

# Lecture 10

# Recap

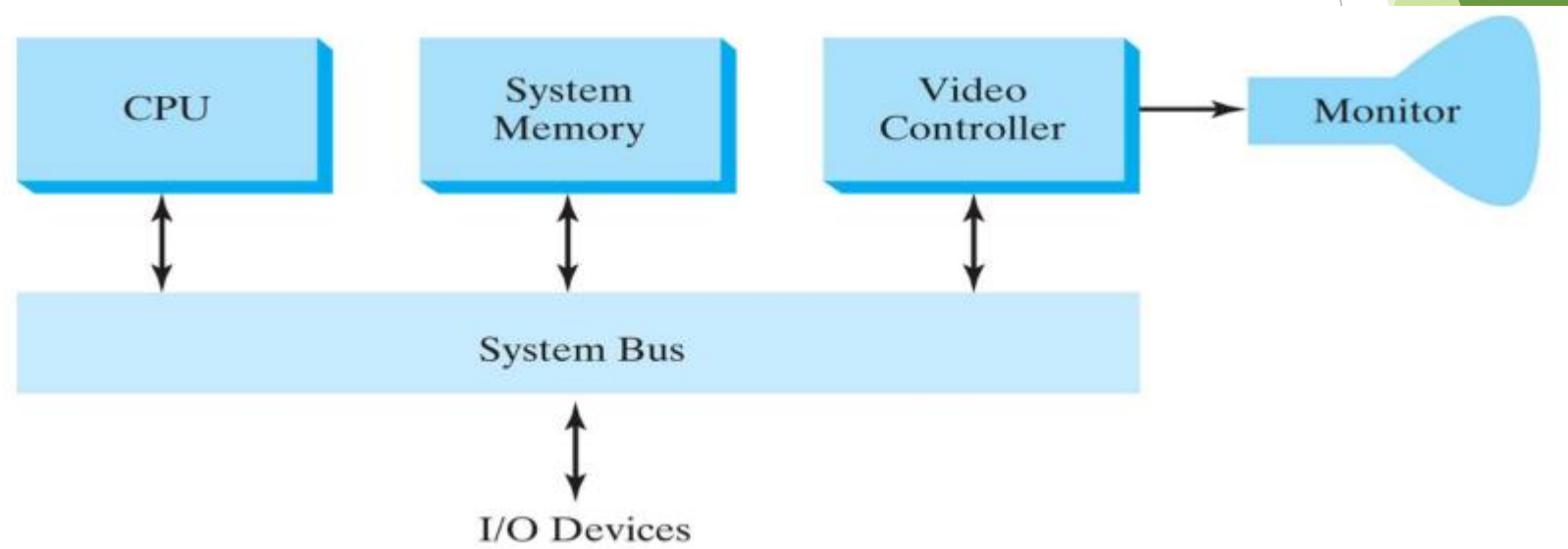
- ▶ HTML Canvas
  - ▶ Comparison to SVG browser graphics
  - ▶ Drawing shapes
  - ▶ Basic Trigonometry
  - ▶ Basic collision detection
  - ▶ Animation and User Interaction
    - ▶ Examples
  - ▶ Advanced collision handling
  - ▶ Linear Algebra and Transformations
- ▶ SVG
- ▶ D3
- ▶ 3D - WebGL/Three.js

# Graphics Hardware

# Graphics Hardware Intro

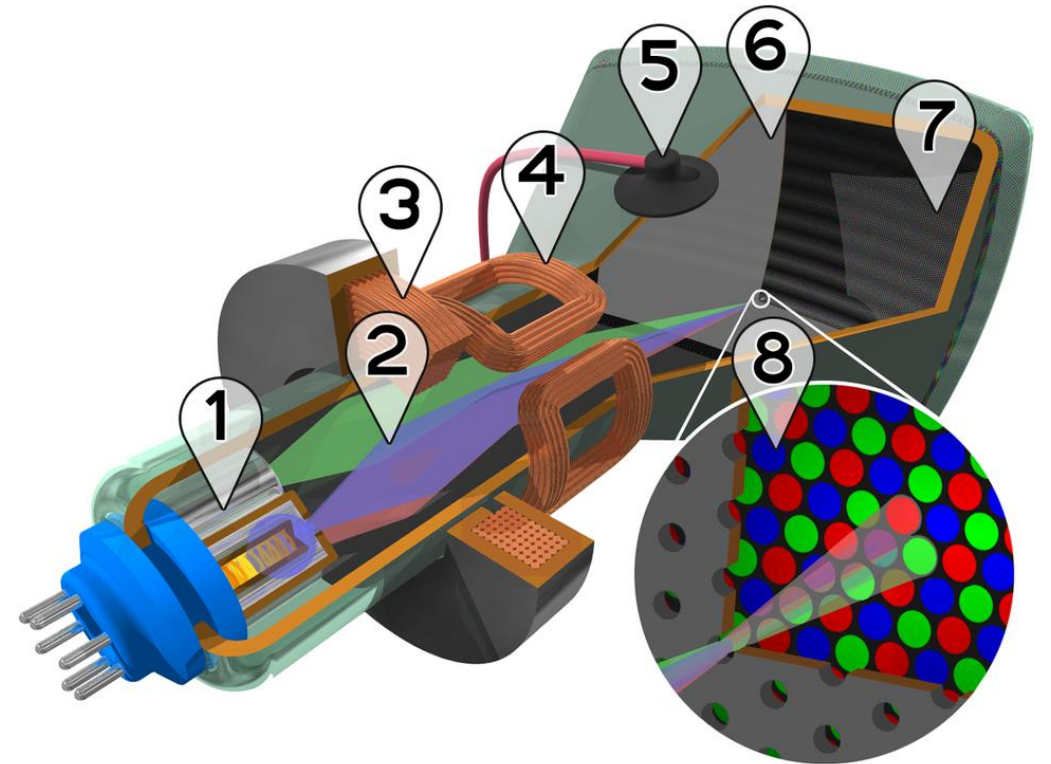
- ▶ Basic graphics hardware

- ▶ Display devices
- ▶ Video controller
- ▶ Memory
- ▶ CPU
- ▶ System bus



# Display Devices

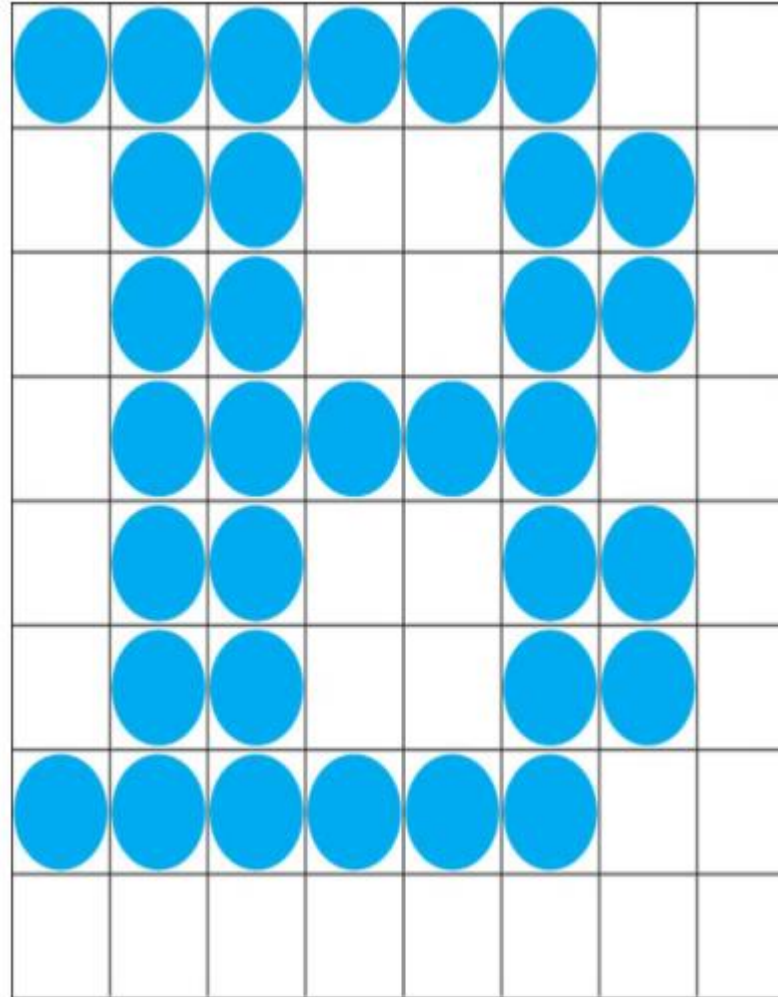
- ▶ Older
  - ▶ CRT
  - ▶ Vector Display



1. Three electron emitters (for red, green, and blue phosphor dots)
2. Electron beams
3. Focusing coils
4. Deflection coils
5. Anode (collector)
6. Mask for separating beams for red, green, and blue part of displayed image
7. Phosphor layer (screen) with red, green, and blue zones
8. Close-up of the phosphor-coated inner side of the screen

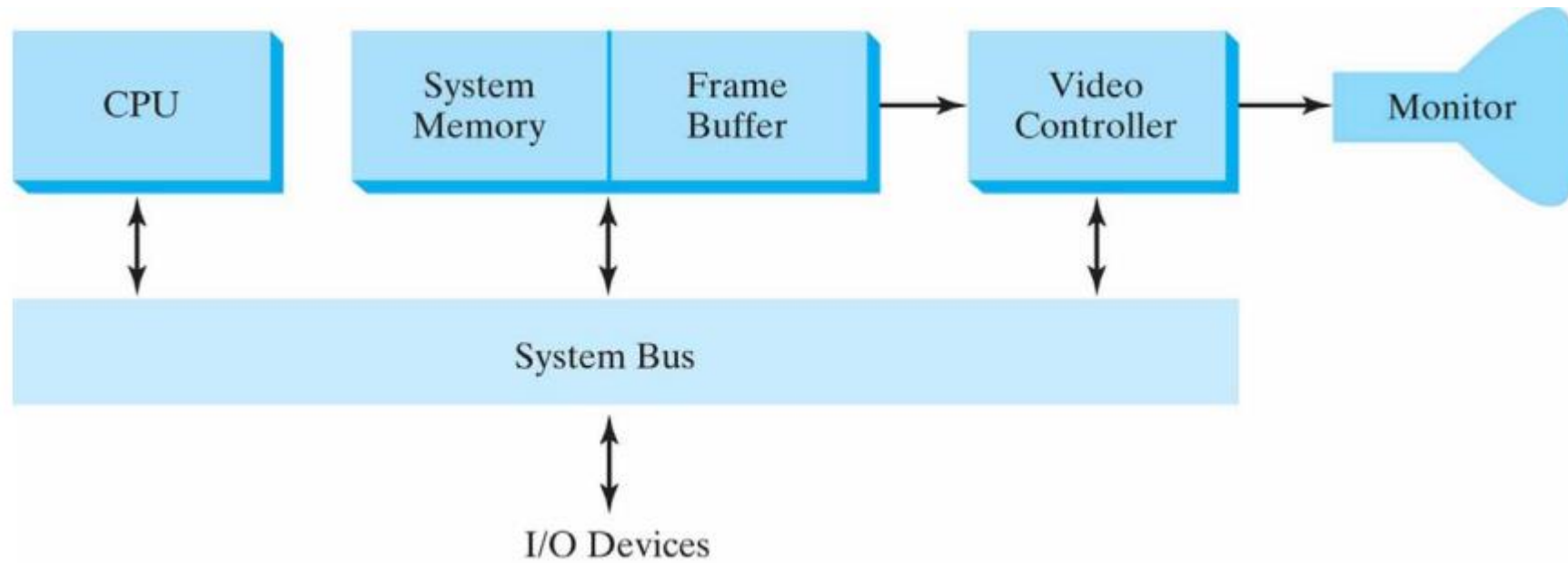
# Raster Displays

- Example - how to draw a character:



# Integrated Graphics Hardware for Raster Display System

- Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer.



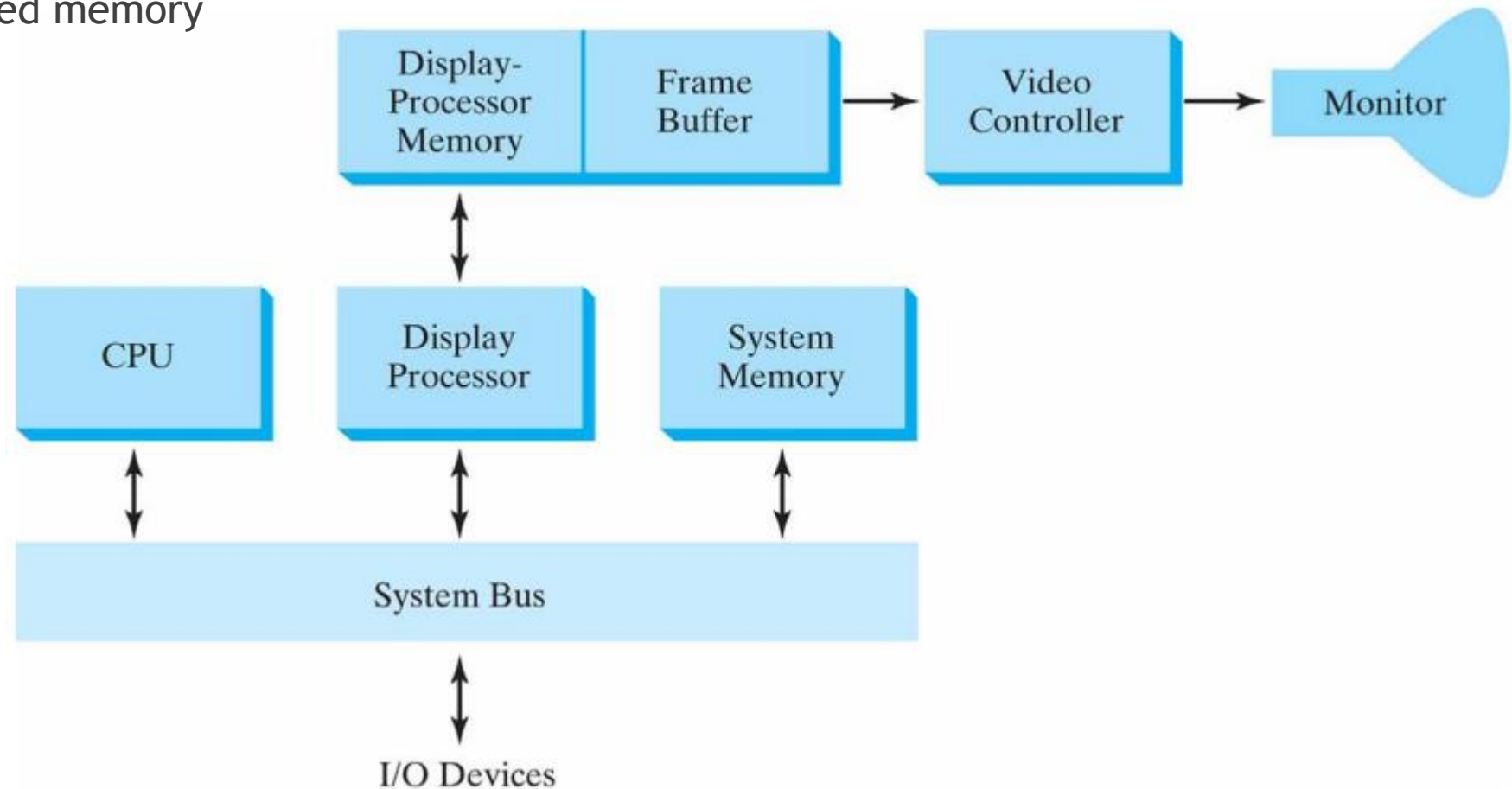
# Display Processor-based Raster-Graphics Computer System.

- ▶ As the demand for better graphics increased, hardware manufacturers created a way to decrease the amount of CPU time required to fill the framebuffer.
  - ▶ Commonly called "graphics accelerating".
- ▶ Common graphics drawing commands (many of them geometric) are sent to the graphics accelerator in their raw form.
  - ▶ The accelerator then rasterizes the results of the command to the framebuffer.
  - ▶ This method can save thousands or millions of CPU cycles per command, as the CPU is freed to do other work.



# Display Processor-based Raster-Graphics Computer System.

- Architecture of a raster-graphics system with a display processor.
- Has dedicated memory



# Graphics Card

- ▶ A graphics card, also known as a graphics accelerator card, display adapter, or video card, is a PC hardware component whose function is to generate and output images to a display. It operates on similar principles as a sound card or other peripheral devices.
- ▶ Components
  - ▶ Graphics processing unit (GPU): a dedicated graphics microprocessor optimized for floating point calculations which are fundamental to 3D graphics rendering.
- ▶ Video memory
  - ▶ DDR RAM, 128 MB to 12.0 GB, 400 MHz to 2.4 GHz.
  - ▶ Store program, data, and frame buffer

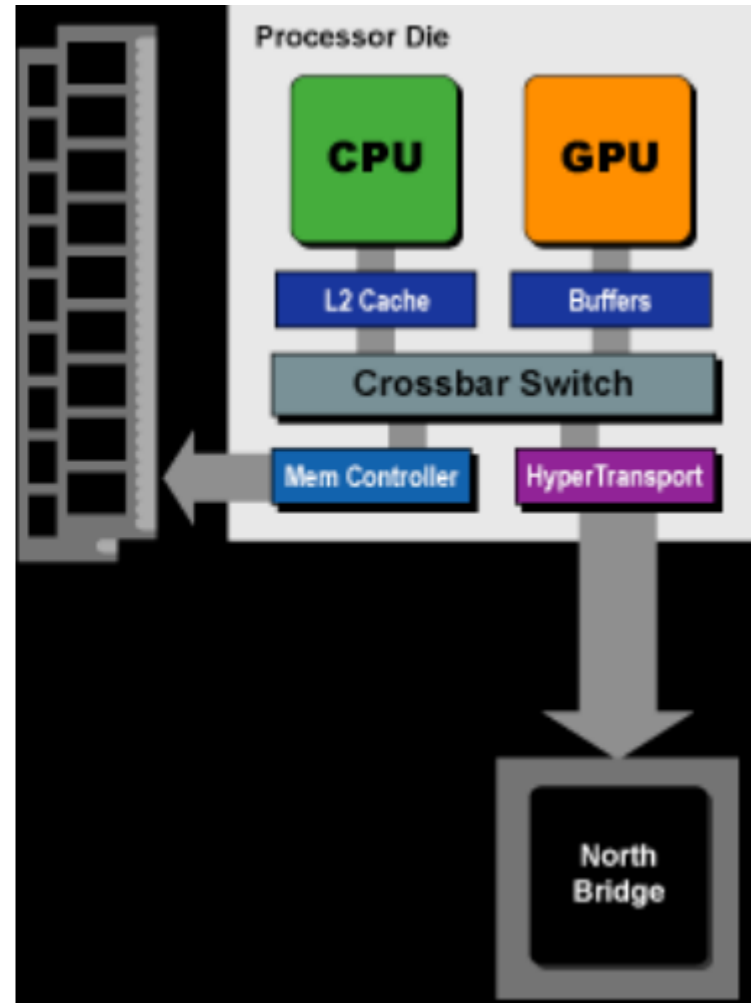
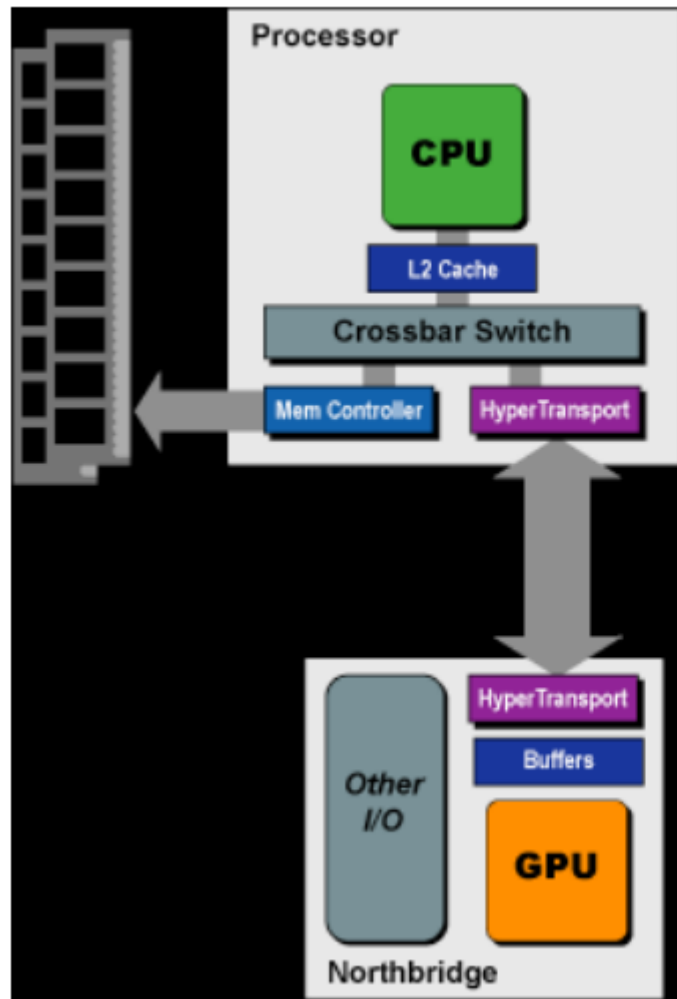
# Frame Buffer

- ▶ The frame buffer is a part of RAM in a computer allocated to hold the graphics information for one frame of image.
- ▶ Frame buffer (FB) size determines the maximum resolution and color depth of the image
  - ▶  $\text{FB size} = \text{resolution} \times \text{color depth}$ ,
  - ▶ E.g.  $640 \times 480 \times 8 \text{ bit} = 2457600 \text{ bit} = 307200 \text{ Byte}$
- ▶ Frame buffer can be a part of main memory, or on the graphics card
- ▶ Image is generated by CPU/GPU (in vector/raster) and written (or loaded) into frame buffer
- ▶ Image in frame buffer is read out by display controller/interface to display on the screen

# GPU has more computing power

- ▶ GPU has a massively parallel architecture
  - ▶ Many problems map well to GPU-style computing
  - ▶ GPUs have large amount of arithmetic capability
  - ▶ Increasing amount of programmability in the pipeline
- ▶ Programmable GPU
  - ▶ New features map well to GPGPU
  - ▶ Unified shaders
  - ▶ Direct access to computing units in new APIs
- ▶ Challenge
  - ▶ How do we make the best use of GPU hardware?
  - ▶ Techniques, programming models, languages


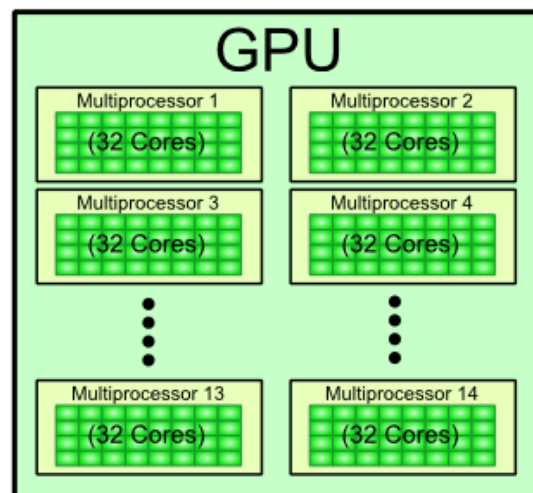
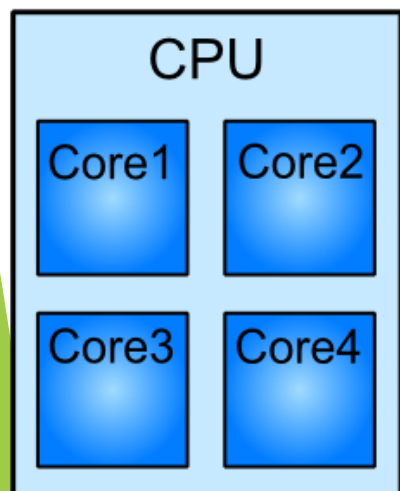
# CPU/GPU Fusion (Integrated Graphics)



# GPU vs CPU

- ▶ Highest spec:
  - ▶ <http://www.nvidia.com/gtx-700-graphics-cards/gtx-titan-z/>
  - ▶ <https://blogs.nvidia.com/blog/2014/03/25/titan-z/>

## CPU/GPU Architecture Comparison



**TITAN Z**

**ULTIMATE POWER. THE NEW GEFORCE® GTX TITAN Z.**

GeForce® GTX TITAN Z is a gaming monster, the fastest card we've ever built to power the most extreme PC gaming rigs on the planet. Stacked with 5760 cores and 12 GB of memory, this dual GPU gives you the power to drive even the most insane multi-monitor displays and 4K hyper PC machines.

**GTX TITAN Z GPU ENGINE SPECS:**

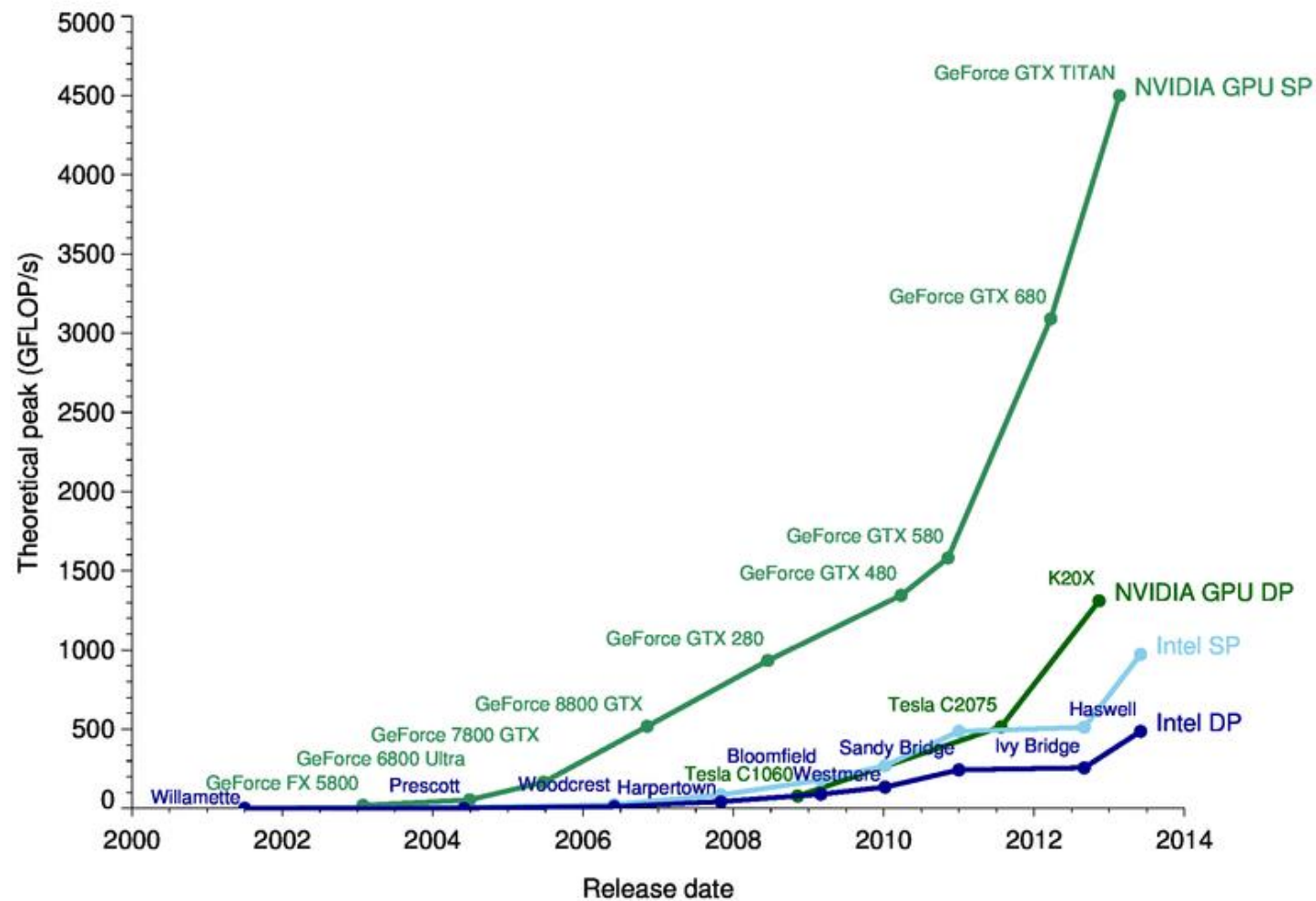
CUDA Cores	5760
Base Clock (MHz)	705
Boost Clock (MHz)	876
Texture Fill Rate (billion/sec)	338

**GTX TITAN Z MEMORY SPECS:**

Memory Speed	7.0 Gbps
Standard Memory Config	12288 MB
Memory Interface	GDDR5
Memory Interface Width	768-bit (384-bit per GPU)
Memory Bandwidth (GB/sec)	672

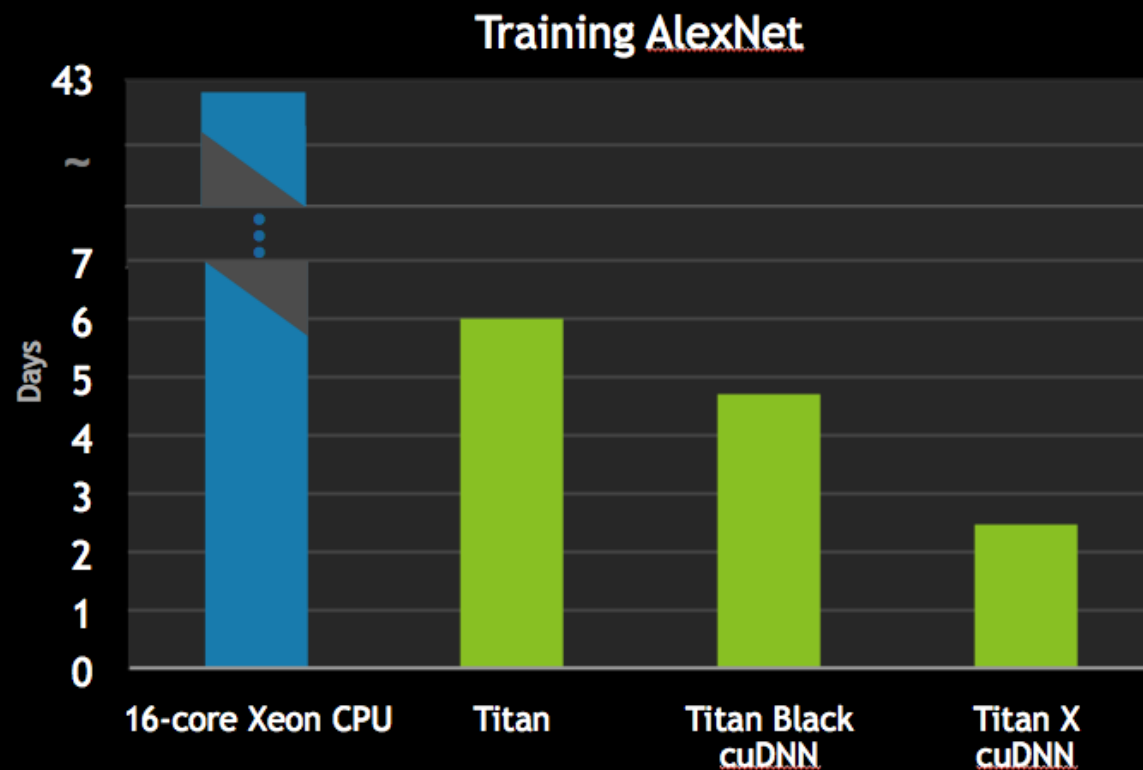
**MORE INFORMATION**

# GPU vs CPU



# GPU vs CPU

## TITAN X FOR DEEP LEARNING





# Refresh rates and Resolution

- ▶ Frequency:
  - ▶ How many frames per second
  - ▶ Typically with CRT, was 60 frames per second
  - ▶ What's the update frequency with 4K TV
    - ▶ <https://www.cnet.com/uk/news/ultra-hd-4k-tv-refresh-rates/>

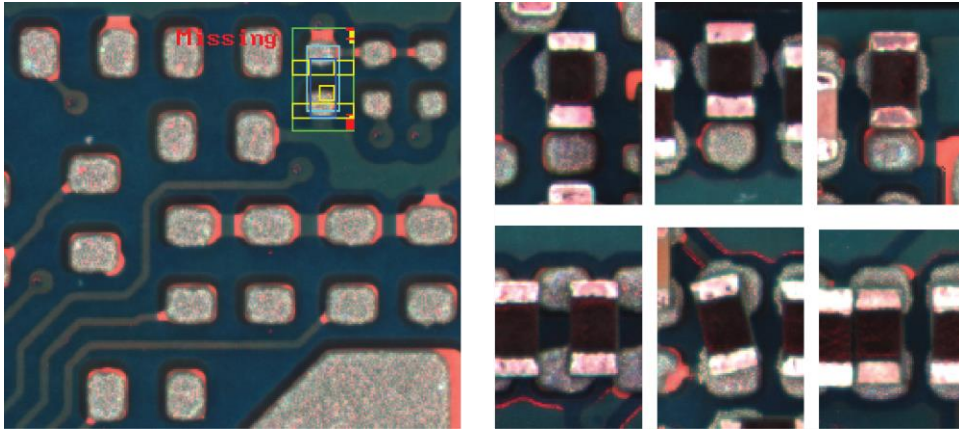
# Computer Vision

The background of the slide is white with abstract green geometric shapes on the right and bottom-left edges. These shapes consist of various overlapping triangles and polygons in different shades of green, ranging from light lime to dark forest green. A thin, light gray line also extends from the bottom-left towards the center of the slide.

# Introduction

- ▶ Computer Vision is about understanding images. These images can be
  - ▶ Greyscale or Colour
  - ▶ Snapshots or video sequences
  - ▶ Taken with a static or moving camera
  - ▶ Taken of a stationary or dynamic scene
  - ▶ Taken with a calibrated or un-calibrated camera
- ▶ What Computer Vision aims to do is to extract some useful information from these images for...
  - ▶ Inspection purposes
  - ▶ Analysis purposes
  - ▶ Control purposes

# Applications - Industrial Inspection



# Applications - Surveillance / Forensics

- ▶ In London there are 1,000,000+ cameras
- ▶ However, only 1 crime solved per 1,000 cameras (BBC, 2009)
- ▶ In July 2005 there was a major terrorist attack in London...
- ▶ Afterwards
  - ▶ 17,000 hours of video was studied
  - ▶ Over 1 year

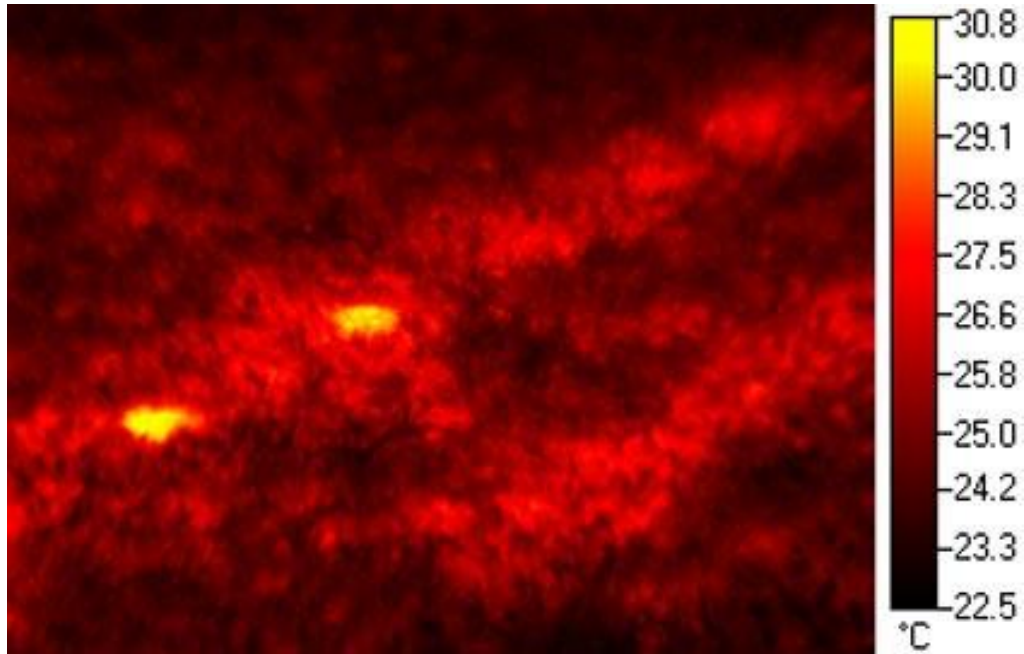


# Applications - Biometrics





# Applications - Landmine detection



# Vision is hard

"What we experience, apparently directly, is actually very different from what is recorded by our sense organs."

[Perception: From Sense to Object  
by J. Wilding]

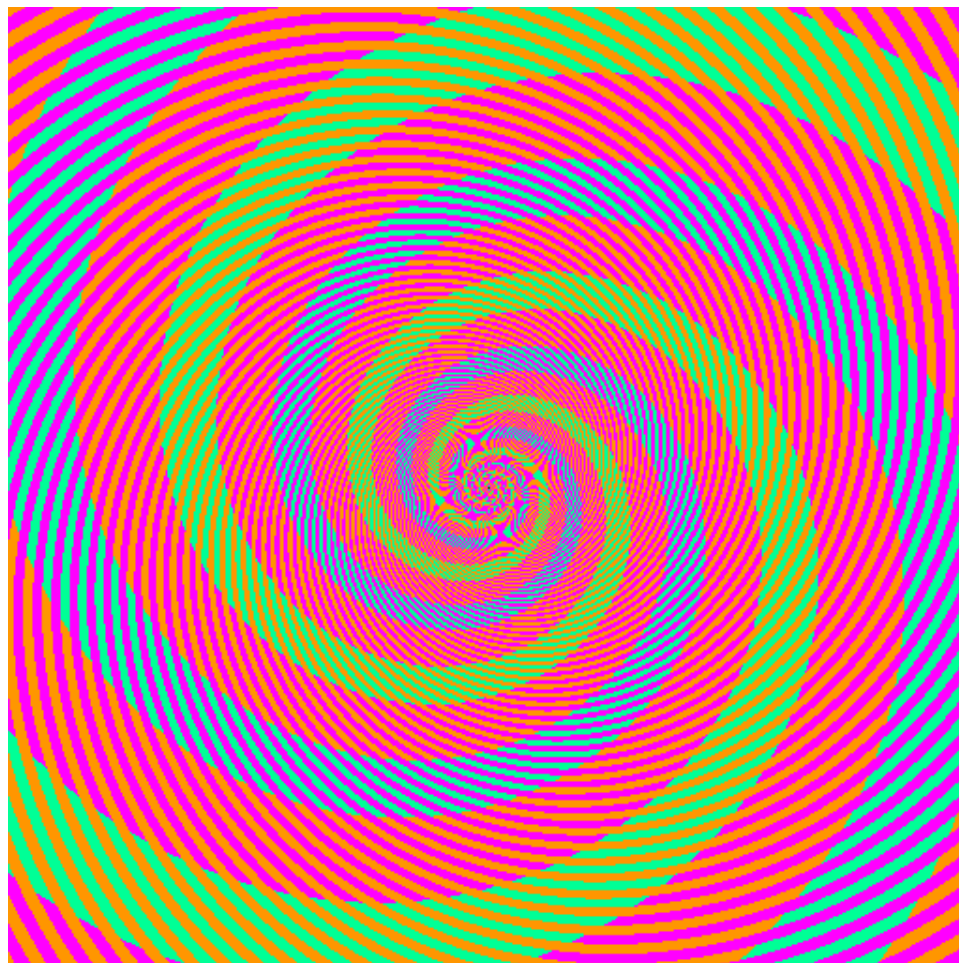
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```











The blue and green colors are actually the same



<http://blogs.discovermagazine.com/badastronomy/2009/06/24/the-blue-and-the-green/>



# A Few Quotes

- ▶ “A breakthrough in machine learning would be worth ten Microsofts” (Bill Gates, Chairman, Microsoft)
- ▶ “Machine learning is the next Internet” (Tony Tether, Director, DARPA)
- ▶ Machine learning is the hot new thing” (John Hennessy, President, Stanford)
- ▶ “Web rankings today are mostly a matter of machine learning” (Prabhakar Raghavan, Dir. Research, Yahoo)
- ▶ “Machine learning is going to result in a real revolution” (Greg Papadopoulos, CTO, Sun)
- ▶ “Machine learning is today’s discontinuity” (Jerry Yang, CEO, Yahoo)



# The Ultimate Goal

"If our long-sought quest to create autonomous anthropomorphic automata is to succeed, we must first impart perceptual abilities to machines".

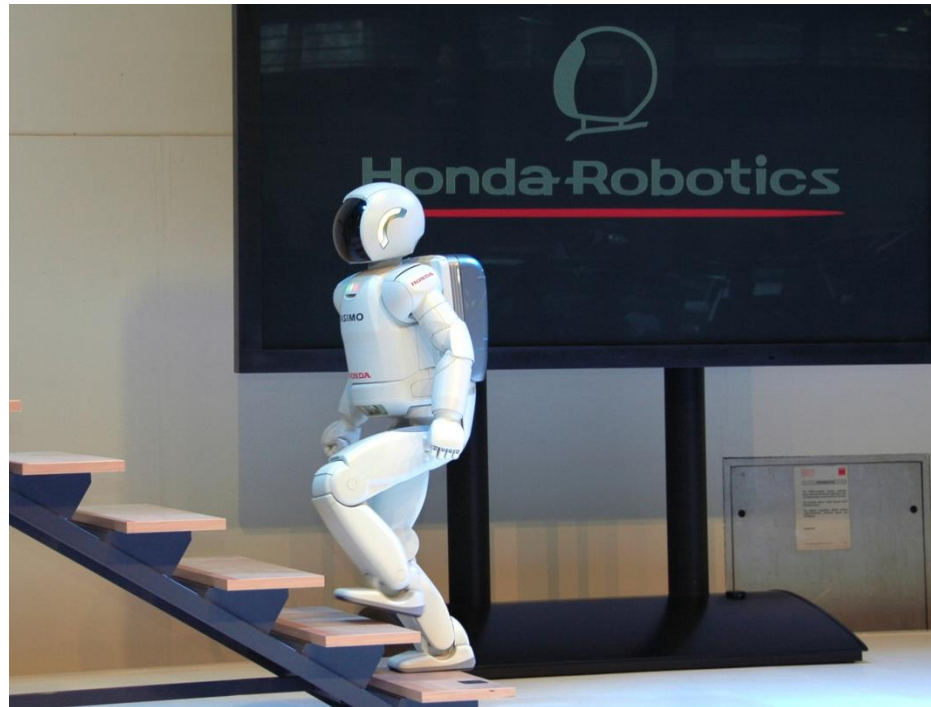
[A Guided Tour of Computer Vision, by V. Nalwa]

# Applications - Robot Vision

Ultimately emulating this...



So, how are we doing?





# Process of Edge Detection

- ▶ Edge detection is the most common approach for detecting meaningful discontinuities.
  - ▶ An edge is a set of connected pixels that lie on the boundary between two regions.
  - ▶ Edge detection is commonly used for image segmentation in computer vision tasks (e.g. face recognition)
- ▶ The magnitude of the first derivative in a particular direction can be used to detect the presence of an edge.

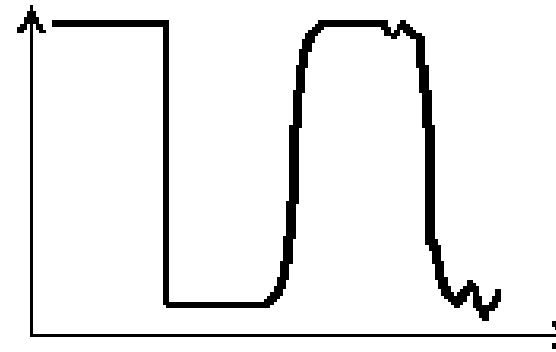
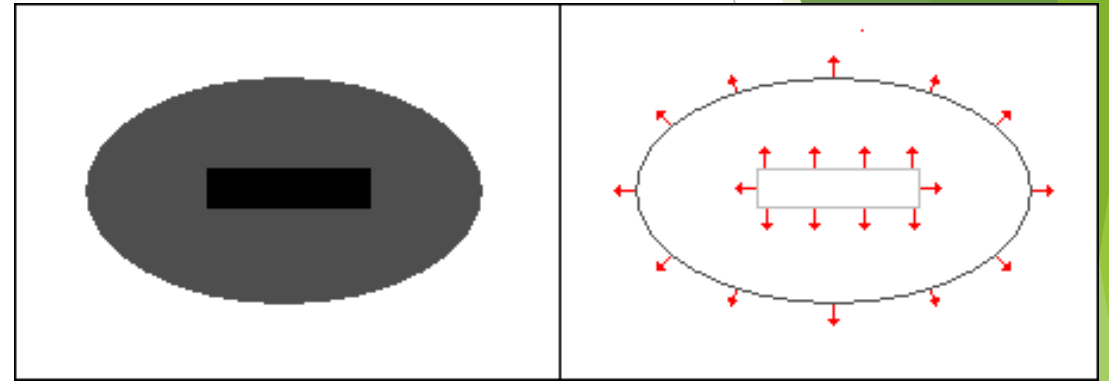


# Edge Detection - Topics

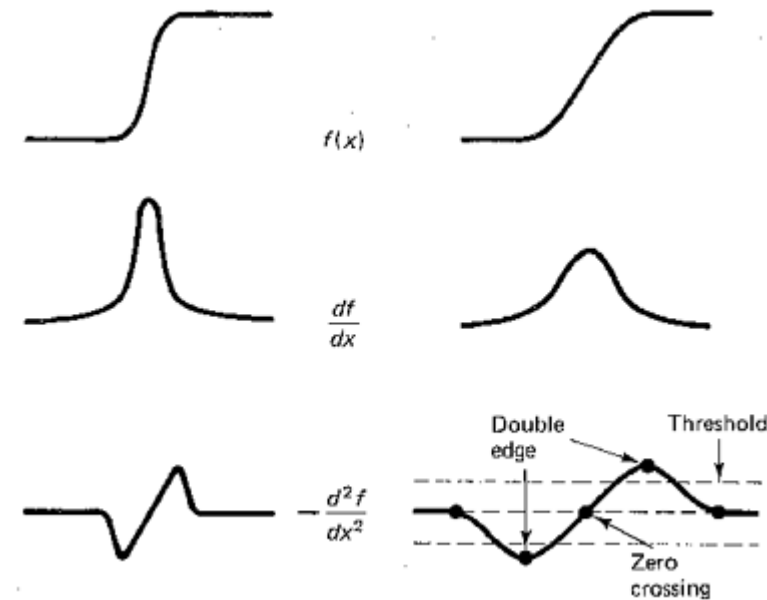
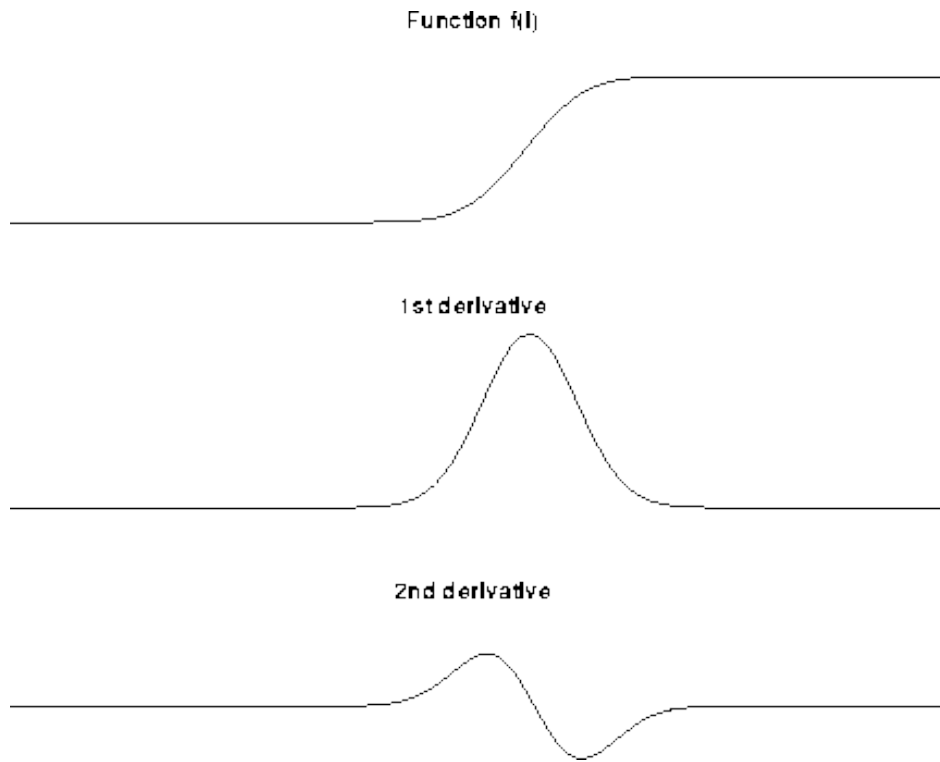
- ▶ 1<sup>st</sup> derivative edge detection - Sobel
- ▶ 2<sup>nd</sup> derivative edge detection - Canny
- ▶ Overview of Multispectral edge detection
- ▶ Application: Image sharpening

# Edge Detection - What is an edge?

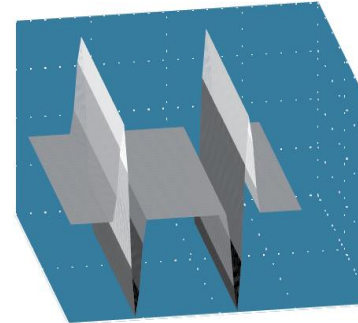
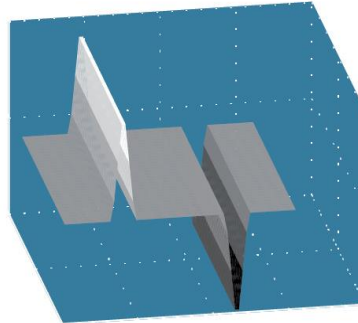
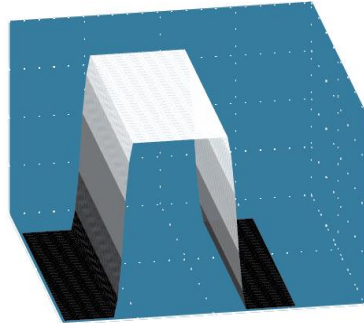
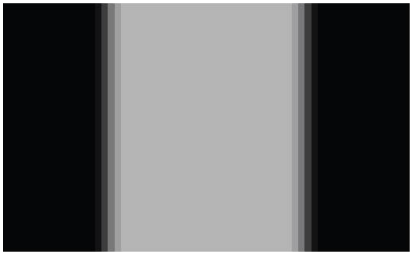
- ▶ Where brightness changes abruptly
- ▶ Edges have
  - ▶ Magnitude (Gradient)
  - ▶ Direction (Orientation)
- ▶ Edge Profiles
  - ▶ Step
  - ▶ Real
  - ▶ Noisy



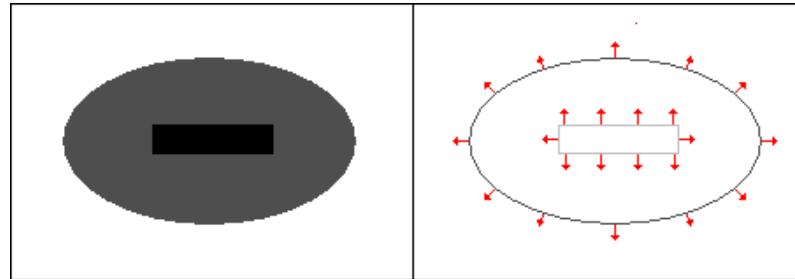
# Edge Detection - derivatives



# Edge Detection - 1st derivative definitions



- Recall: Vector variable -
  - Gradient Magnitude
  - Orientation (0 degrees is East)



# Edge detection - 1st derivative - Sobel

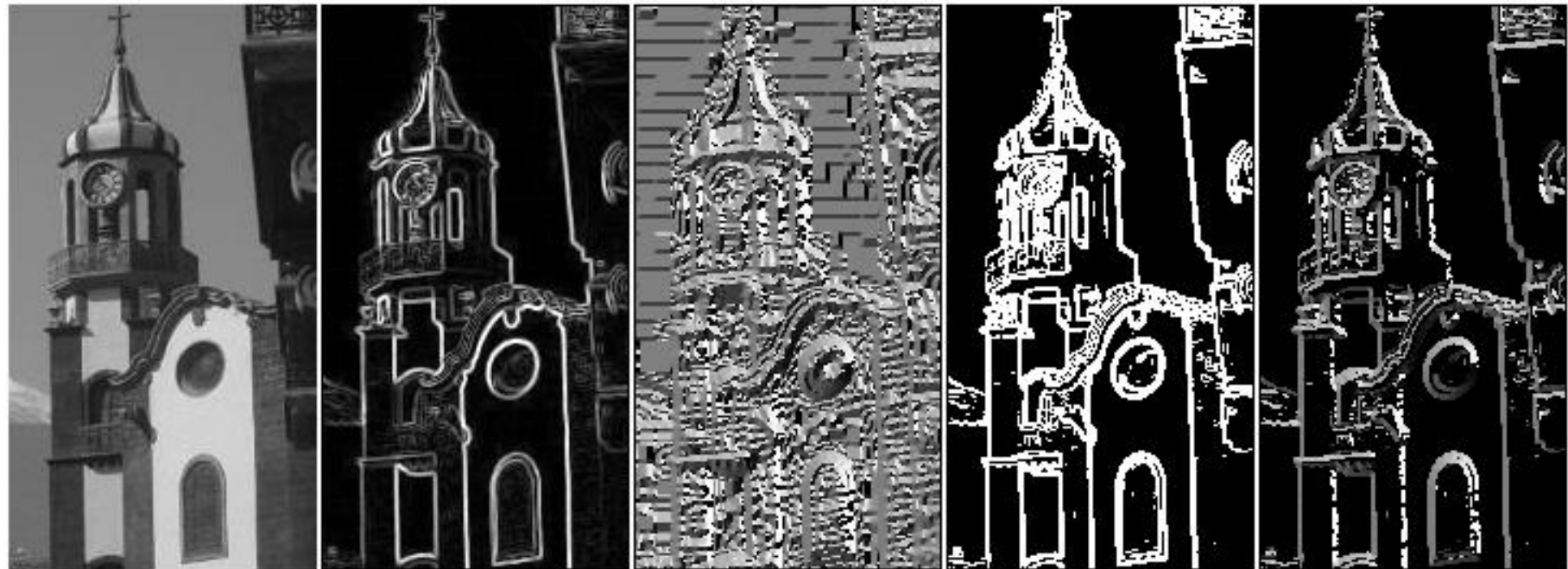
- ▶ The Sobel operator is used to find the approximate absolute gradient magnitude at each point in an input gray-scale image.
- ▶ **Sobel detection** uses these two below 3\*3 convolution kernels to find edge in an image.

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

$G_x$

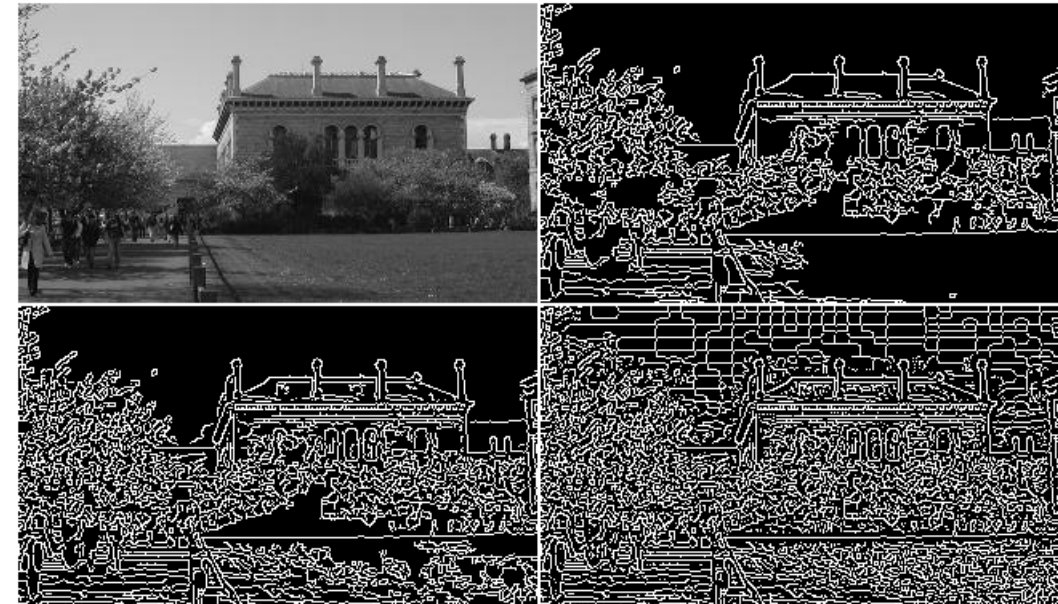
-1	-2	-1
0	0	0
1	2	1

$G_y$



# Edge detection - 2nd derivative - Canny algorithm

- ▶ Canny edge detection improved upon Sobel edge detection by:
  - ▶ Removing speckle noise with a low pass Gaussian filter first
  - ▶ Then applying a Sobel filter to detect edges
  - ▶ Then doing non-maximum suppression to pick out the best pixel for edges when there are multiple possibilities in a local neighborhood.
  - ▶ Offers more refined edges than Sobel
- ▶ Both can only function with grey-scale images





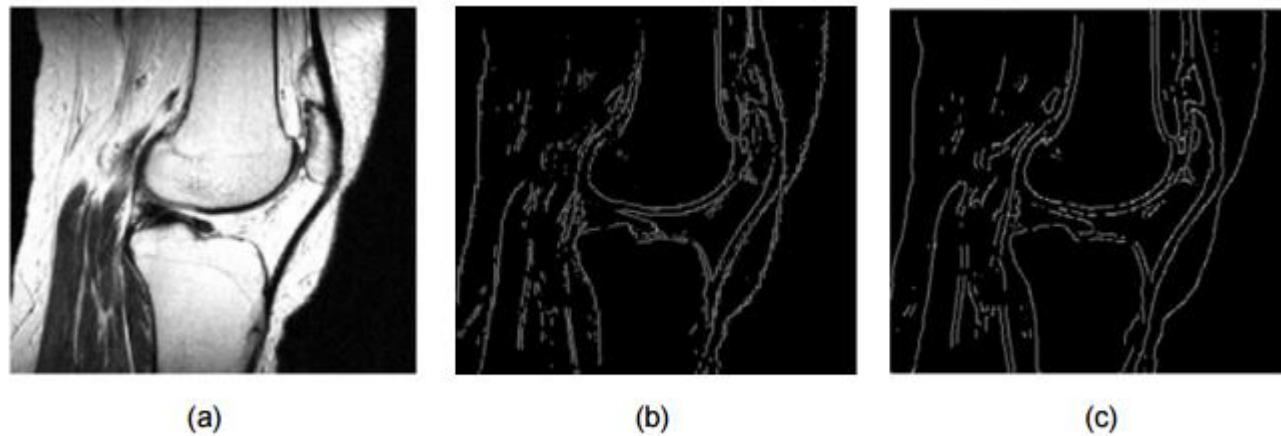


Figure 6: (a) Original image. Sobel (b). Canny (c)

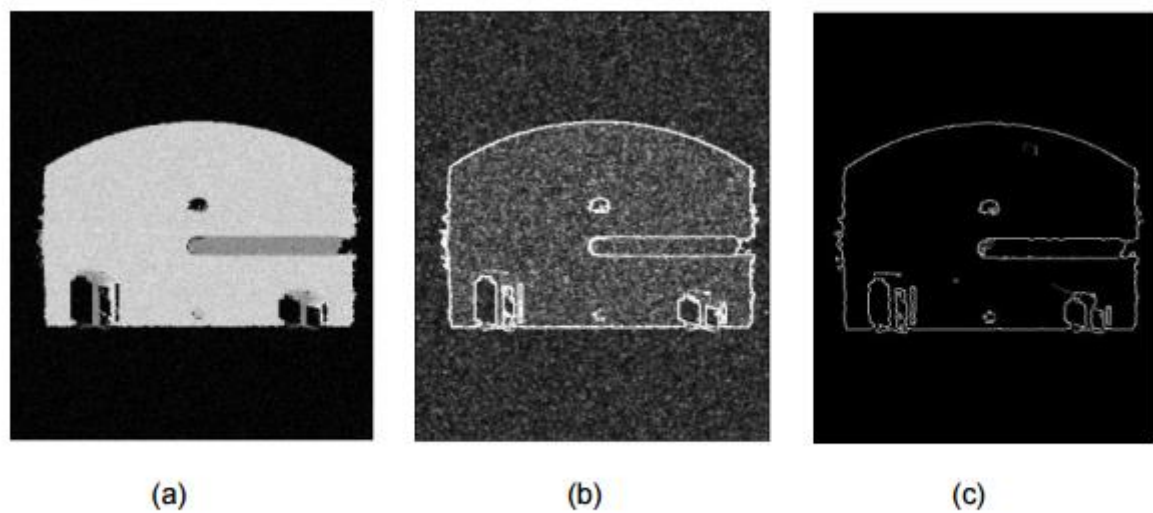
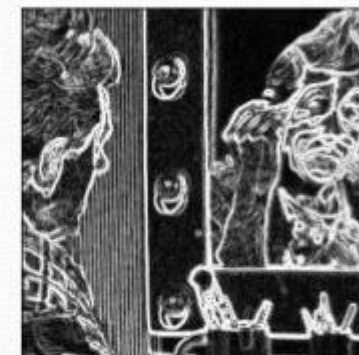


Figure 7: (a) Original image. Sobel (b). Canny (c)



Canny

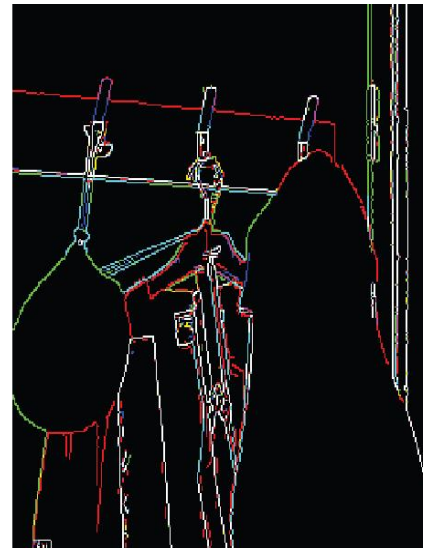
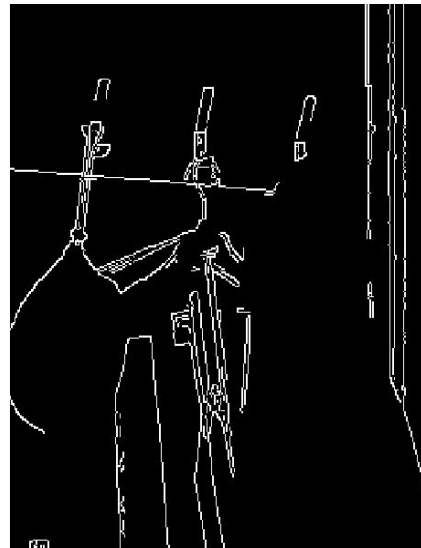


Sobel



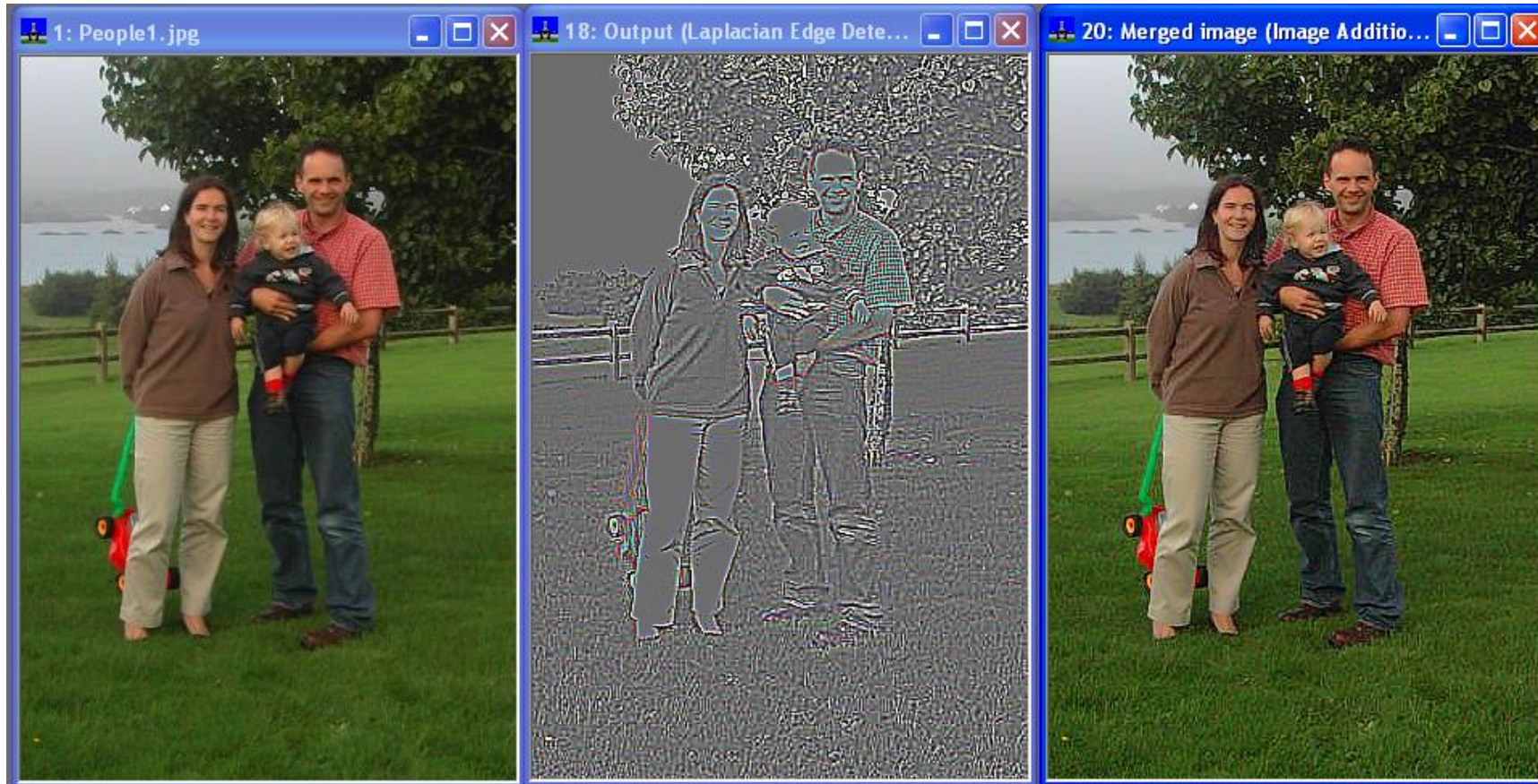
# Overview: Multispectral edge detection

- ▶ Detect edges separately in each spectral band
  - ▶ Use maximal value OR some linear combination



# Application: Image sharpening

- Making edges steeper.



# Application: Image sharpening

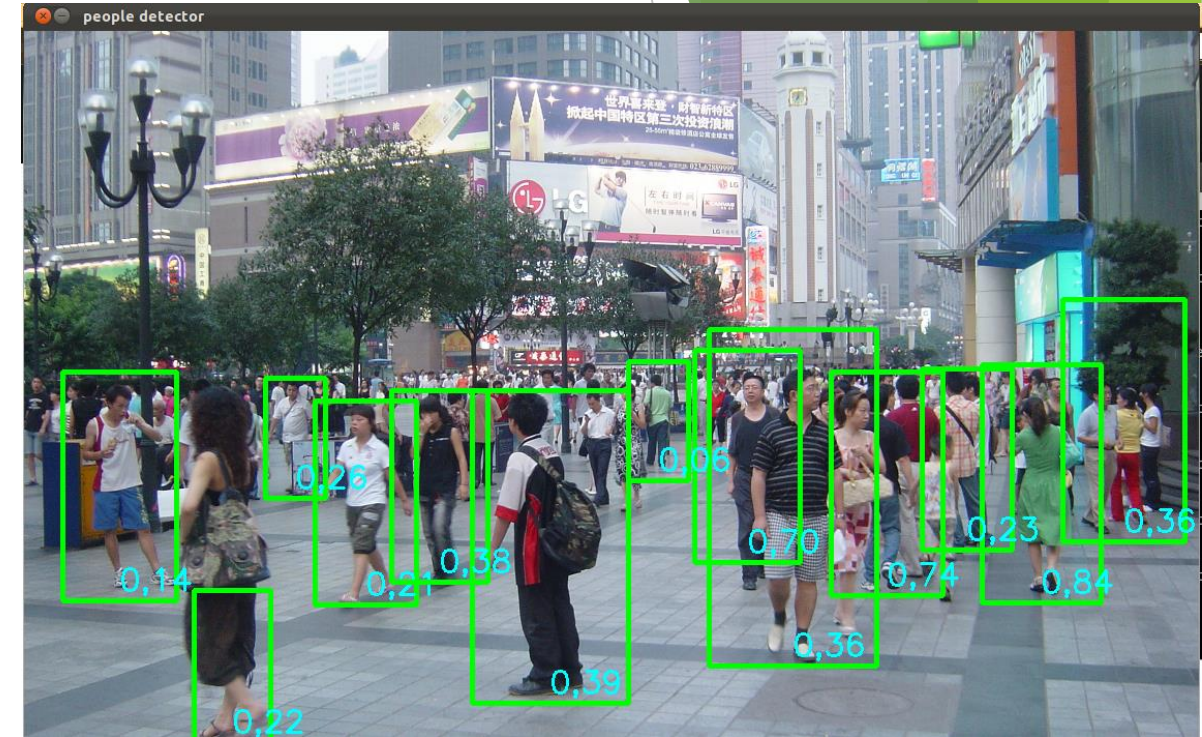
- Subtract a multiple (e.g. 0.3) of the Laplacian from the image.





# OpenCV

- ▶ Open Source Computer Vision is a library of programming functions mainly aimed at real-time computer vision.
- ▶ Originally developed by Intel
- ▶ OpenCV is released under a BSD license - free for commercial use.
- ▶ Has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android.
- ▶ Designed for computational efficiency. Written in optimized C/C++, the library can take advantage of multi-core/GPU processing.



# Lab this week

- ▶ Intro to OpenCV
- ▶ Edge detection with Sobel and Canny