

ROBOT VISION

Introduction

- The process of extracting, characterizing and interpreting information from images.
- Potential application in many industrial operation.
- Selection from a bin or conveyer, parts identification, limited inspection like gauging, print quality inspection etc.
- Researches undergoing in vision based guidance of robot arm, complex inspection, improved recognition and part location capabilities.
- Challenges- Low cost, rapid response time.

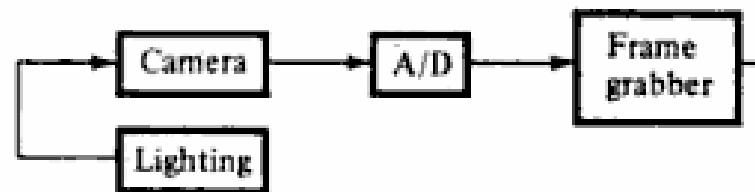
Six Steps

- Sensing - Process that yields a visual image.
- Pre-processing – Noise reduction, enhancement of details.
- Segmentation – Partitioning of an image into object of interest.
- Description – Computation of features to differentiate objects.
- Recognition – Process to identify objects
- Interpretation – Assigning meaning to group of objects.

Operation of machine vision system

1. Sensing and Digitizing Image Data

- Hardware



- Typical techniques and applications

I. Signal Conversion

Sampling.

Quantization.

Encoding.

Sensing and Digitizing Image Data

II. Image Storage/ frame grabber.

III. Lighting

Structured light

Front/ back lighting

Beam splitter

Retroreflectors

Specular Illumination

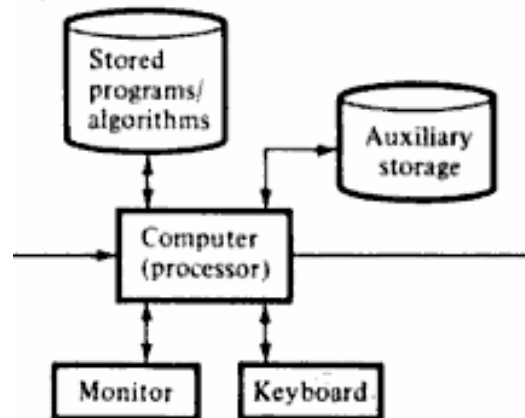
Diffuse lighting

Directional lighting etc.

Image processing and Analysis

2) Image processing and Analysis

- Hardware



- Typical techniques and applications

1. Data reduction

Windowing

File formats and Compressions

Digital conversion

Image processing and Analysis

2. Segmentation

Thresholding

Region oriented Segmentation

Edge linking and boundary detection

Motion based segmentation

3. Feature extraction

Boundary and Regional Descriptors

4. Object recognition

Template matching etc.

Applications

3. Applications

- Hardware



- Typical techniques and applications

Inspection

Identification

Orientation

Presence Verification

Visual Servoing and navigation etc.

Classification

1. 2D or 3D model

Checking dimensions of a part, presence of a component on a subassembly etc can be done by 2D analysis which includes simple thresholding techniques.

3D requires special lighting and image processing algorithms.

2. Number of grey scale

Binary images using black or white. Otherwise a grey scale is used.

Image Acquisition

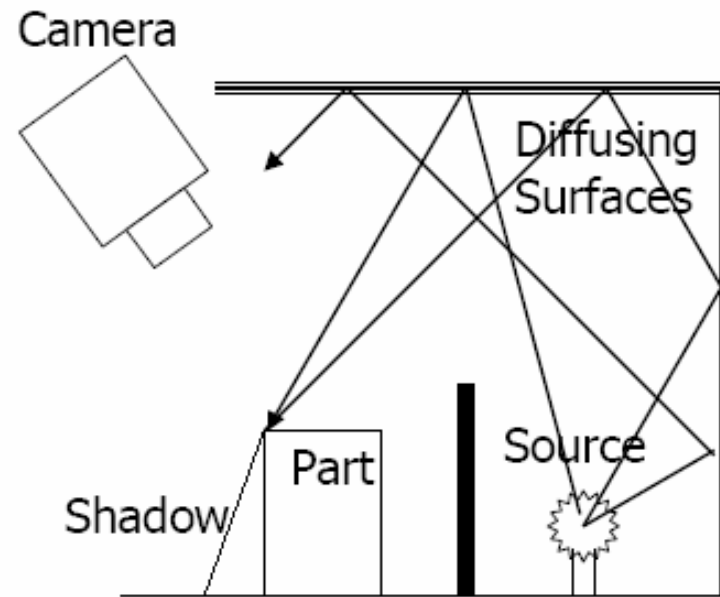
- Capturing the image using vision camera.
- Relative light intensities from Analog to digital conversion.
- Sampled spatially.
- Quantized in amplitude
- Results in digital image
- The frame grabber for image storing (pixel array) and computation.

Hardware

- Vidicon tube
- Solid state imagers
 1. CCD – Charged Coupled Devices
 2. CID – Charge Injection Devices
 3. CMOS – Complimentary Metal Oxide Semiconductors.
 4. Foveon – a chip of transparent quartz containing 3 layers of CMOS.

Illumination

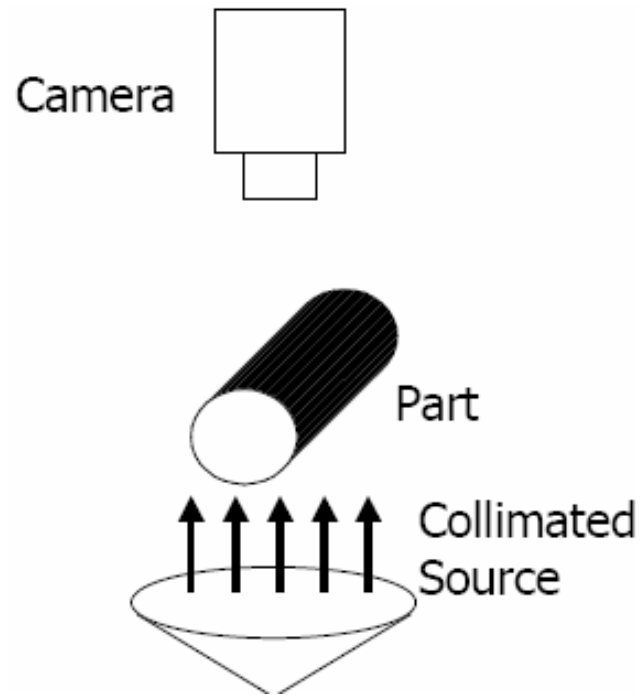
1. Diffuse lighting



- For smooth regular objects.

Illumination

1. Back Lighting



- Binary image
- For recognition, measurement etc.

A/D signal Conversion

- Sampling

A given analog signal is sampled periodically to obtain a series of discrete time analog signals.

- Quantization

Each sampled discrete time voltage level is assigned to a finite number of defined amplitude levels. These amplitude levels corresponds to the grey scale used.

- Encoding

Amplitude levels to binary digit sequence

Image processing and analysis

1. Image data reduction

Objective is to reduce the volume of data.

- Digital Conversion

It reduces the number of grey levels used.

- Windowing

Portion of the total image for analysis.

- File formats and Compression

Orderly sequence of data used to encode digital information for storage or exchange.

Image processing and analysis

- Common file formats

- I. Tagged Image File Format (TIFF)

- II. Portable Network Graphic (PNG)

- III. Joint Photographic Experts Group File Interchange Format (JPEG or JFIF)

- IV. Graphic Interchange Format (GIF)

- Compression

- I. Redundancy reduction

- Looks for patterns and repetitions can be expressed efficiently.

Image processing and analysis

II. Irrelevancy reduction

Removes or alter information that makes little or no difference to the perception of the image.

- Lossless compressions

Based on redundancy reduction and typically concentrate on more efficient ways of encoding the image data.

- LZW compression

Lempel, Ziv and Welch. Looks for recurrent patterns in the image's raster data, replacing these with codes, giving the most common patterns the shortest codes. Eg. Gif files.

Image processing and analysis

- Lossy compressions

Based on irrelevancy reduction, giving larger reduction and it is Irreversible

- Jpeg compression

First step is Discrete Cosine Transforms to shift the image's colour values into a mode that can be more efficiently compressed and coded.

Next step is Quantisation, simplifies and round the colour values before they are encoded.

Image processing and analysis

- Blockiness

Higher compressions so low quality. Boundaries between the blocks will begin to show, causing the “blockiness”

- Newer Approaches

Fractal compression

Looks for recurrent shapes and patterns and replace with equations. More computing power. eg. STN format

Wavelet compression

Image as a signal or wave. eg. jp2.

ROBOT TASK PLANNING

Introduction

- Task planning generally describes only initial and final states of a given task
- It is very much essentials to specify the detailed robot motions necessary to achieve an operation
- Task planners need more detailed information about intermediate states
- It need to transform a task-level specifications into manipulator-level specifications
- To carryout this transformation the task planner must have a description of:
 - Object being manipulated
 - Task environment
 - Robot carrying out the task
 - Initial state of the environment
 - Desired (goal) state

3 phases in task planning

- Modeling
- Task specification
- Manipulator program synthesis

World Model for a task involves:

1. Geometric description of all objects and robots in the task environment
2. Physical description of all objects
3. Kinematic description of all linkages
4. Descriptions of robot and sensor characteristics

Modeling

- The geometric description of objects
Using CAD systems and computer vision
- Three types of three dimensional object representation schemes are
 - Boundary representation
 - Sweep representation
 - Volumetric representation
 - Three types
 - Spatial occupancy
 - Cell decomposition
 - Constructive solid geometry (CSG)

Task specification

- Task are defined by sequences of states of the world model

Three methods of specifying configurations:

1. Using a CAD system to position models of the objects at the desired configurations
2. Using robot itself to specify robot configurations and to locate features of the objects
3. Using symbolic spatial relationships among object features to constrain the configurations of objects

Manipulator program synthesis

- Important face of task planning

Steps involved are

1. Grasp planning
2. Motion planning
3. Error detection

Output of motion synthesis phase is a program composed of

- Grasp commands
- Several motion specifications
- Error tests

Basic problems in task planning

1. Symbolic Spatial Relationship
2. Obstacle Avoidance
3. Grasp Planning

Symbolic spatial relationships

- Basic steps in obtaining configuration constraints from symbolic spatial relationships are
 1. Defining a coordinate system for objects and object features
 2. Defining equations of object configuration parameters for each of the spatial relationships among features
 3. Combining the equations for each object
 4. Solving the equations for the configuration parameters of each object

Obstacle avoidance

- Ability to plan motions to avoid collision in the environment
 - Algorithms for robot obstacle avoidance can be grouped into
 - Hypothesize and test
 - Penalty function
 - Explicit free space

- Hypothesize and test

- Method consists of three steps

- Hypothesize a candidate path between the initial and final configuration of the manipulator
- Test a selected set of configurations along the path of possible collisions
- If a possible collision is found, propose an avoidance motion by examining the obstacles that would cause the collision

For modified motion entire process is repeated

- **Penalty function**

- Obstacle avoidance is based on defining a penalty function on manipulator configurations that encodes the presences of objects.
- Total penalty function is computed by adding the penalties from individual obstacles and adding penalty term for deviations from the shortest path
- On the basis of local information, the path search function must decide which sequence of configuration to follow
- The decision can be made to follow local minima in the penalty function

- **Explicit free space**

- Builds explicit representation of subsets of robot configurations that are free of collisions
- Obstacle avoidance is then the problem of finding a path that connects initial and final configurations

Grasp planning

- Robot grasping an object
 - Target object
 - Gripping surface
 - Initial grasp configuration
 - Final grasp configuration
- Three principle considerations in choosing a grasp configuration for objects are
 - Safety
 - Reachability
 - stability