

Lecture 6

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Vision System, Sensor Selection + Transformations

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Announcement

- Outlines of figure slides (yellow colored links in the lectures) as per book Chapters 1-5 are available from:

<http://web.iitd.ac.in/~saha/ethiopia/ch1fig.pdf>

[/ch2fig.pdf](#) [/ch3fig.pdf](#) [/ch4fig.pdf](#)

[/ch5fig.pdf](#)

- Today's lecture outlines were uploaded as 06lec.pdf

Review of Lecture 5

- Purpose and classifications of sensors
- Internal sensors
 - Position: Encoders (digital), Pot, LVDT (analog), etc.
 - Velocity: Tachometer, Hall-effect sensor
 - Acceleration: Based on force measurement
 - Force: Strain gauge-, Piezoelectric-based
- Integration-based sensors reduce noise
- External sensors: Contact, Non-contact

Questions/Doubts/Comments?

- What is a gauge factor in strain-gauges?
- How to detect metallic object?
- Can the same be used for non-metallic objects too?
- Do you know that non-optical computer mouse has encoders inside?

Outline

- **Vision Sensor: Elements**
- **Steps**
 - Image acquisition
 - Image processing
- **Difficulties and Remedies**
- **Sensor Selection**
- **Transformations**
 - Robot architecture, configuration, DOF

Vision Sensor

- External non-contact type
- In Robotics
 - To let them look around
 - Find parts for picking/placing in app. loc.
 - Earlier fixtures were used for accurate positioning (expensive) → Now vision
- Other tasks
 - Determination of configuration, obj. mot.
 - Reconstruction of 3D geometry

Elements in Vision Sensor

- A camera (Vidicon, CCD, etc.)
 - Sensing array, Associated electronics
 - Output signal format, Lens
- Five major parameters for choice of camera
 - Field of view
 - Resolution
 - Working distance
 - Depth of field
 - Image data acquisition rate

Requirements

- For size measurement
 - No. of pixels $> 2 \times$ largest-smallest object size ratio
- Lighting to illuminate the object of interest
- Frame grabber card or video capture card to interface with computer
- Vision software for processing image data
- Digital input/output interface for control

Vision Sensing (M/c Vision)

- Image Acquisition
 - Image is obtained
 - Digitized for further processing: Partitioning the image into cells (Pixels)
 - Assigning a number based on brightness



Four Elements for Acquisition

- A light source
- Lens to focus reflected light from object to image sensor
- Image sensor to convert light signal to electrical signal
- Electronics to read sensed image

Image Processing

- Examines the digitized data
- Locate and recognize object within image field
- Different steps
 - Segmentation
 - Parameter extraction
 - Pattern recognition

Image Processing ...

- Segmentation
 - Breaks the scene into several segments
 - If multiple objects, separate images are formed
- Parameter extraction
 - Looks at segmented objects to find key features, e.g., size, shape, intensity, etc.
- Pattern recognition
 - Attempts to match observed features with the stored criterion $\rightarrow$ To identify objects

Classification

- Low-level vision
 - Processing image for feature (edge, corner, etc.) extraction
 - Operations are carried on pixels → Extracts above features w.r.t. intensity
- Intermediate-level vision
 - Objects are recognized and 3D scenes are interpreted
 - Concerned with grouping of entities (pixels into line)

Classification ...

- High-level vision
 - Equivalent to image understanding
 - Interpretation of scenes in terms of the objects in it
 - Based on knowledge of objects and relationships
 - Distinguishes a line as a part of object structure from those as a surface texture

Difficulties

- Cannot represent all data due to computational problem
 - Memory
 - Processing time
- System must compromise
- Other problems
 - Variations of light
 - Part-size, part-placement, etc.

Remedies

- Binary Vision (For B/W information)
 - Converts to binary image by thresholding
 - A brightness level is selected → Any brightness above is white. Others are black 
- Placement of object so that no overlap happens → Reduces processing time
- Considering small window of actual data: Object of interest within that window
- Take statistical sample of data → decide

Sensor Selection

- Range
 - Measure of diff. betn. min. and max. value
 - A strain gauge can measure 0.1-10 N
- Sensitivity
 - Ratio of change in output to a change in input → Smallest change in input that will be observable as a change in output
 - 0.8 volts per mm

Sensor Selection ...

- Linearity
 - Constancy of ratio of output to input
- Response time
 - Time required for a change in input to be observable as a stable change in output
 - For initially oscillating signals, settled value is considered
- Accuracy
 - Measure of diff. betn. meas. & act. values

Sensor Selection ...

- Repeatability
 - Measure of diff. in value betn. two successive measurements under same condition
- Resolution
 - Measure of no. of measurements within a range from min. to max. → Smallest increment of value that is observable
- Type of output
 - Mech. movement or elect. signal

Physical Characteristics

- Size and Weight
 - Becomes a part of robot mass
- Reliability
 - Can be measured in terms of Mean Time to Failure (MTTF)
 - Also, ease of maintenance. Maintainability is measured by MTTR
- Interfacing
 - Sensor with signal conditioning devices

Questions/Doubts/Comments?

- Let's take a break here!
- Let's move to next Chapter 5 of the book ([Transformations](#))

Transformations

- To control robot
 - Relationship between joint motion (input) and end-effector motion (output) is reqd.
 - Transformations betn. diff. coordinate frames are reqd.
- Robot Architecture
 - Links: A rigid body with 6-DOF
 - Joints: Couples 2 bodies. Provide restrictions

Joints or Kinematic Pairs

- Lower Pair
 - Surface contact: Hinge joint of a door
- Higher pair
 - Line or point contact: Roller or ball rolling
- Several Lower Pair Joints
 - Slides 1-8 of Chapter 5 

Kinematic Chain

- Series of links connected by joints
- Simple Kinematic Chain: When each and every link is coupled to at most two other links
 - Closed: If each and every link coupled to two other links → Mechanism 
 - Open: If it contains only two links (end ones) that are connected to only one link → Manipulator 

Degrees of Freedom (DOF)

- No. of independent (or minimum) coordinates required to fully describe its pose or configuration
 - A rigid body in 3D space has 6 DOF
- Grubler formula (1917) for planar mechanisms
- Kutzbach formula (1929) for spatial mechanisms

Grubler-Kutzbach Criterion

$$n = s(r - 1) - c, \quad c \equiv \sum_{i=1}^p c_i \quad \dots (5.1)$$

s : dim. of working space
 (Planar, $s = 3$; Spatial, $s = 6$);
 r : no. of rigid bodies or links in the system;
 p : no. of kinematic pairs or joints in the system;
 c_i : no. of constraints imposed by each joint;
 c : total no. of constraints imposed by p joints;
 n_i : relative degree of freedom of each joint;
 n : DOF of the whole system.

Note that, $s = c_i + n_i$

$$c = \sum_{i=1}^p c_i = \sum_{i=1}^p (s - n_i) = s p - \sum_{i=1}^p n_i \quad \dots (5.2)$$

Substituting eq. (5.2) into eq. (5.1) →

$$n = s(r - p - 1) + \sum_{i=1}^p n_i \quad \dots (5.3)$$

Four-bar Mechanism, 

$$n = 3 (4 - 4 - 1) + (1 + 1 + 1 + 1) = 1 \quad \dots (5.4)$$

Six-DOF Manipulator 

$$n = 6 (7 - 6 - 1) + 6 \times 1 = 6 \quad \dots (5.5)$$

Five-bar Mechanism 

$$n = 3 (5 - 5 - 1) + 5 \times 1 = 2 \quad \dots (5.6)$$

Double Parallelogram 

$$n = 3 (5 - 6 - 1) + 6 \times 1 = 0 \quad \dots (5.7)$$

Summary

- Vision sensor is explained
 - Elements are shown
 - Difficulties and remedies
- Characteristics of sensors for selection purposes
- Transformation
 - Robot architecture
 - DOF
 - Examples

Thank You

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