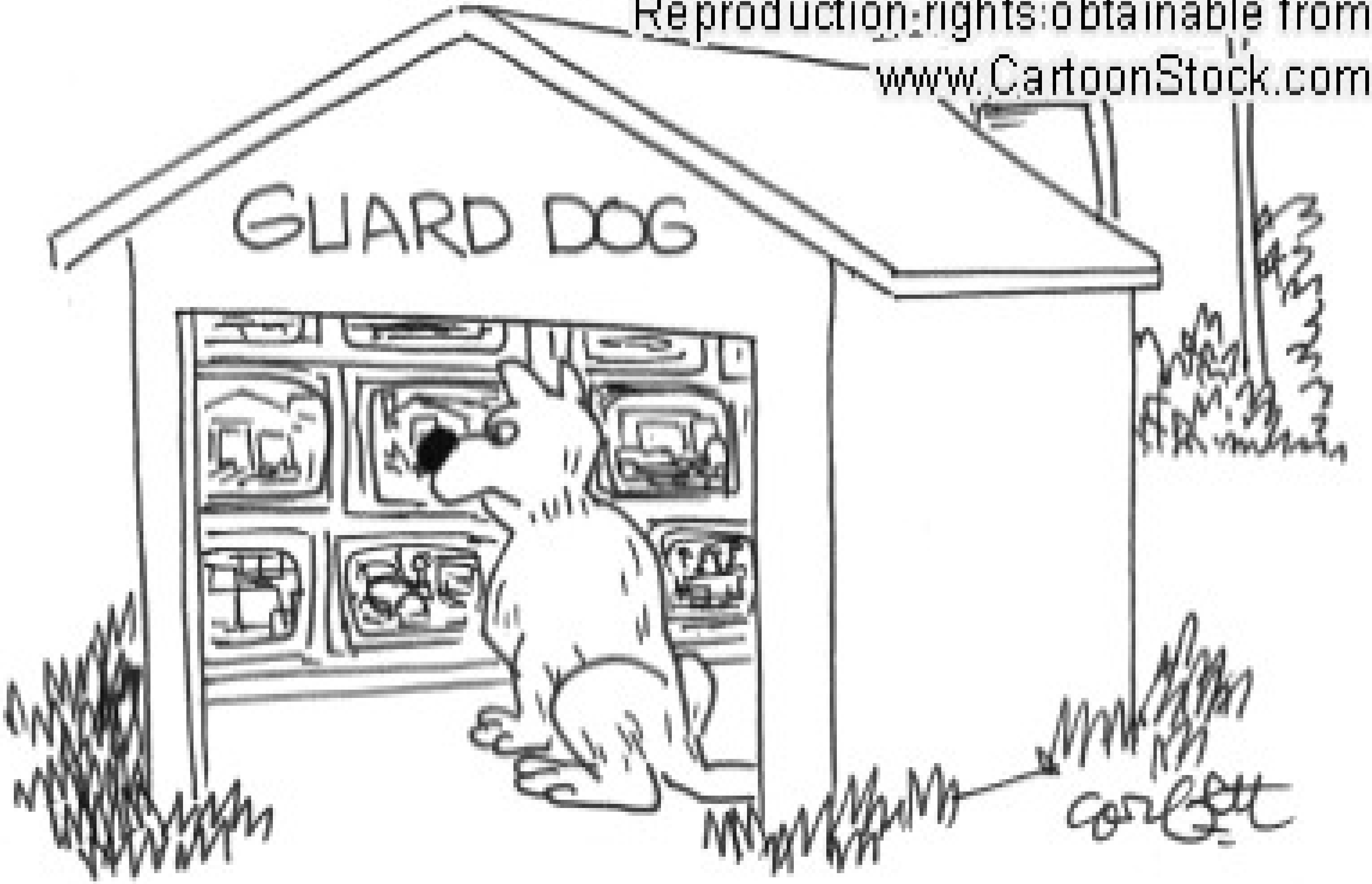

GUARD DOG

Vision Based Autonomous Security Robot (VBASR)

Bradley University – ECE Department
Senior Capstone Project

Sponsored by Northrup Grumman

February 23, 2010

Student:	Kevin Farney
Advisor:	Dr. Joel Schipper

Presentation Outline

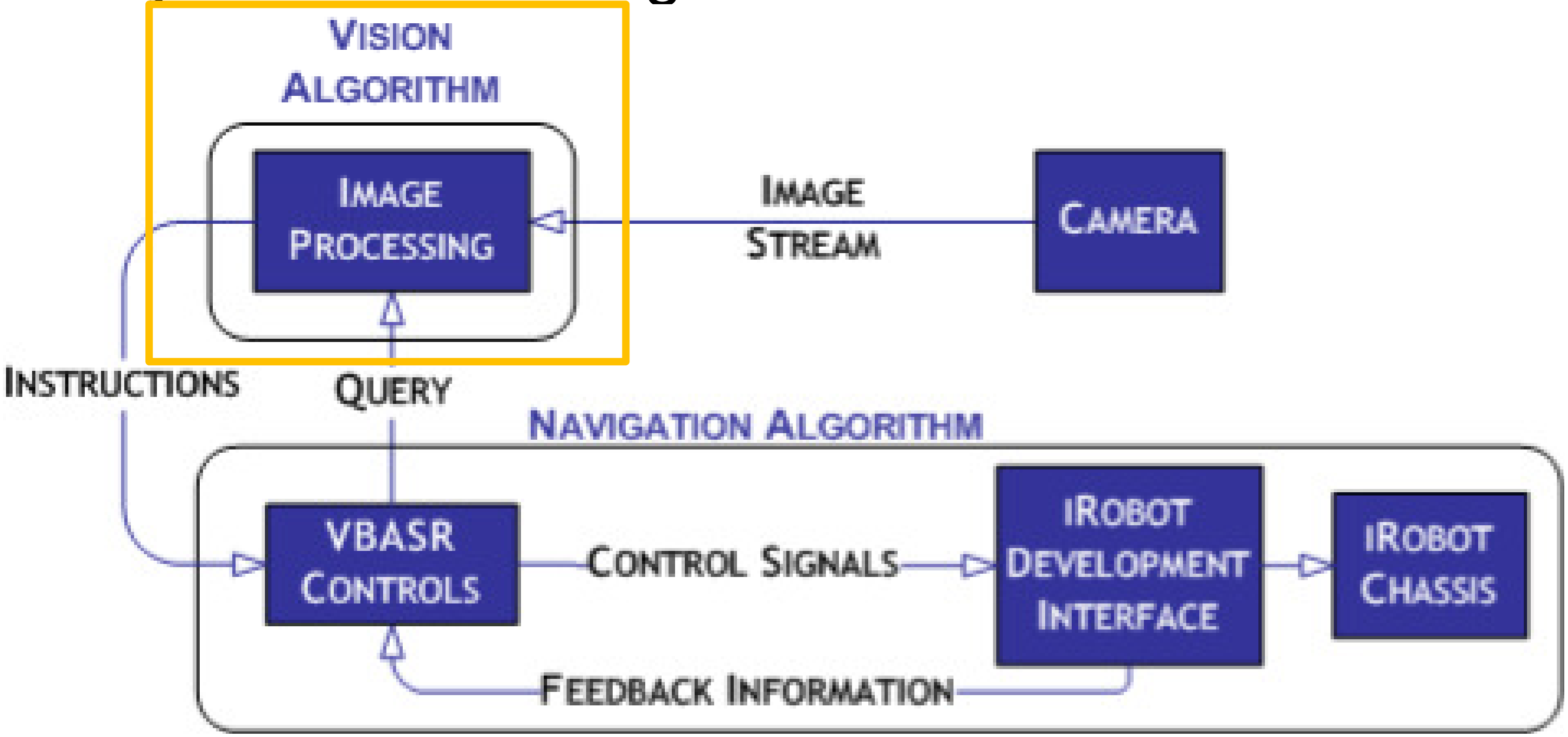
- What the project is…
- What has been completed so far…
- Where the project is going…

Project Summary

- What is VBASR?
  - Autonomous, Mobile, Security Camera
- VBASR is a computer vision project
  - Computer vision is defined as making useful decisions about real physical objects and scenes based on sensed images [1].
- Primary Goals – Using Computer Vision
  - Navigation
  - Obstacle Avoidance

Vision Algorithm

- System Block Diagram



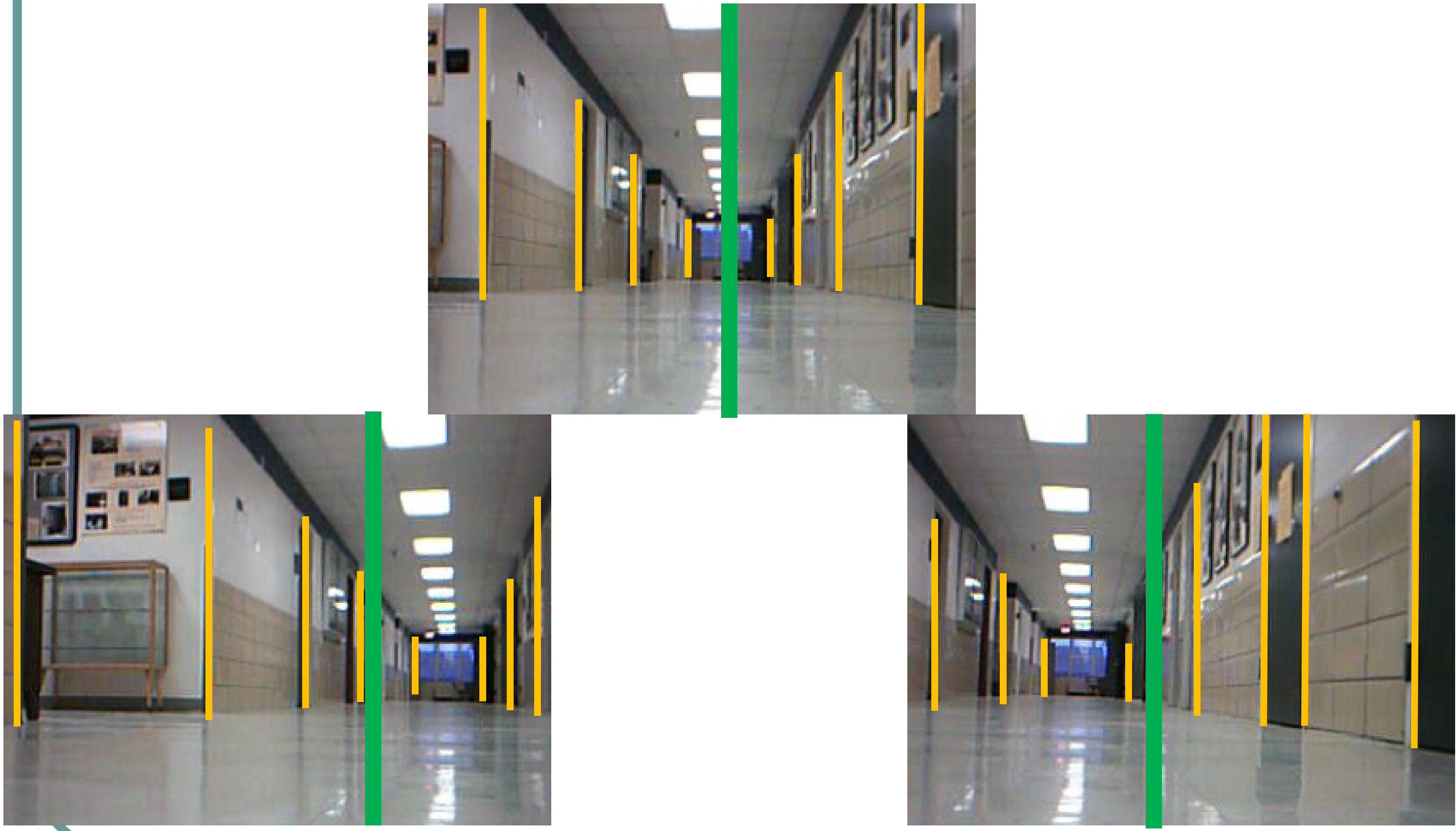
OpenCV 2.0

- Intel
- Computer vision library
  - Image processing/computer vision
  - User interfacing
  - Core functionality
  - Machine learning

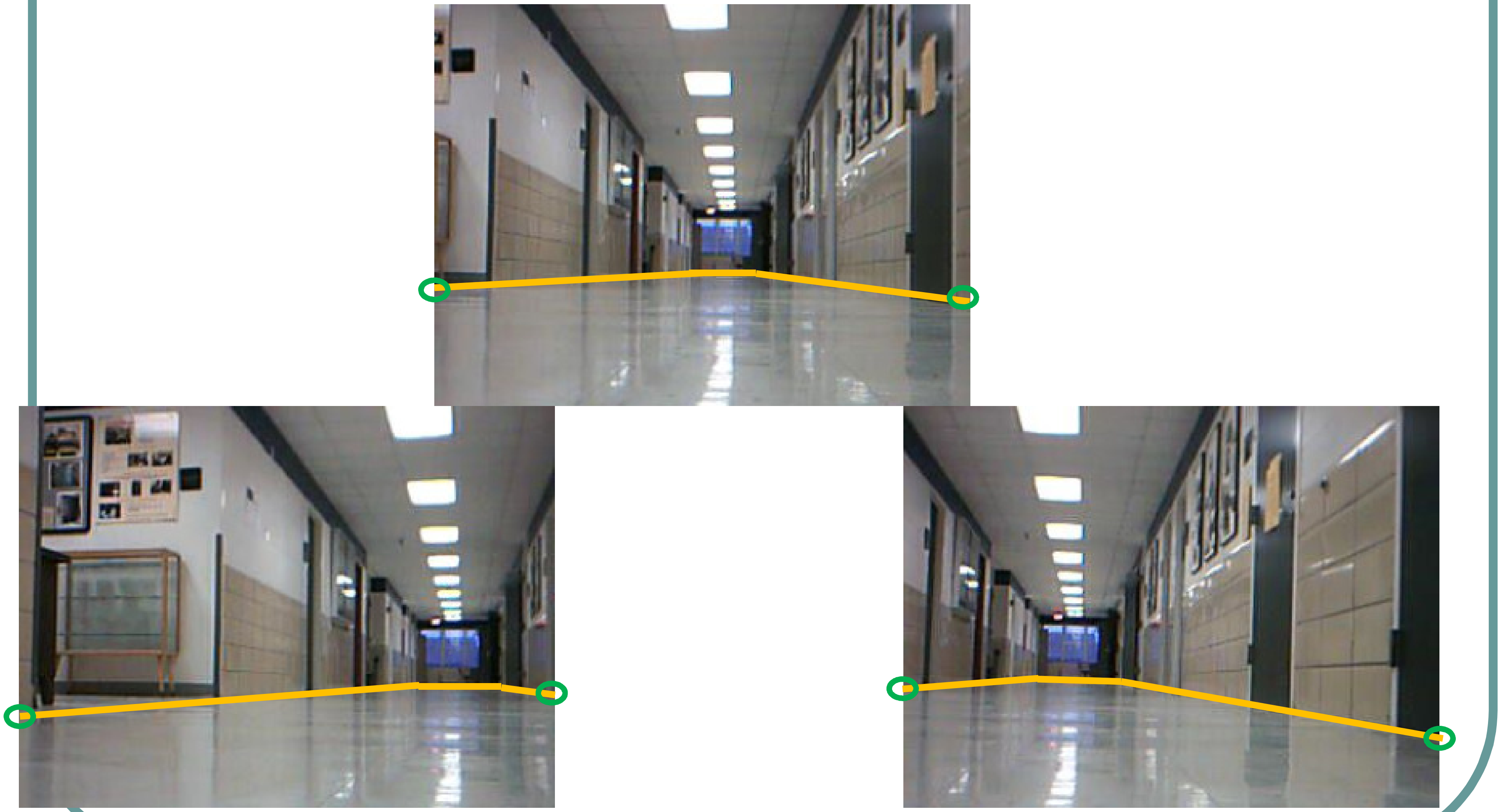
Image Processing

- Basic Ideas
  - Digital Signal Processing
  - Convolving Masks
  - Linear Algebra
  - Image Properties
    - Grayscale, RGB, RGBA (alpha, opacity)
    - Bits per pixel

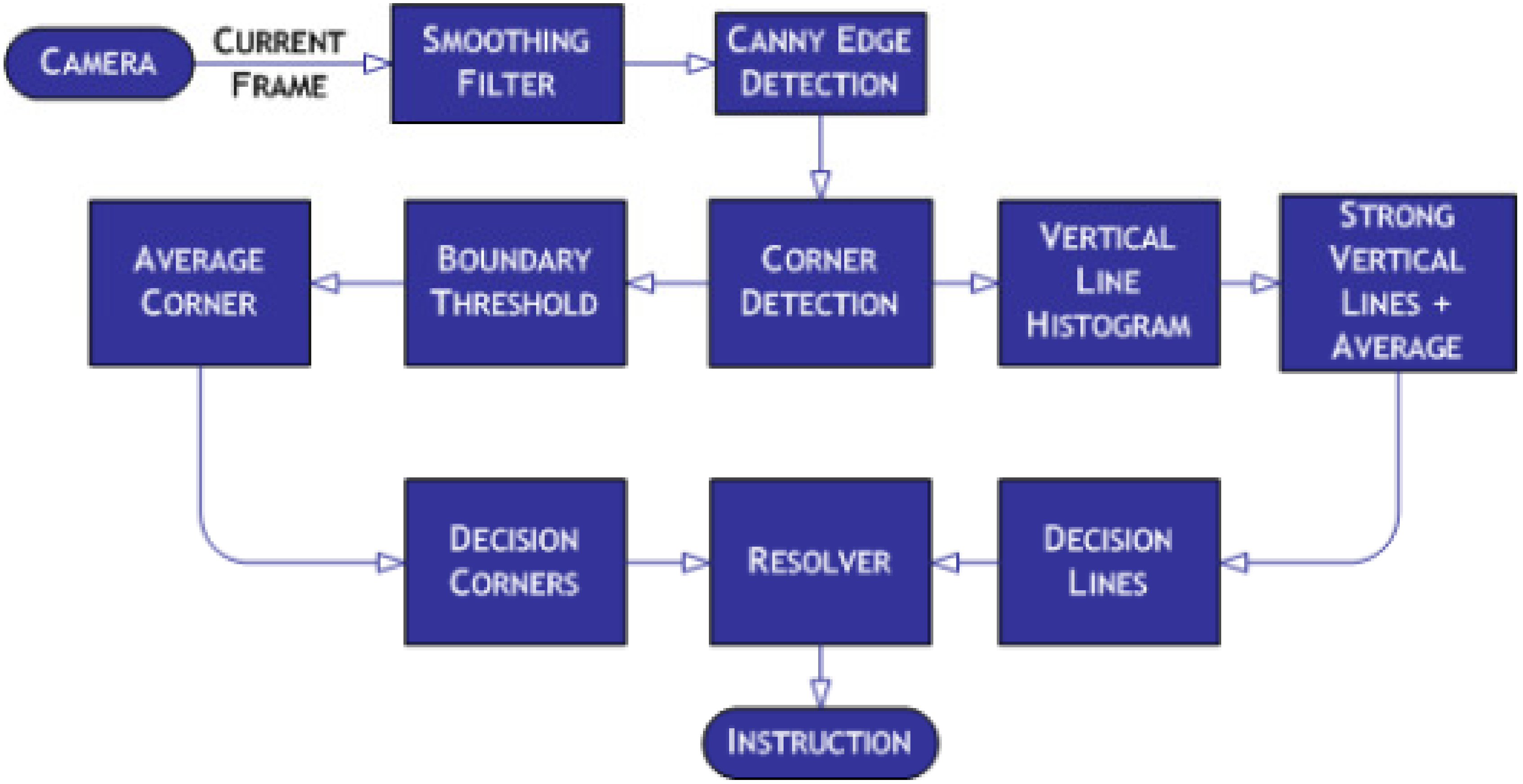
Vision Algorithm – Idea #1



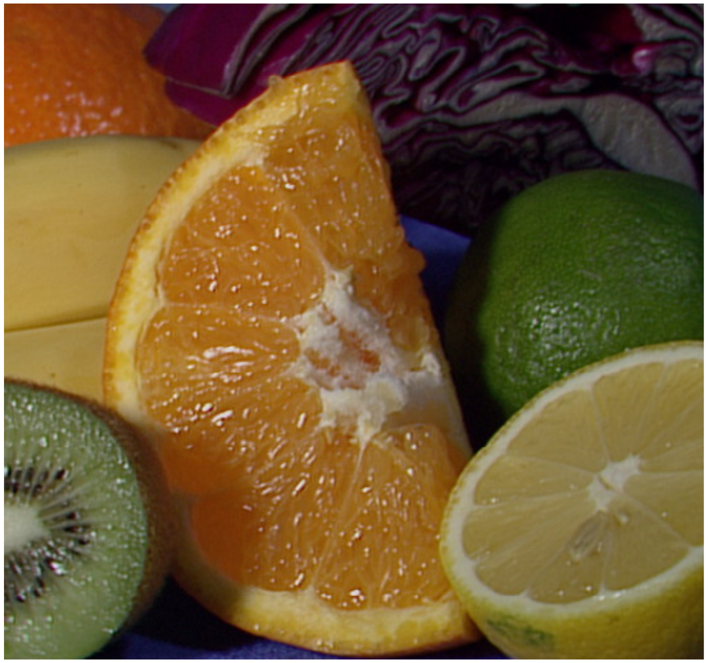
Vision Algorithm – Idea #2

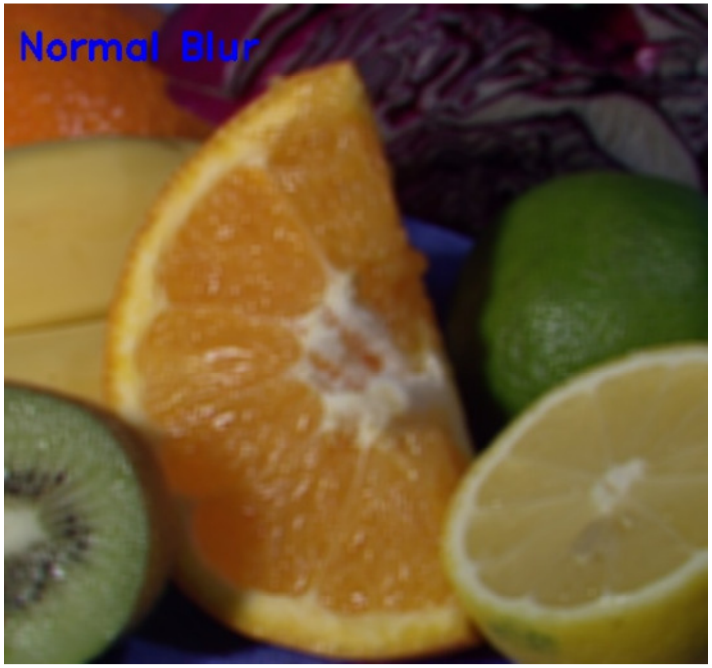


Vision Algorithm

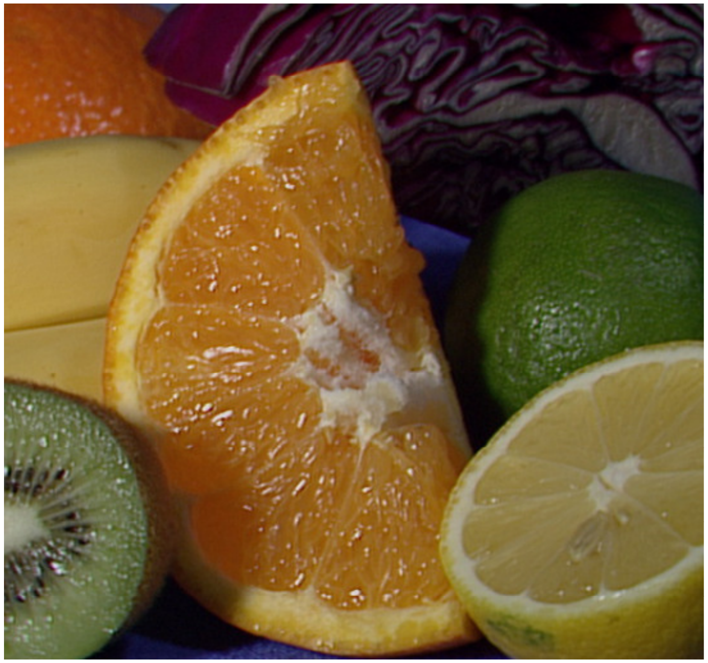


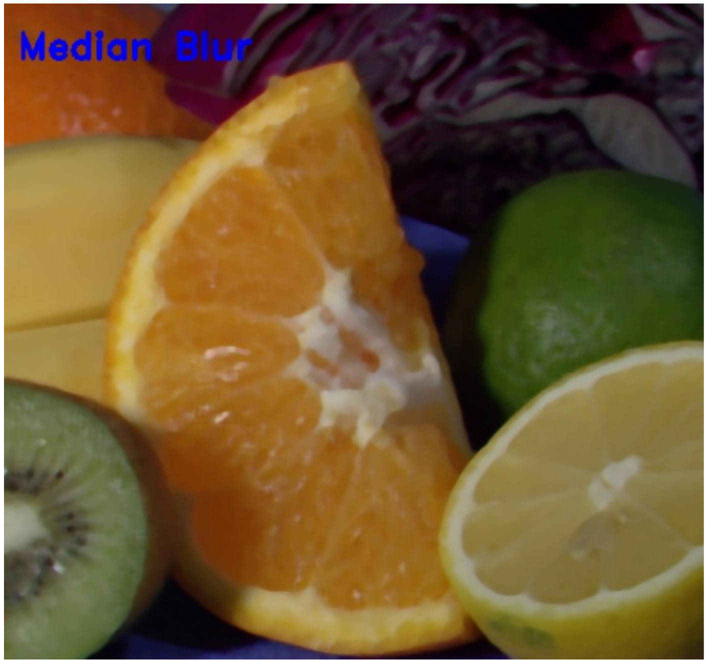
Testing OpenCV - Filters



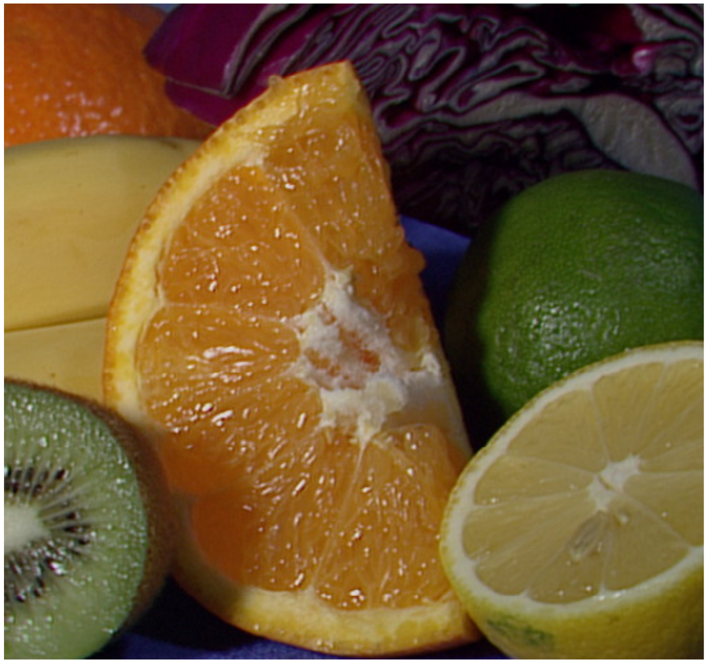


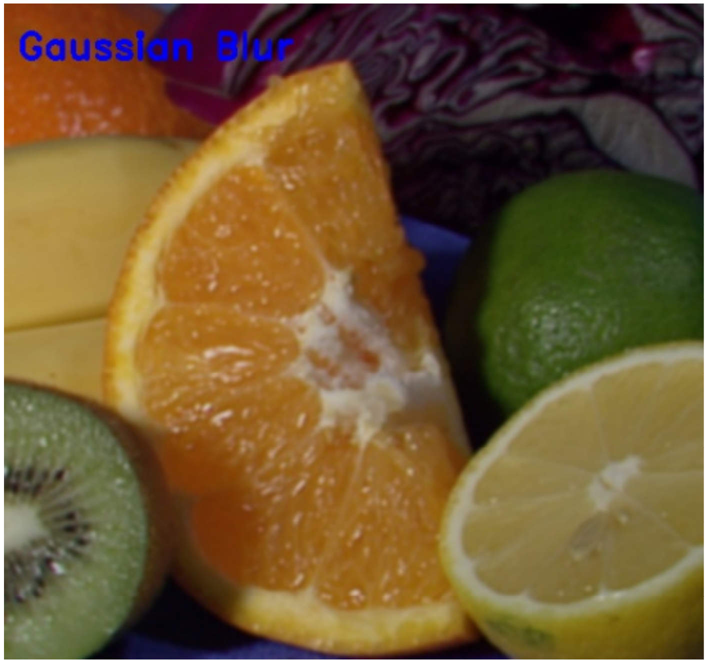
Testing OpenCV - Filters



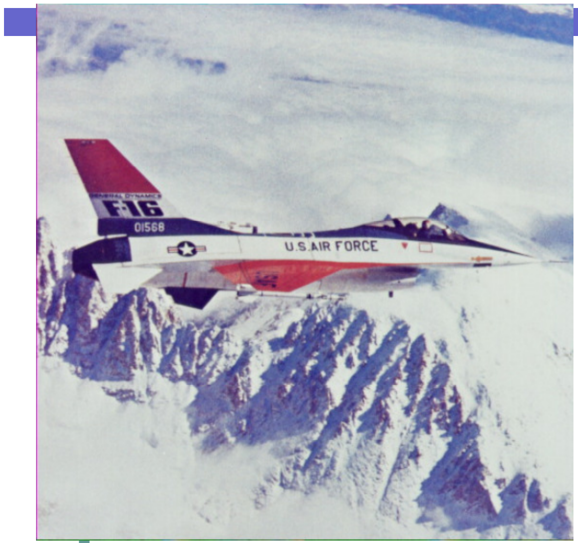


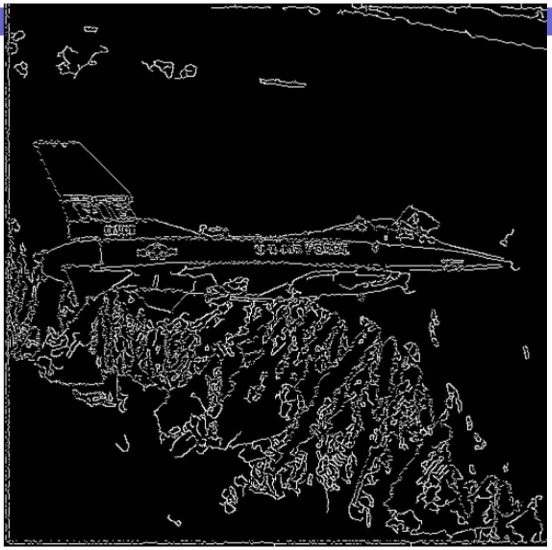
Testing OpenCV - Filters

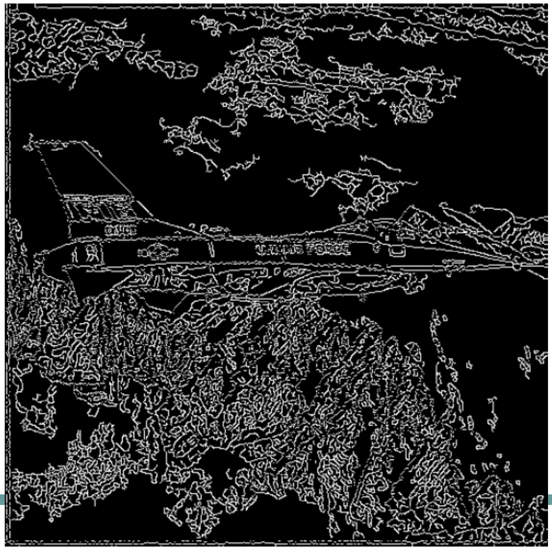


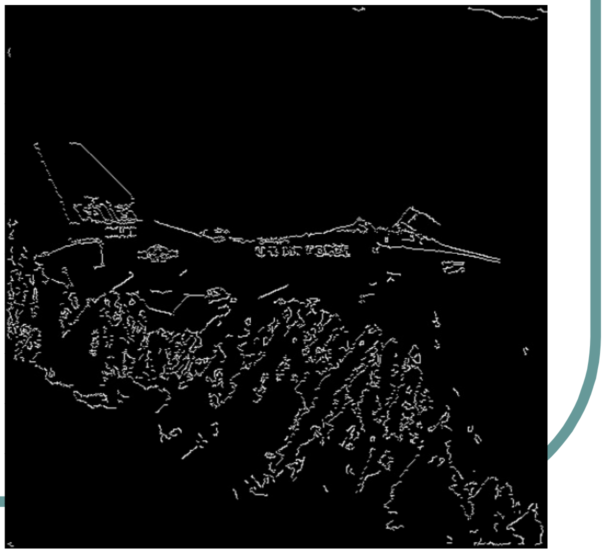


Testing OpenCV - Edge



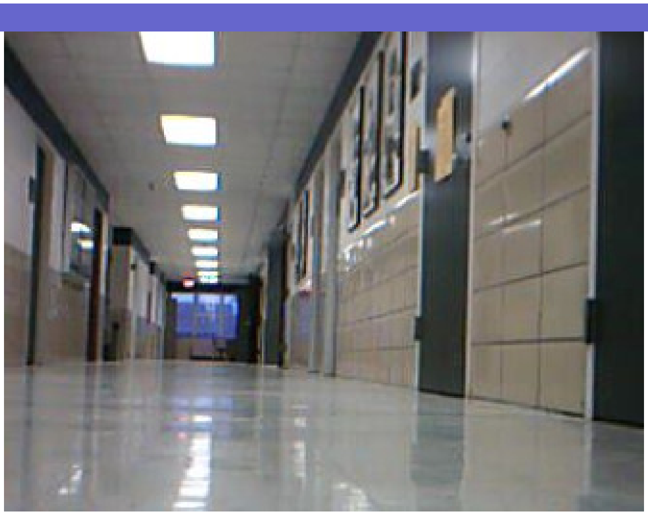


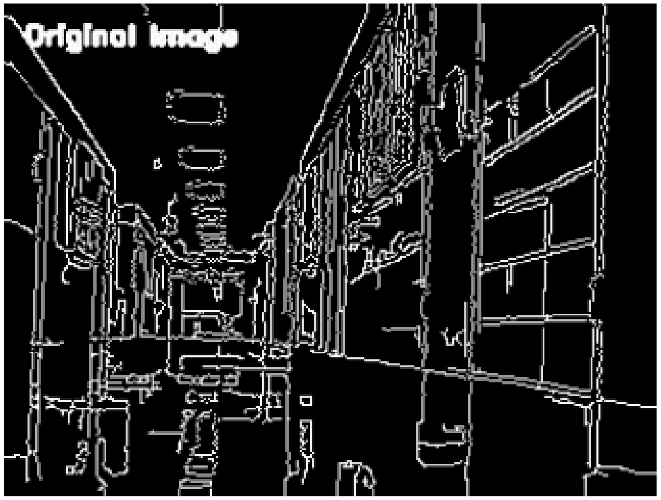


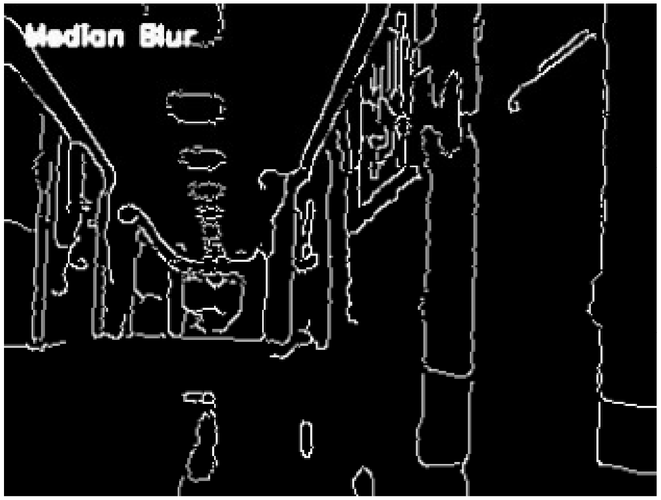


Why Filters?

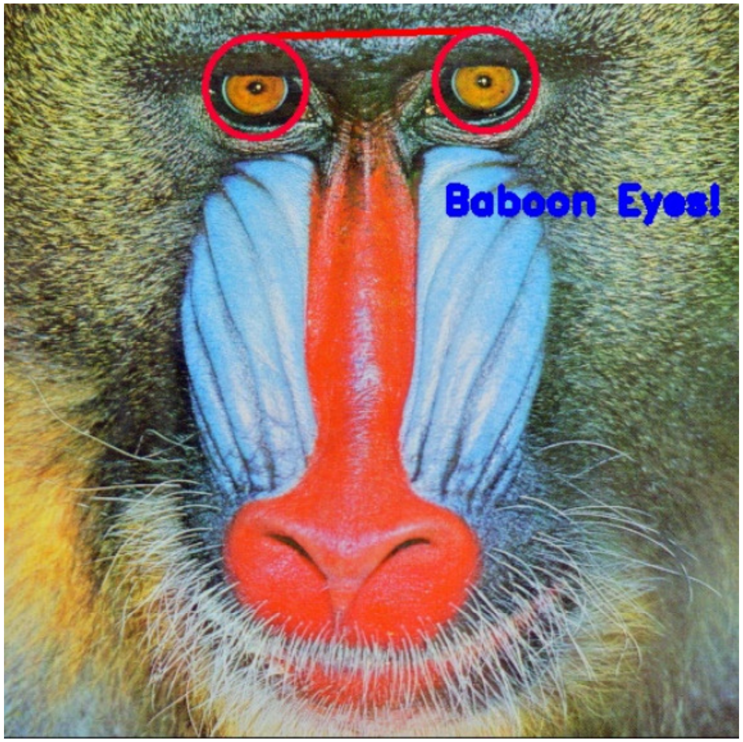
- Noise Reduction



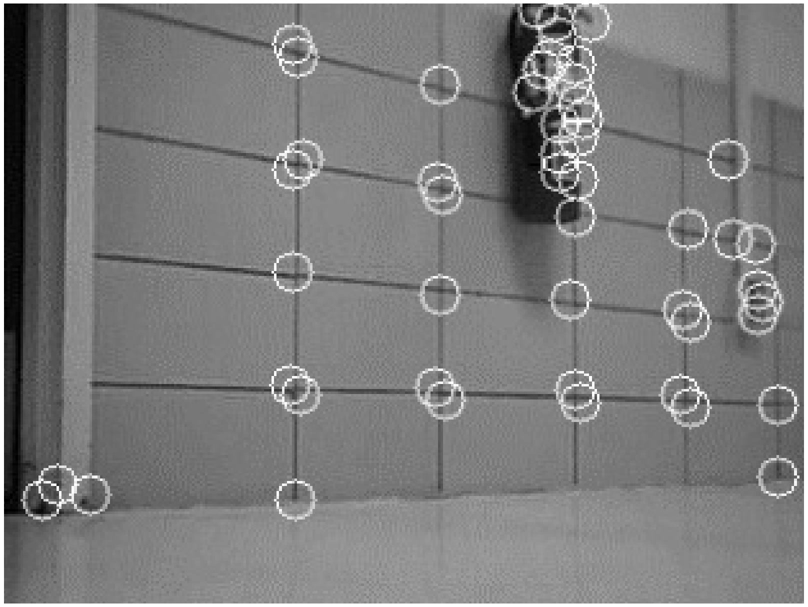




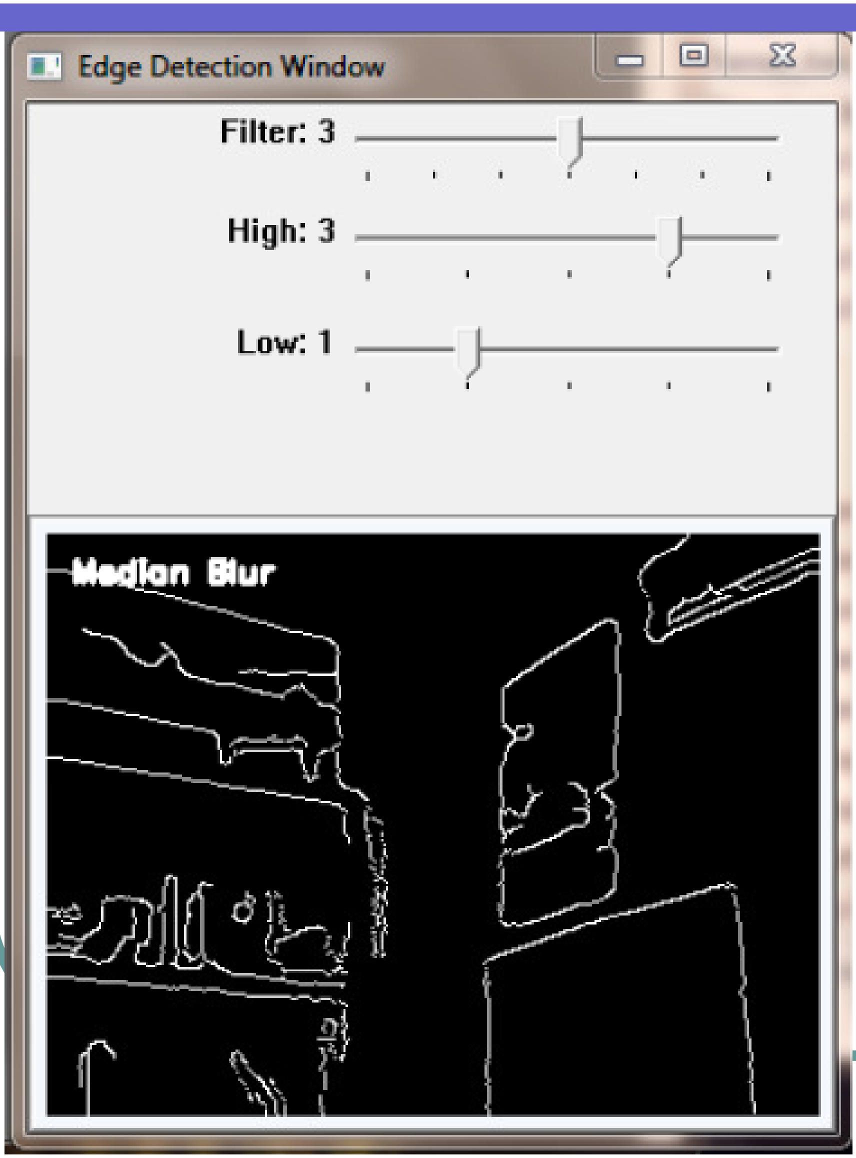
Testing OpenCV - HighGui



Testing OpenCV - Corners



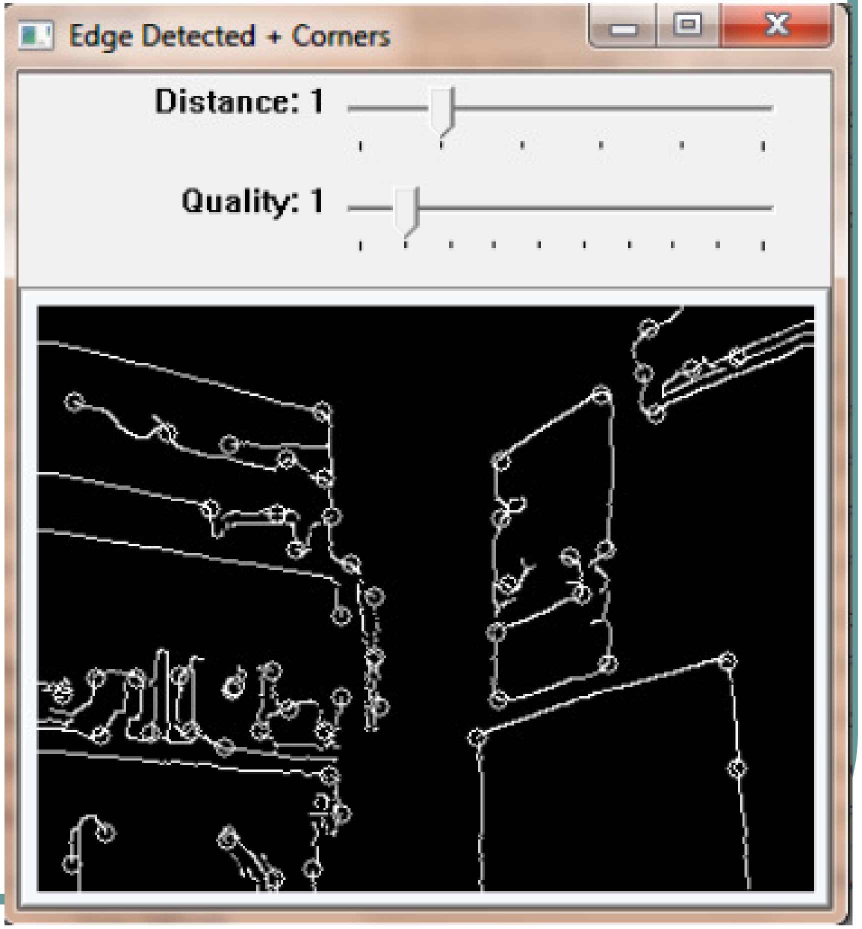
Selecting Parameter Values



Filter: 3

High: 3

Low: 1

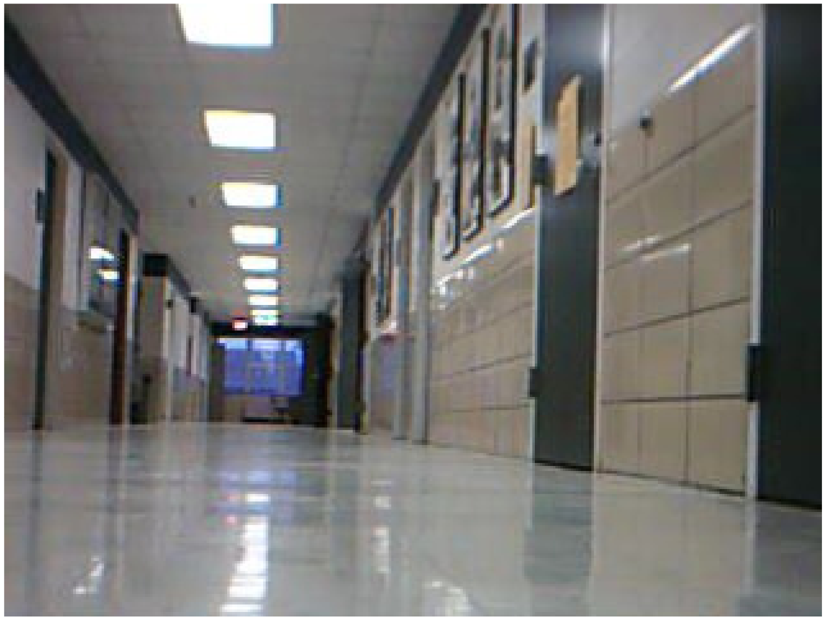


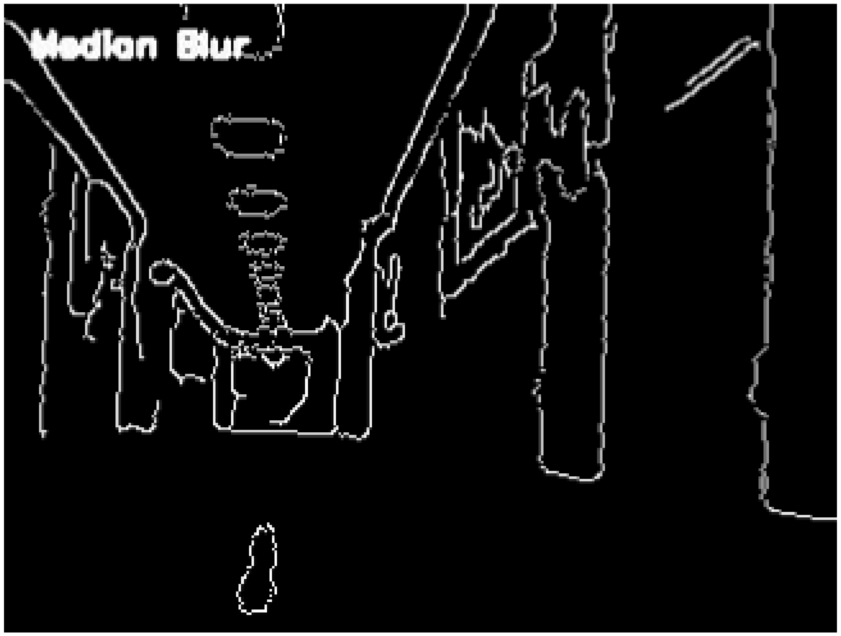
Distance: 1

Quality: 1

Vision Algorithm - Example One

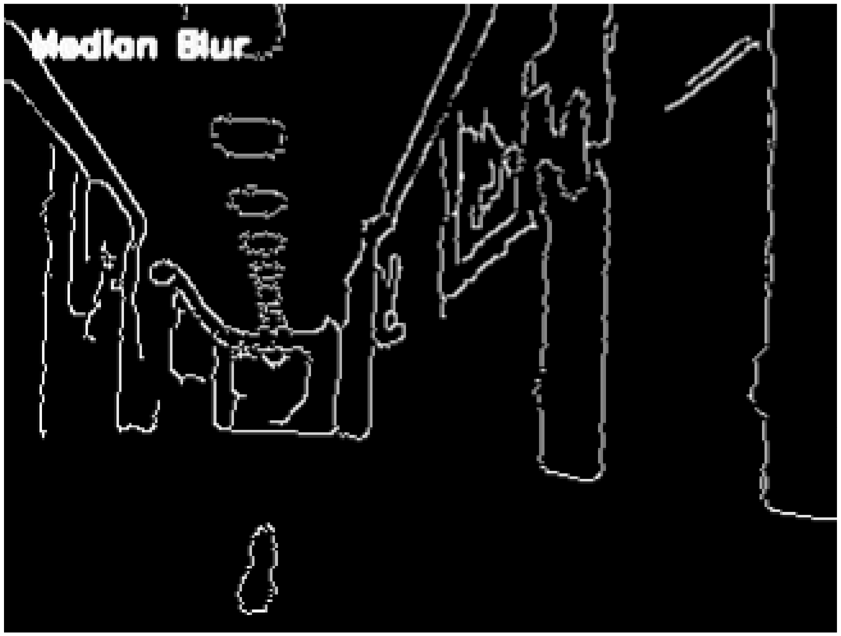
- Original Image to Edge Detection

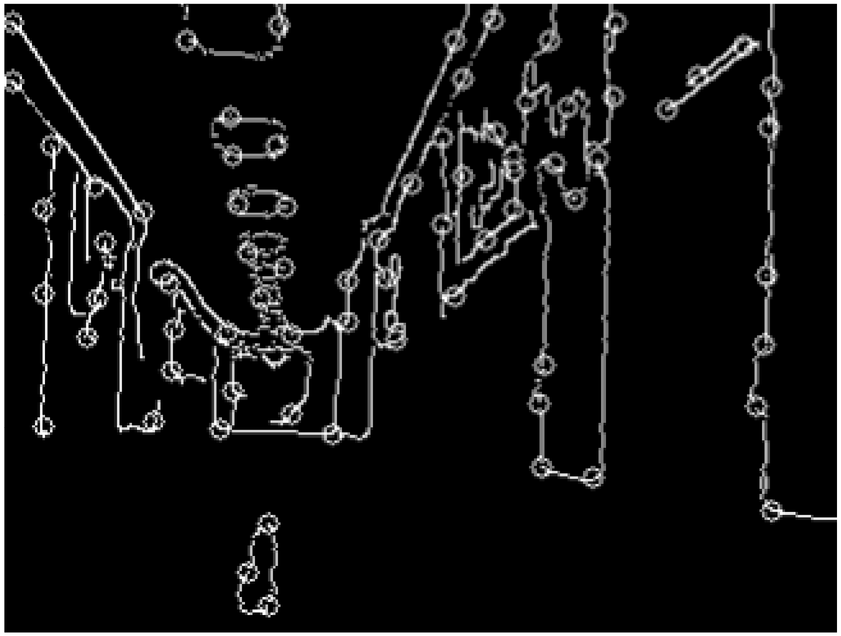




Vision Algorithm - Example One

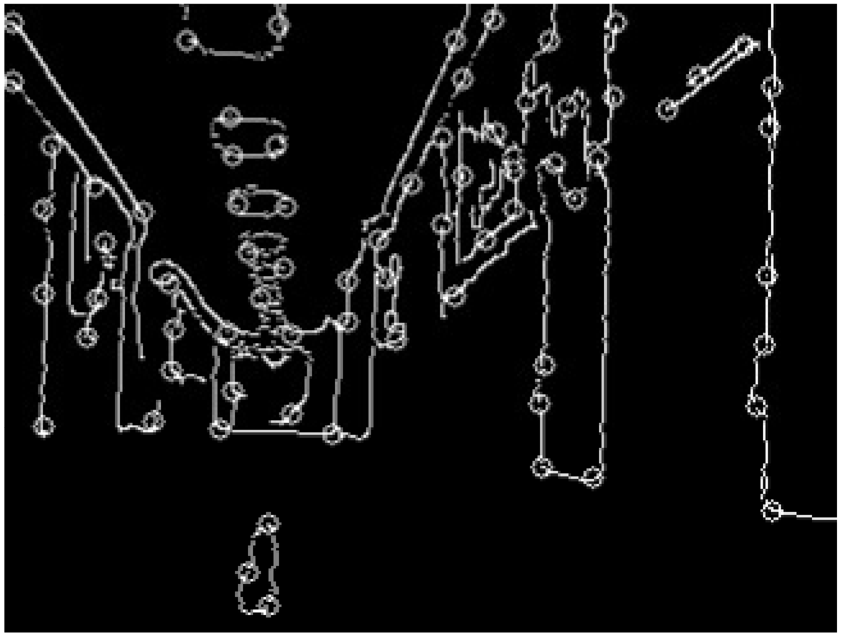
- Edge Detection to Corner Detection

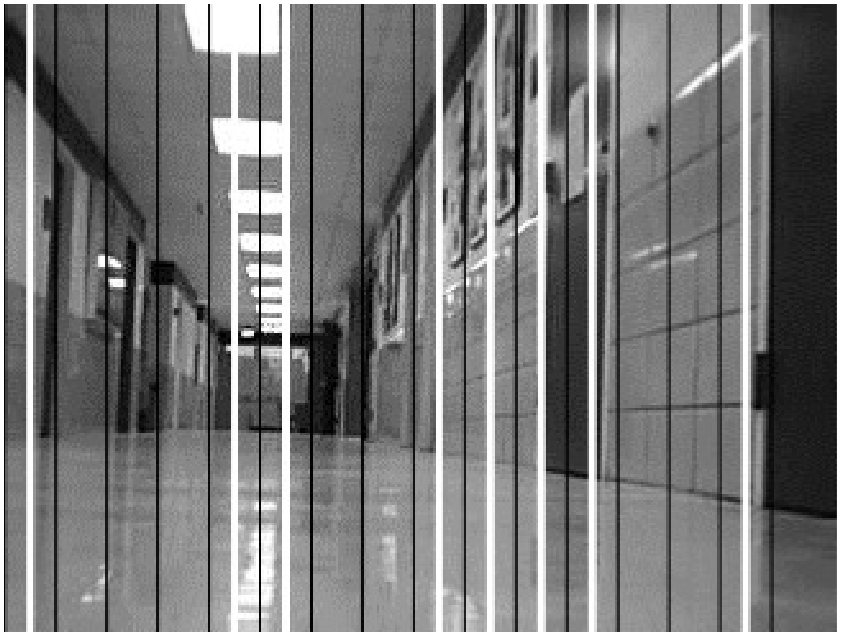




Vision Algorithm - Example One

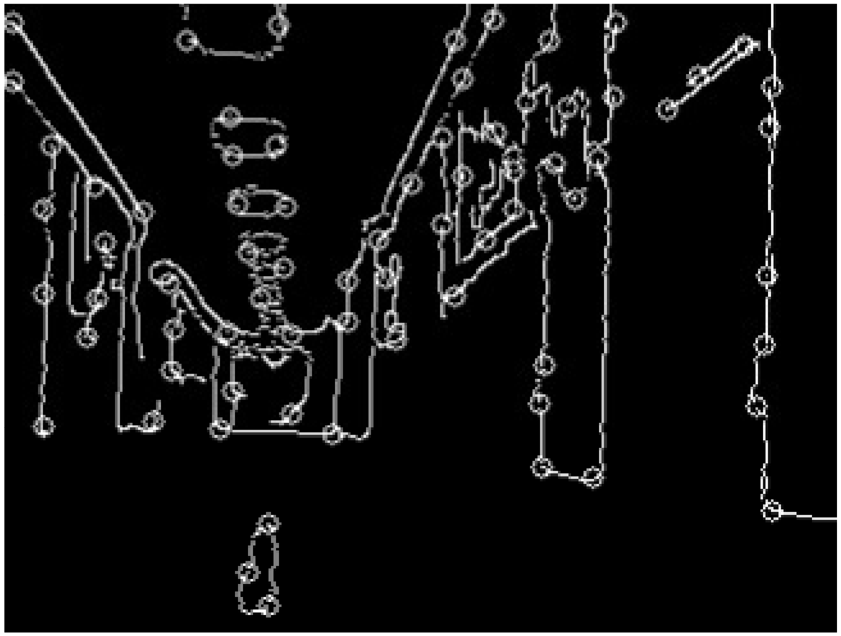
- Corner Detection to Vertical Lines

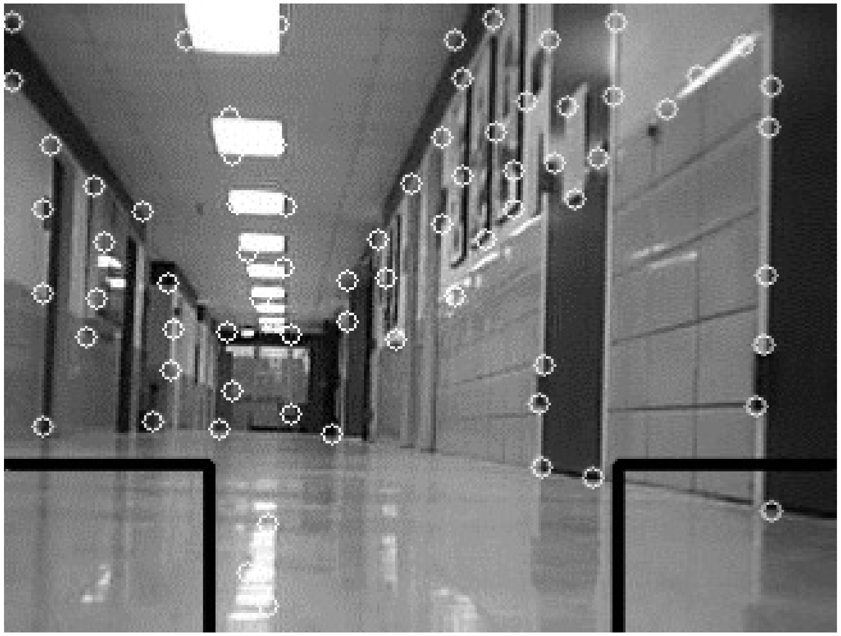




Vision Algorithm - Example One

- Corner Detection to Average Corners

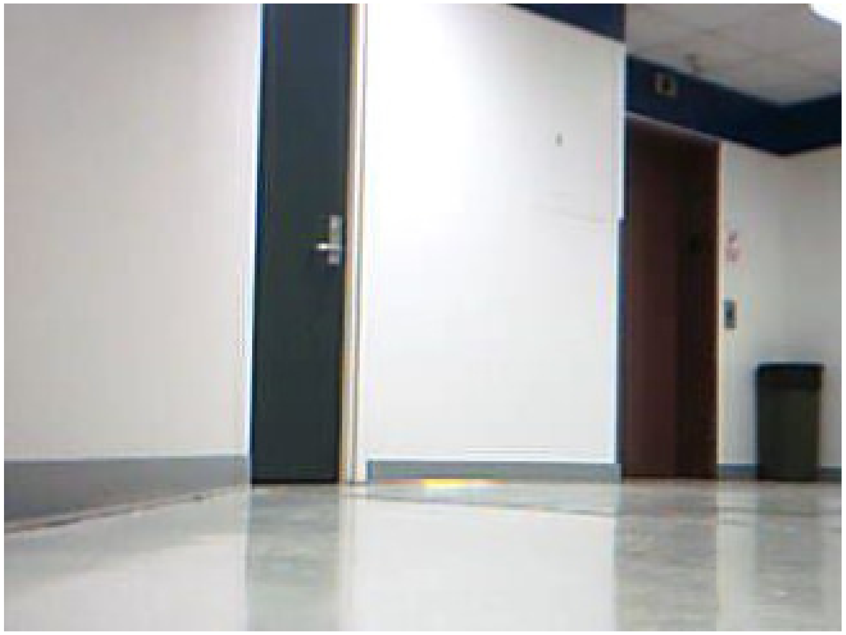


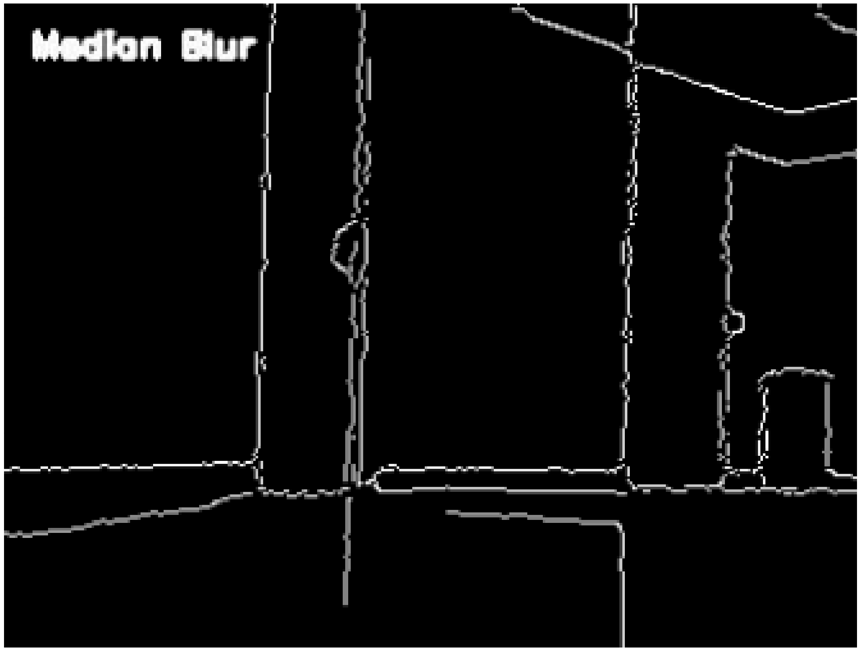


Vision Algorithm - Example One

Vision Algorithm - Example Two

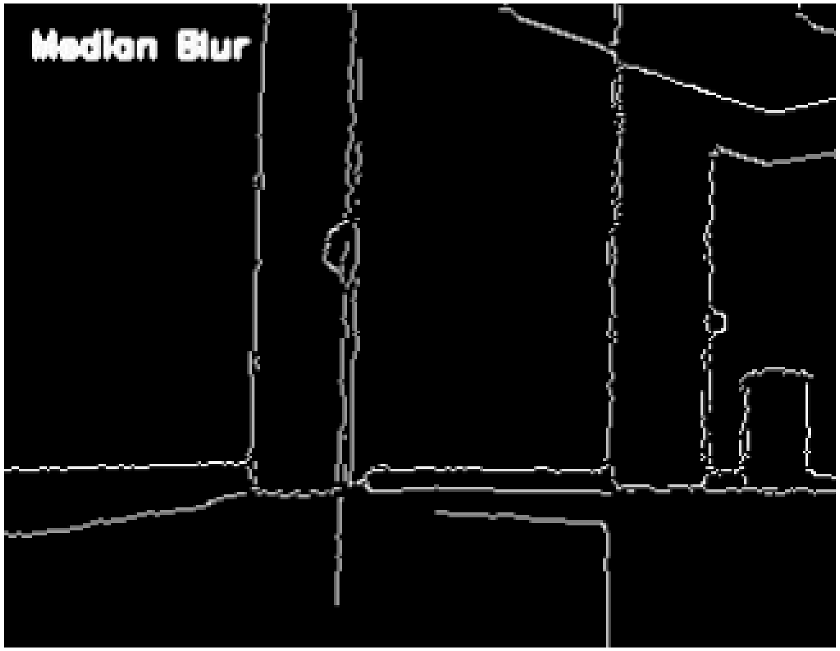
- Original Image to Edge Detection

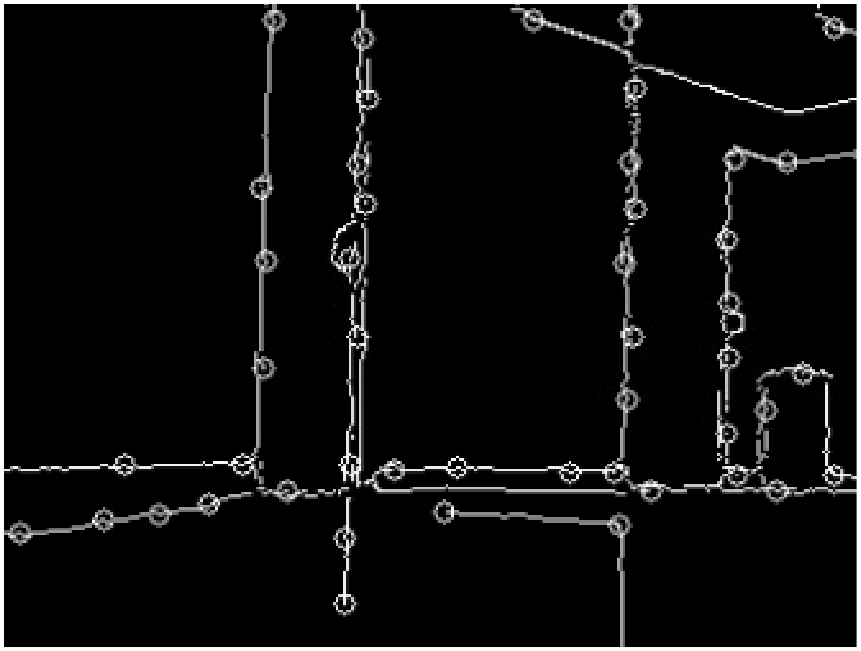




Vision Algorithm - Example Two

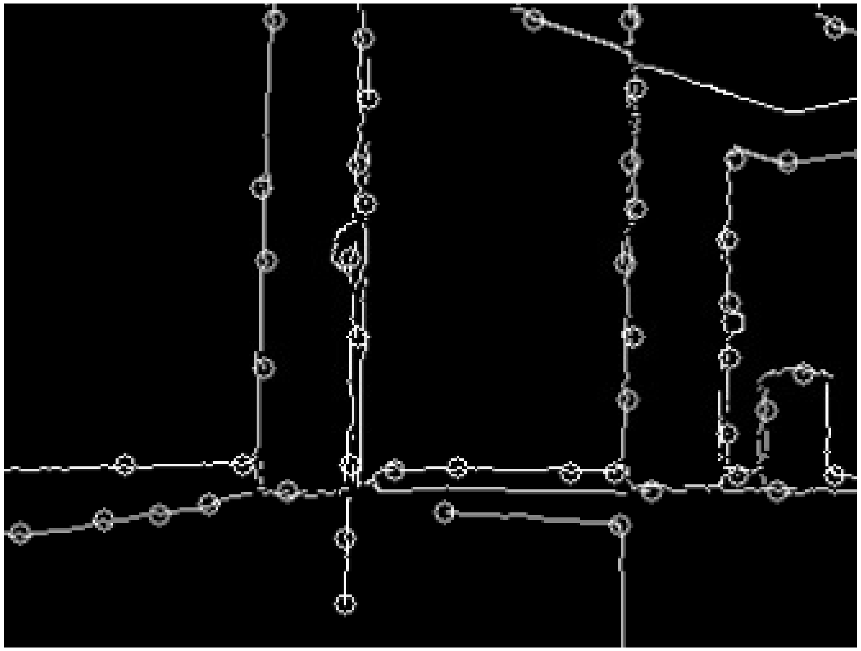
- Edge Detection to Corner Detection

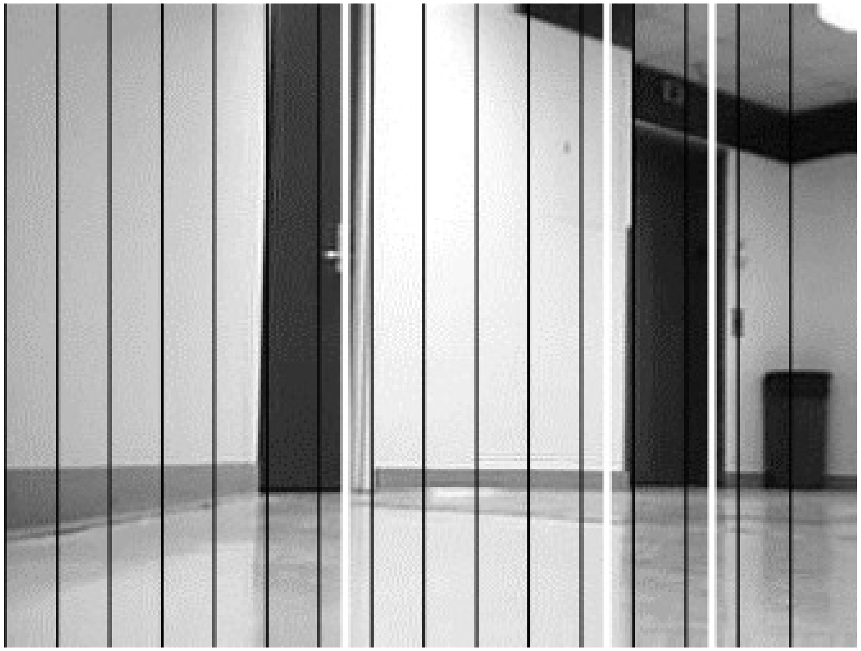




Vision Algorithm - Example Two

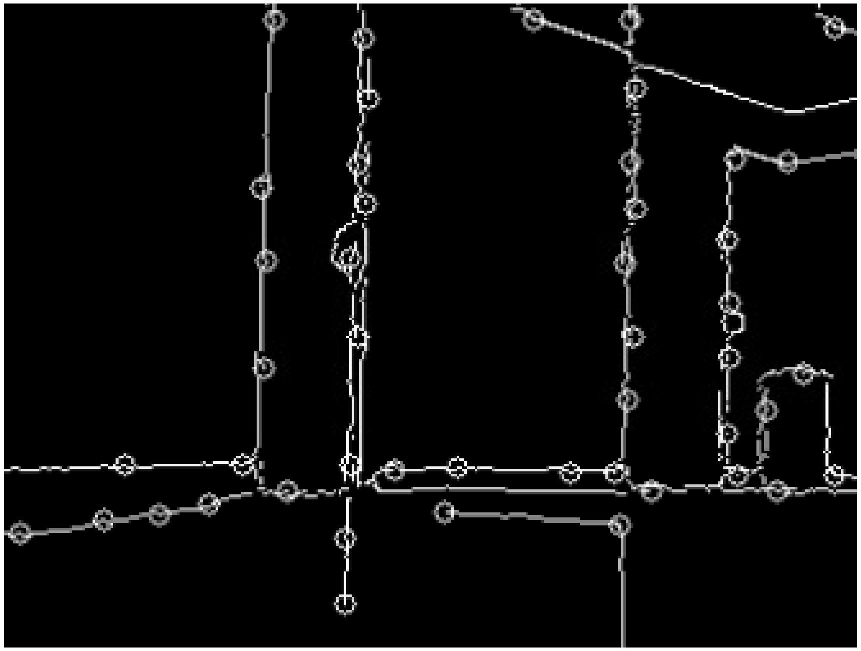
- Corner Detection to Vertical Lines

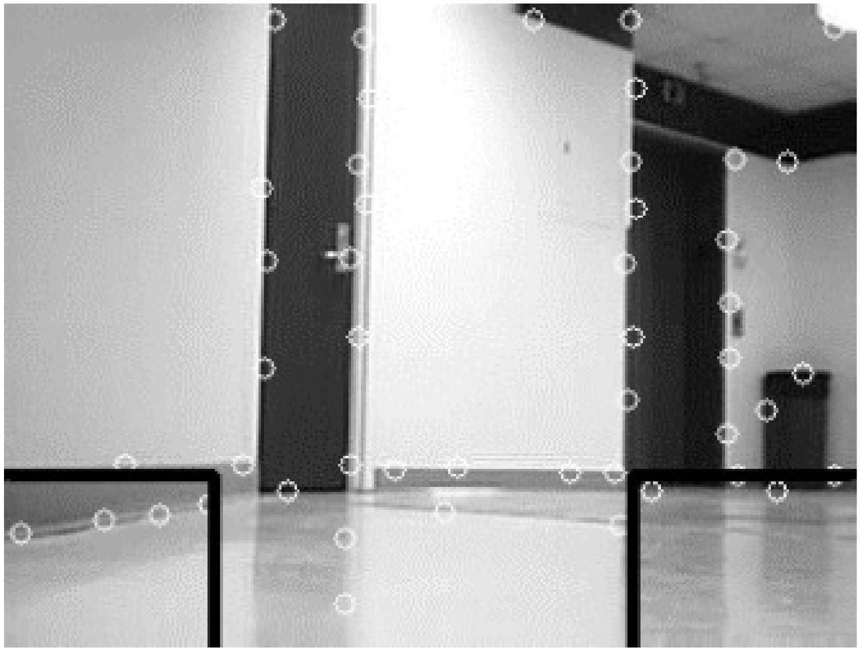




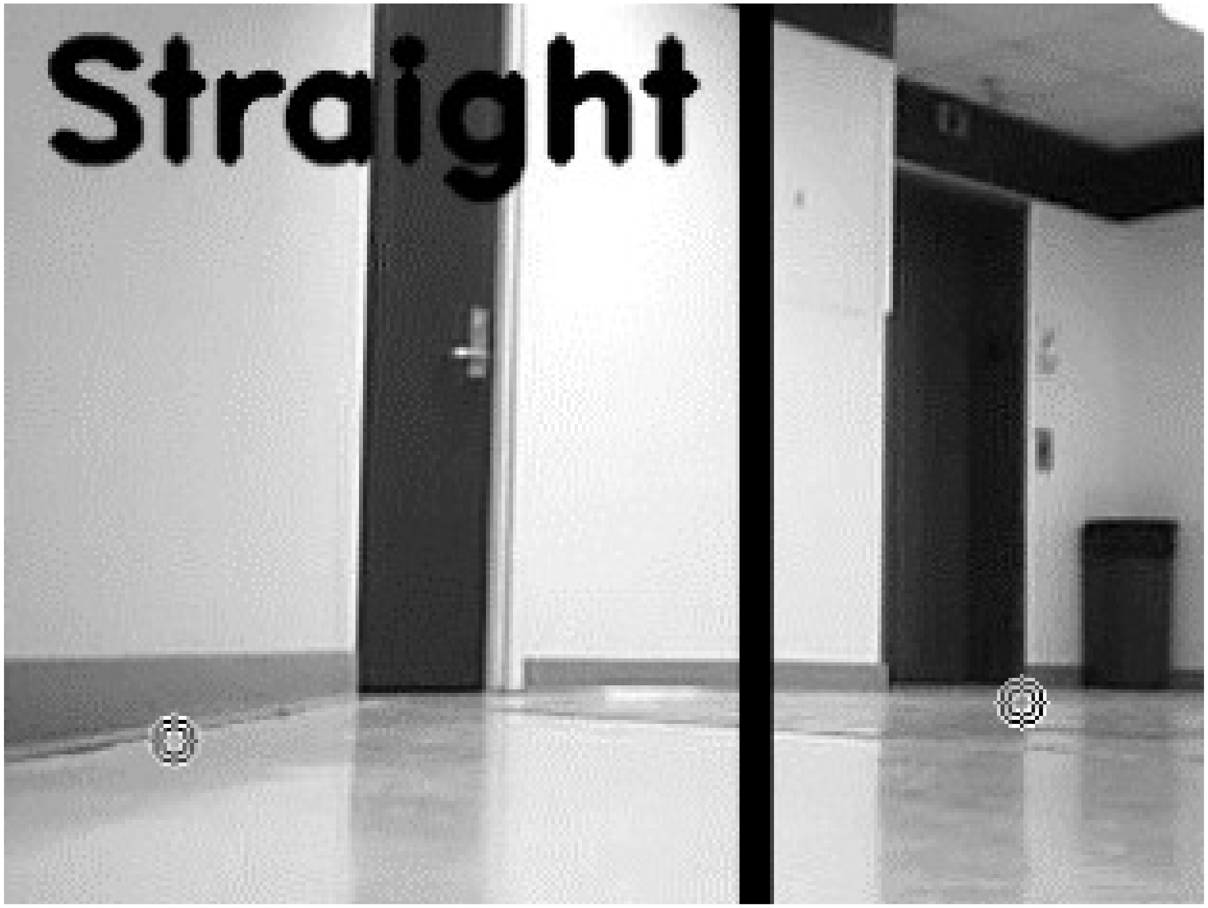
Vision Algorithm - Example Two

- Corner Detection to Average Corners





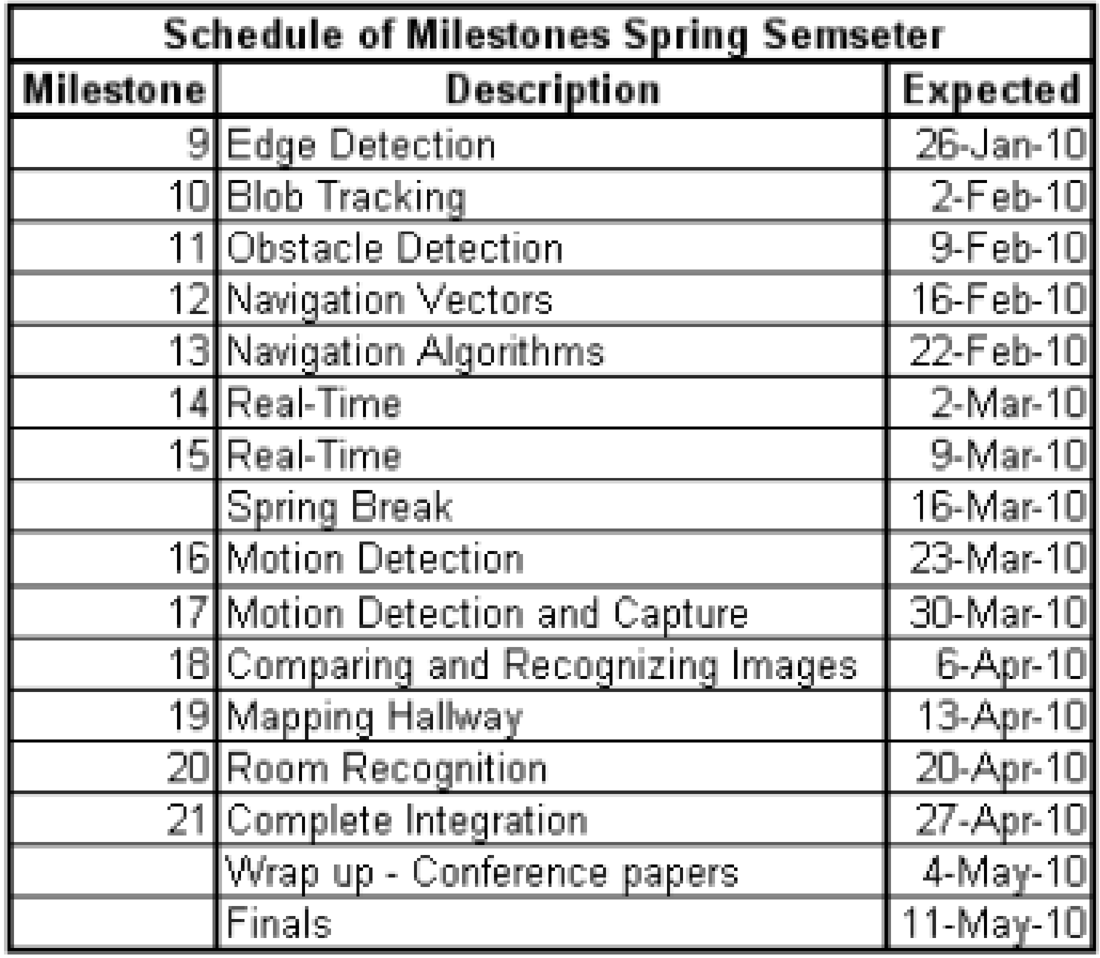
Vision Algorithm - Example Two



Next Steps

- Large Test Data Set Analysis
- OpenCV to control iRobot
  - Writing manifests within Microsoft Robotics Developers Studio (C#)
  - Utilizing OpenCV in C#
    - Wrapping my current functions (.cpp files)
    - Porting libraries and re-writing (.cs files)
- Netbook

Schedule – Spring Semester



Schedule of Milestones Spring Semseter		
Milestone	**Description**	**Expected**
9	Edge Detection	26-Jan-10
10	Blob Tracking	2-Feb-10
11	Obstacle Detection	9-Feb-10
12	Navigation Vectors	16-Feb-10
13	Navigation Algorithms	22-Feb-10
14	Real-Time	2-Mar-10
15	Real-Time	9-Mar-10
	Spring Break	16-Mar-10
16	Motion Detection	23-Mar-10
17	Motion Detection and Capture	30-Mar-10
18	Comparing and Recognizing Images	6-Apr-10
19	Mapping Hallway	13-Apr-10
20	Room Recognition	20-Apr-10
21	Complete Integration	27-Apr-10
	Wrap up - Conference papers	4-May-10
	Finals	11-May-10

Questions?

- VBASR by Kevin Farney

References

- [1] Shapiro, Linda G., Linda G. Shapiro, and George Stockman. Computer Vision. Upper Saddle River: Prentice Hall, 2001. Print
- [2] Kosinski, Robert J. "Literature Review on Reaction Time." Clemson University, Aug. 2009. Web. 10 Nov. 2009. <http://biae.clemson.edu/bpc/bp/Lab/110/reaction.htm>.
- [3] Cavallaro, Andrea. Image Analysis and Computer Vision for Undergraduates. Tech. ICASSP, 2005. IEEEXPLORE. Web. 20 Oct. 2009. <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1416369&isnumber=30654>
- [4] "iRobot Create Premium Development Package." IRobot. IRobot Corporation, 2009. Web. 10 Nov. 2009. <http://store.irobot.com/product/index.jsp?productId=2591901&cp=2591511&parentPage=family>.
- [5] Sage, Kingsly, and Stewart Young. Security Applications of Computer Vision. Tech. IEEE AES Systems Magazine, 1999. IEEEXPLORE. Web. 20 Oct. 2009. <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=756080&isnumber=16393>

Filters - Normal

- Normal Blur
  - Normalized box filter – summation of pixels over a neighborhood

$$\texttt{K} = \alpha \begin{bmatrix} 1 & 1 & 1 & \cdots & 1 & 1 \\ 1 & 1 & 1 & \cdots & 1 & 1 \\ \multicolumn{6}{c}{\dotfill} \\ 1 & 1 & 1 & \cdots & 1 & 1 \end{bmatrix}$$

$$\alpha = \begin{cases} \frac{1}{\texttt{ksize.width*ksize.height}} & \text{when } \texttt{normalize=true} \\ 1 & \text{otherwise} \end{cases}$$

Filters – Gaussian

- Gaussian Blur
  - Convolution of source image with specified gaussian kernel

Matrix of ksize (parameter) x 1 with filter coefficients:

$$G_i = \alpha * e^{-(i-(\mathtt{ksize}-1)/2)^2 /(2*\mathtt{sigma})^2},$$

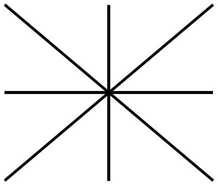
$$\alpha = \sum_i G_i = 1$$

Filters

- Median Blur
  - Returns median of pixel neighborhood into the destination image for each pixel

Canny Edge Detection

- Implements Canny Algorithm
  - First noise-reduction needed (filters)
  - Intensity Gradients $\mathbf{G} = \sqrt{{\mathbf{G}_x}^2 + {\mathbf{G}_y}^2}$ $\mathbf{\Theta} = \operatorname{arctan}\left(\frac{\mathbf{G}_y}{\mathbf{G}_x}\right)$
    - 8 points



  - Non-Maximum Suppression
  - Hysteresis Thresholding
    - High – discards noisy pixels
    - Low – connects the edges into lines (binary)

Corner Detection

- Good Features To Track
  - Calculates minimal eigenvalue per pixel
    - Covariation Matrix of derivatives
    - Then eigenvalues represent corners
  - Non-maxima suppression (3x3 pixels)
  - Rejection by quality level (parameter)
    - qualityLevel•max(eigImage(x,y))
  - Rejection by distance (parameter)

Price Breakdown

- iRobot Create Premium Development Package
  - $299
- Pioneer 3-DX
  - upwards of $5000
- Microsoft Robotics Developers Studio R2
  - free download
- Visual Studio 2008
  - $500 and up
  - Visual C# editor – free download
- Small Netbook
  - Looking for around $300

Microsoft Robotics Developer Studio

- CCR (Concurrency and Coordination Runtime)
- DSS (Decentralized Software Services)
- VPL (Visual Programming Language)
- VSE (Visual Simulation Environment)