Lecture 40 of 42

A Brief Survey of Computer Vision and Robotics

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KSOL course page: http://snipurl.com/v9v3
Course web site: http://www.kddresearch.org/Courses/CIS730
Instructor home page: http://www.cis.ksu.edu/~bhsu

Reading for Next Class:

Chapter 24, p. 863 – 894, Russell and Norvig 2e
Chapter 25, p. 901 – 938, Russell and Norvig 2e

Lecture Outline

- This Week: Chapter 26, Russell and Norvig 2e
- Today: Chapter 23, R&N 2e
- Wednesday (Last Lecture!): Chapter 24, R&N 2e
- References
  - *Robot Vision*, B. K. P. Horn
  - Courses: http://www.palantir.swarthmore.edu/~maxwell/visionCourses.htm
  - UCB CS 280: http://www.cs.berkeley.edu/~efros/cs280/
- The Vision Problem
  - Early vs. late vision
  - Marr's 2 ½ - D sketch
  - Waltz diagrams
- Shape from Shading
  - Ikeuchi-Horn method
  - Subproblems: edge detection, segmentation
- Optical Flow

Line Drawing Interpretation

2.1 Definitions

Contour generator: is a 3D space curve.
Contour: is its projection on an image.
Limbs: these occur when a surface curves smoothly and hides itself.
Edges: are when there are discontinuities in surface normals.

2.2 Symbols

+ convex
- concave
> sharp changes in visibility (i.e. occluding edges)–these can only arise from convex edges
>> occluding contours (smooth surface that occludes itself)

The convention with the arrows (>,>>) is that if you are walking like an ant on an edge, following the direction of the arrow, then the belonging surface is on your right.

2.3 Discontinuities

z - changes in depth arise from occluding limbs/edges.
p(rho) - variations in reflectances from surface markings etc.
L(Illumination) - shadows.

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Line Labeling [1]: Solid Polyhedra and Other Shapes

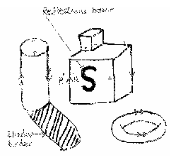

Figure 1: Some sample diagrams

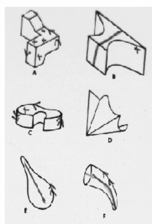

Figure 2: More sample diagrams

Line labelling: Classifying the image curves as depth or orientation discontinuities (and then further sub-classifying them).

Waltz, others

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Line Labeling [2]: Junctions

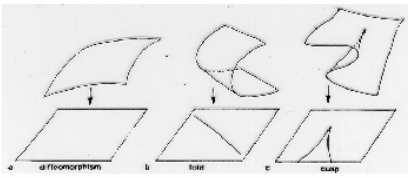


Figure 3: Junctions

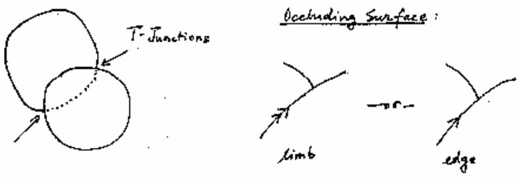
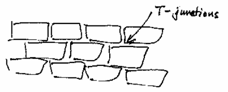


Figure 4: T-Junctions



False
T-junctions

Junctions occur at tangent discontinuities

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Orientation and Texture Discrimination (Textons) [1]

Textons and Julesz' Theory
Julesz' theory for finding boundaries in texture:
Julesz proposed that texture is composed of elementary units called textons. Differences in these textons help us in finding boundaries in texture.

Textons are classified in terms of:
- length, width, & orientation (for elongated blobs)
- # of crossings
- # of terminators

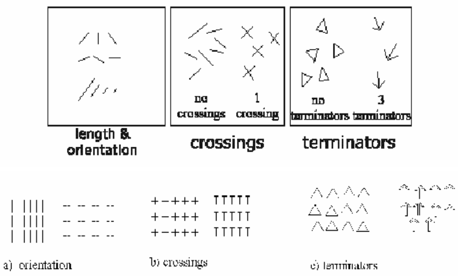

Figure 1: Textons

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Orientation and Texture Discrimination (Textons) [2]

Using textons, we can distinguish between different textures:
Examples:
1) Triangles versus arrow (see image#3): distinguishable through terminators (triangle has 0 terminators, whereas arrows have three terminators)
2) T's versus slanted T's (see image#5): distinguishable through orientation
3) R's and mirror R's (see image#1): indistinguishable because textons are the same

Julesz said that we can distinguish texture if there is a density difference of texton distribution in different areas of an image.

Segmentation (Grouping) [1]: Definition

Boundaries of image regions defined by a number of attributes.

- Brightness and color
- Texture
- Motion
- Stereoscopic depth
- Familiar configuration

Segmentation (Grouping) [2]: Physical Factors

Figure 7: Example picture – bedroom

Factors that lead to grouping:

- Similarity of brightness, color, texture, disparity, motion, ...
- Proximity
- Good continuation of boundary contour
- Closure
- Symmetry and parallelism
- Familiar configuration

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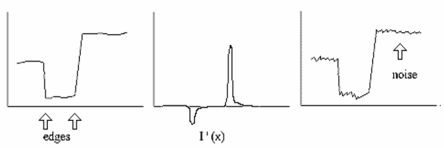
Edge Detection [1]: Convolutional Filters and Gaussian Smoothing

Smoothing and Edge Detection:

Consider an intensity function I(x) shown in the graph below. The values of x for which || I'(x) || is large corresponds to edges.



I(x) [leftmost], I'(x) [center], and noisy I(x) [rightmost]

PROBLEM: When we introduce noise to I(x), we can produce undesirable edges. Consider: $I(x) + \alpha \sin(\omega x)$, where I(x) is our original intensity function and "$\alpha \sin(\omega x)$" is the noise. After differentiation of this function, we get $I'(x) + \alpha\omega \cos(\omega x)$. When ω is large (i.e. high frequency noise), we can get a lot of undesirable edges.

IDEA: Do smoothing before differentiation. This can be done by convolving I(x) with a Gaussian $G_\sigma(x)$ before differentiation:

$$I(x) * G_\sigma(x) \text{ for smoothing}$$

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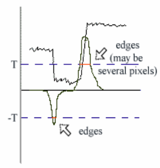
EDGE DETECTION [2]: DIFFERENCE OF GAUSSIAN

Thresholding and Non-maximum suppression:

Consider edge detection by convolution with the derivative of a Gaussian:

$(I(x) * G_\sigma(x))' = I(x) * G_\sigma'(x)$

PROBLEM: Just using ($I(x) * G_\sigma'(x)$) > 0 for edge detection does not work well because the edges can spread over several neighboring pixels. This means that too many pixels will be classified as edges.



IDEA#1: Pick a threshold T and mask edges where $\| I * G_\sigma' \| > T$
IDEA#2: (Non-maximum suppression) Take only the pixels with local maximum values in $\| I * G_\sigma' \|$; i.e., mark only those pixels where $\| I * G_\sigma' \|$ is greater than its neighbors.

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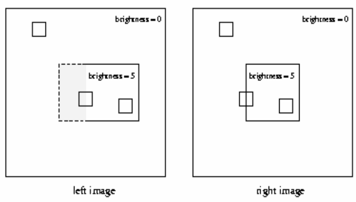
BINOCULAR STEREO [1]: STEREO CORRESPONDENCE – PROPERTIES

1 Stereo Correspondence

Corresponding points have

- Similar values of brightness: result in high cross correlation score.
- Piecewise smoothness of disparity field.
- Uniqueness constraint: less than 1 corresponding point.
- Ordering constraint.
- Epipolar constraint: corresponding point lies on the epipolar lines.



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Binocular Stereo [2]: Stereo Correspondence – Open Problems

1.3 Stereo correspondence – still open

There are still some unsolved problems.

- regions without texture. Certain regions like a white wall make it impossible to find out the disparity.
- depth discontinuities, that is, regions of half-occlusion. We met this kind of problem when choosing the size of matching window. See Figure 2, 3.

Also, current continuity constraint is only one-dimensional case. Ohta and Kanade extend dynamic programming and use inter-scanline constraint. Figure 6 shows the idea.

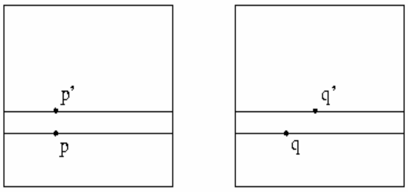

Figure 6: Extended DP by Ohta and Kanade, using the information that if p and p' are close, q and q' should also be close.

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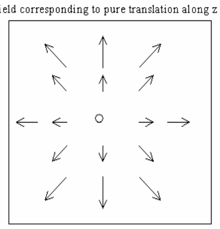
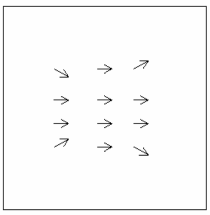
Optical Flow

you can create optic flow diagrams by plotting the (u,v) vector
at the appropriate (x,y) locations

This is the optic flow field corresponding to pure translation along z



Rotation about y – axis



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Terminology

- Vision Problem
  - Early vs. late vision
  - Marr's 2 ½ - D sketch
  - Waltz diagrams
- Shape from Shading
  - Ikeuchi-Horn method
  - Subproblems: edge detection, segmentation
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Summary Points

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- Next Week
  - Natural Language Processing (NLP) survey
  - Final review