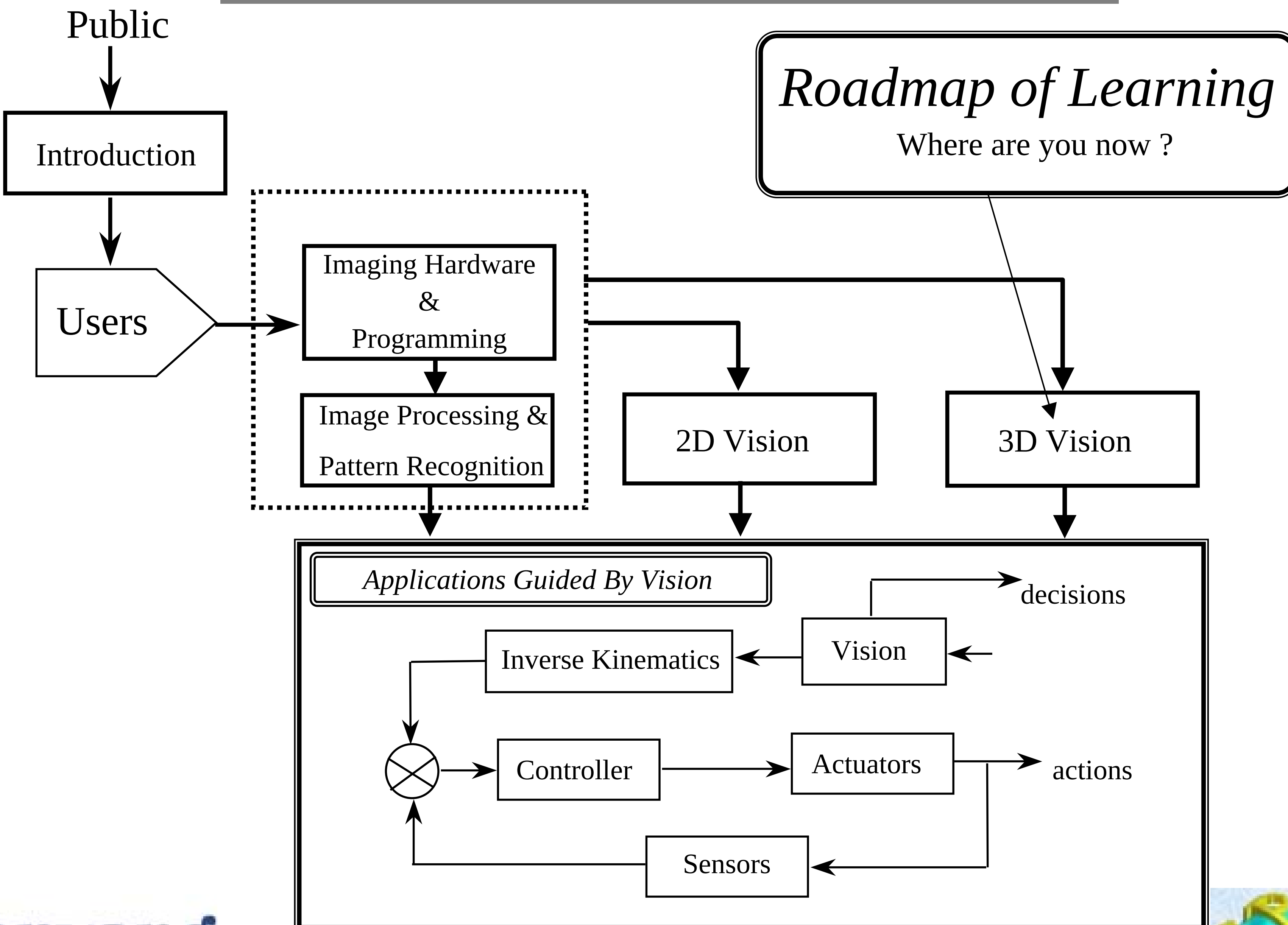
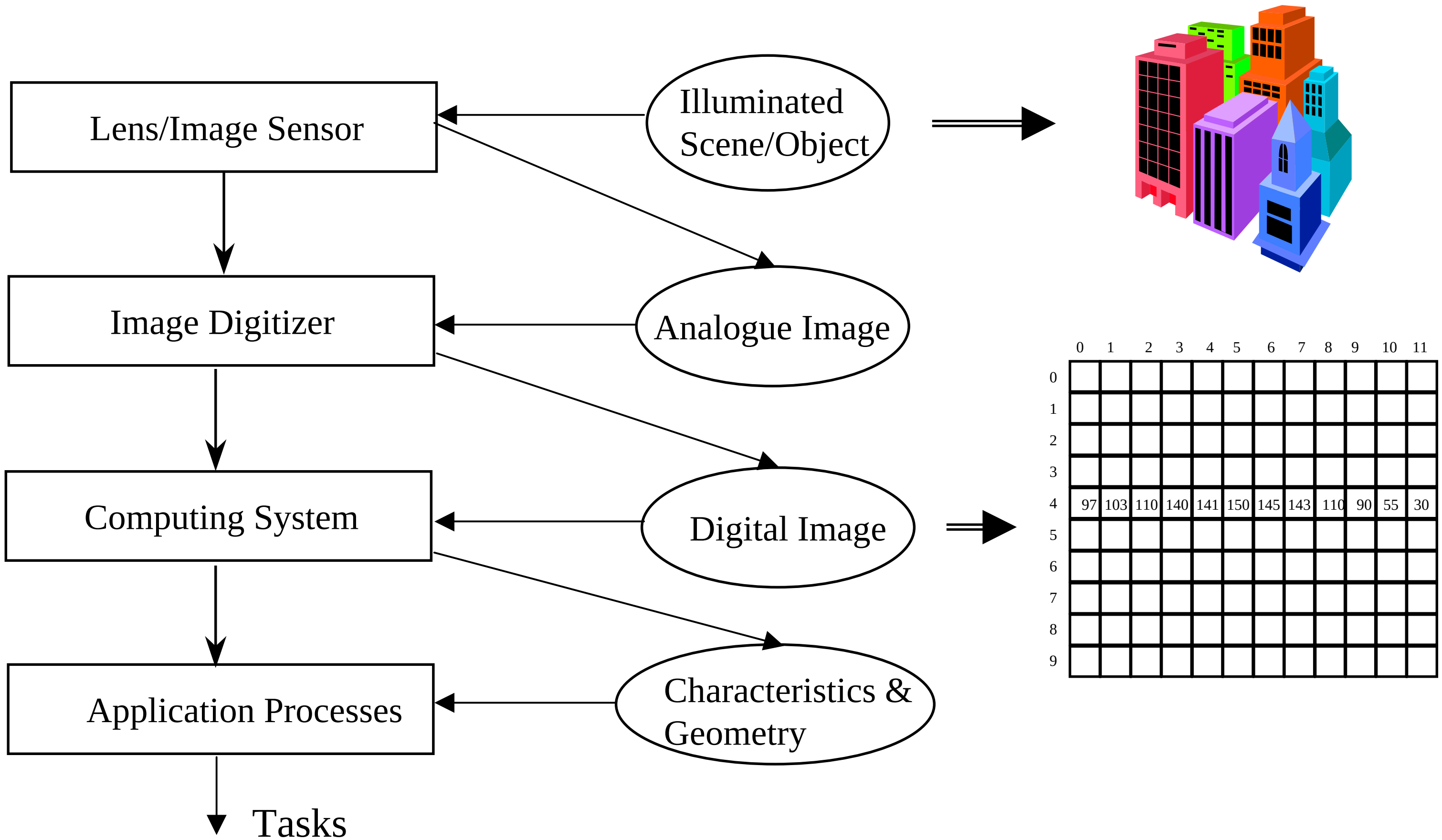

Roadmap of Learning
Where are you now ?
Public
Introduction
Users
Imaging Hardware & Programming
Image Processing & Pattern Recognition
2D Vision
3D Vision
Applications Guided By Vision
decisions
Vision
Inverse Kinematics
Controller
Actuators
actions
Sensors

CONTENT

To Learn

What is a machine vision system ? (A Review)

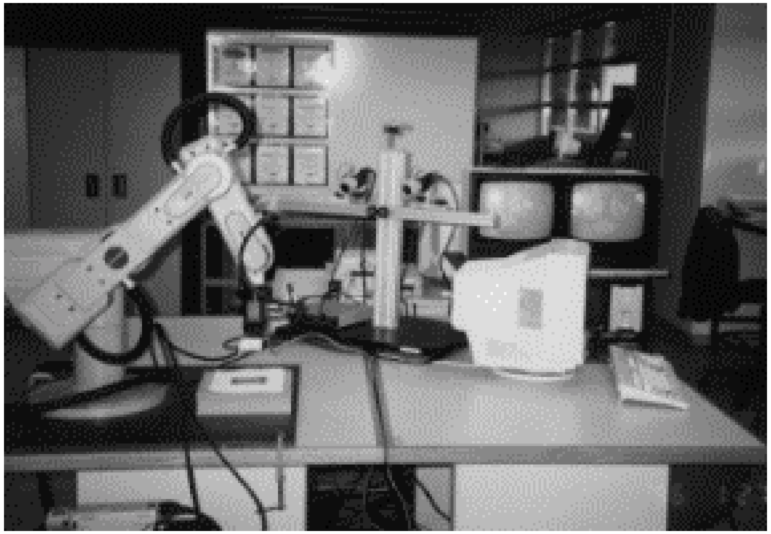
ANSWER:



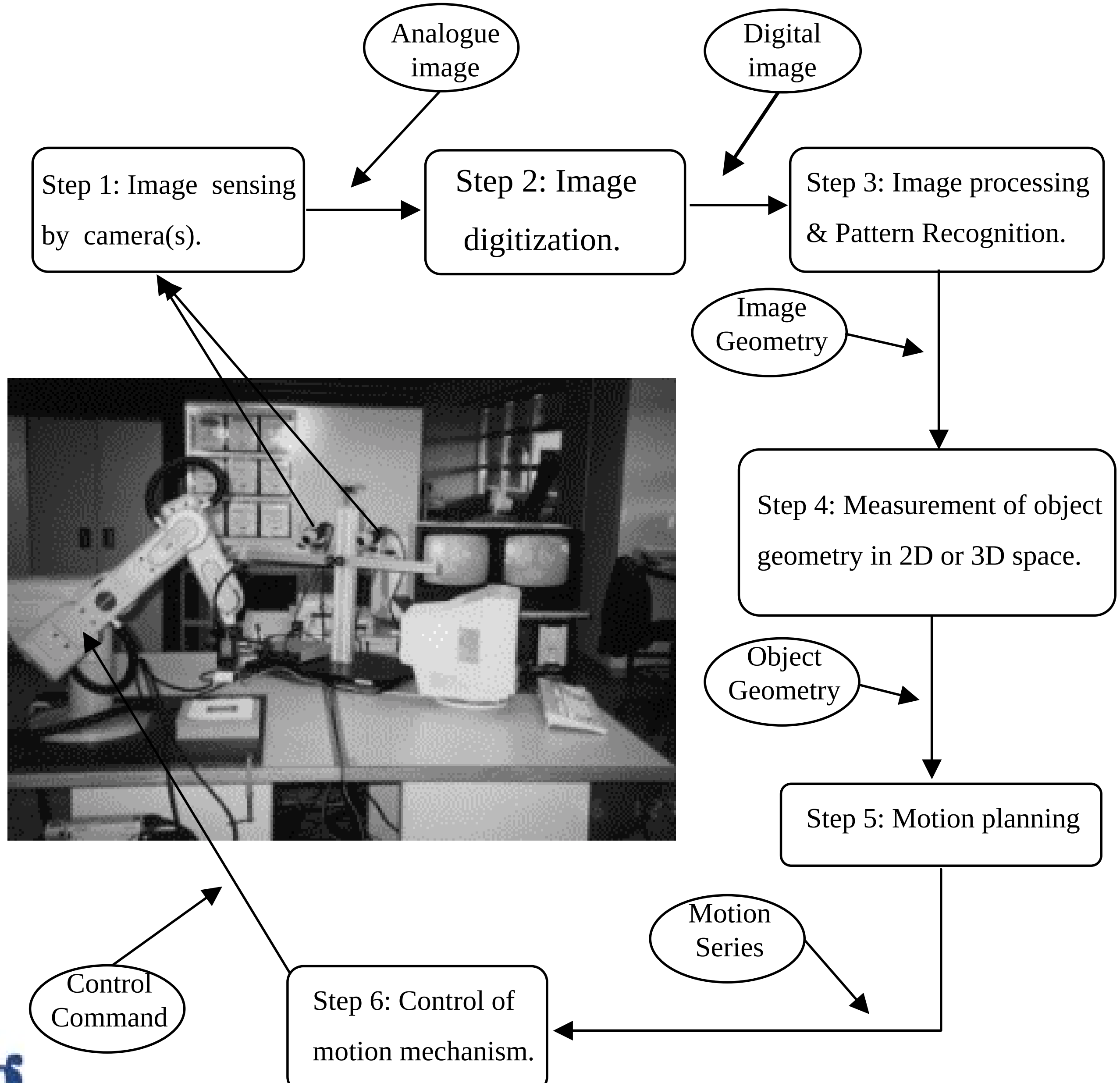
Question:

The environment surrounding us is three dimensional. Is it possible to recover the 3D geometry of object through 2D images ?

How does a machine vision system work for the task of visual guidance or measurement ?



Answer:

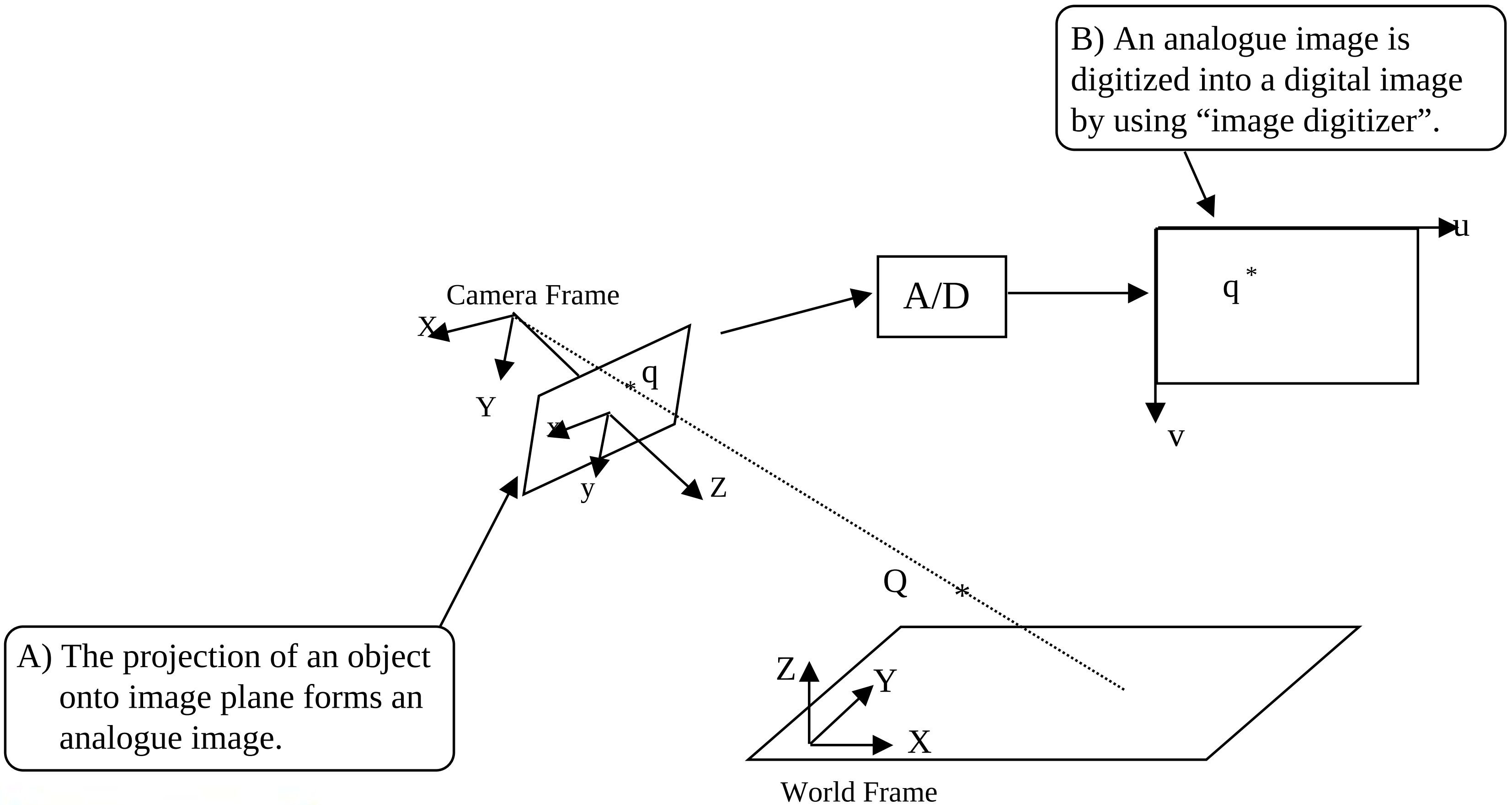

Analogue image
Digital image
Step 1: Image sensing by camera(s).
Step 2: Image digitization.
Step 3: Image processing & Pattern Recognition.
Image Geometry
Step 4: Measurement of object geometry in 2D or 3D space.
Object Geometry
Step 5: Motion planning
Motion Series
Step 6: Control of motion mechanism.
Control Command

How to determine the geometry of an object in a 3D space ?

How to determine the geometry of an object in a 3D space ?

ANSWER:

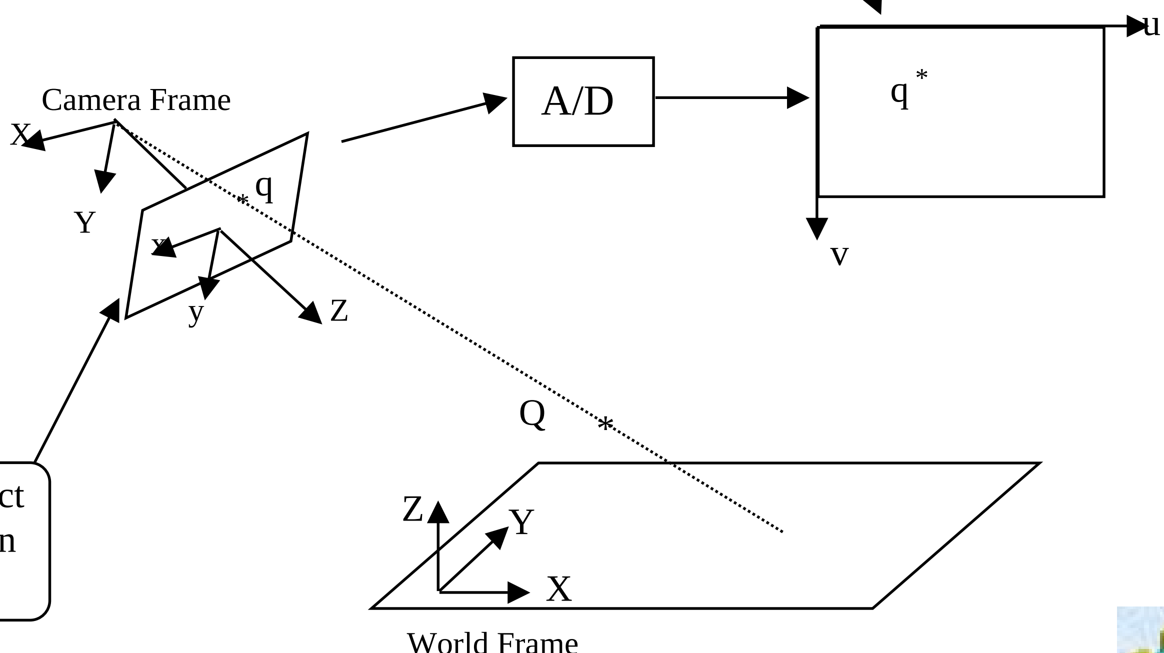
1. Problem description/analysis:



C) The relationship between the 3D coordinates of an object point and its 2D image coordinates is (see Lecture 7-1):

$$\begin{pmatrix} s \bullet u \\ s \bullet v \\ s \end{pmatrix} = M_{3\times 4} \bullet \begin{pmatrix} {}^{r}X \\ {}^{r}Y \\ {}^{r}Z \\ 1 \end{pmatrix}$$

B) An analogue image is digitized into a digital image by using “image digitizer”.



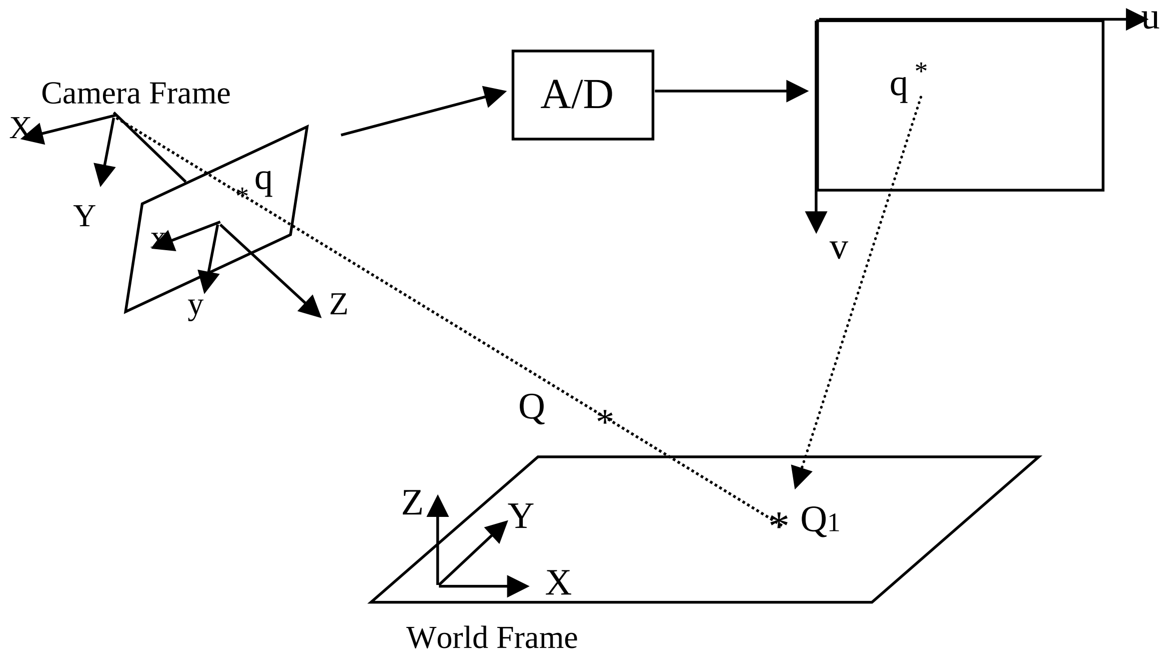
A) The projection of an object onto image plane forms an analogue image.

Nanyang Technological University

D) Question:

Is it possible to determine object's geometry in 3D space with only one image ?

The answer is "No" in general because the back-projection only allows to determine a point constrained by a 2D plane.



How to determine the geometry of an object in a 3D space ?

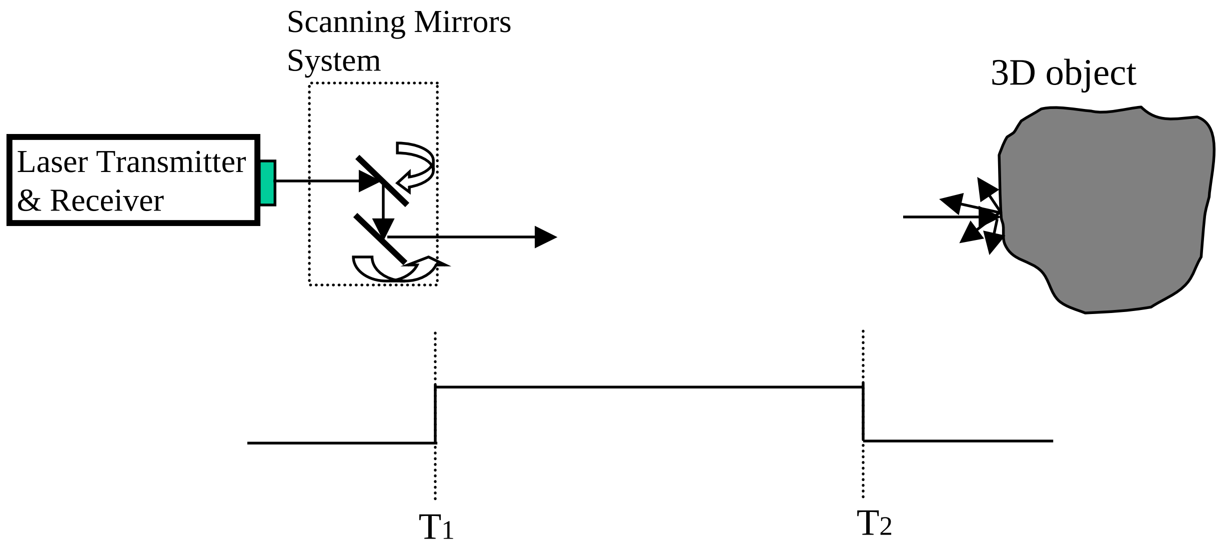
ANSWER:

2. Possible solutions:

- Asynchronous Methods:
  - Laser Range Finder.
  - 3D Scanner.
  - Motion stereo vision.
- Synchronous Methods:
  - Binocular stereo vision.
  - Structured lighting.

Laser Range Finder

1. System Set-up:



Laser Range Finder

2. Principle:

Step 1: A laser generator sends out a laser beam.

Step 2: The laser beam goes through a “scanning mirrors” system.

Step 3: A 3D object reflects the laser beam back to the receiver.

Step 4: The distance traveled by the laser beam can be determined if we know: a) the time of flight, or b) the phase shift of the laser wave.

Laser Range Finder

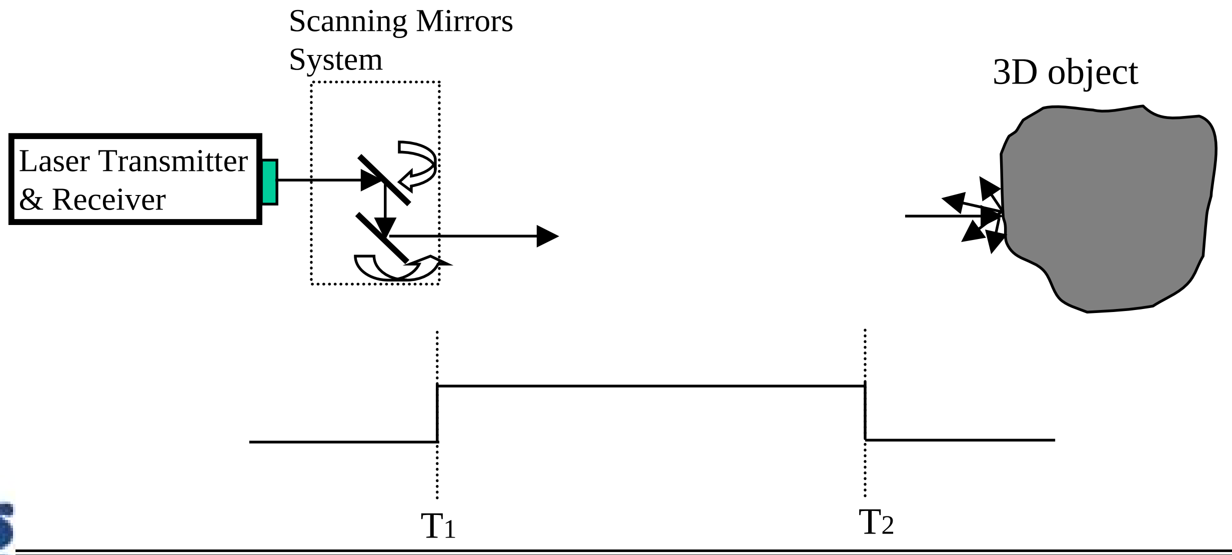
3. Mathematical Description:

Input: v -- Speed of light

ΔT -- Time of flight

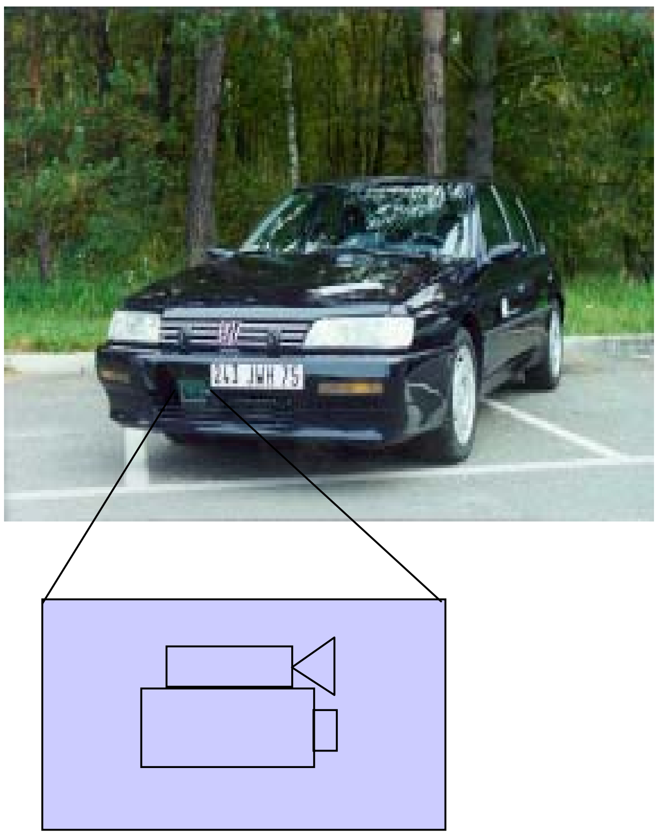
Output: D -- Distance to object

Solution: $D = \frac{v \bullet \Delta T}{2}$



Laser Range Finder

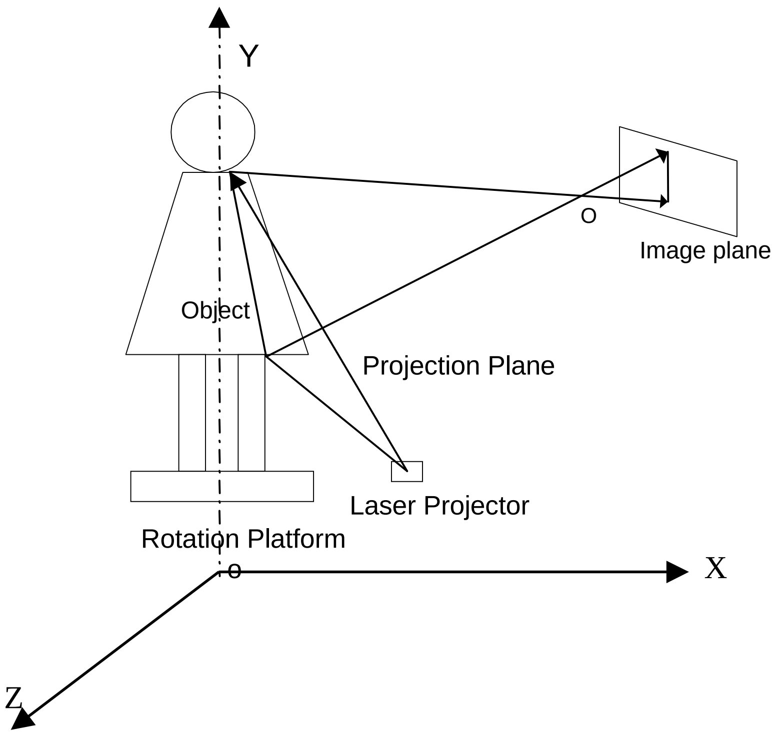
4. Experimental Results:



(a) (b) (c) (d)

(Active) 3D Scanner

1. System Set-up:



(Active) 3D Scanner

2. Principle:

Step 1: According to the geometric principle of 2D vision, object coordinates in a 2D plane can be easily computed from the corresponding image coordinates.

Step 2: We can use a laser projector to create a 2D plane of laser projection.

Step 3: The intersection between this “laser projection” plane and a 3D object forms a intersection line.

Step 4: All object points on this line can be computed.

Step 5: If we rotate the object to scan its whole surface with the laser projection plane, we can compute a matrix of 3D points that cover the surface of object.

(Active) 3D Scanner

3. Mathematical Description:

Input :

H_{3x3} -- The 3x3 matrix relating image coordinates to 2D object coordinates on the laser projection plane.

$\Delta\theta$ -- The incremental rotation angle for each rotation.

$k \bullet \Delta\theta$ -- The total rotated angle after the k^{th} rotation.

(u(k), v(k)) -- The image coordinates of a point on the k^{th} intersection line.

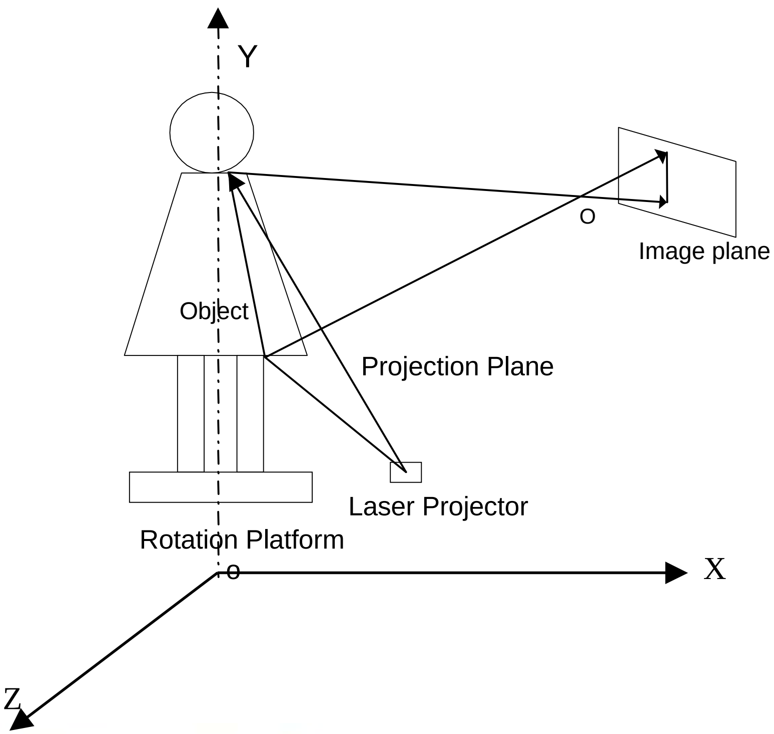
Output :

$({}^{r}X(k), {}^{r}Y(k), {}^{r}Z(k))$ -- The 3D coordinates (in the world frame) of a point on the k^{th} intersection line.

(Active) 3D Scanner

3. Mathematical Description:

Solution:



Step 1: The 2D object coordinates can be computed from the corresponding image coordinates:

$$\begin{bmatrix} \rho \bullet {}^{o}X(k) \\ \rho \bullet {}^{o}Y(k) \\ \rho \end{bmatrix} = H_{3x3} \bullet \begin{bmatrix} u(k) \\ v(k) \\ 1 \end{bmatrix}$$

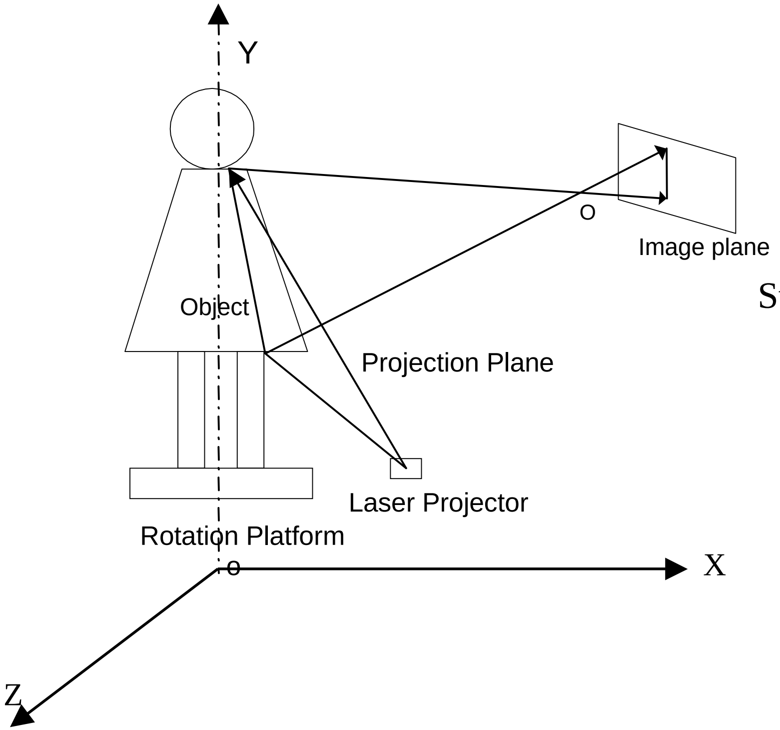
$({}^{o}X(k), {}^{o}Y(k))$ -- The 2D coordinates (in the projection plane) of a point on the k^{th} intersection line.

(Active) 3D Scanner

3. Mathematical Description:

Solution:

Step 2: The object frame of the k-th intersection line is related to the world frame by a rotation around the OY axis with $k \bullet \Delta\theta$ angle.

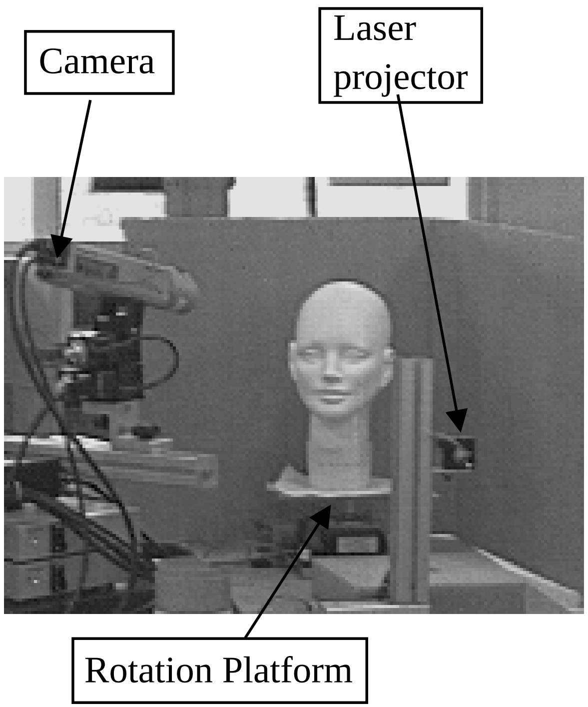


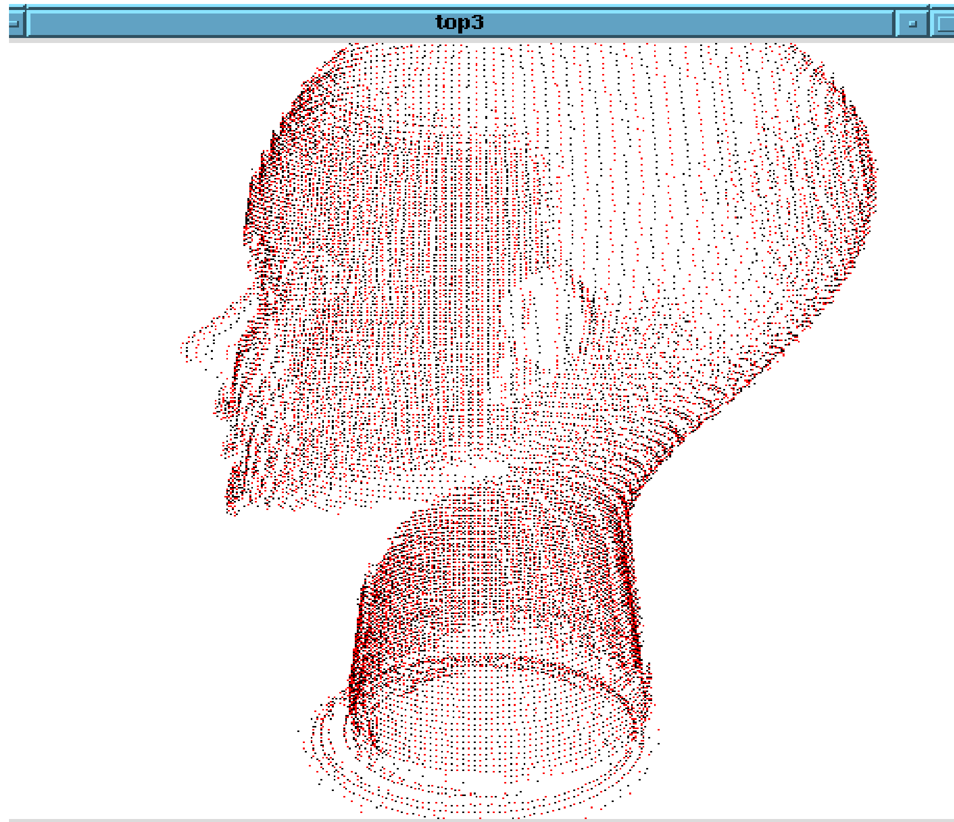
Step 3: The 3D object coordinates on the k-th intersection line in the world frame are:

$$\begin{bmatrix} {}^{r}X(k) \\ {}^{r}Y(k) \\ {}^{r}Z(k) \end{bmatrix} = \begin{bmatrix} \cos(k \bullet \Delta\theta) & 0 & -\sin(k \bullet \Delta\theta) \\ 0 & 1 & 0 \\ \sin(k \bullet \Delta\theta) & 0 & \cos(k \bullet \Delta\theta) \end{bmatrix} \bullet \begin{bmatrix} {}^{o}X(k) \\ {}^{o}Y(k) \\ 0 \end{bmatrix}$$

(Active) 3D Scanner

4. Experimental Results:

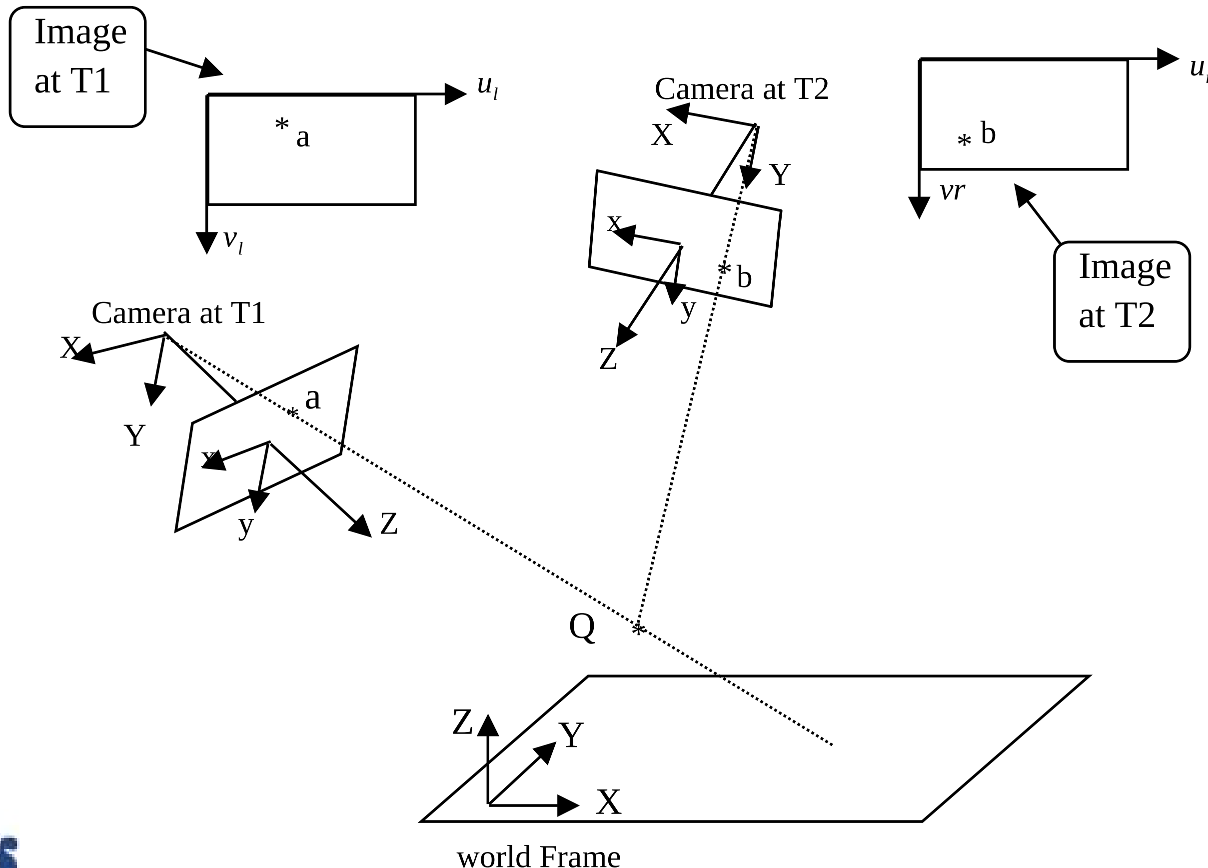




Moving Monocular Vision

(or Motion stereo vision)

1. System Set-up:



Moving Monocular Vision

(or Motion stereo vision)

2. Principle:

Step 1: We move the camera with a known motion while maintaining the scene to be static (This is equivalent to move the scene while maintaining the camera to be static).

Step 2: We have two images: the one captured at time T1 and the one captured at time T2.

Step 3: The 3D object coordinates in the world frame can be determined by a simple triangulation.

Moving Monocular Visio

(or Motion stereo vision)

3. Mathematical Description:

Same as Binocular stereo vision

(next lecture)

4. Experimental Results:

Same as Binocular stereo vision

(next lecture)

SUMMARY

1. In general, it is not possible to compute 3D object coordinates from a single image.

2. It is possible to use laser beam to develop a range finder to derive the distance information from: a) time of flight or b) phase shift of laser wave.

3. It is also possible to make use of the principle of 2D vision and the scanning technique to develop a 3D vision system that can compute the coordinates of 3D points on the surface of an object.

4. It is possible to develop a closed form solution for the reconstruction of 3D points if we can move the camera with known motion to acquire a second image. This is called “moving monocular vision” or “motion stereo vision”.

We call the above methods “asynchronous methods” because the range or image data acquisition is operated in a sequential way.