Chapter 9. Computer Vision

The Quest for Artificial Intelligence, Nilsson, N. J., 2009.

Lecture Notes on Artificial Intelligence

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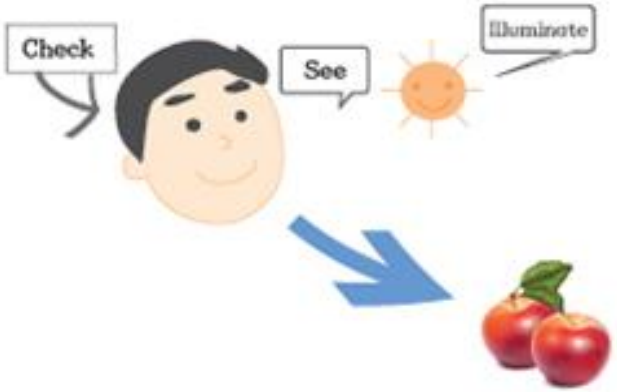
Contents

Overview of Chapter 9

- Computer Vision - Getting information through vision by computer
- Why difficult for computer?
  - The image is a two-dimensional project of a three-dimensional scene
  - the imaging process loss information.
- Human has stereo vision
  - Providing depth information
  - Sometimes cause errors (Shepherd's diagram)

Human Vision vs Computer Vision



Human VS
Computer Vision

Chapter 9. Computer Vision

9.1 Hints from Biology

9.1 Hints from Biology

- "What the Frog's Eye Tells the Frog's Brain" (Lettvin et al., 1968.)
  - Frogs only has some detectors for objects which can help for survive. (e.g. food, predator)

- Neurophysiologic research about 'Simple cells' (Hubel et al, 1962, 1968)
  - Certain neurons respond selectively to images and parts of images of specific shapes.

Chapter 9. Computer Vision

9.2 Recognizing Faces

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- Early works in 1960s and 1970s
  - Trials to automatically recognize faces
  - Panoramic Research
    - Extracting set of features by human (the coordinates of center of pupils)
    - Computer calculate distance of feature like width of mouth
    - Build the database with value of features
  - Michael Kelly
    - Automatically detect facial features in pictures and use them to identify people
    - Find the location of features such as eyes, nose, or shoulders
    - match by nearest-neighbor method
  - Takeo Kanade
    - Use Program coded by assembly language
    - Run on a machine with 10ms cycle CPU and 20kB main memory
- Limitation
  - Images should be of faces of standard scale, pose, expression, and illumination

Chapter 9. Computer Vision

9.3 Computer Vision of Three-Dimensional Solid Objects

Early Vision Approaches

- Summer Vision Project in MIT
  - Trial to develop a visual system
- Two areas on early computer vision for 3D solid objects
  - Low-level vision: constructing a representation of the image (image filtering)
  - Analyzing the line drawing as an assemblage of separate objects

Early computer vision for 3D solid objects

- Image filtering
  - Extracting features by image filtering using averaging windows
  - Examples
    - Sobel operator: Finding large gradient points on vertical and horizontal directions
    - Marr-Hildreth edge detector
  - Marr argued that “brain use edge detector as operator in produce “primal sketch”

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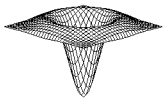
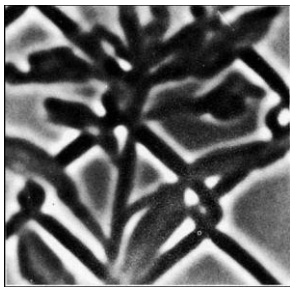


LoG filtering window

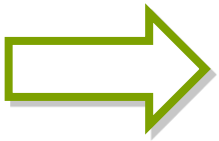
→

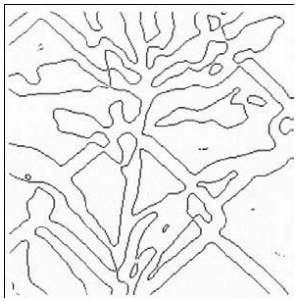


Original image

LoG-processed version

Passing Sobel operator

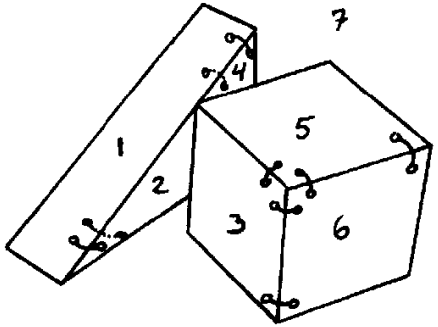


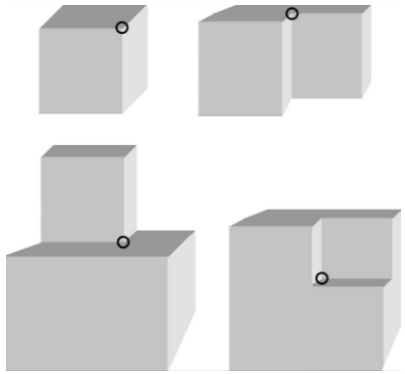


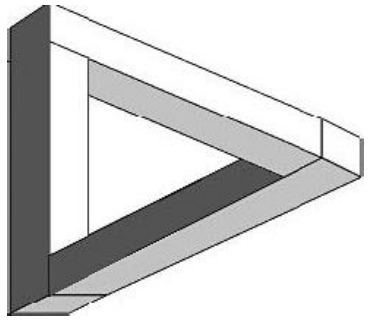
Final result

Early computer vision for 3D solid objects

- Processing line drawing
  - Methods for analyzing line drawings to find objects in images
  - Huffman-Clowes labeling 
    - Assigning labels to the lines by the ways in which planes could come together of the object
    - Impossible object case
      - Labels might be locally consistent, but globally inconsistent







An impossible object

Chapter 9. Computer Vision

Appendix

Computer Vision- Shepard table

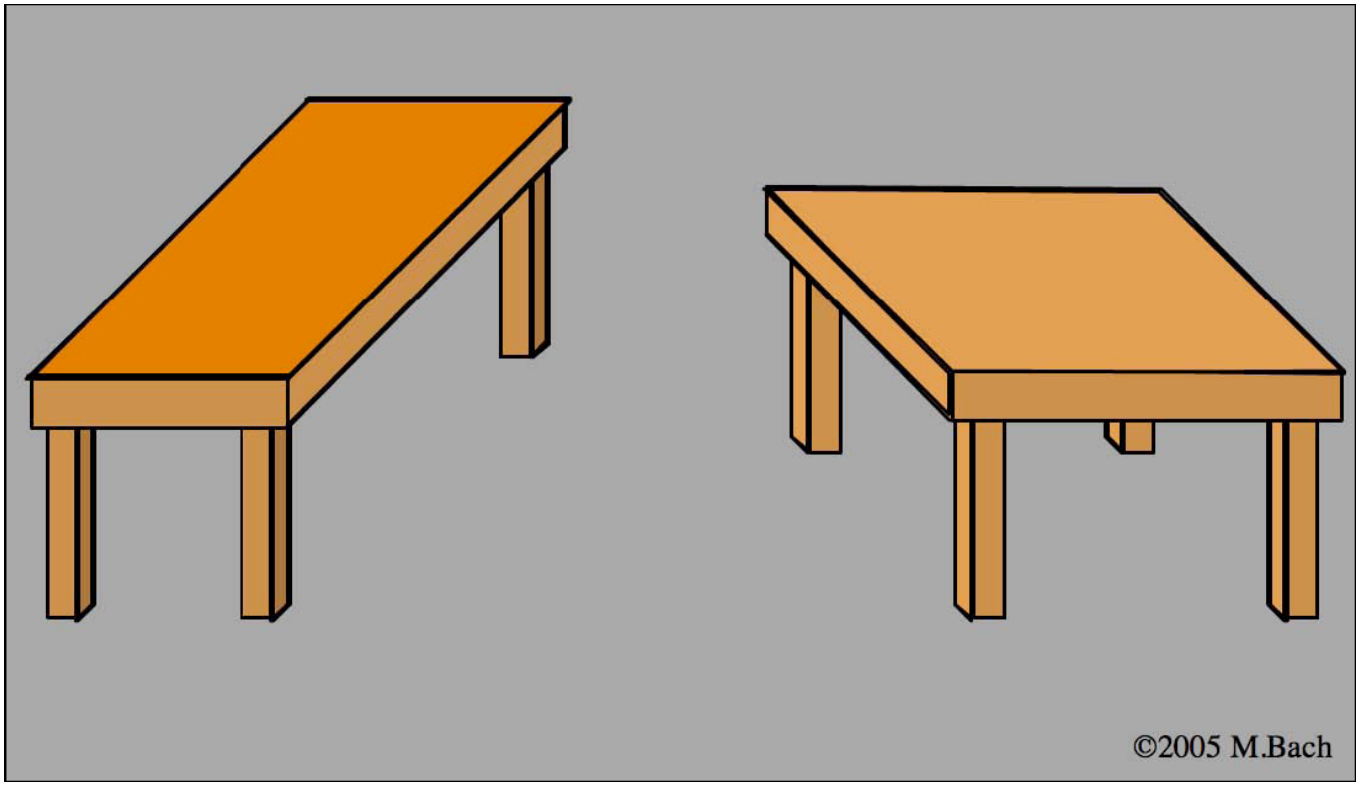


Figure 9.1: Two tables (Illustration courtesy of Michael Bach.)

Visit Bach's Web site, http://www.michaelbach.de/ot/sze_shepardTables/

9.3.1 An Early Vision System

- Roberts's System
  - Identify objects in black-and-white photographs and determine their orientation and position in space.
  - Produce a representation of a line drawing.
  - Roberts Cross
    - Detecting abrupt brightness changes in an image

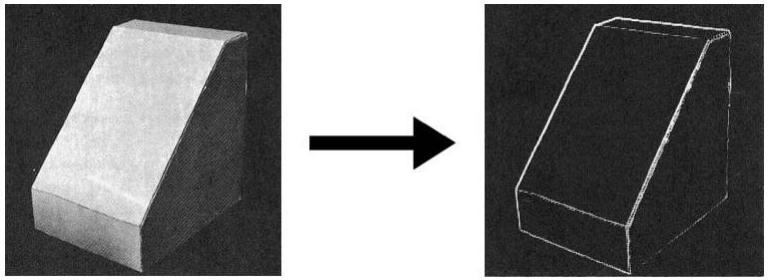


Figure 9.2 :
Detecting changes in intensity.

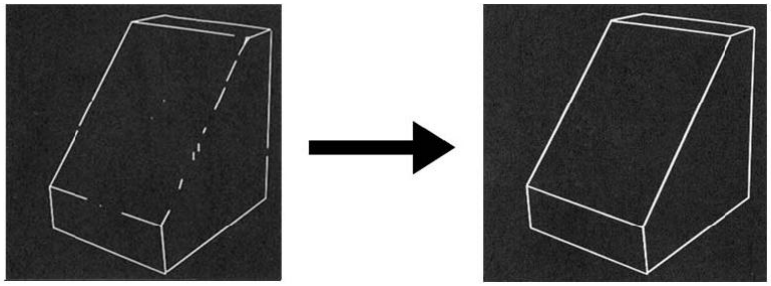


Figure 9.3 :
Producing the final line drawing.

9.3.2 The “Summer Vision Project”

- Trial to develop a visual system in MIT
  - Goal
    - Building a vocabulary of known objects
    - Analyzing a picture from a “videsector” (scanner)
    - Naming objects by matching
- Two areas on early computer vision
  - Low-level vision: constructing a representation of the image (image filtering)
  - Analyzing the line drawing as an assemblage of separate objects

9.3.3 Image Filtering

- Why filtering images?
  - correct for noise
  - enhance image features.
- Averaging Window
  - Image averaging takes into account adjacent values and combine them
  - These intensity values correspond to an image whose right side is bright and whose left is dark with a sharp edge.

0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10
0	0	0	0	0	10	10	10	10	10

Figure 9.4: An array of image intensity values and an averaging window.

9.3.3 Image Filtering

- Sobel Operator
  - Operator use two filtering windows
    - sensitive to large gradients in the vertical direction
    - sensitive to large gradients in the horizontal direction
  - The image intensity at each point is multiplied by the number in the corresponding cell of the filtering window before adding all of the numbers.

-1	0	+1
-2	0	+2
-1	0	+1

+1	+2	+1
0	0	0
-1	-2	-1

Figure 9.5: Sobel's vertical (left) and horizontal (right) filters.

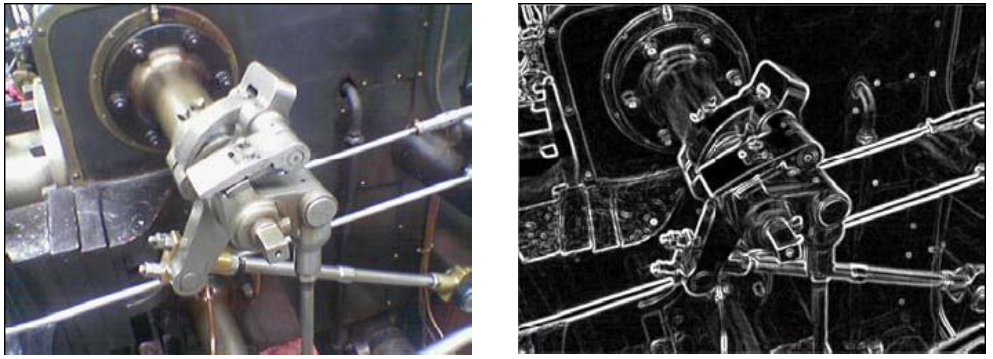


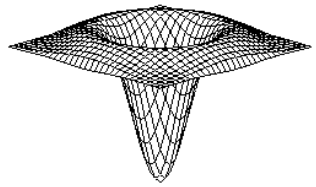
Figure 9.6: Finding abrupt changes in image brightness with the Sobel Operator.
Visit http://en.wikipedia.org/wiki/Sobel_operator.

9.3.3 Image Filtering

- Marr-Hildreth edge detector
  - Laplacian of Gaussian (LoG)
    - Mexican hat
    - Sombrero function
  - LoG-processing
    - Giving whitish bands surrounding darker parts
  - Finding the transitions from light to dark (and vice versa)
  - Marr argued that “brain use edge detector as operator in produce “primal sketch”

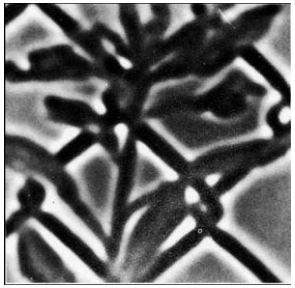
0	0	3	2	2	2	3	0	0
0	2	3	5	5	5	3	2	0
3	3	5	3	0	3	5	3	3
2	5	3	−12	−23	−12	3	5	2
2	5	0	−23	−40	−23	0	5	2
2	5	3	−12	−23	−12	3	5	2
3	3	5	3	0	3	5	3	3
0	2	3	5	5	5	3	2	0
0	0	3	2	2	2	3	0	0

LoG filtering window

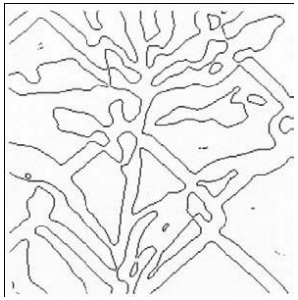


LoG surface

Original image



LoG-processed version



Final result

9.3.4 Processing Line Drawing

- Methods for analyzing line drawings to find objects in images
- Guzman-Arenas' SEE
  - Developed LISP program called SEE
  - Procedure
    - Sorting its vertices into a number of different types.
    - For each vertex, depending on its type, SEE connected adjacent planar surfaces with "links."
  - Capable of finding bodies in rather complex scenes.
  - Could not identify blocks that had holes in them.

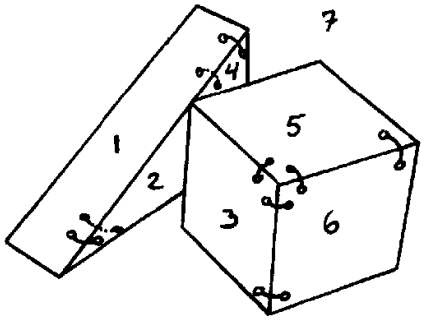


Figure 9.11: Links established by SEE for a sample scene.

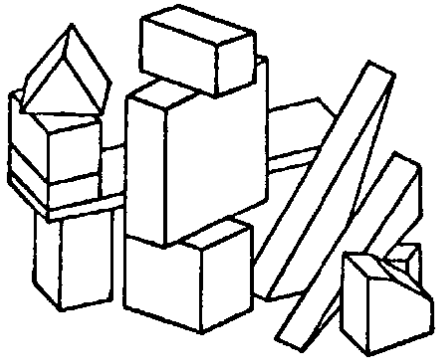


Figure 9.12: A scene analyzed by SEE.

9.3.4 Processing Line Drawing

- Huffman's Work (and Max Clowes)
  - Huffman-Clowes labeling
    - Assigning labels to the lines by the ways in which planes could come together of the object
    - T-nodes
      - Four types in which three plane surface can come together at a vertex
      - Line intersection types caused by one object in a scene occluding another
    - Impossible object case
      - Labels might be locally consistent, but globally inconsistent

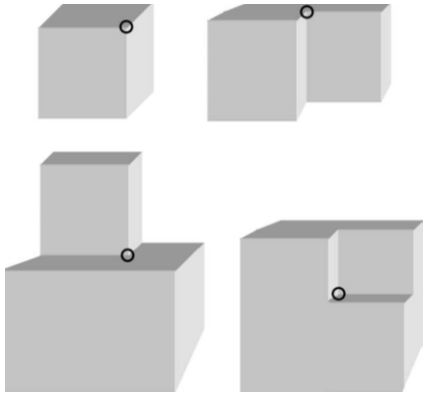


Figure 9.13: The four different kinds of vertices that can occur in trihedral solids.

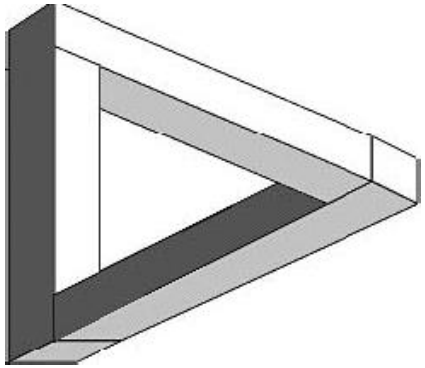


Figure 9.14: An impossible object.

9.3.4 Processing Line Drawing

- Waltz's Work
  - Extend Huffman's scheme to allow for line drawings of scenes with shadows and possible "cracks" between two adjoining object.
  - Propose and implement an efficient computational method for satisfying the constraint that all of the lines must be assigned only one label

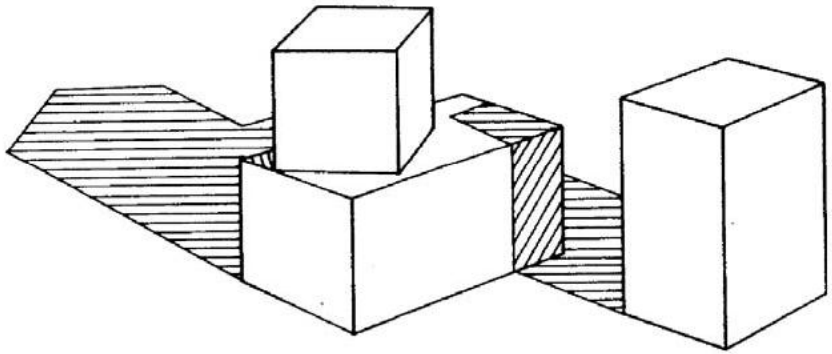


Figure 9.15: A scene with shadows analyzed by Waltz's program.