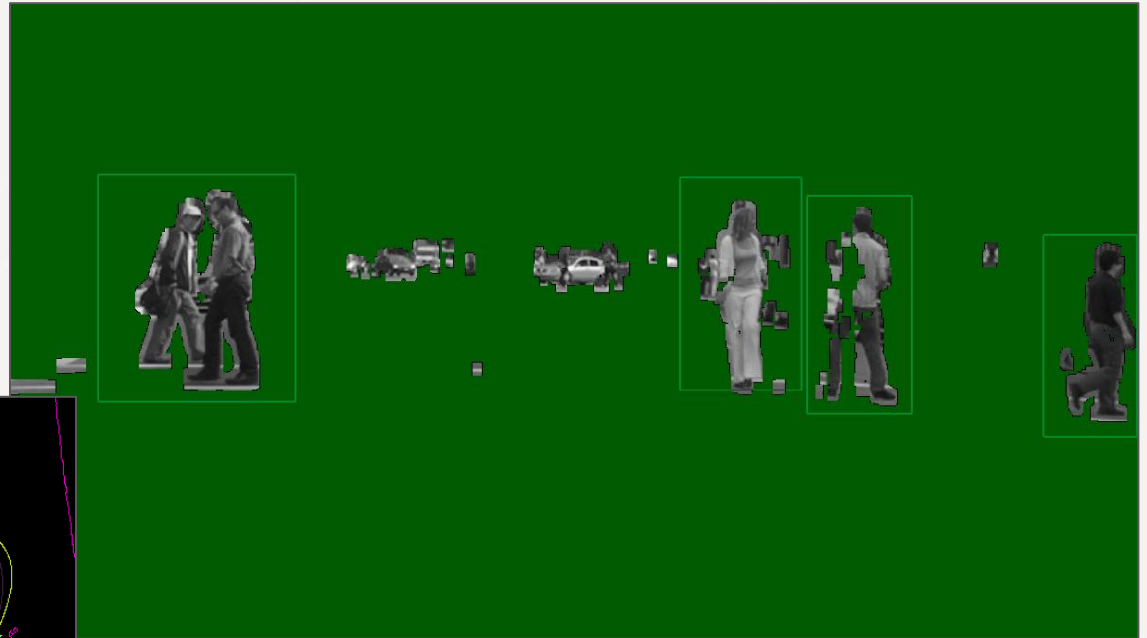
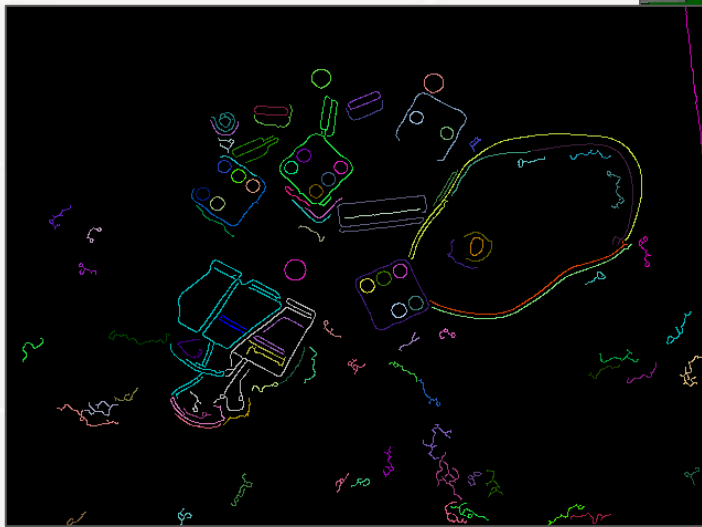


Finding Objects Using Canny Edge Detection

Eric Gregori—Embedded Vision Specialist (BDTI)

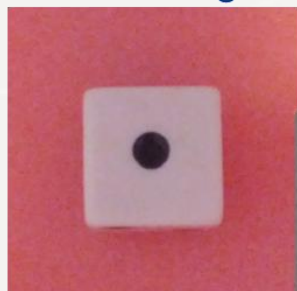
- Image Segmentation is a Core Operation for Many Embedded Vision Algorithms
- What is an Edge in an Image?
- Using Edges to Define Boundaries for Segmentation
- Finding Edges Using the 1st Derivative Operator
- The Canny Edge Detector
- Grouping Boundary Edges Into Contours
- Classifying Objects Using Mathematical Models
- How are CPU Cycles Distributed with Canny
- Using Configurable Hardware to Accelerate Canny
- Software Performance Versus Hardware Performance
- An Example of Edge Detection and Classification

Image Segmentation is a Core Operation for Many Embedded Vision Algorithms

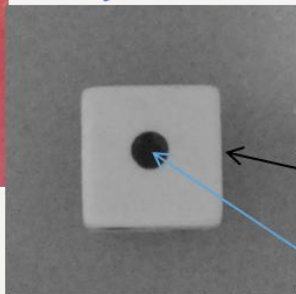


What is an Edge in an Image?

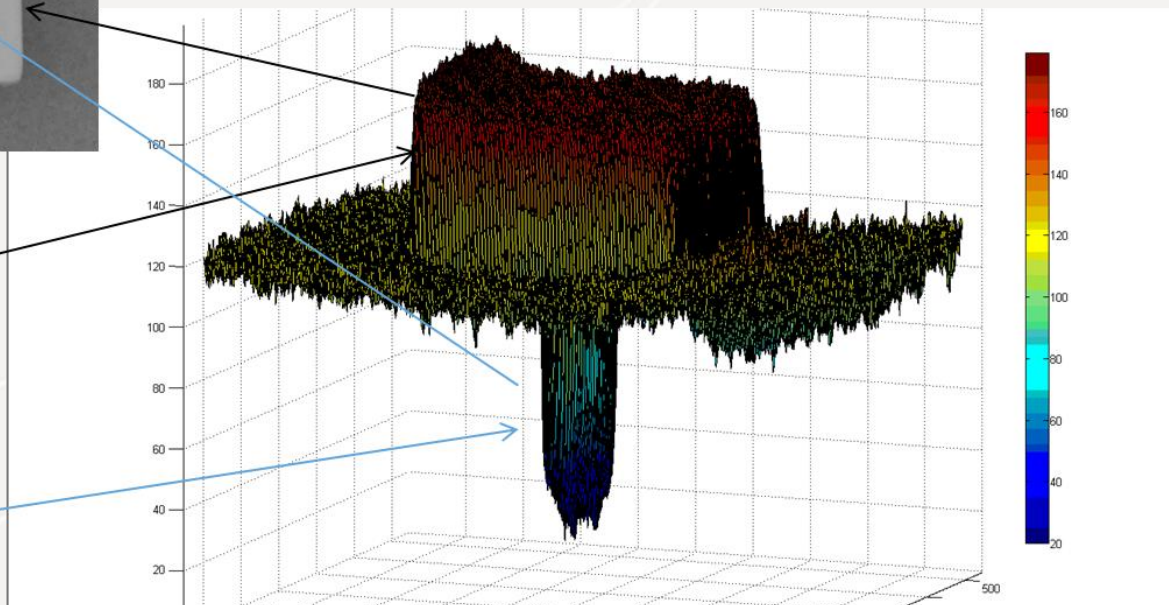
Color image of die



Gray scale image of die



3D plot of gray scale image of die

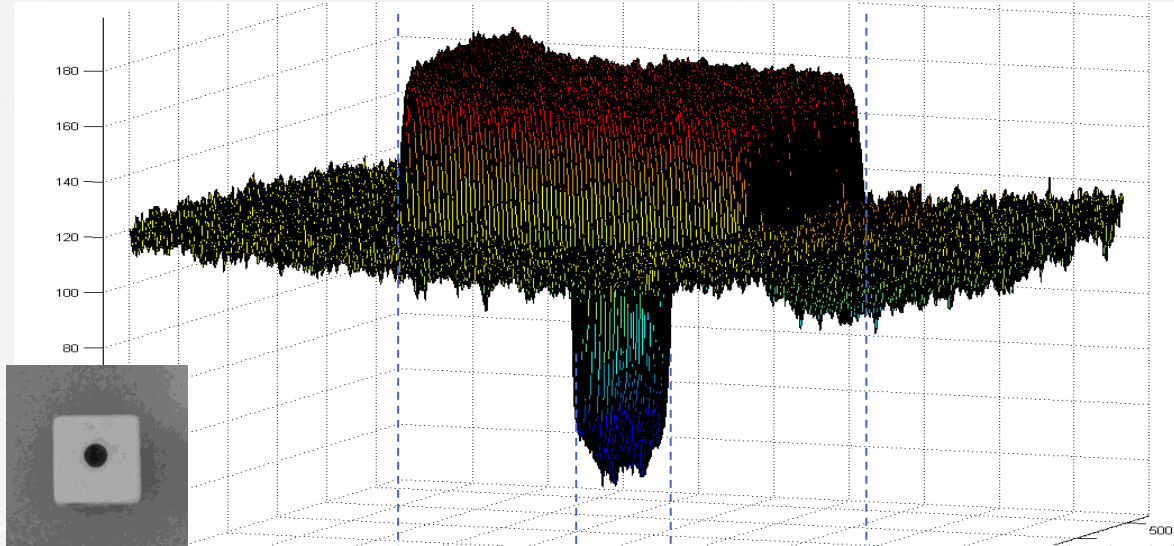


White portion of die

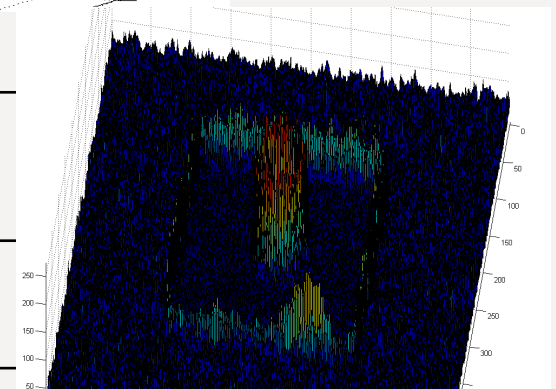
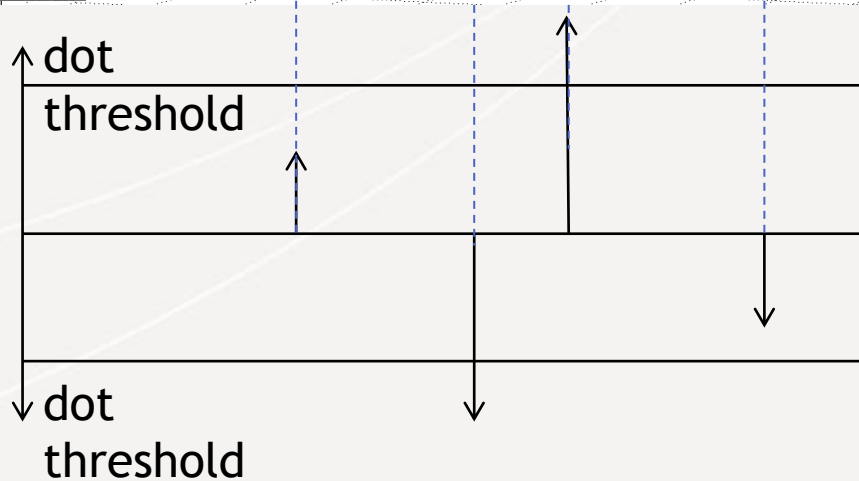
The dot of the die

Finding Edges Using the 1st Derivative Operator

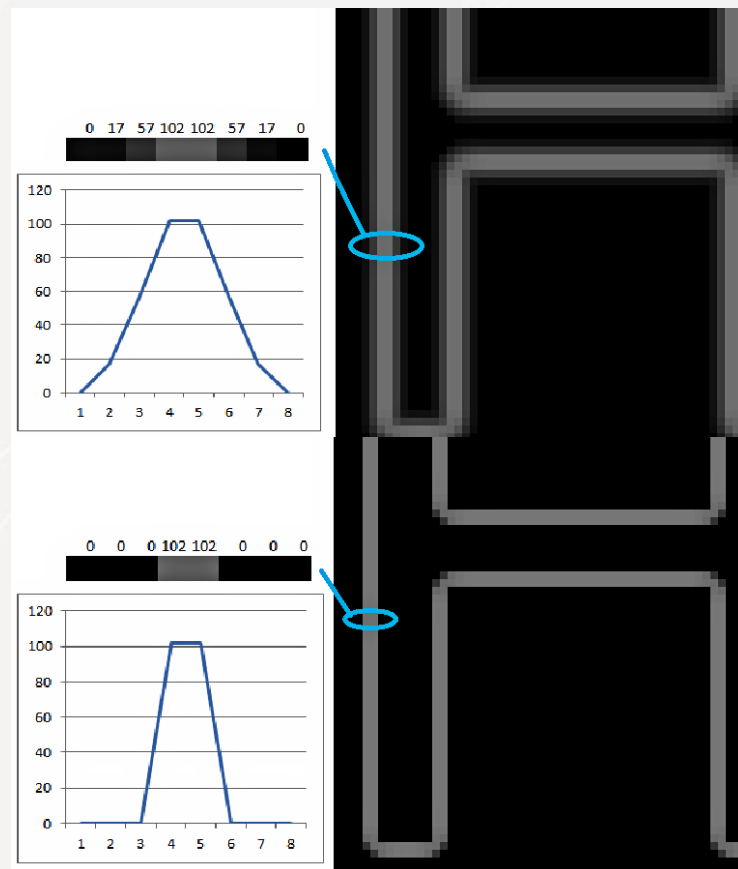
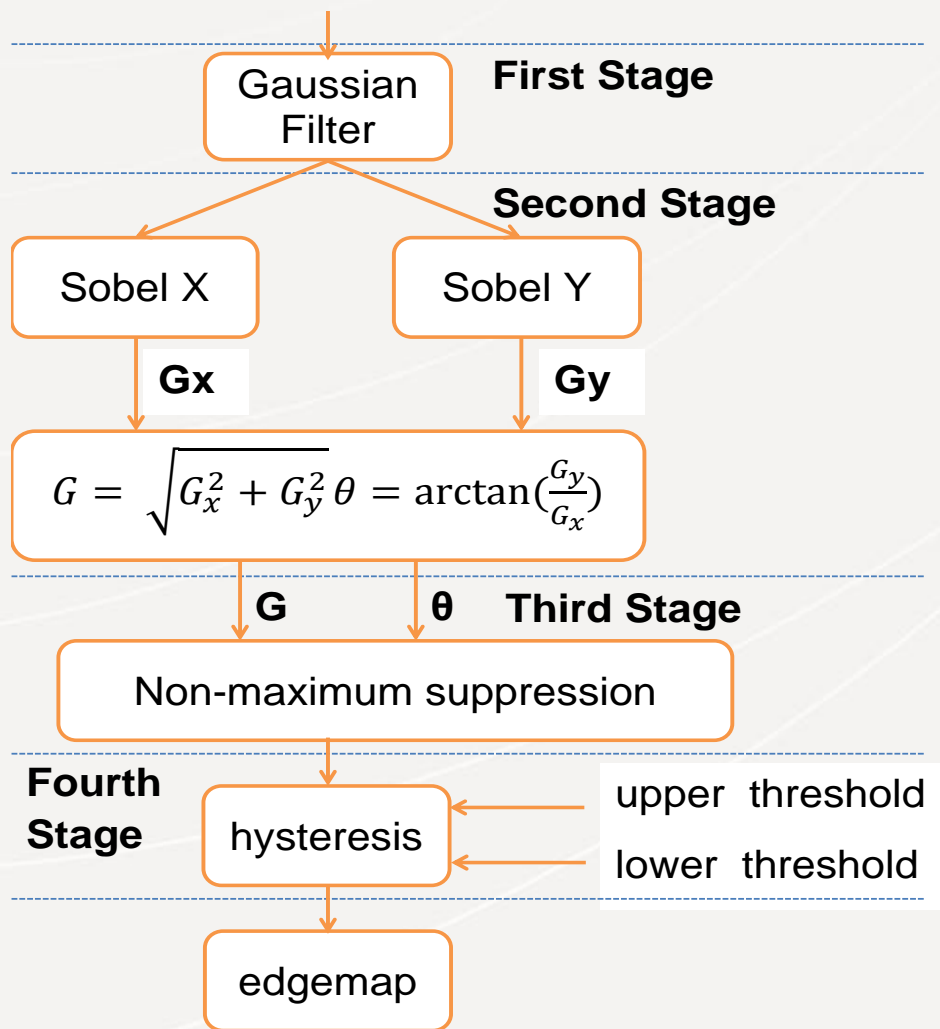
3D
plot of
gray
scale
image



1st
derivative
in X
direction
of gray
scale
image



The Canny Edge Detector



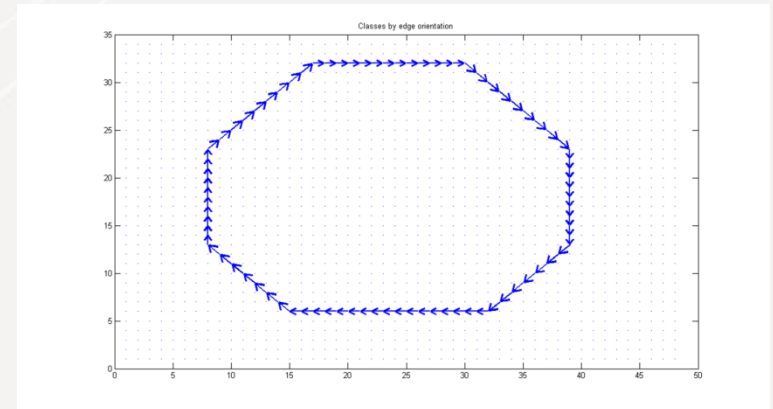
**Before and after
Non-Maximum Suppression**

Grouping Boundary Edges Into Contours

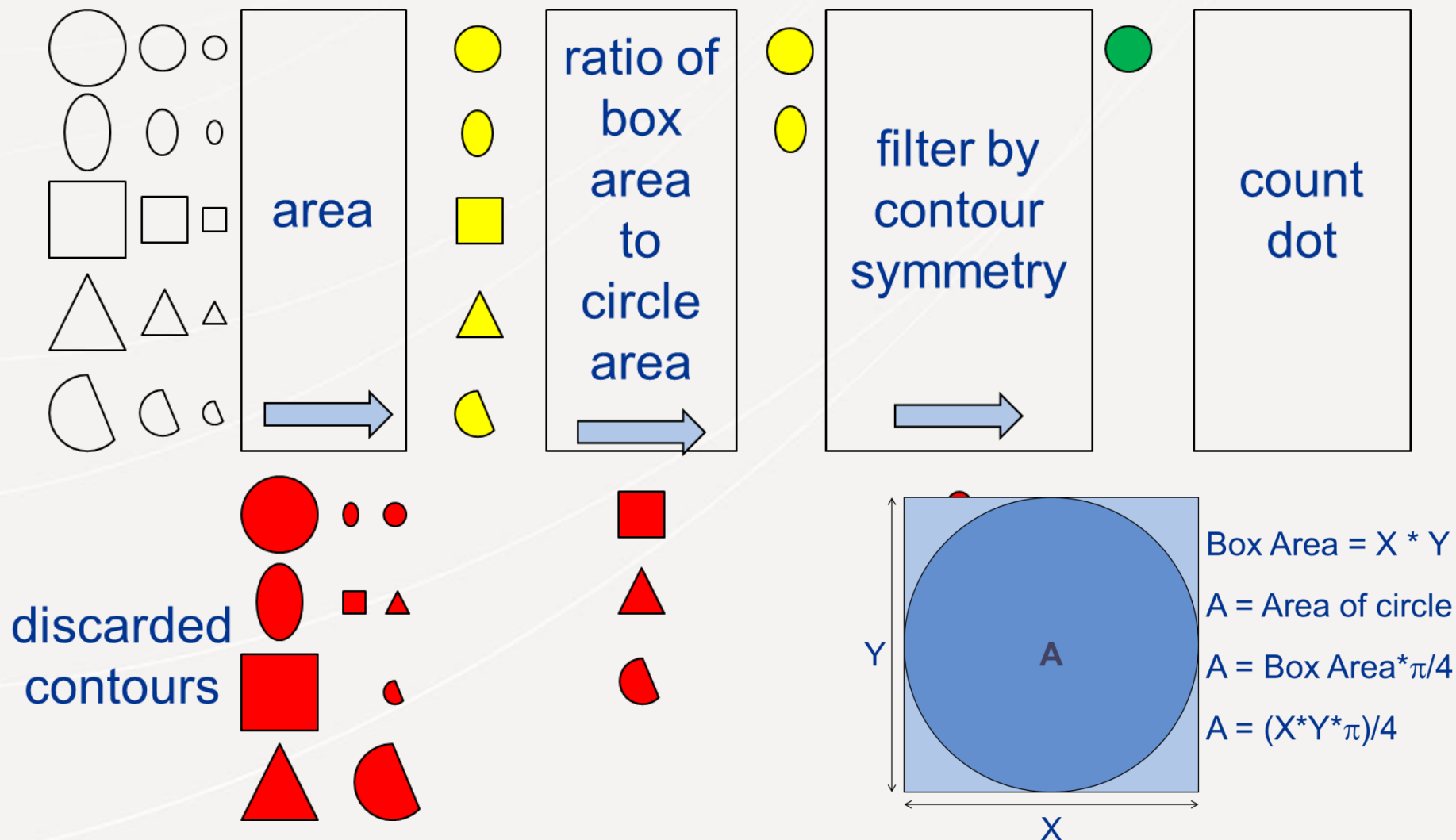
- Canny classifies individual pixels as edges
- Object boundaries are edge pixels grouped together by connectivity
- One method of grouping edges is Eight-way connectivity

	7	0	1	
	6	origin	2	
	5	4	3	

Eight-way Connectivity



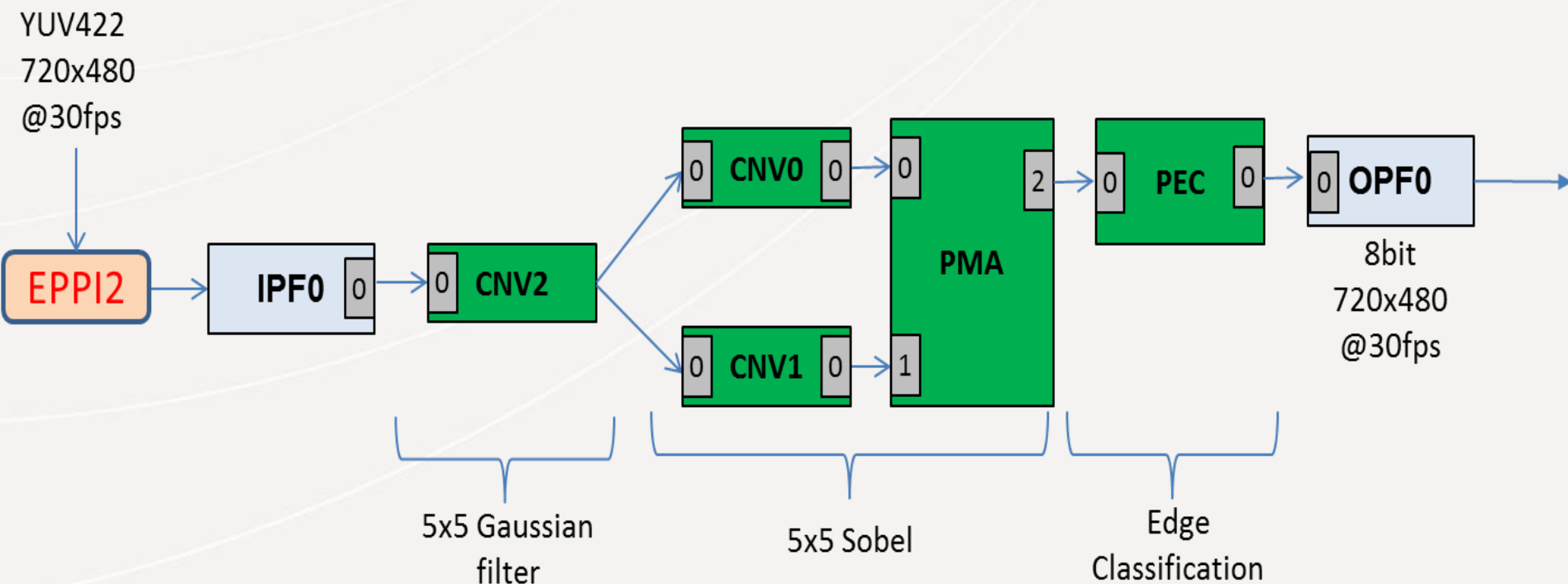
Classifying Objects Using Mathematical Models



Using Configurable Hardware to Accelerate Canny

Key Operations to Accelerate:

1. 5×5 Convolution
2. Cartesian to Polar Conversion
3. Edge Classification



Other Algorithms that can be Accelerated by the PVP

- Histogram of Oriented Gradients (HoG)
 - “Macro” feature detector
 - Commonly used for Human/Pedestrian Detection
- Difference of Gaussian (DoG)
 - Blob Detection
 - Scale-Invariant Feature Transform (SIFT)
- Haar Feature Based Object Detection
 - Viola/Jones face detection
 - Uses PVP Integral Image Block

Host PC (320×240 image)

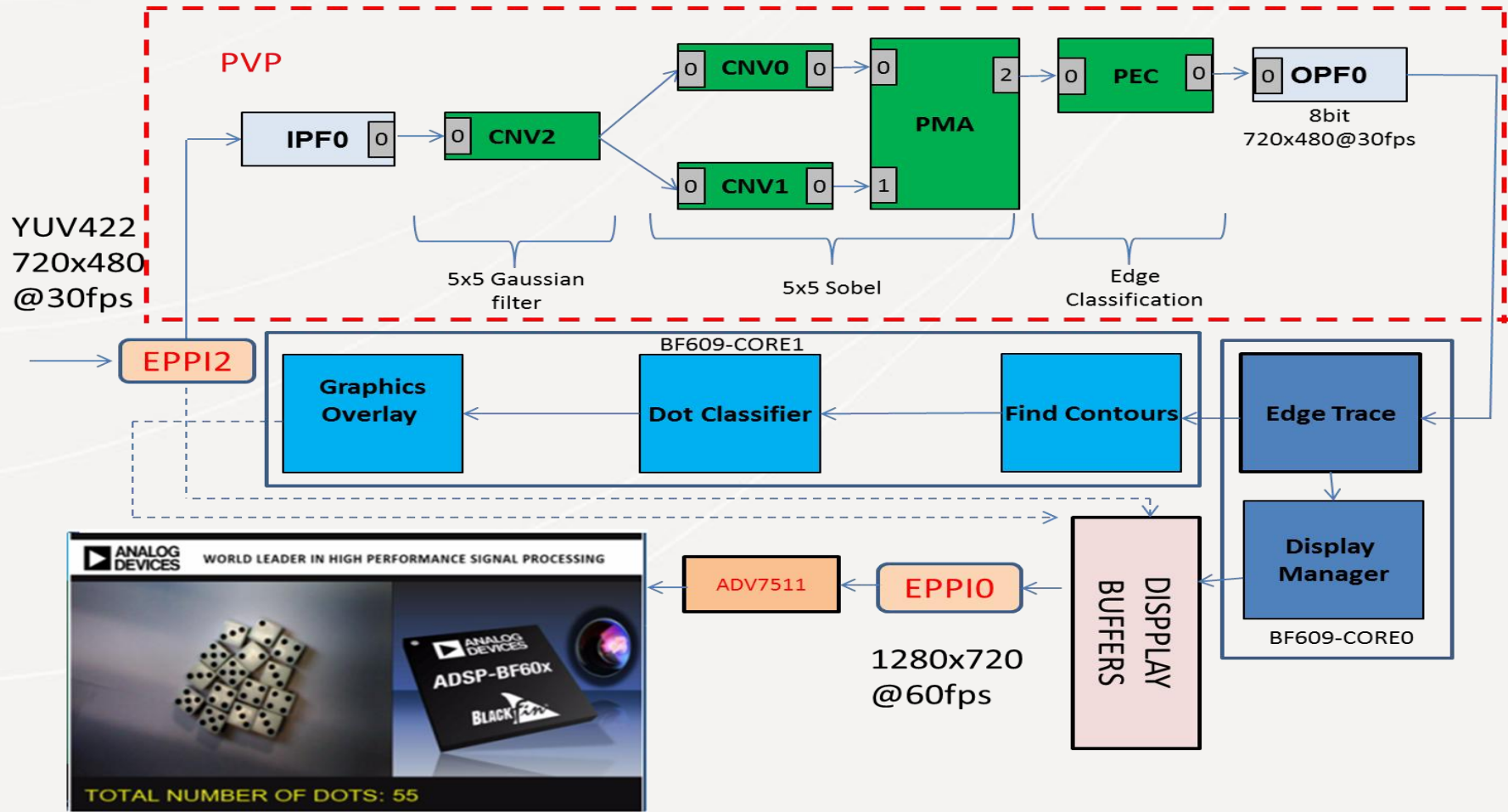
- Takes 11 ms on Intel x86 machine running at Ghz
- Consumes 10s of watts
- Does not take into consideration data capture
 - Images are assumed to be on the PC
- Larger image sizes take longer and consume more power

BF60x with PVP

- PVP max clock = 83 Mhz
 - Canny edge detection for 320×240 = 0.9 ms (plus few lines of initial latency)
- In camera pipe mode, PVP operates at external pixel clock
 - Edge detection in real-time at any supported resolution
 - Canny takes as long as it takes one frame to be clocked in
- VAT canny edge tracing –
 - PVP accelerated – *14 MIPS*
 - Only Core – *140 MIPS*
- PVP power for canny edge detection at 720p <50mW
 - Full chip typical power consumption at 25C is 400mW

An Example of Edge Detection and Classification

Canny Dot Detection PVP Pipeline



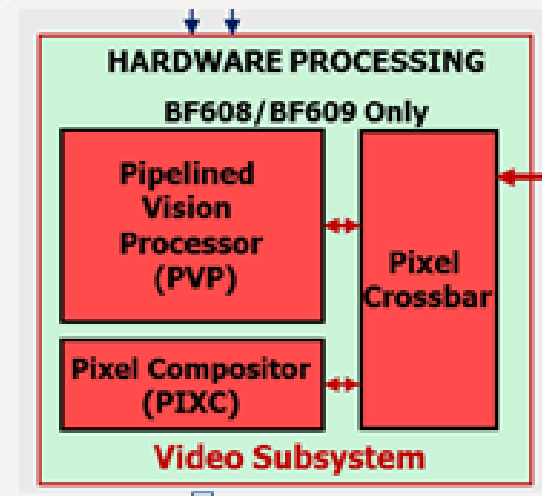
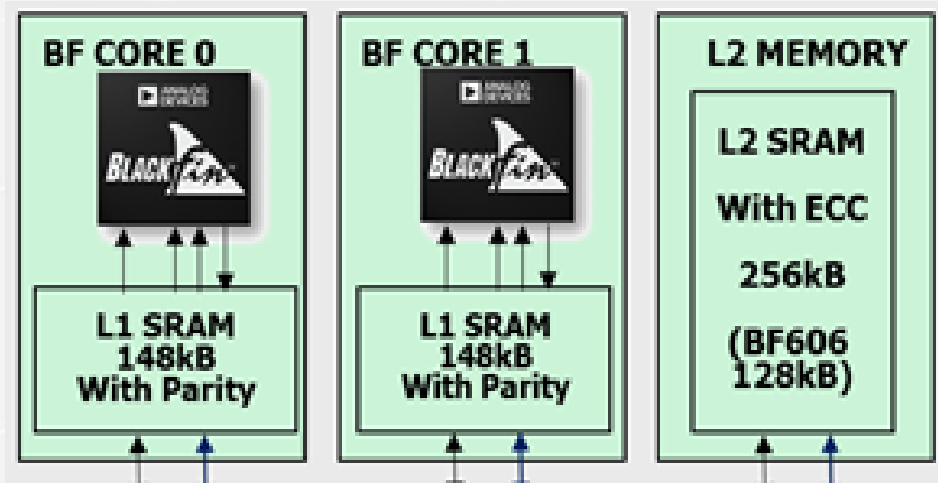
Full Canny Edge Detection with Contour Segmentation at 720 480 30 fps

ADSP-BF609

1GHz of programmable Blackfin
processor performance across two cores

Pipelined Vision Processor

- 25 Billion Math Ops/sec
- Up to 1280x960P input
- Up to 83M Pixels/second X 4



BDTI provides embedded vision engineering services for product development

BDTI:

- Is highly trusted partner—consistently delivering projects right the first time, on time and on budget
- Has extensive, hands-on experience in embedded software development
- Knows vision applications, algorithms and tools, including OpenCV
- Has 20 years of experience developing highly optimized embedded code

See our demo table!

Contact us at info@BDTI.com or www.BDTI.com

- Mark S. Nixon & Alberto S. Aguado. Feature Extraction & Image Processing for Computer Vision, Academic Press, 2012
- J.R. Parker. Algorithms for Image Processing and Computer Vision Second Edition, Wiley, 2011
- Building Machines That See: Finding Edges in Images, by Eric Gregori, BDTi: www.embedded-vision.com/platinum-members/bdti/embedded-vision-training/documents/pages/building-machines-see-finding-edges-i
- Finding Objects in Live Video Using the Blackfin BF609 Canny Edge Detection Example by BDTi: <http://finboard.org/videos/part-3-bdti-finding-objects-live-video-using-blackfin-bf609-canny-edge-detection-example>
- ADSP-BF609 product information: www.analog.com/en/processors-dsp/blackfin/adsp-bf609/products/product.html

Q/A

