Computer Vision

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What is Computer Vision?

- Broadly it can refer to a number of fields in computer science, including computer graphics, image processing, image analysis, scene analysis, etc.
- Computer Vision can be structured into two branches:
  - Image Processing
    - Process images to create new images for *human* viewing; enhancement, restoration of degraded images, bandwidth reduction
  - Image Analysis
    - Interpret extracted data contextually, can be viewed as perception, involves both high-level and low-level techniques
- Image Processing Paradigm
  - All necessary information is in the image
- Image Analysis Paradigm (more AI-ish)
  - Image + context is required

Problem of Perception

A A A

- Perception is involuntary to a certain extent for humans
  - Immediate
  - Effortless
- Size? Font? Orientation? How would you describe the letter A taking all of these factors into account?
- What happens when lines are no longer connected? "THE CAT" example…
  - Context
  - Expectations

Historical Overview

- Approaches to Computer Vision
  - "Bottom Up"
    - Extract features, interpret into lines, curves, regions, etc., use a priori knowledge to interpret semantically
    - L. G. Roberts (1960)
      - 3-D polyhedral objects from a single view
      - Extracted line drawings from input, matched against computed projections of known objects (primitives)
      - Segmentation - Focus of efforts
        - Determining which edge/surface belongs to which polyhedral or object
        - Solved, but only for complete and perfect line drawings
      - Perfect line drawings rarely extracted from actual images of polyhedra
  - Heterarchical
    - Monitor overall process, give feedback to avoid unnecessary feature extraction and processing
    - Shairai (1975)
      - Developed heterarchical system for polyhedral objects – detect outer boundaries first, create hypotheses for presence of other lines which are verified by other processes

History (continued)

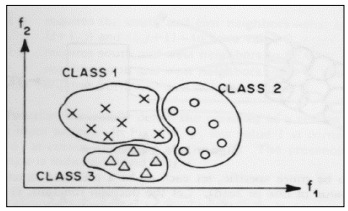
- "Blackboard" approach (Reddy and Newell – 1975)
  - Keep all acquired data available for every other stage in the process to use
  - Each process (feature extraction, semantic interpretation, symbolic representation) has access to common data storage area, and acts independently of other processes
- General Idea of Vision
  - Simple notion of vision – looking for patterns
  - Distinguish objects by shape (box, circle) because those shapes are easily recognized

Pattern Classification Methods

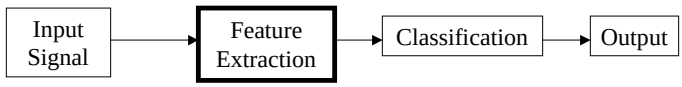
- To better understand higher-level processing techniques, examine classical pattern classification methods
- Pattern Recognition – assign a pattern to one of known, finite classes
- Pattern Classification Methods:
  - Template Matching
    - Compare patterns with stored models of known patterns and choose the best match
    - Templates are images of known patterns, classes are libraries of templates
    - Templates moved over new image to find best match
    - Useful for applications where number of classes and variability within a class is small
    - Example: Optical Character Readers (OCR's)

Pattern Class. Methods (cont'd)

- Pattern Classification in Feature Space
  - Abstract measurements or features from pattern and classify it based on those measurements
    - Define *n* features, span *n*-dimensional feature space
    - Different regions of feature space correspond to different pattern classes



    - Features depend on problem, classification algorithm independent



Pattern Class. Methods (cont'd)

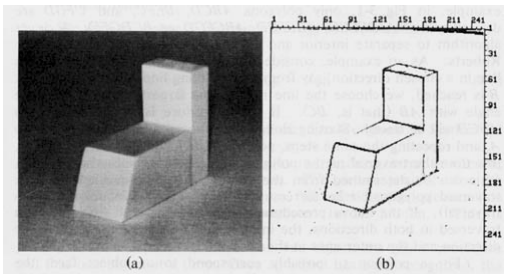
- Syntactical Approaches
  - Divide pattern into primitive subpatterns
  - Use relations between subpatterns, or their features
  - Example
    - Pattern: Triangle
    - Subpattern (primitive): straight line
    - Define Pattern (Triangle) as three primitives (lines) connected at their endpoints
  - Syntactical approaches used in parsing of sentences in programming and natural languages

Scene Analysis (High Level)

- Pattern Classification Methods applied to 2-D, not 3-D
- Problems in 3-D
  - Projecting 3-D onto 2-D can be ambiguous
  - Image changes with viewing angle
  - Scenes of multiple objects may introduce occlusion (one object partially blocked by another)
- Scene analysis methods must deal with these issues based on partial information

Scene Analysis (cont'd)

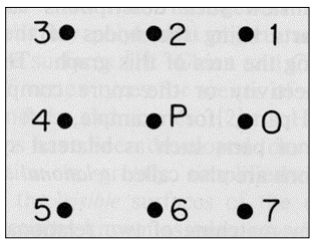
- Extraction of Line Drawings
  - Instead of working on image directly, may be simpler to extract line drawing (Roberts 1960's)



  - Determine edges by applying gradient to pixel at (i, j) and accepting as an edge if R(i, j) > t, where R is the gradient and t is a certain tolerance (ideally 0 but because of noise is chosen as trade off between noise and edges)

Scene Analysis (cont'd)

- Line extraction can be applied to non-polyhedral objects
- Curves are important for special characters and objects
  - Chain Coding (H. Freeman) – technique for defining curves by points
    - Keep track of only the starting point, define other points incrementally in relation to starting point
    - Assign integer code to each of eight neighbors of pixel



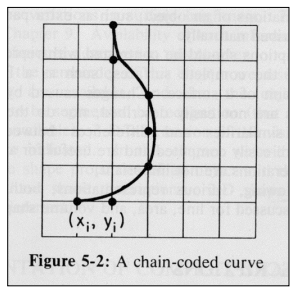


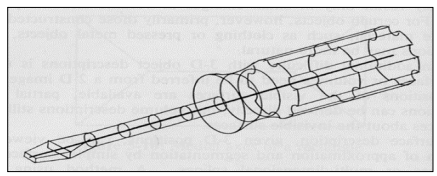
Figure 5-2: A chain-coded curve

Scene Analysis (cont'd)

- From One Image to Multiple Images
  - Using multiple images or camera shots, extract lines, curves, generate a model of object in image
  - One method is to use generalized cones (Agin 1972)
  - Volume generated by sweeping arbitrary-shaped planar figure (cross section) along an arbitrary 3-D space curve (axis)
  - Axis passes through centers of cross sections, normal to them (perpendicular)
  - Size, shape of cross section may change (specified by a cross section function)
  - Capable of producing simple descriptions for many natural shapes: animals, tree trunks, manufactured objects

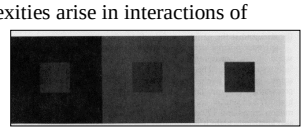
Scene Analysis (cont'd)

- Generalized Cones is an example of a method that can be used to obtain a model of an object
- Other methods exist, involving areas, volumes, graphs, and other geometric relationships
- Model Matching (Recognition)
  - Once an object is described by generalized cones, graphs, or another method, recognition can be achieved by determining which models can generate a line drawing, curve object, or generalized conical object that is most similar, under some permissible transformation
    - The two drawings must match topologically
      - number of lines must match
      - number of vertices must match
      - interconnections must match



Low-Level Image Analysis

- Scene Analysis (High-Level Image Analysis) relies on perfect boundaries and a small number of objects
- In actuality, boundaries are difficult to extract
- Methods of extracting boundaries generally referred to as Low-Level Image Analysis
- Low-Level Image Analysis includes:
  - Brightness and Color
    - Straightforward for a single pixel, complexities arise in interactions of neighboring pixels
  - Edge and Curve Detection
    - Recall template matching (edge masks)
    - Recall Threshold: R(i,j) > t
      - Can use other operators to determine whether or not a point is an edge
      - Can use other forms of edge detectors besides a threshold value



Applications

- Computer Vision has many practical applications
  - Industrial Applications
    - Huron Plastics Group, Port Huron, MI
      - Plastic Molds
    - Ford
      - Bearing assemblies
      - Spark Plugs

Applications

- Industry Applications cont'd
  - Volvo
    - Vision Technology
    - Robotics
    - At the Volvo Koping factory, seven robots assemble 17 components in 30 seconds.

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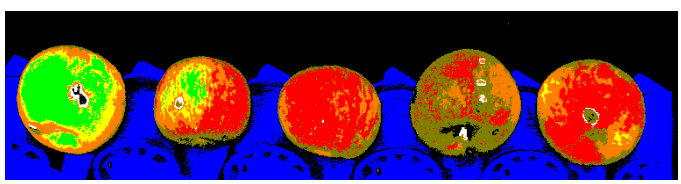
Applications

- 3D Vision
  - Companies who utilize vision technology
    - United States Marine Corps
    - Department of Defense

Applications

- 3D Vision
  - An example of error detection with vision technology



  - Intruder detection
    - Motion detection algorithm

References

- Machine Perception by Ramakant Nevatia
- Intelligent Machines, an introductory perspective of artificial intelligence and robotics by William B. Gevarter

- http://pipes.creighton.edu/csc550/ComputerVision.ppt