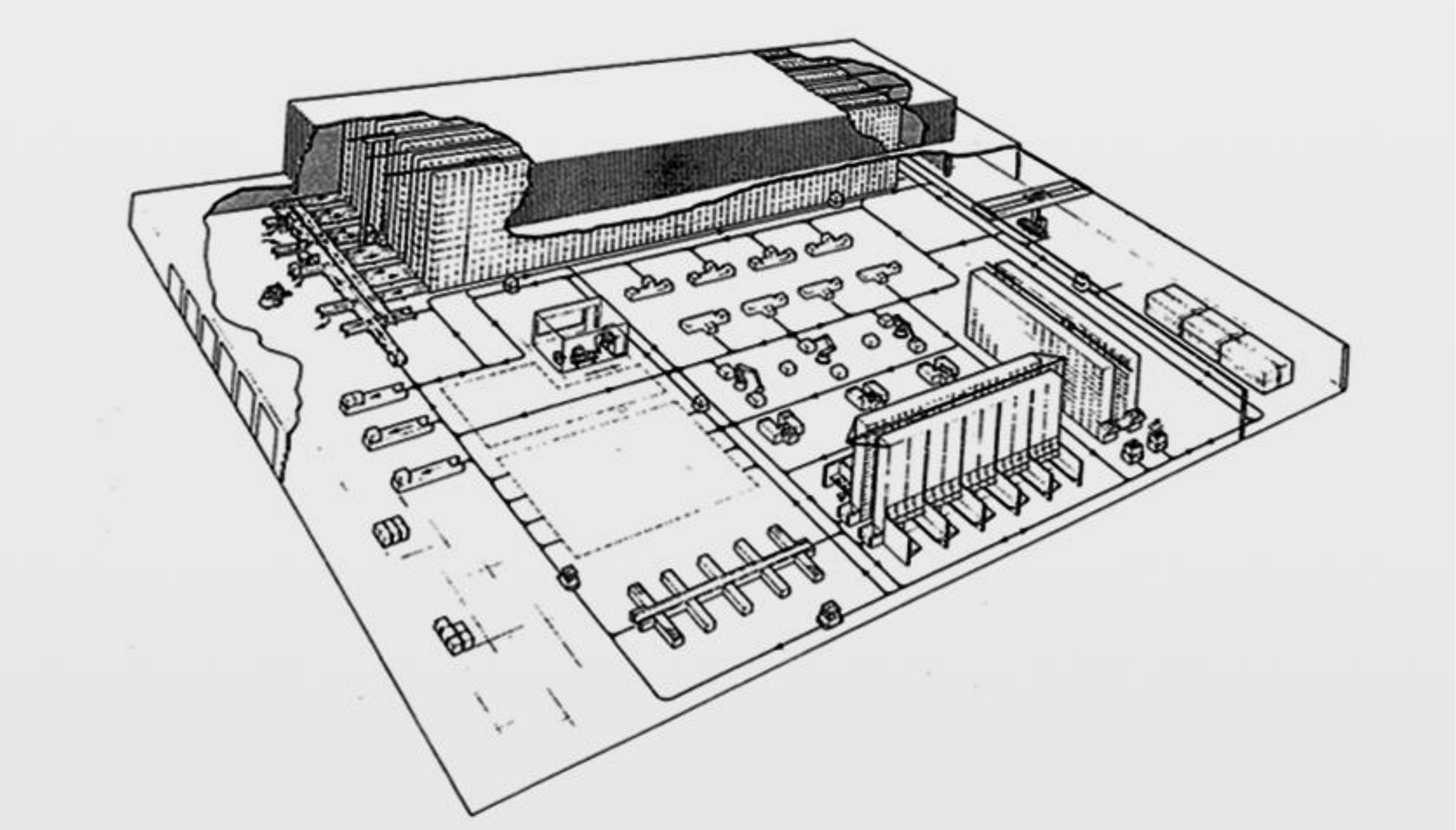
2. Material Handling

- Automated Transfer Systems
- Automatic Storage and Retrieval Systems

Automated Transfer Systems

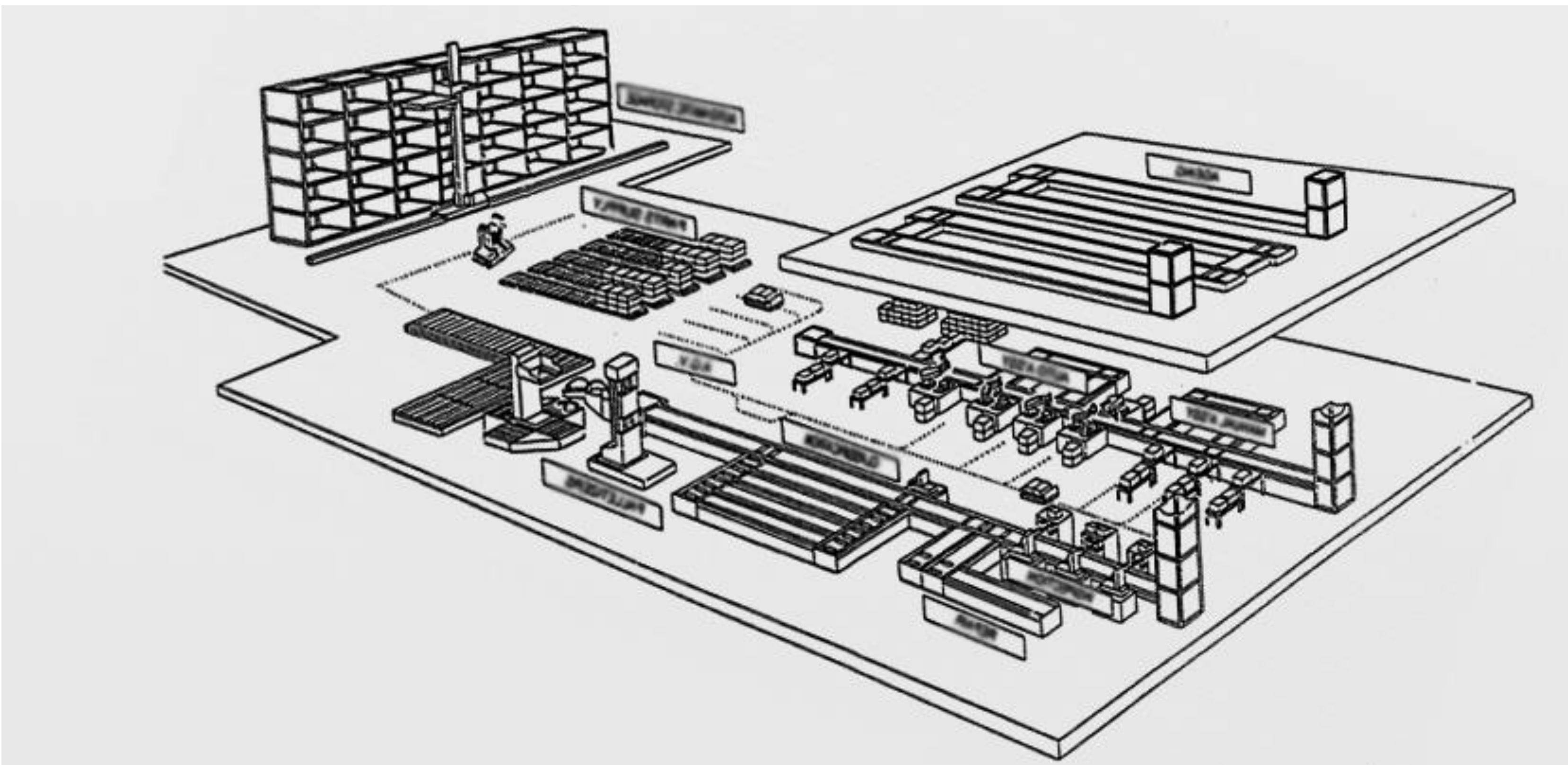
- Continuous transfer
- Intermittent transfer
- Asynchronous transfer

Automated Storage and Retrieval Systems (ASRS)

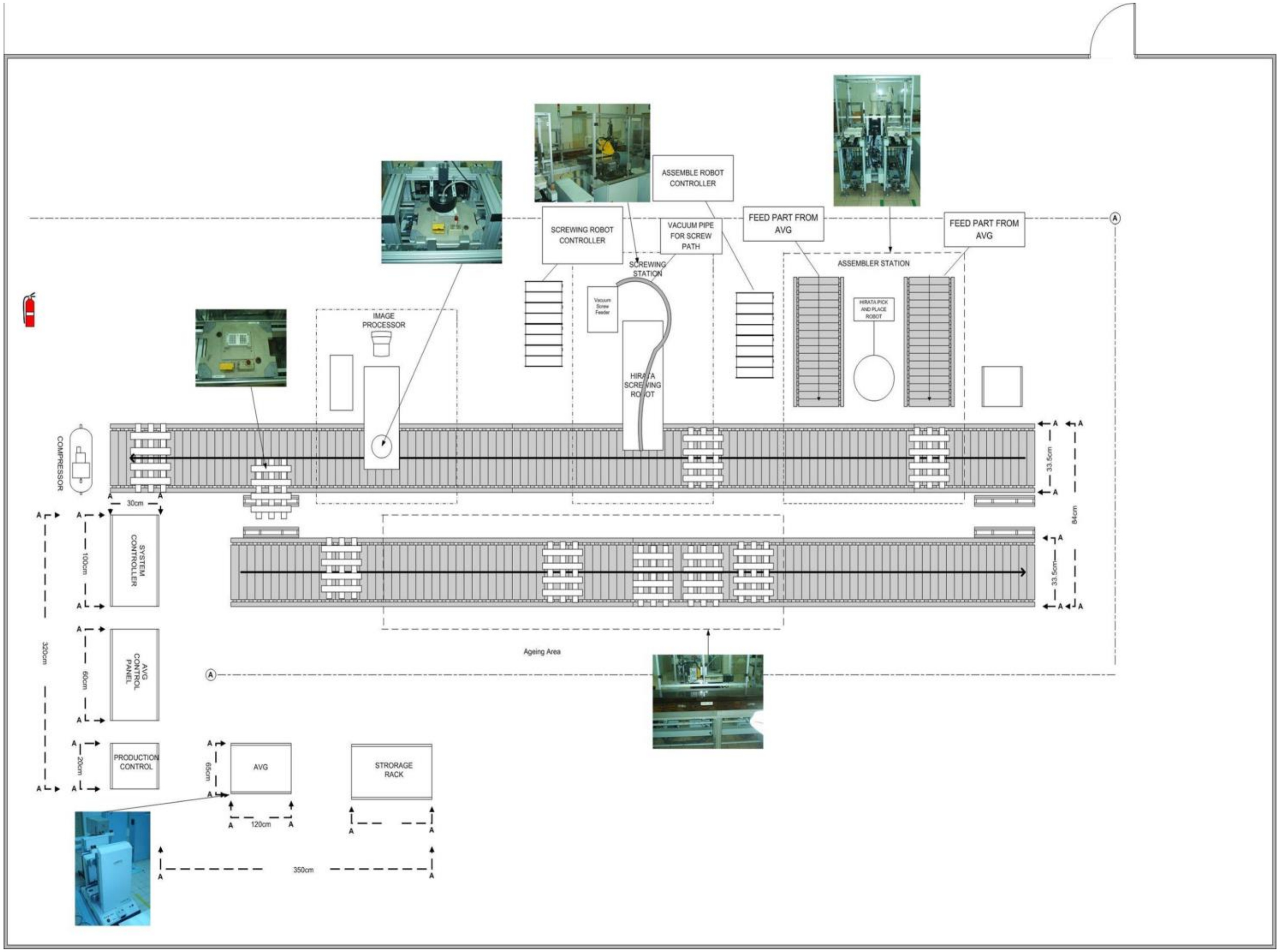


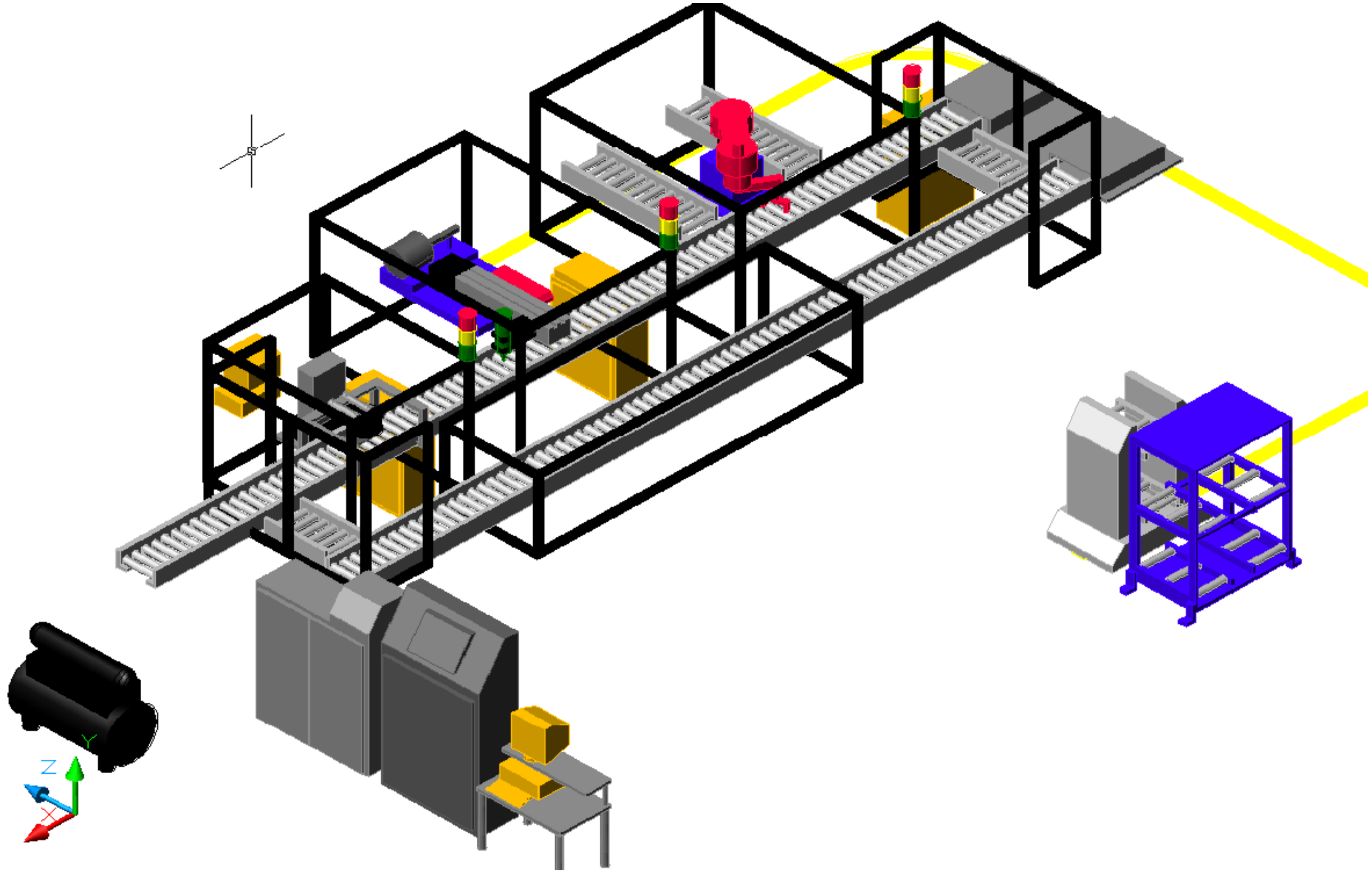
Automated Storage and Retrieval Systems (ASRS)

Storage/Retrieval



Layout of the CIM System for Assembling ID Cards

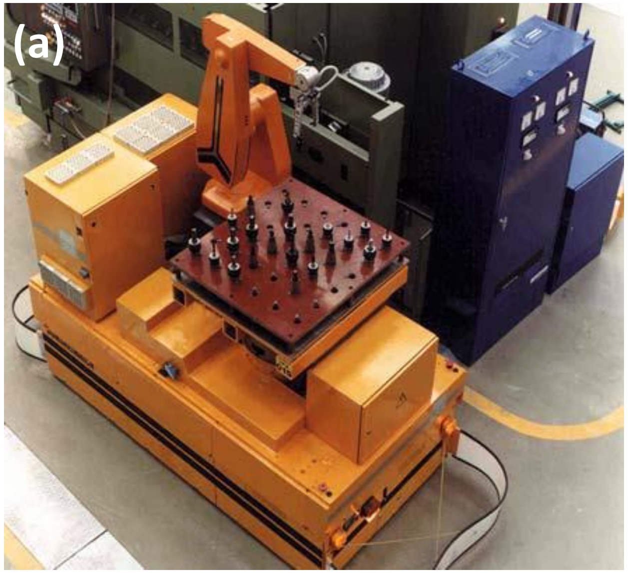



Z
Y
X

Two-level Conveyor System on AGV

AGV Auto-Charger Station

Automated Guided Vehicle Systems



Types of vehicles:
- Driverless trains
- Pallet trucks
- Unit load carriers

Fig. A mobile robot arm for machine (un)loading and an autonomous fork lift (a) The MORO (mobile robot, 1984), developed at Frauenhofer IPA, Stuttgart, was one of the first prototypes to combine a robot arm on a wire-bound mobile platform which follows a wire buried in the floor. Mobile arms were particularly used in highly automated clean room manufacturing facilities to automatically load and unload process equipment (**b) This automated fork-lift by MLR** combines manual operation with fully autonomous navigation and (un-)loading of boxes and pallets. A laser scanner using retro-reflecting tapes or other landmarks (walls, pillars) avoids constraints imposed by simple buried wire guidance technology (by courtesy MLR System, Ludwigsburg)

Automated Guided Vehicle Systems

- Application areas:
  - Carry partially completed subassembly through a sequence of assembly workstations to build the product
  - For storage and distribution (automated storage and retrieval system)
  - Assembly line applications, for internal loopings
  - Flexible manufacturing systems
  - Office mail delivery
  - Hospital material transport

Technologies for AGV Guidance

- Embedded Guide Wires
- Paint strips
- Self-guided Vehicles

Technologies for AGV guidance

- **Embedded Guide Wires**
- Consists of electrical wires placed on a small channel (3-12mm wide) cut into the surface of the floor. The channel is then filled with cement to smoothen the surface.
- Guide wire is connected to a frequency generator (1-15kHz), which emits a low voltage, low current signal that induces a magnetic field along the pathway that can be detected by sensors on-board AGV.
- Two sensors are mounted on either side of the wire, thus detecting the difference in intensity if AGV strays to one side of the path way.
- Typical path ways consist of loops and branches, hence a frequency select method or a switch select method is used in deciding the branching off.

Technologies for AGV guidance

- **Paint strips**
- Used to define the path way.
- AGV uses optical sensor to track the paint.
- Strips can be painted, taped or sprayed on the floor. E.g. a 2.5cm wide paint strip containing fluorescent particles that reflect an ultraviolet light source from the vehicle.
- On board sensor detects the reflected light in the trips and controls the steering mechanism to follow it.
- Useful in environments where electrical noise renders the guide wire system unreliable or when the installation of guide wires in the floor surface is not practical.
- However, the paint strip deteriorates with time, and must be kept clean and periodically repainted.

Technologies for AGV guidance

- **Self Guided Vehicles**
- This is the latest technology for vehicle guidance. Operates without continuously defined path ways.
- Use a combination of dead reckoning and beacons located throughout the plant, which can be identified by on board sensors. Beacons are used for correcting the errors associated with dead reckoning.
- Flexible, can be redefined by software. New docking points can be defined.
- Pathways can be extended by establishing new beacons.
- Changes can be made quickly without major alterations to the plant.

Analysis of Material Transport Systems

- Charting Technique in Material Handling
- Analysis of Vehicle Based Systems

Analysis of Material Transport Systems

- Charting Technique in Material Handling

- **From-To Chart shows flow rates, load/hr (value before the slash mark) and travel distances, m (value after the slash mark) between stations in a layout.**

- **The Chart is organized for possible material flows in both directions between load/unload points in the layout.**

- **From-To Chart can be used to represent various parameters of the material flow problem, including the number of deliveries or flow rates between locations in the layout and travel distances from between from-to locations.**

Charting Technique in Material Handling

- **Table: From-To Chart showing flow rates, load/hr (value before the slash mark) and travel distances, m (value after the slash mark) between stations in a layout**

Unloading stations

	To	1	2	3	4	5
From	1	0	9/50	5/120	6/205	0
	2	0	0	0	0	9/80
	3	0	0	0	2/85	3/170
	4	0	0	0	0	8/85
	5	0	0	0	0	0

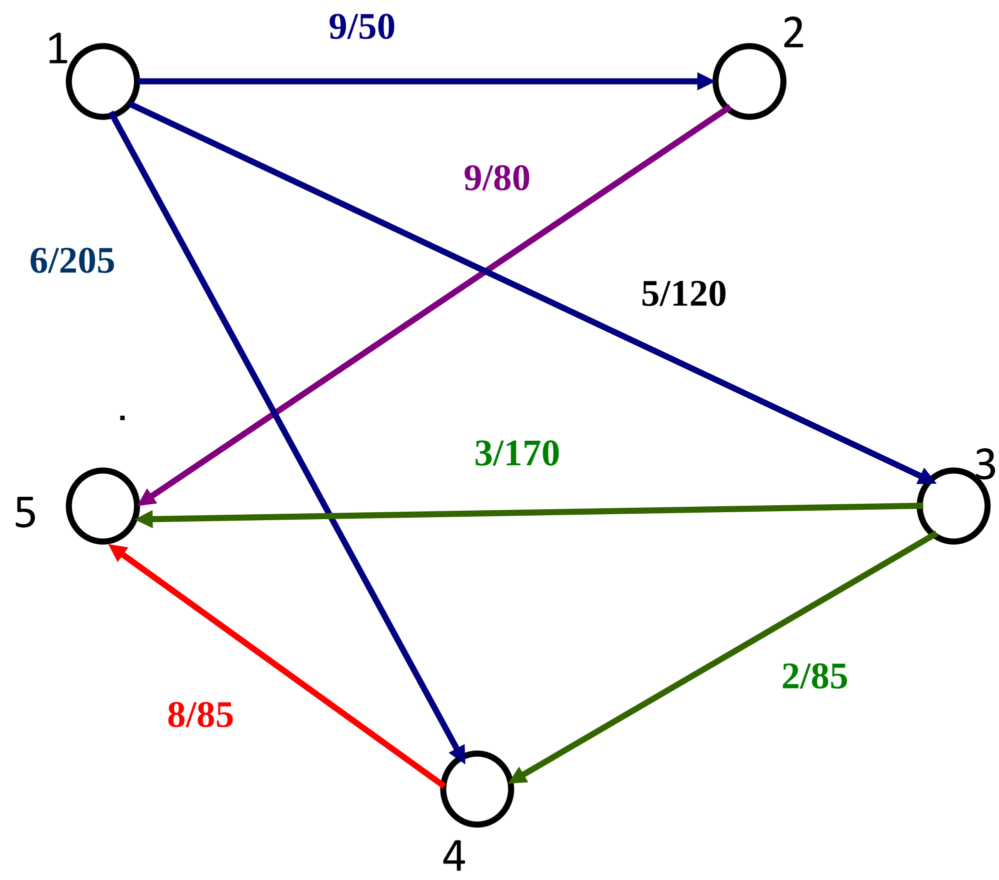
Loading stations

8 loads per hour, 85m

Flow Diagram: Alternative representation

Flow diagram showing material deliveries between load/unload stations.

Arrows indicate flow rates and distances, and nodes represent load/unload stations



Analysis of Material Transport Systems

- Analysis of AGV-Based Systems

Assuming vehicle operates at a constant velocity, ignoring effects of acceleration, deceleration and other speed differences (loaded or unloaded).

The time for a typical delivery cycle in the operation of an AGV-based transport system consists of:

1. Loading at the pickup station
2. Travel time to the drop-off station
3. Unloading at the drop-off station
4. Empty travel time of the AGV between deliveries

Total cycle time per delivery per vehicle is given by:

$$T_C = T_L + \frac{L_d}{v_c} + T_U + \frac{L_e}{v_c} \qquad \text{Eq(6.1)}$$

where

T_C = delivery cycle time (min/del)

T_L = time to load at load station (min)

L_d = distance the AGV travels between load and unload station (m, ft)

v_c = carrier velocity (m/min, ft/min)

T_U = time to unload at unload station (min)

L_e = distance the vehicle travels empty until the start of the next delivery cycle

Some comments:

- Tc ignores any time losses due to reliability problems, traffic congestion, and other factors that may slow down delivery.
- Ld and Le terms are average values
- We will use Tc to determine:

(1) rate of deliveries per AGV

(2) number of AGVs required to satisfy a specific total delivery requirement.

Hourly rate of deliveries = 60 min / Tc

- Adjustments to time losses due to:

1. Availability, *A*: is a reliability factor defined as the proportion of total shift time that the AGV is operational (not broken down or being repaired)
2. Traffic congestion: Traffic factor *Tf* (typical values 0.85 – 1.0), due to blocking, waiting at intersections, waiting in-line while others are loading/unloading.
3. Efficiency, *E*.

Available time per hour per vehicle as 60 min adjusted by A, Tf and E:

$$AT = 60 A T_f E \qquad \text{Eq}(6.2)$$

- AT = available time (min/hr per vehicle)
- A = availability
- T_f = traffic factor
- E = efficiency (worker efficiency)

Rate of delivery per AGV

$$R_{dv} = \frac{AT}{T_C} \quad \text{Eq(6.3)}$$

- Where
- R_{dv} = hourly delivery rate per AGV (del./hr per AGV)
- T_c = delivery cycle time computed by Eq (4.1) (min/del)
- AT = availability time in 1 hr with adjustments for time losses (min/hr).

Number of AGVs required to satisfy a specific delivery schedule:

Work load = the total amount of work, expressed in terms of time, that must be accomplished in 1 hour.

$$WL = R_f T_C \quad \text{Eq}(6.4)$$

- WL = workload (min/hr)
- R_f= specific flow rate of total deliveries per hour for the system (del/hr)
- T_C= delivery cycle time (min/del).

Number of vehicles required:

$$n_C = \frac{WL}{AT} \quad \text{Eq}(6.5)$$

- n_C = number of AGVs required
- WL = workload (min/hr)
- AT = available time per AGV (min/hr per vehicle)

$$n_C = \frac{R_f}{R_{dv}} \quad \text{Eq}(6.6)$$

R_{dv} = delivery rate per AGV (del/hr per vehicle)

Example 1: Determining Number of AGVs in an AGVS

- Referring to Fig. Example 6.1, AGVs travel counterclockwise from load station to unload station. Loading time at the load station = 0.75 min, unloading time at unload station = 0.5 min.
- It is desired to determine how many AGVs are required to satisfy demand for this layout if a total of 40 del/hr must be completed by the AGVS.
- Given: vehicle velocity = 50 m/min, availability=0.95, traffic factor=0.9, operator efficiency does not apply, hence E=1.0.
- Determine:

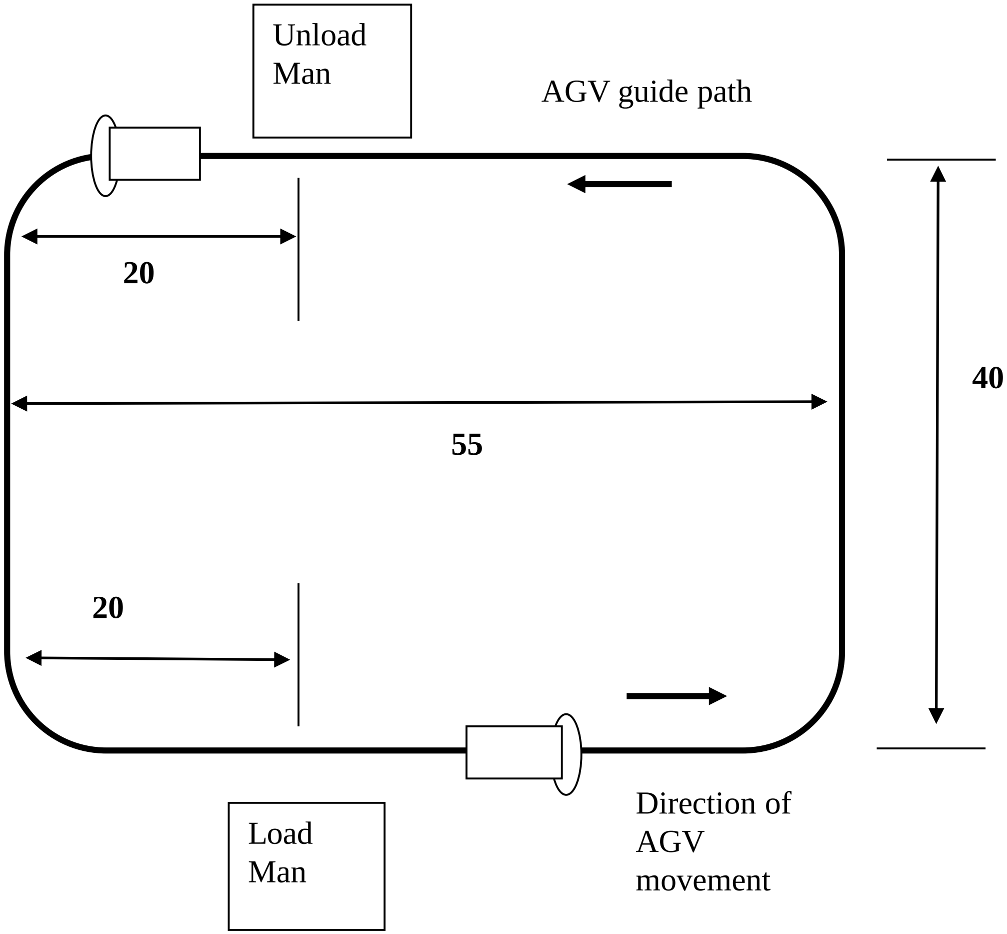
(a) travel distances loaded and empty

(b) Ideal delivery cycle time

(c) Number of vehicles required to satisfy the delivery demand.

Fig 6.1 AGVS loop layout.

Key: Man= manual operation, dimensions in meters.



Solution:

(a) Ignoring effects of slightly shorter distances around the curves at corners of the loop, the values of Ld and Le are readily determined from the layout to be 110 m and 80 m respectively.

b) Ideal cycle time per delivery per vehicle is given by Eq (4.1)

$T_c = 0.75 + 110/50 + 0.5 + 80/50 = 5.05$ min

(c) To determine the number of vehicles required to make 40 del/hr, we compute the workload of the AGVS and the available time per hour per vehicle.

WL = 40 (5.05) = 202 min/hr

AT = 60(0.95)(0.9)(1.0) = 51.3 min/hr per vehicle

Therefore the number of vehicles required is

$n_c = 202 / 51.3 = 3.94$ vehicles

This values is rounded up to $n_c = 4$.

Frontier technology:

- Use of Swarm theory for highly populated factory floor.
- Ant colony theory.

3. Part Feeding

- Gravity Feeders
- Magazine Feeders
- Tape Feeders
- Waffle-Tray Feeders
- Vibratory Feeders

Gravity Feeders

- Parts move due to gravitational effect. Many different styles to feed single or multiple parts.
- Advantage – relatively simple design
- Disadvantage – do not hold large supply of parts

Magazine Feeders

- Parts are stacked in a vertical tube with a pneumatic cylinder ejection mechanism to push out one part at a time.

- The exiting part slides out and the ejection mechanism prevents the parts in the tube from dropping until the mechanism is completely retracted.

Tape Feeders

- Components are trapped between two layers of tape with equal spacing and a fixed orientation.
- The feeder moves the part to a fixed point and removes the top layer of tape so that the component is ready
- Tape feeders are most frequently used with small components that are not suitable for a vibratory type feeder.

Waffle-Tray Feeders

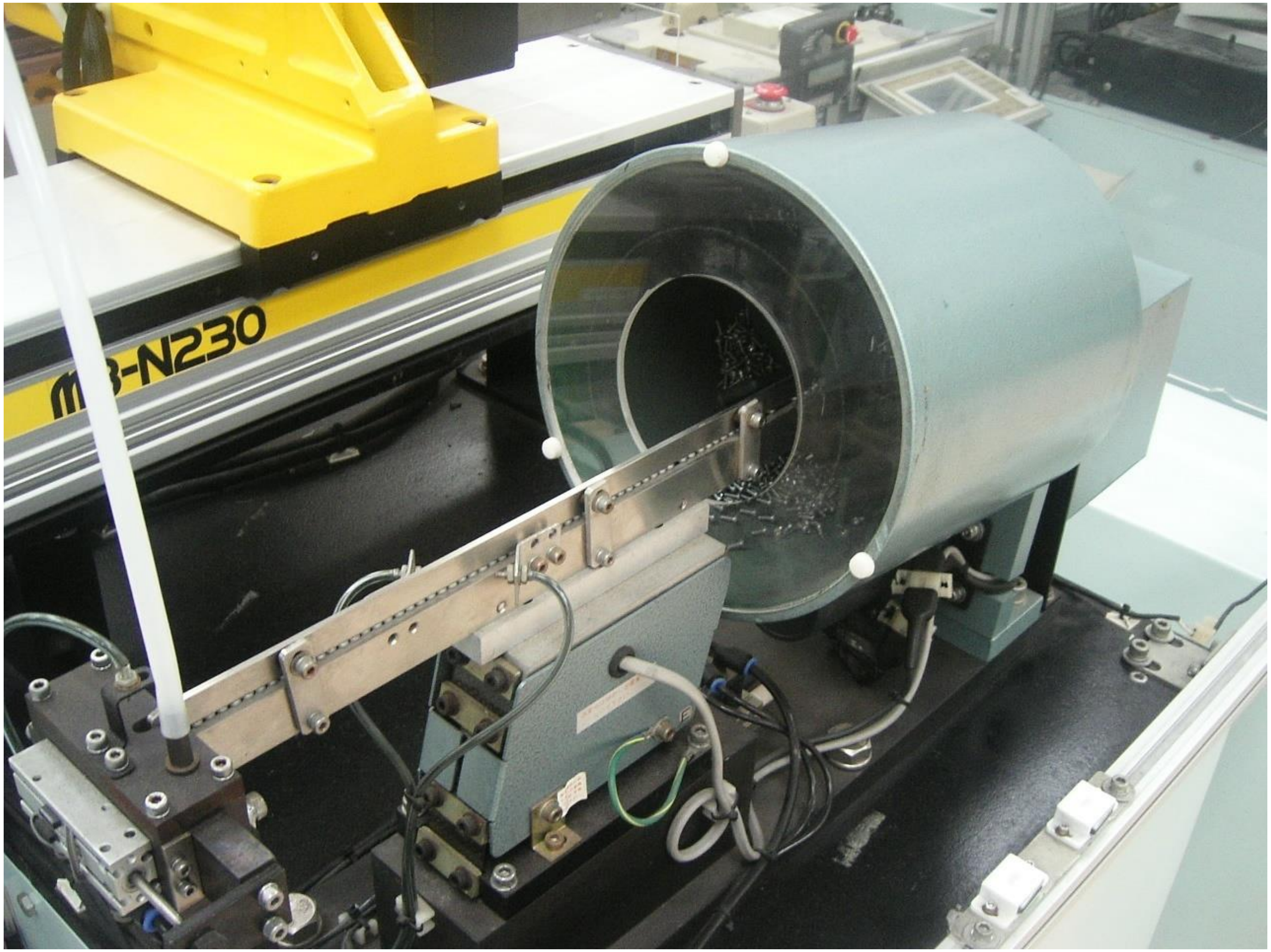
- Usually a plastic tray with equal spaced compartments, each containing a single component for retrieval by automatic part-handling equipment.

Waffle Tray Feeder

Vibratory Feeders

- Two types: linear track and bowl.
- Vibrating motion on bowl feeders causes parts to move up the circular ramps around the inside of the bowl.
- When parts are near the top of the bowl, tabs on the ramp push parts that are not in the correct orientation off the ramp, dropping the rejects to the bottom of the bowl.

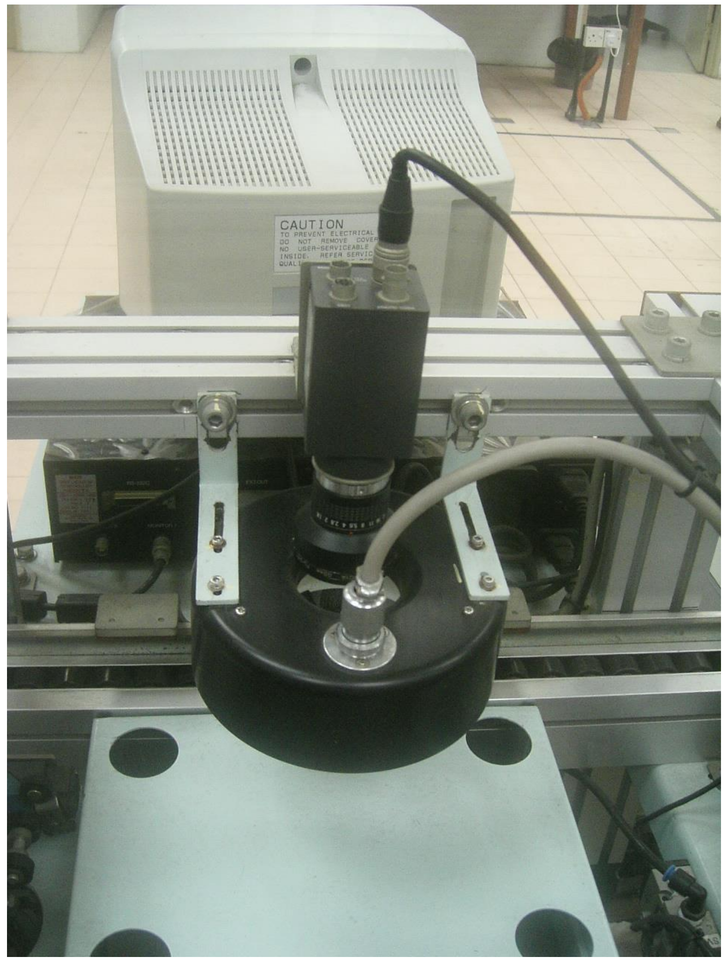
Vibratory bowl feeder



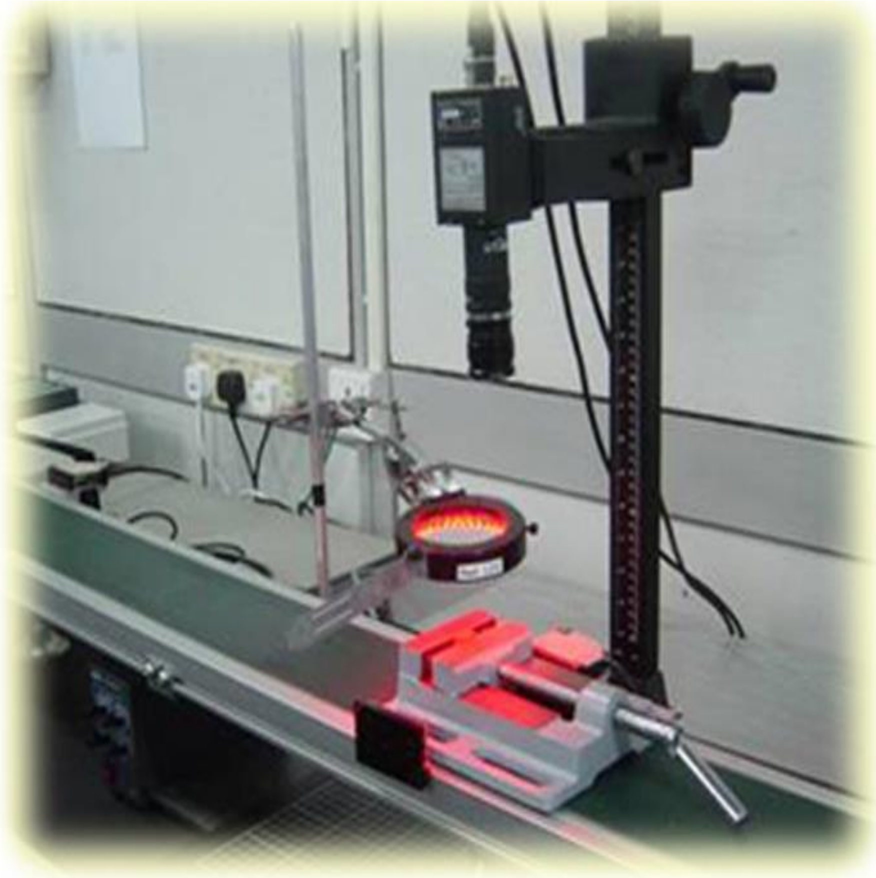
4. Inspection

- To ensure quality products, free from defects.
- Several different devices are used for inspection – manual inspection gages, and measuring instruments.
- Automated systems – range from manual measuring instruments with digital outputs to coordinate measuring machines (CMM).
- CMMs are programmed to measure part parameters with little or no human intervention.
- In many applications, the quality data are transferred to a computer in the work cell through a digital interface.
- With computer interface, product quality can be analysed quickly and saved as part of the product database.

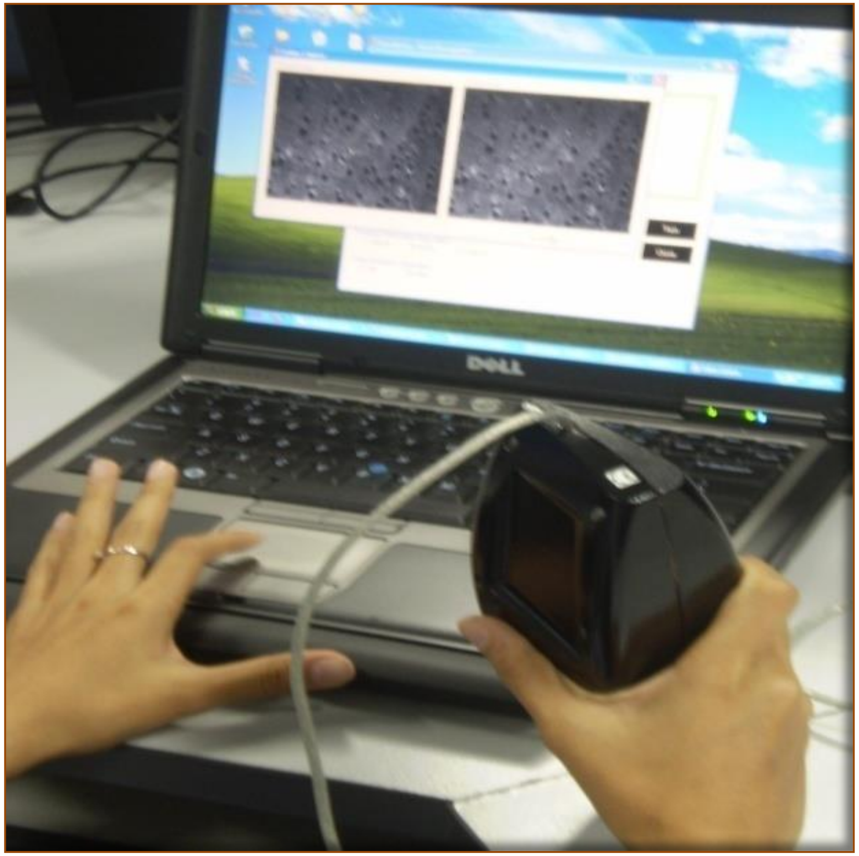
Vision Inspection Station



Vision Inspection Station – wood recognition



Laboratory-based set=up



Portable device for Kenal Kayu

5. Automatic Tracking

Bar code – most popular

- Two standards: interleave 2 of 5, and code 39
- Bar codes generated by printers
- Code 39 is preferred due to its self checking nature and very low reading error.
- Basic components:
  - Photo transmitter
  - Photo detector / scanners : picks up data from reflection of transmitted light from bar code.
  - Microcomputer: To interpret bar code & identify part type.

5. Automatic Tracking

Radio frequency tags.

- Ideal for parts or material that are covered / coated with solvents, dust or coatings that prevent the reading of bar code effectively.
- Mini RF circuitry is coated with epoxy or protective material. RF transmitter transmits certain RF. RF circuit will respond with specific type of Radio frequency unique to the type of part.

Electronic Data Tagging

5. Automatic Tracking

Binary code

- Especially for pallet production. Holes are built into a corner of the pallet. Certain holes are inserted with pins. A specific pattern of pins and holes correspond to specific type of parts.
- Touch sensors or proximity sensor are used to detect this pattern to identify type of parts / materials.
- This system is very simple yet effective without the needs of high computing capability.
- Since the pallets are usually moved by tape conveyors, its orientation does not vary much and the sensors could easily detect the holes 8 pins even with slight variations.`

TEXT AND REFERENCE BOOKS

- **Textbook:**

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2. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey: Industrial Robotics: Technology, Programming, and Applications, McGraw-Hill. 1986.
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4. Richard K. Miller, Industrial Robot Handbook. Van Nostrand Reinhold, N.Y. (1987).