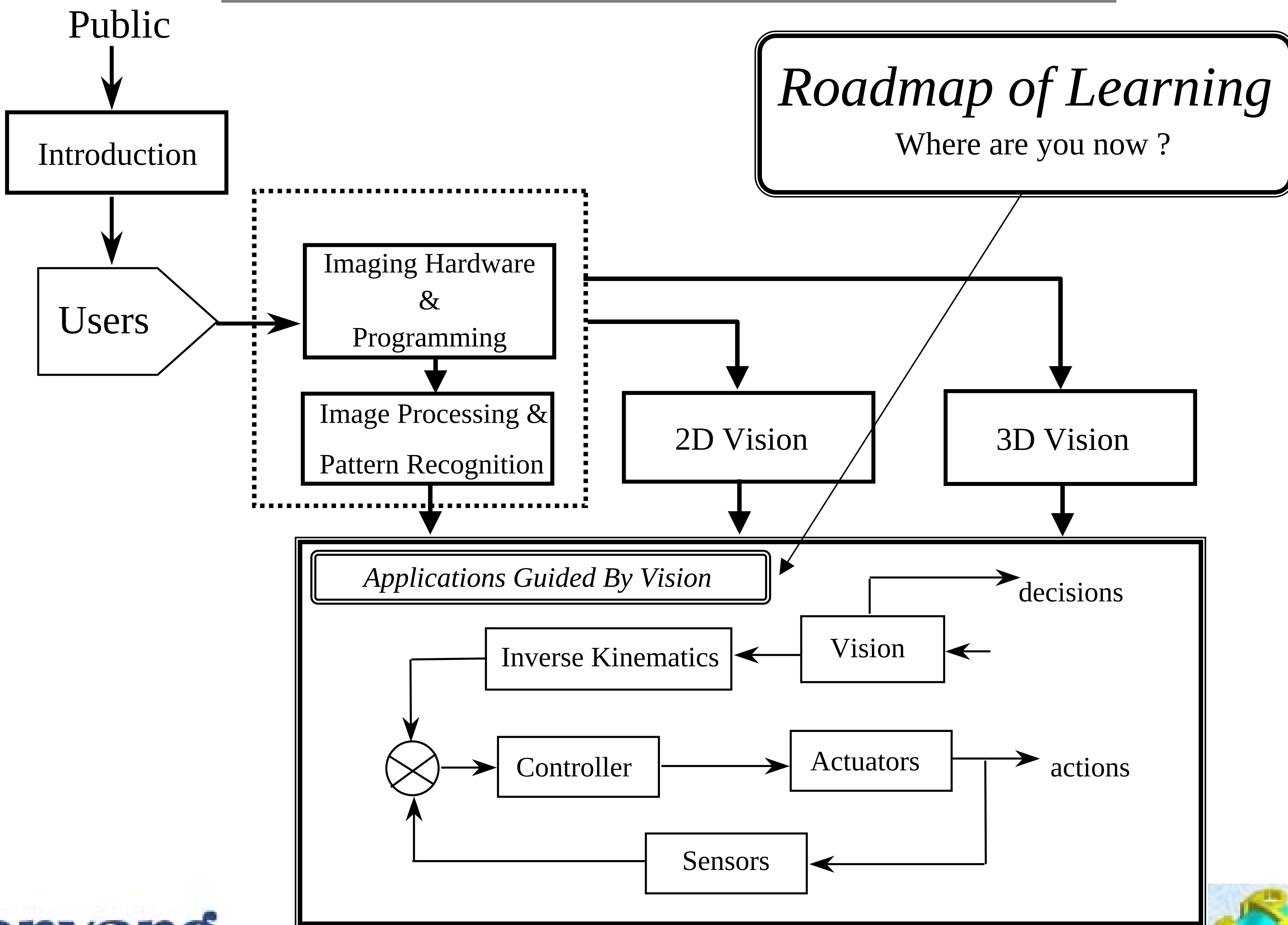
Roadmap of Learning
Where are you now ?
Public
Introduction
Users
Imaging Hardware & Programming
Image Processing & Pattern Recognition
2D Vision
3D Vision
Applications Guided By Vision
decisions
Vision
Inverse Kinematics
Controller
Actuators
actions
Sensors

CONTENT

Have Learnt

Chapter 9: Machine Vision Applications

- 9.1 Visual Inspection
- 9.2 Visual Guidance of Robot Manipulator
- 9.3 Visual Guidance of Robotic Head
- 9.4 Visual Guidance of Vehicle
- 9.5 3D Model Acquisition

To Learn

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What can be done with a machine vision system ? (A Review)

ANSWER:

Visual Guidance:

To obtain a geometric (full or partial) description of a scene necessary to the safe planning and control of the movement of machine (eg, robot).

Visual Inspection:

To obtain photometric and/or geometric measurement of goods or parts or machined outputs (like printing) for the sake of ensuring the highest quality if possible.

Visual Measurement:

To obtain photometric and/or geometric measurement of machined outputs for different purposes (inspection, surveillance, etc)

Visual Identification:

To obtain metric features from images for the sake of identifying the belonging of objects under the viewing.

3D MODEL ACQUISITION USING VISION

1. Applications:

a) Rapid Prototyping or Reverse Engineering

(to establish 3D CAD model of a clay model or a real part)

b) Customized Clothing or Product Design

(to capture 3D model of body or volume)

c) 3D Animation in Computer Graphics

(to build 3D objects or characters in cartoon films, etc)

d) 3D Catalogue on Internet

(to build 3D model of products to be advertised on Internet)

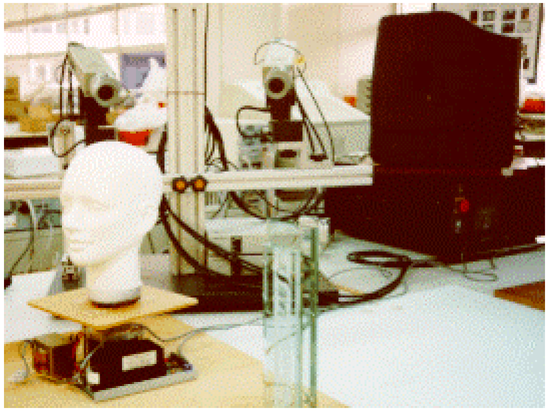
e) Medical Application

(to obtain 3D model of the face of a burn victim in order to re-build a plastic protection mask, etc)

3D MODEL ACQUISITION USING VISION

2. Problem Statement:

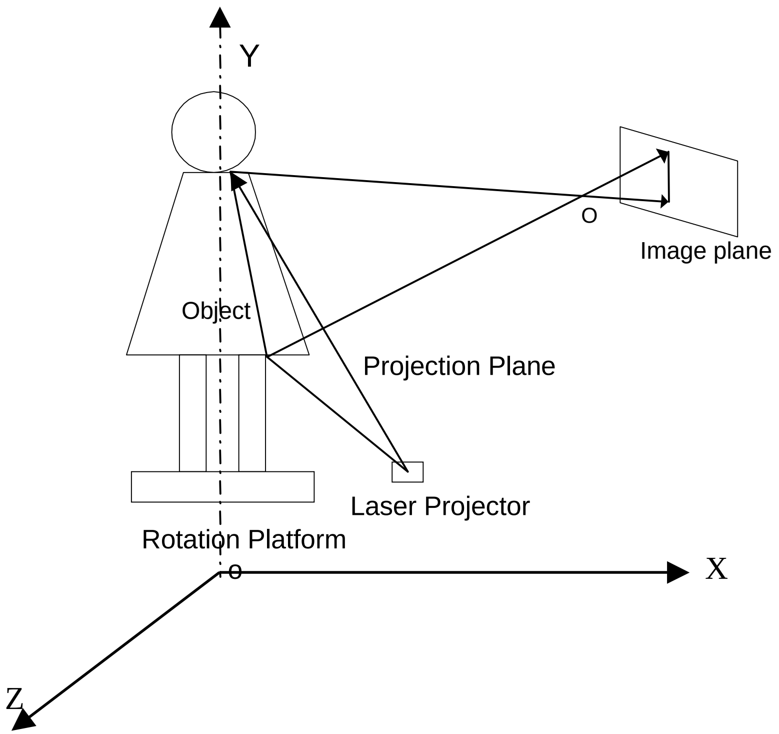
How to compute the 3D coordinates of points on the surface of an object ? And, how to interpolate these 3D coordinates with more compact mathematical descriptions that can be easily edited by standard CAD/CAM tools ?



3D MODEL ACQUISITION USING VISION

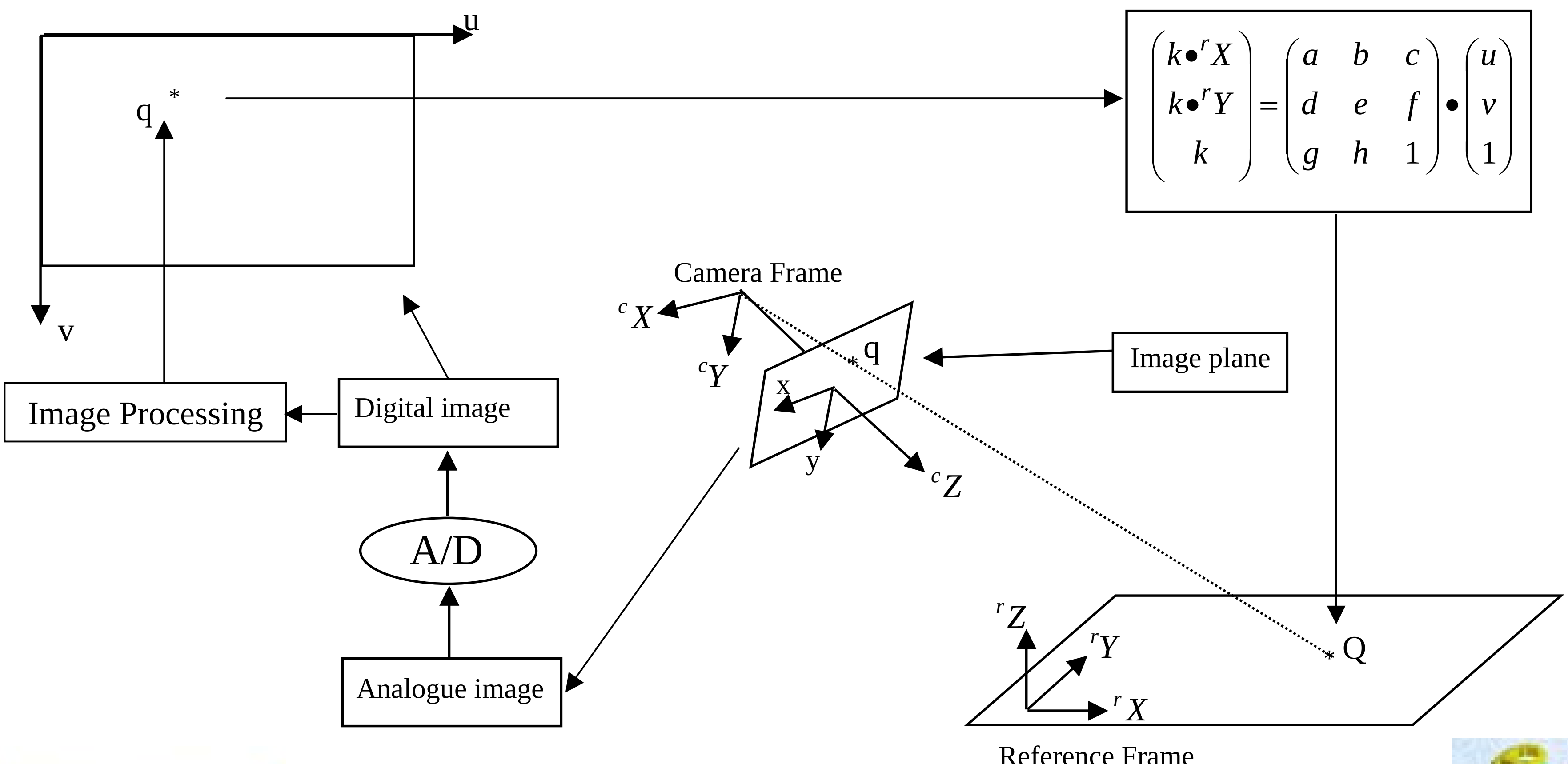
3. Vision Techniques: Active 3D Scanner

a. System Set-up:



b. Solution description:

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



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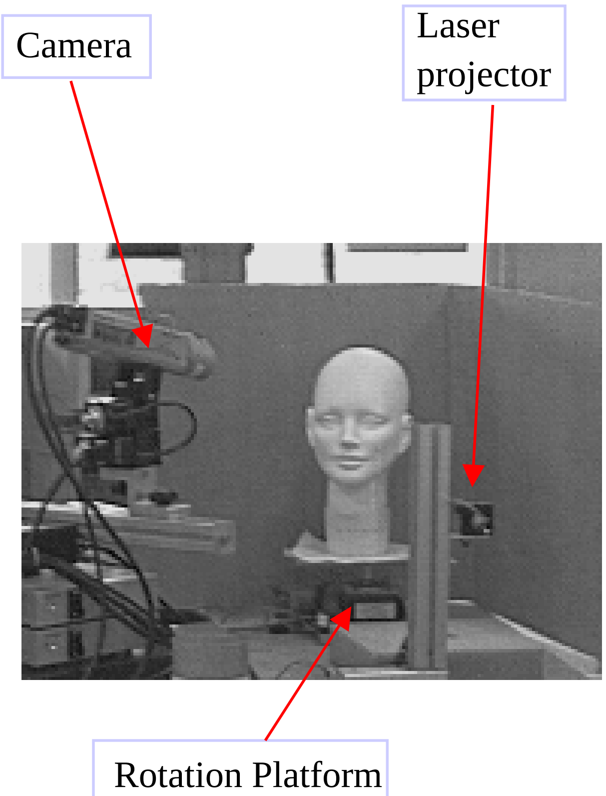
Step 2: We can use a laser projector to create a 2D plane of laser projection.

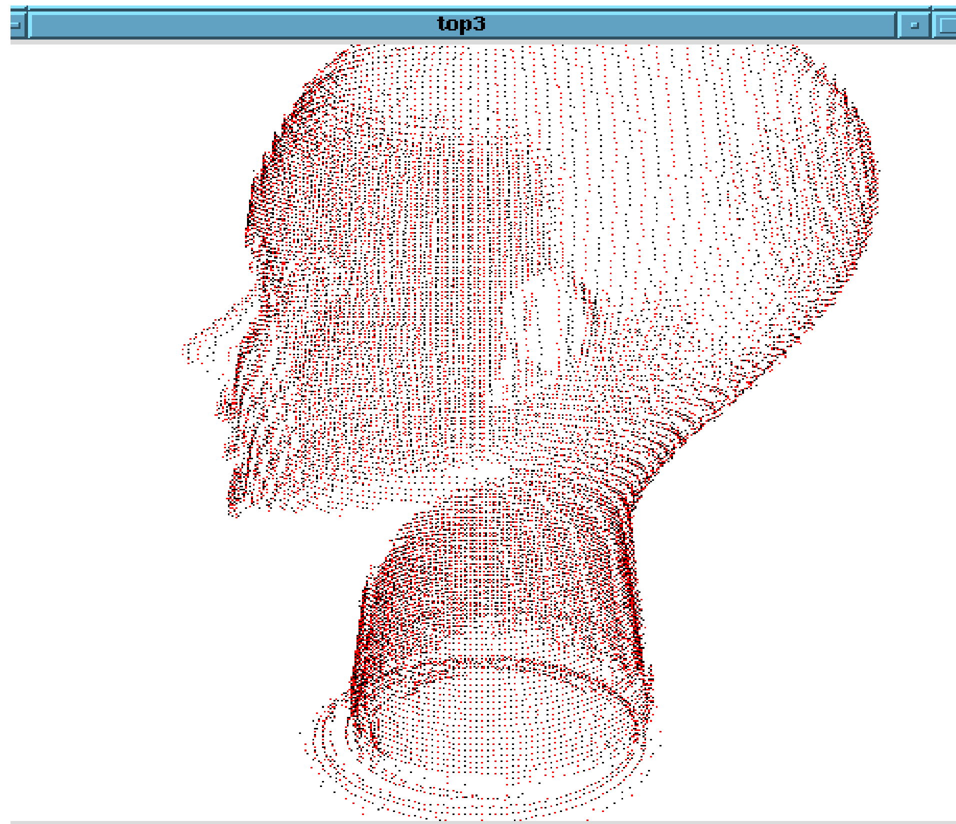
Step 3: The intersection between this “laser projection” plane and a 3D object forms a intersection line.

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

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

c. Experimental results:

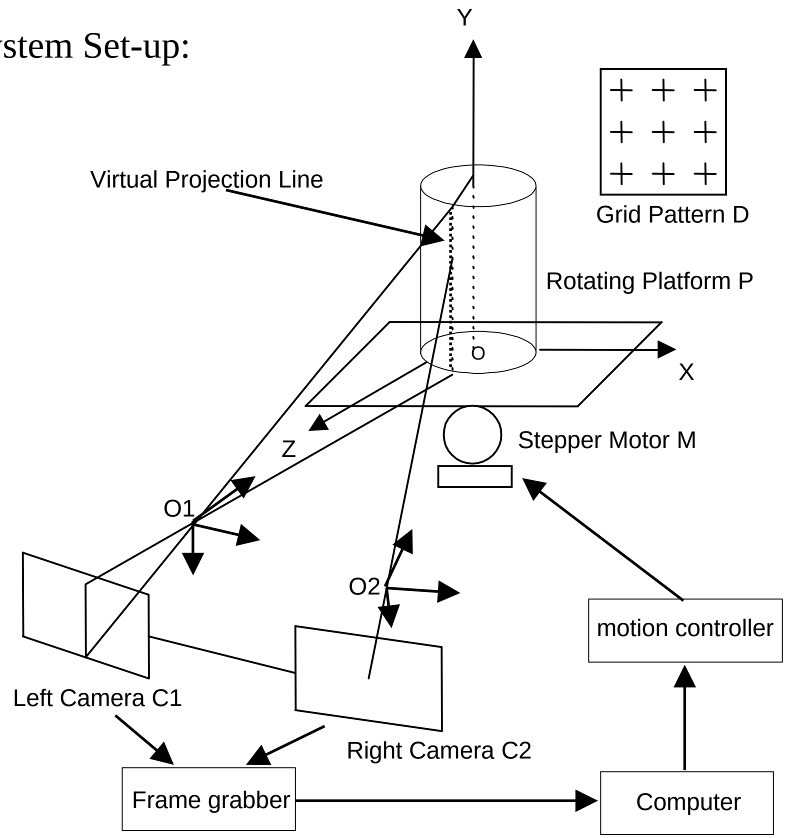




3D MODEL ACQUISITION USING VISION

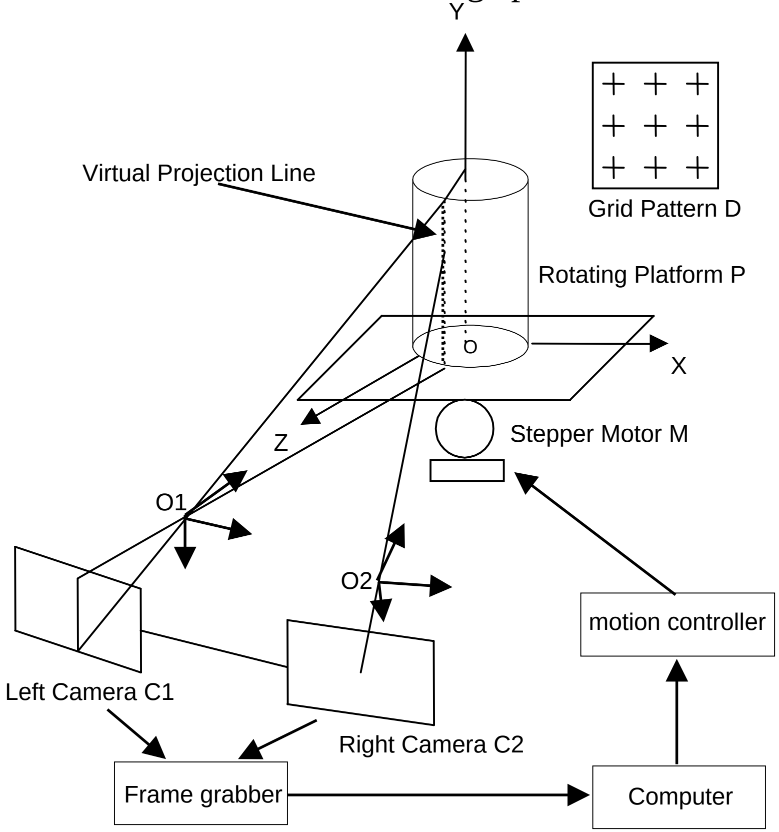
4. Vision Techniques: Passive 3D Scanner or 3D Discrete Stereo Vision

a. System Set-up:



b. Solution description:

Step 1: We use two cameras (like conventional stereo vision) but one camera serves as a virtual projector. We detect and select edge primitives to do 3D reconstruction.



Input:

$$I = \{I(i, j);\ \ 0 \le i < n;\ 0 \le j < m\}$$

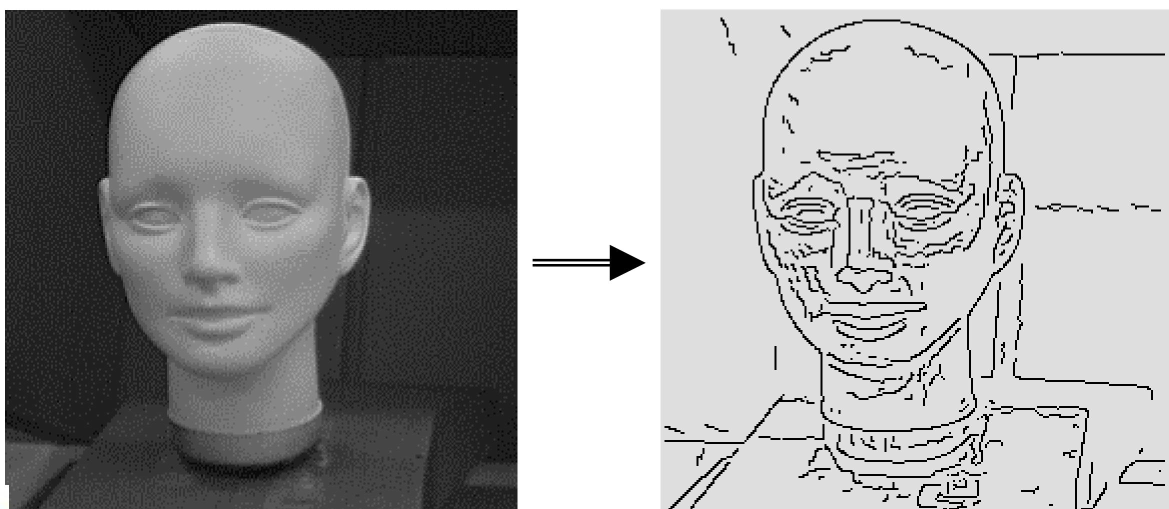
Output:

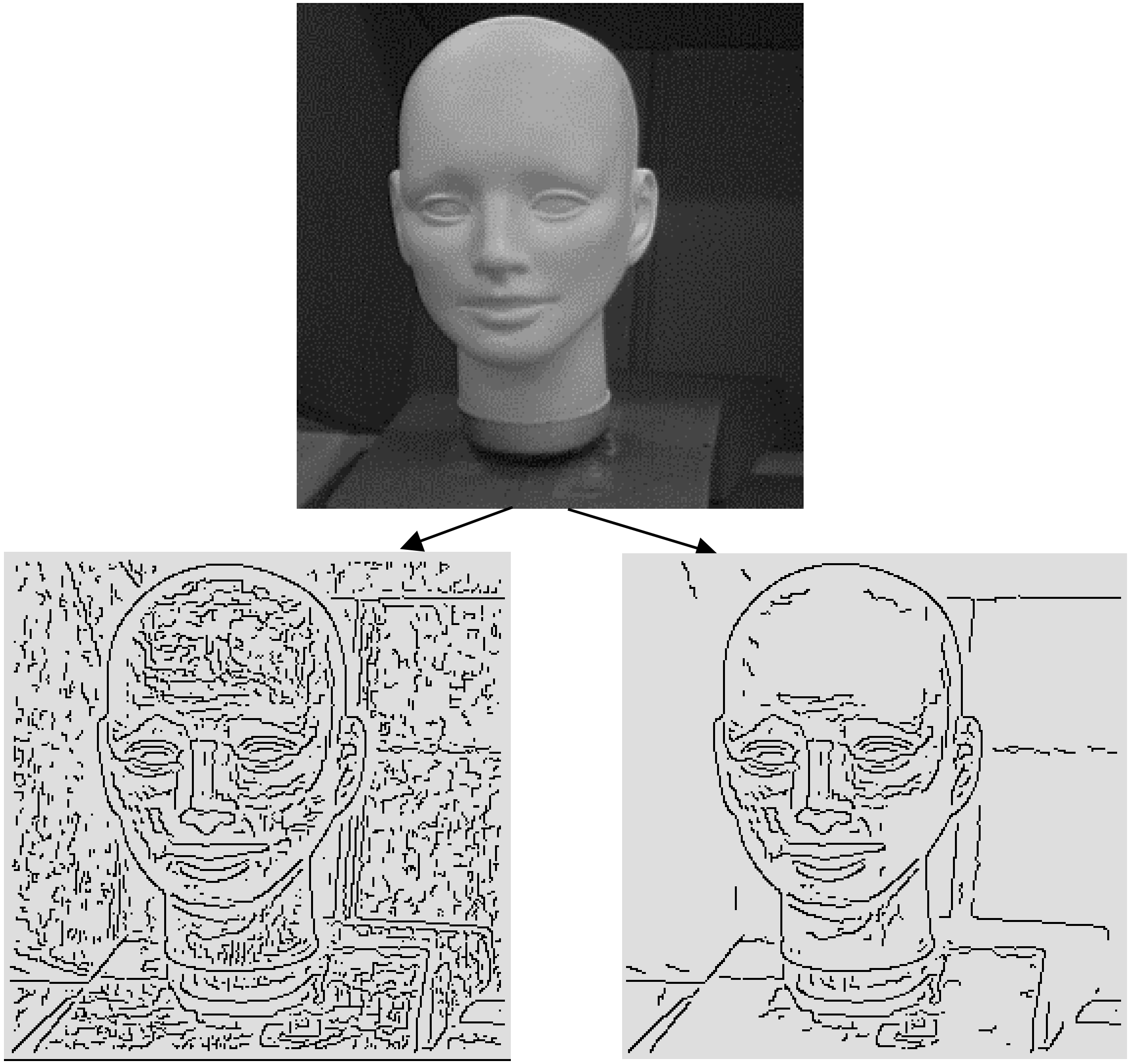
$$G = \{G(i, j);\ \ 0 \le i < n;\ 0 \le j < m\}$$

Computation:

$$\begin{cases} G = \sqrt{\dot{I}_x^2(i, j) + \dot{I}_y^2(i, j)} \\ G(i, j) = \begin{cases} G & \text{if } G > G_0 \text{ and G is a local maxima.} \\ 0 & \text{otherwise.} \end{cases} \end{cases}$$

(G_0 is a threshold)





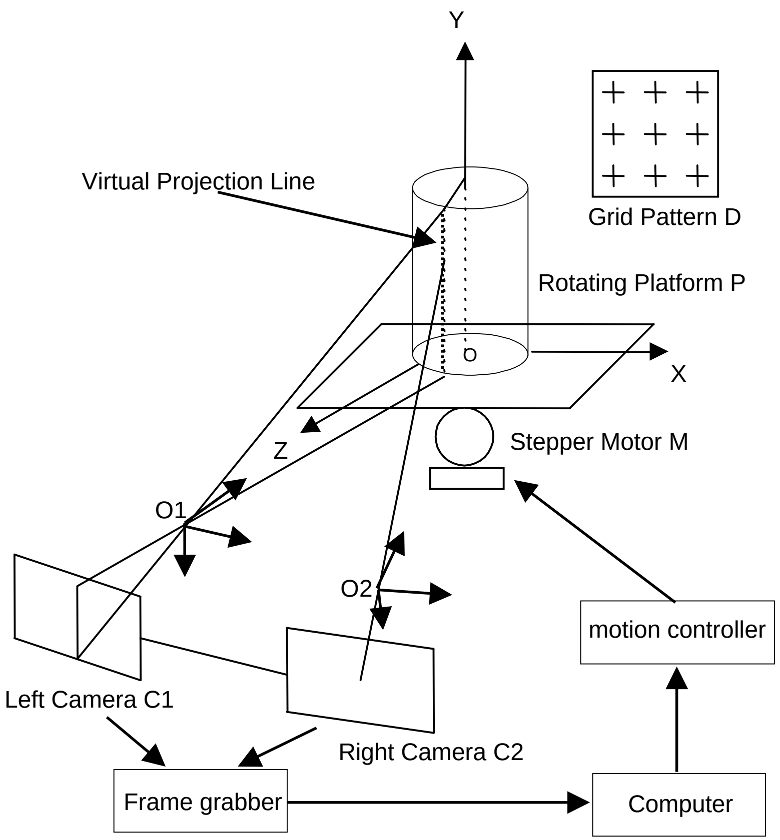
With a small threshold on gradient values

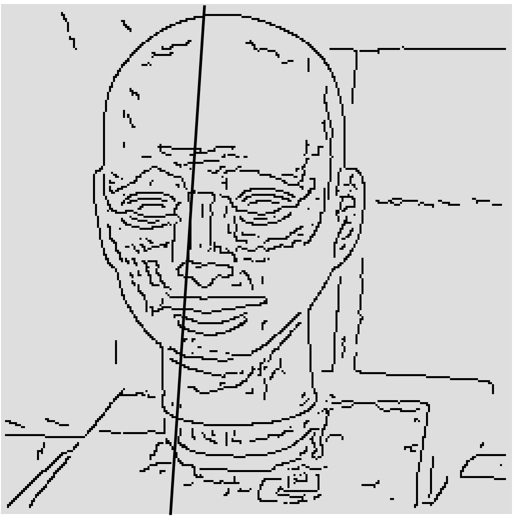
With a high threshold on gradient values

Step 2: The projection plane is defined by the projection of one principal axis of the world coordinate system onto the camera serving as virtual projector. Then, the equation of the virtual projection line can be computed as follows:

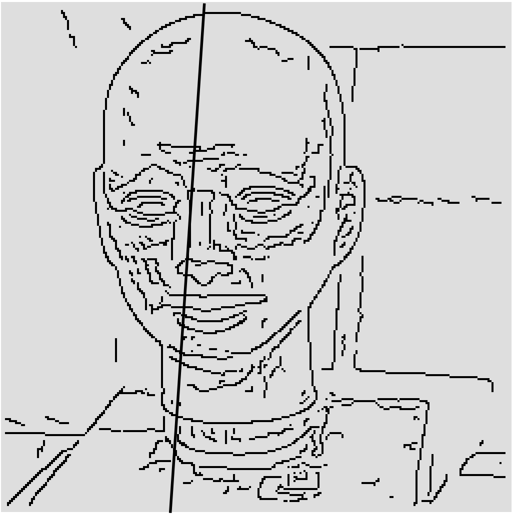
$$\begin{pmatrix} \rho \bullet u \\ \rho \bullet v \\ \rho \end{pmatrix} = M_{c1} \bullet \begin{pmatrix} 0 \\ Y \\ 0 \\ 1 \end{pmatrix}$$

(M_{c1} is the 3D calibration matrix of Camera C1)

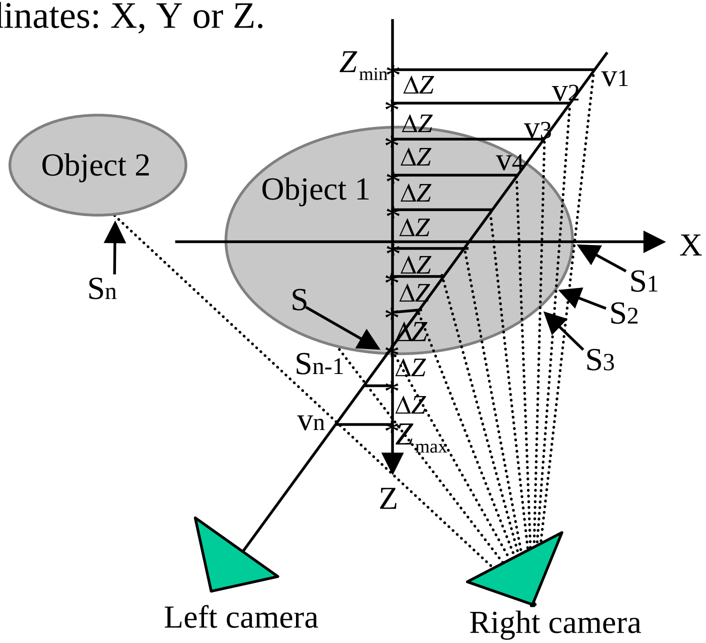




Step 3: The primitives on the virtual projection line in image plane are chosen as the candidates for 3D reconstruction.



Step 4: We identify the match candidates in the other camera by using a template matching technique. The search space is largely reduced if we employ the knowledge about the predefined accuracy of one of the three 3D coordinates: X, Y or Z.



$$Z = Z_{\min} + i \bullet \Delta Z, \quad i = 0,1,2,\ldots$$

$$\begin{pmatrix} k_l \bullet u_l \\ k_l \bullet v_l \\ k_l \end{pmatrix} = M_l \bullet \begin{pmatrix} X \\ Y \\ Z_{\min} + i \bullet \Delta Z \\ 1 \end{pmatrix} \qquad \begin{pmatrix} k_r \bullet u_r \\ k_r \bullet v_r \\ k_r \end{pmatrix} = M_r \bullet \begin{pmatrix} X \\ Y \\ Z_{\min} + i \bullet \Delta Z \\ 1 \end{pmatrix}$$

(M_l and M_r are the 3D calibration matrices of the stero cameras)

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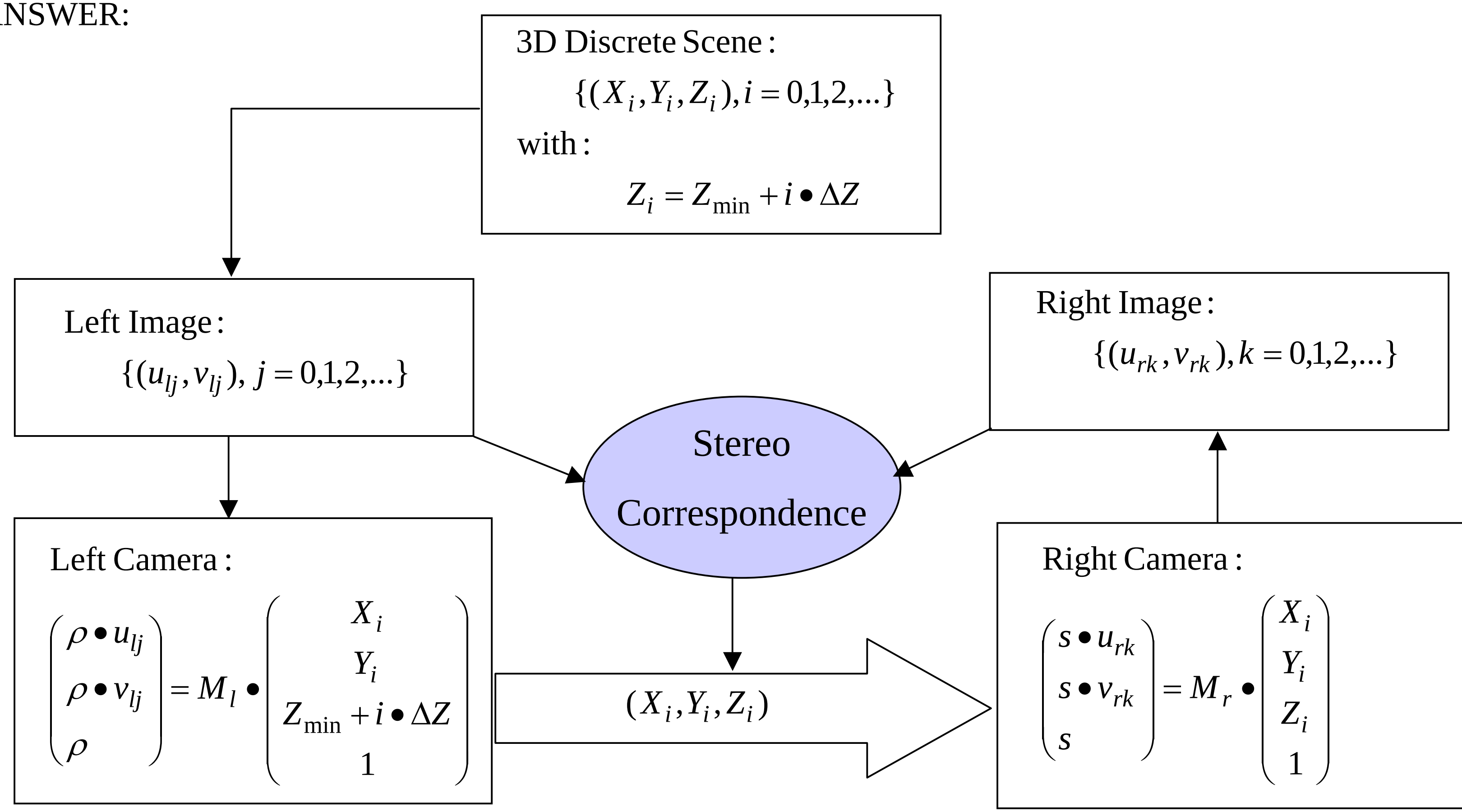
What is the geometric principle of 3D discrete stereo vision ?

ANSWER:



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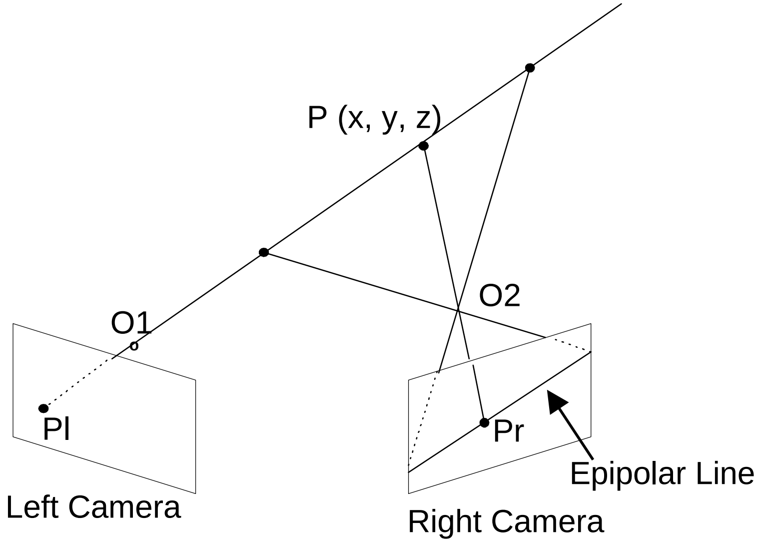
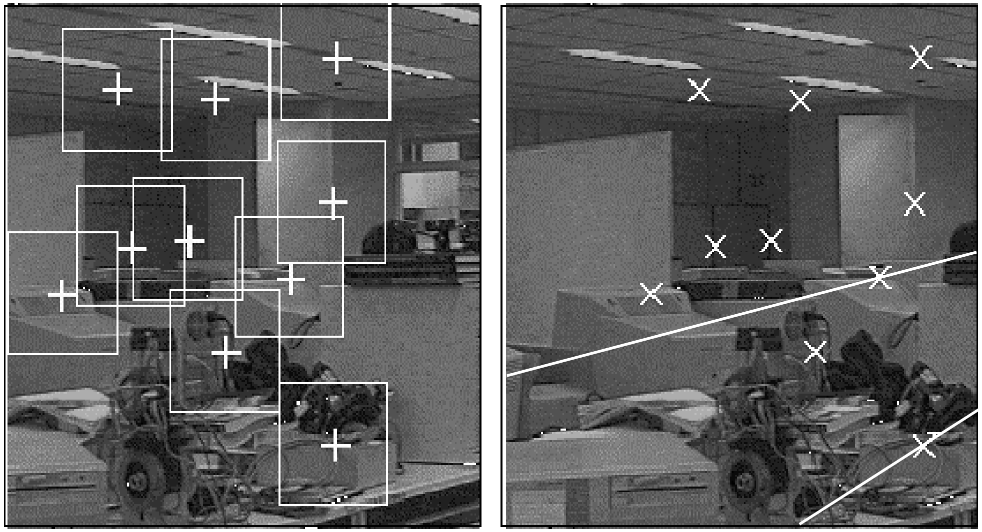
Conventional Searching Method:

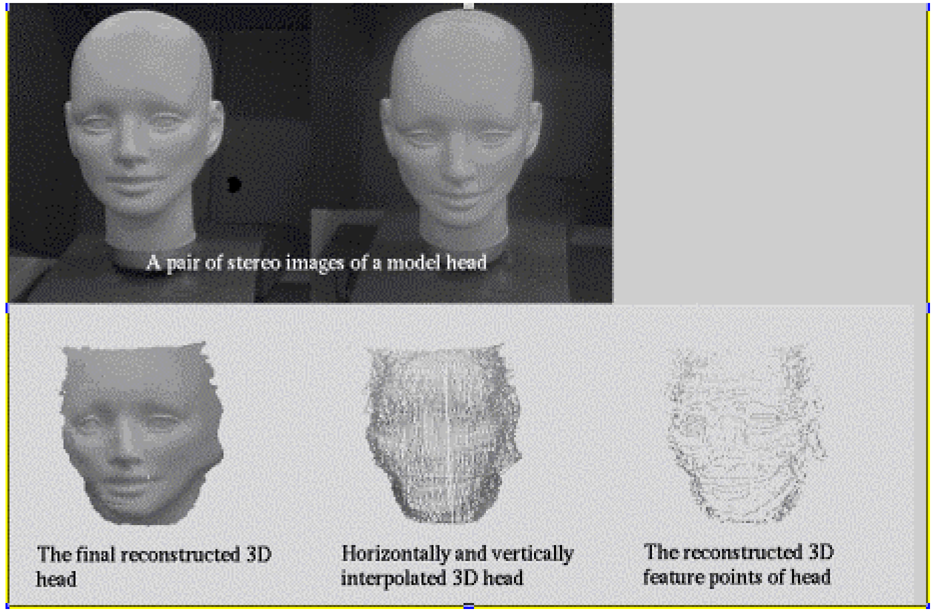
To search all the points on an Epipolar Line

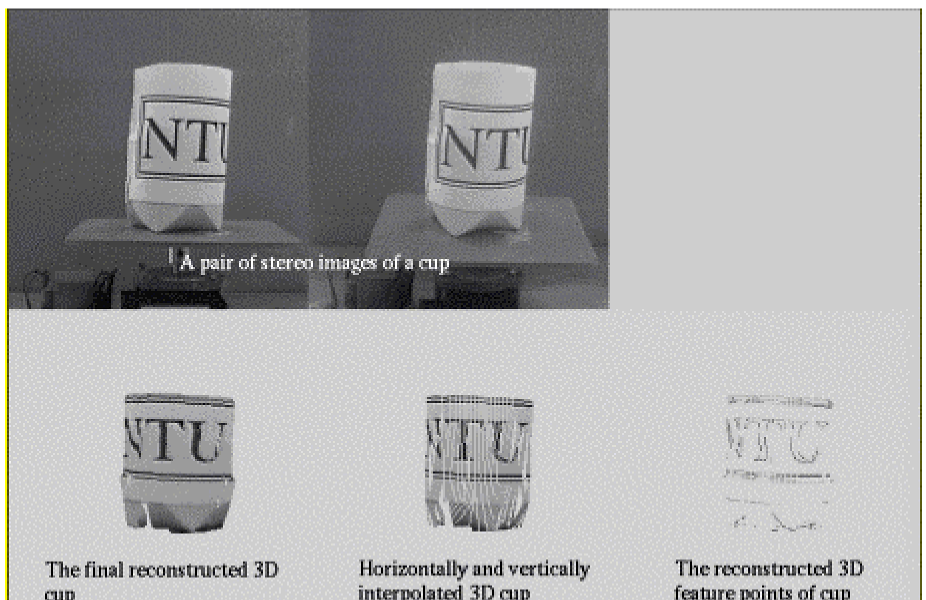
(Drawback: The number of points varies with image resolution !)





c. Experimental Results:





SUMMARY

1. 3D scanner has many applications in industry.

2. 3D scanner based on active scanning has some drawbacks:
   - Dependency on surface properties
   - Difficulty in calibration
   - Inconvenience to human user if exposed to laser beam.

3. It is possible to develop 3D scanner using passive scanning approach. Technical issues of passive 3D scanner includes:
   - Selection of candidates for 3D reconstruction
   - Selection of match candidates by exploring the information on predefined 3D accuracy.
   - Establishment of stereo matches and Simultaneous output of 3D coordinates.
   - Calibration of cameras (conventional stereo vision set-up)
   - Surface modeling and representation (not being treated here)