

COMP 152: Probabilistic Robotics for Human-Robot Interaction

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Today

- Introduction to Computer Vision
- Project Team-up

Reading Assignment

• Chapter 5 of PR

Project Proposals

Research Papers Presentations

- Each team is required to present one article together
- Presentations should be ~ 20 minutes
- Sign-up sheet to be posted on Canvas

This Thursday

- Preliminary Project Proposal Presentations
- ~ 10 minutes per team

What is an image?

A grayscale image

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An RGB Image



Intensity Levels

- 2
- 32
- 64
- 128
- 256 (8 bits)
- 512
- •
- 4096 (12 bits)

How did computer vision start?

"In 1966, Marvin Minsky at MIT asked his undergraduate student Gerald Jay Sussman to "spend the summer linking a camera to a computer and getting the computer to describe what it saw". We now know that the problem is slightly more difficult than that!"

Human vs Computer Vision





What we see

What a computer sees

Image Plane v.s. Image Array



Point Operations



Local Operations

[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 1]

Local Operations

[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 1]

Edge Detection

[https://www.mathworks.com/matlabcentral/fileexchange/51124-shannon-edge-detector-for-grayscale-images]

Early Example of Edge Detection by Robots

Global Operations

Thresholding an Image

[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 1]

Dark Image on a Light Background

$$F_T[i,j] = \begin{cases} 1 & \text{if } F[i,j] \leq T \\ 0 & \text{otherwise.} \end{cases}$$

Selecting a range of intensity values

$$F_T[i,j] = \begin{cases} 1 & \text{if } T_1 \leq F[i,j] \leq T_2 \\ 0 & \text{otherwise.} \end{cases}$$

Generalized Thresholding

A general thresholding scheme in which the intensity levels for an object may come from several disjoint intervals may be represented as

$$F_T[i,j] = \begin{cases} 1 & \text{if } F[i,j] \in Z \\ 0 & \text{otherwise} \end{cases}$$
(2.4)

Thresholding Example (1)

Thresholding Example (2)

Original grayscale Image

Area of a Binary Image

$$A = \sum_{i=1}^{n} \sum_{j=1}^{m} B[i, j].$$

This figure now becomes important

Calculating the Position of an Object

The center is given by

$$\bar{x} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} jB[i,j]}{A}$$
$$\bar{y} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} iB[i,j]}{A}.$$

Horizontal and Vertical Projections

Projection Formulas

$$H[i] = \sum_{j=1}^{m} B[i, j]$$
$$V[j] = \sum_{i=1}^{n} B[i, j].$$

Diagonal Projection

[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 2]

The area and the position can be computed from the H and V projections

$$A = \sum_{j=1}^{m} V[j] = \sum_{i=1}^{n} H[i]$$
$$\bar{y} = \frac{\sum_{i=1}^{n} iH[i]}{A}$$
$$\bar{x} = \frac{\sum_{j=1}^{m} jV[j]}{A}.$$

Neighbors and Connectivity
4-Connected



[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 2]

8-connected

8-neighbors [i + 1, j + 1], [i + 1, j - 1], [i - 1, j + 1], [i - 1, j - 1] plus all of the 4-neighbors



Examples of Paths



[Jain, Kasturi, and Schunck (1995). Machine Vision, Ch. 2]

Boundary, Interior, and Background



An Image (a) and Its Connected Components (b)



Color Perception

The RGB Color Space



[http://www.arcsoft.com/images/topics/darkroom/what-is-color-space-RGB.jpg]

The RGB Color Space



[http://www.arcsoft.com/images/topics/darkroom/what-is-color-space-RGB.jpg]



https://upload.wikimedia.org/wikipedia/commons/thumb/1/11/RGBCube_b.svg/2000px-RGBCube_b.svg.png

3D Scatter Plot for a patch of skin





The HSV Color Space

Hue



Color-based Tracking



Color-based Tracking



How should we determine the min and max thresholds for each color channel?

Color Histograms



Color Histogram (4 x 4 x 4 = 64 bins)

Motion

What is this?



What is this?



What action is being performed?









Motion Energy Image (MEI)



[http://www.cse.ohio-state.edu/~jwdavis/CVL/Research/MHI/mhi.html]

Average MEI for various viewing angles



50°





80°

90°

Motion History Image (MHI)





[http://www.cse.ohio-state.edu/~jwdavis/CVL/Research/MHI/mhi.html]

Definitions

Image Sequence

I(x, y, t)

 Binary Images indicating regions of motion

D(x, y, t)

• Binary Motion Energy Image

 $E_{\tau}(x,y,t)$

Motion Energy

$$E_{\tau}(x, y, t) = \bigcup_{i=0}^{\tau-1} D(x, y, t-i)$$

Motion History

$$H_{\tau}(x, y, t) = \begin{cases} \tau & \text{if } D(x, y, t) = 1\\ \max & (0, H_{\tau}(x, y, t - 1) - 1)\\ \text{otherwise} \end{cases}$$

The result: more recently moving pixels appear brighter



[http://www.cse.ohio-state.edu/~jwdavis/CVL/Research/MHI/mhi.html]

MHI pyramid



[http://www.cse.ohio-state.edu/~jwdavis/CVL/Research/MHI/mhi.html]

Motion templates for finishing LEFT-ARM-RAISE and FAN-UP-ARMS.





[http://www.cse.ohio-state.edu/~jwdavis/CVL/Research/VirtualAerobics/aerobics.html]



sit-down MHI



arms-wave MHI



 ${\rm crouch-down}~{\rm MHI}$



sit-down



arms-wave



 ${\rm crouch}{\rm -down}$

Aerobics Dataset



Video



A. Bobick, S. Intille, J. Davis, F. Baird, C. Pinhanez, L. Campbell, Y. Ivanov, A. Schutte, and A. Wilson (1999)

``The Kidsroom: A Perceptually-Based Interactive and Immersive Story Environment"

Presence: Teleoperators and Virtual Environments, Vol. 8, No. 4, 1999, pp. 367-391.

The Kid's Room



[Bobick et al. 1996]





The Blue Monster



[http://vismod.media.mit.edu/vismod/demos/kidsroom/kidsroom.html]


The Technology



[http://vismod.media.mit.edu/vismod/demos/kidsroom/kidsroom.html]

Motion History Templates







Making a 'Y'

Flapping

Spinning

[http://vismod.media.mit.edu/vismod/demos/kidsroom/kidsroom.html]

Detecting the Bed



[http://vismod.media.mit.edu/vismod/demos/kidsroom/kidsroom.html]

Man Overboard Detector





[http://vismod.media.mit.edu/vismod/demos/kidsroom/kidsroom.html]



OpenCV Book and Code

"Learning OpenCV"



• Code from book is on github:

https://github.com/Itseez/opencv_extra/tree/m aster/learning_opencv_v2

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- Connected Components:
 - http://nghiaho.com/?p=1102
 - https://davidlavy.wordpress.com/opencv/connected
 -components-in-opencv/



- Circle Detection:
 - http://docs.opencv.org/3.1.0/d4/d70/tutorial_hough_ circle.html#gsc.tab=0



- Face Detection:
 - http://stackoverflow.com/questions/20757147/detect
 -faces-in-image
 - https://github.com/Itseez/opencv_extra/blob/mast er/learning_opencv_v2/ch13_ex13_4.cpp

- Blog full of OpenCV examples:
 - http://opencvexamples.blogspot.com/

Resources

- OpenCV in ROS:
 - http://wiki.ros.org/vision_opencv
 - http://wiki.ros.org/cv_bridge/Tutorials
 - http://docs.opencv.org/2.4/doc/tutorials/tutorials.html

Grabbing image data with ROS

• Example ROS node that subscribes to an image topic and does image processing:

http://www.cs.tufts.edu/comp/50AIR/code/comp 50_computer_vision.zip

Next time...interest points and registration



Later in the course...3D Vision



Project Activity

- Get with your group
- Sketch an outline of your proposal and assign individual responsibilities

THE END