Lecture 10

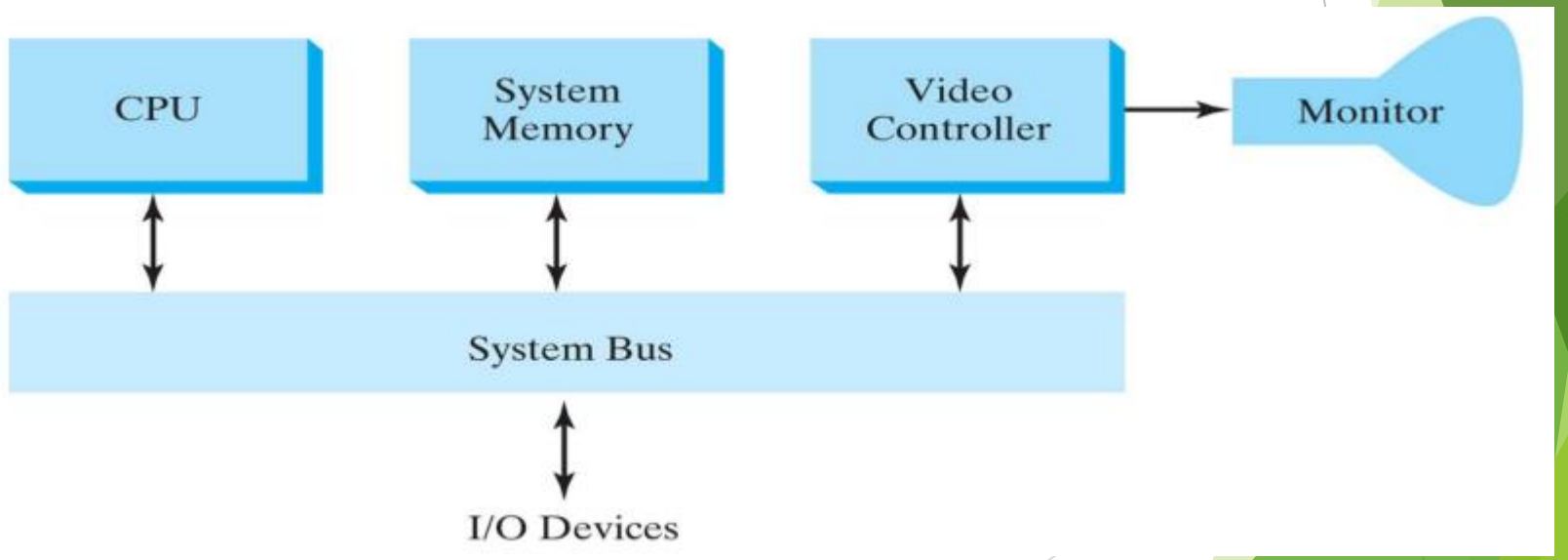
Recap

- 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

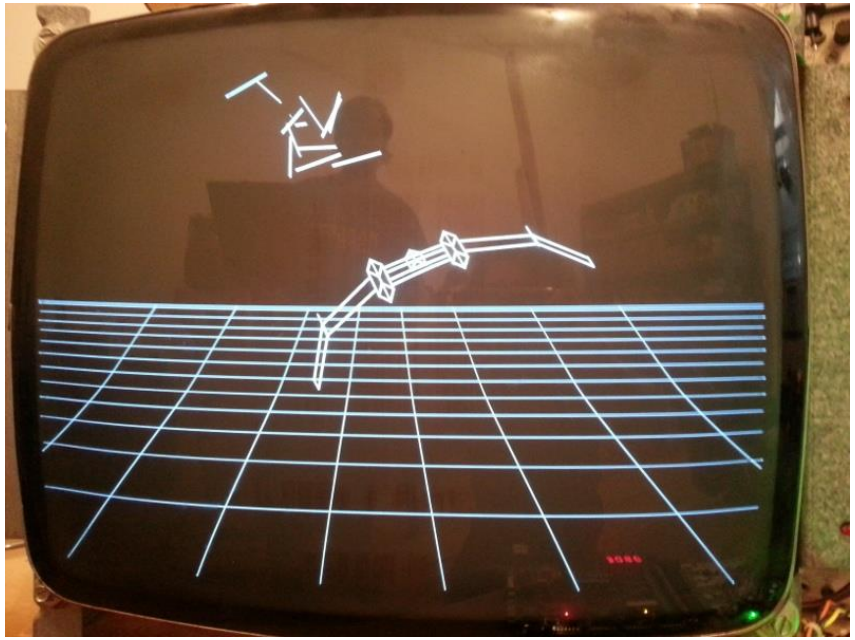
Graphics Hardware Intro

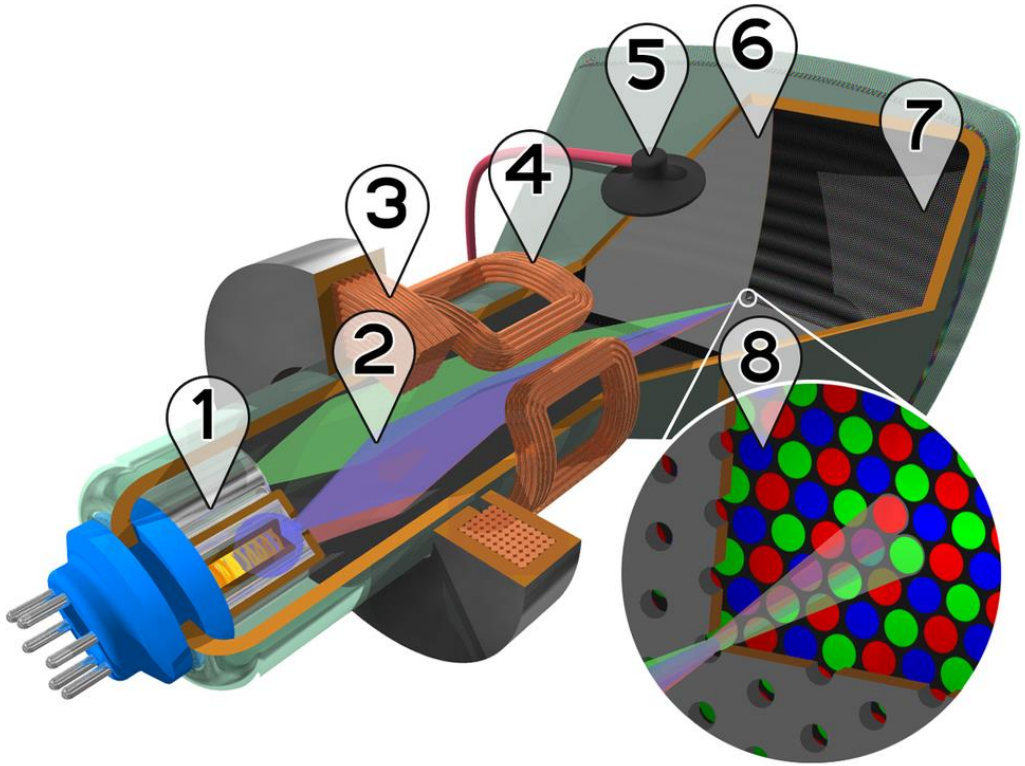
- Basic graphics hardware
  - Display devices
  - Video controller
  - Memory
  - CPU
  - System bus



Display Devices

- Older
  - CRT
  - Vector Display

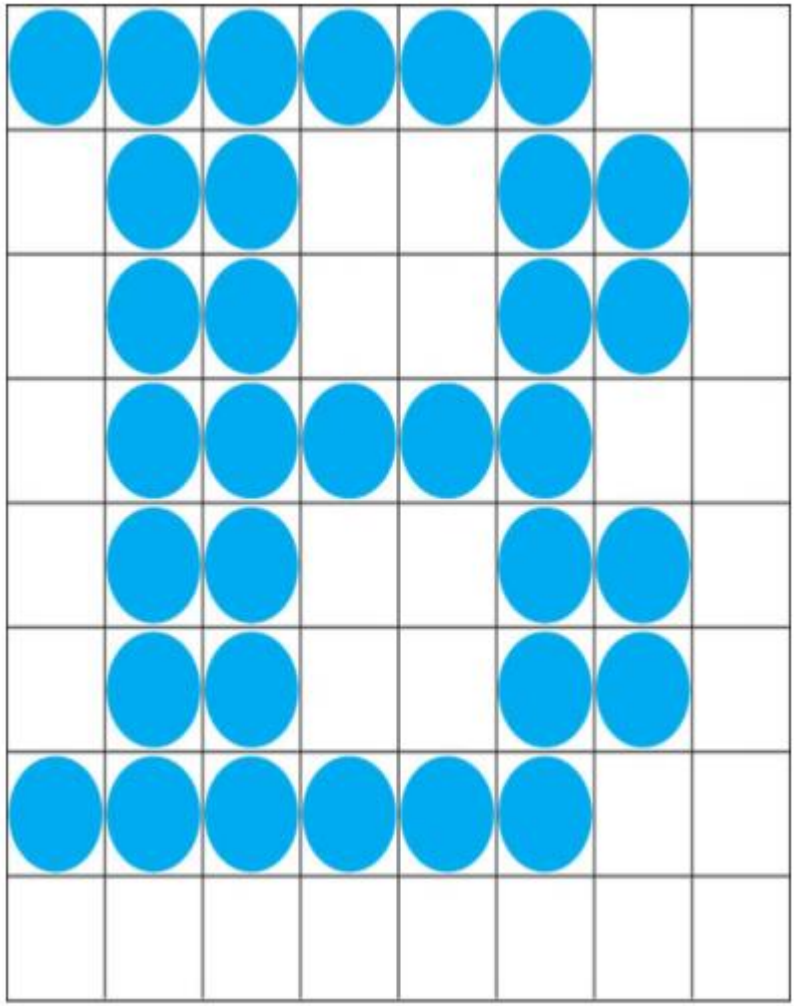




1. Three electron emitters (for red, green, and blue phosphor dots)
2. Electron beams
3. Focusing coils
4. Deflection coils
5. Anode (collector)
6. Mask for separating beams for red, green, and blue part of displayed image
7. Phosphor layer (screen)with red, green, and blue zones
8. Close-up of the phosphor-coated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

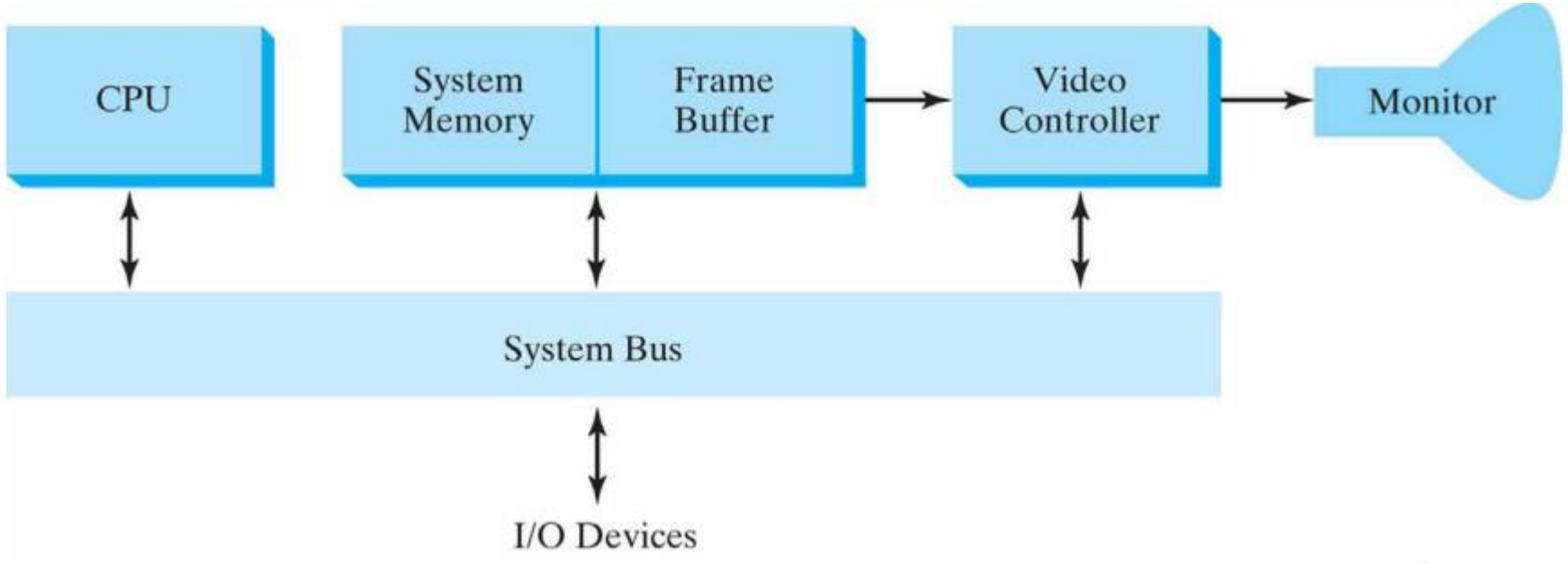
Raster Displays

- 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.

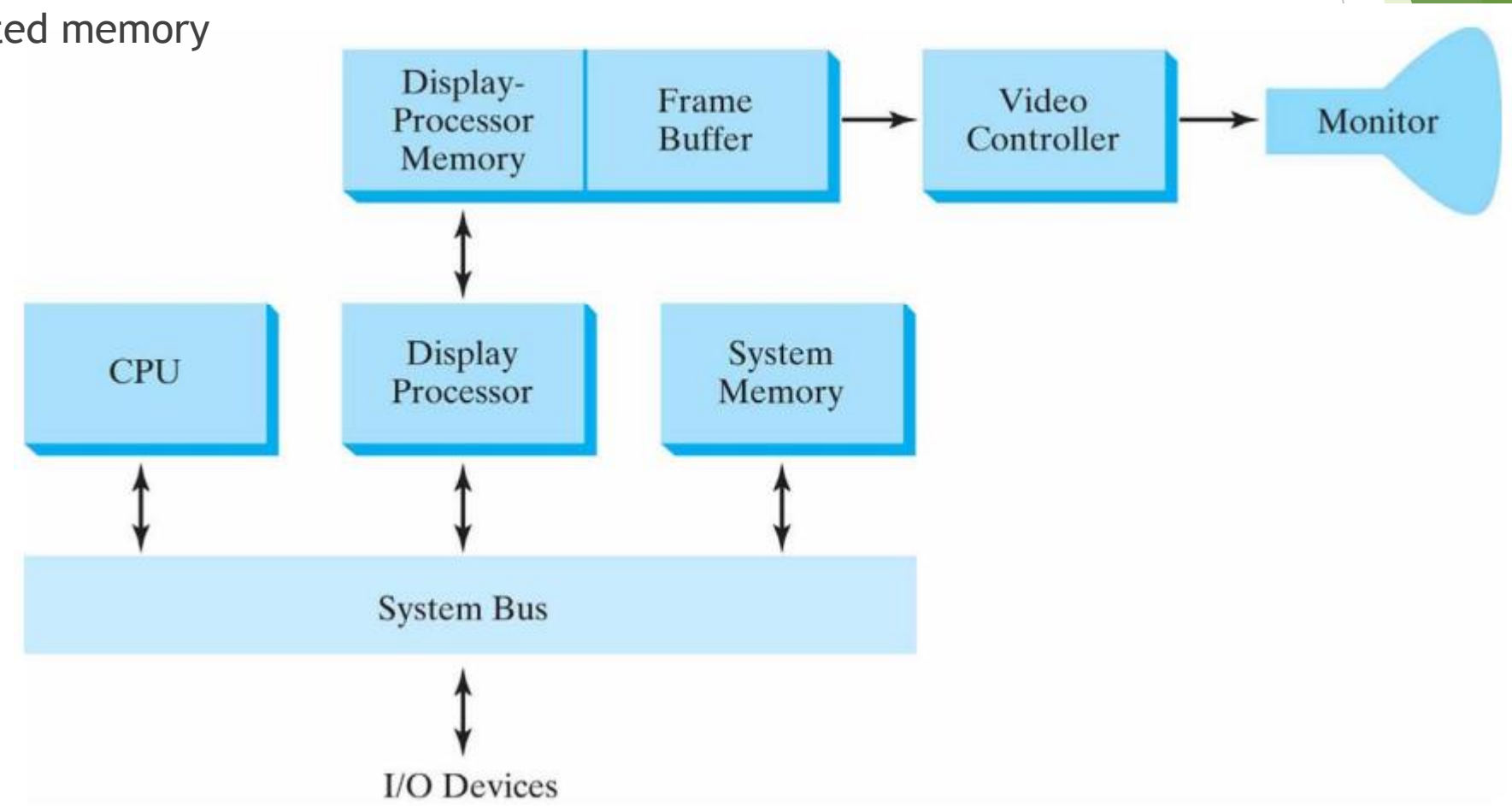


Display Processor-based Raster-Graphics Computer System.

- 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

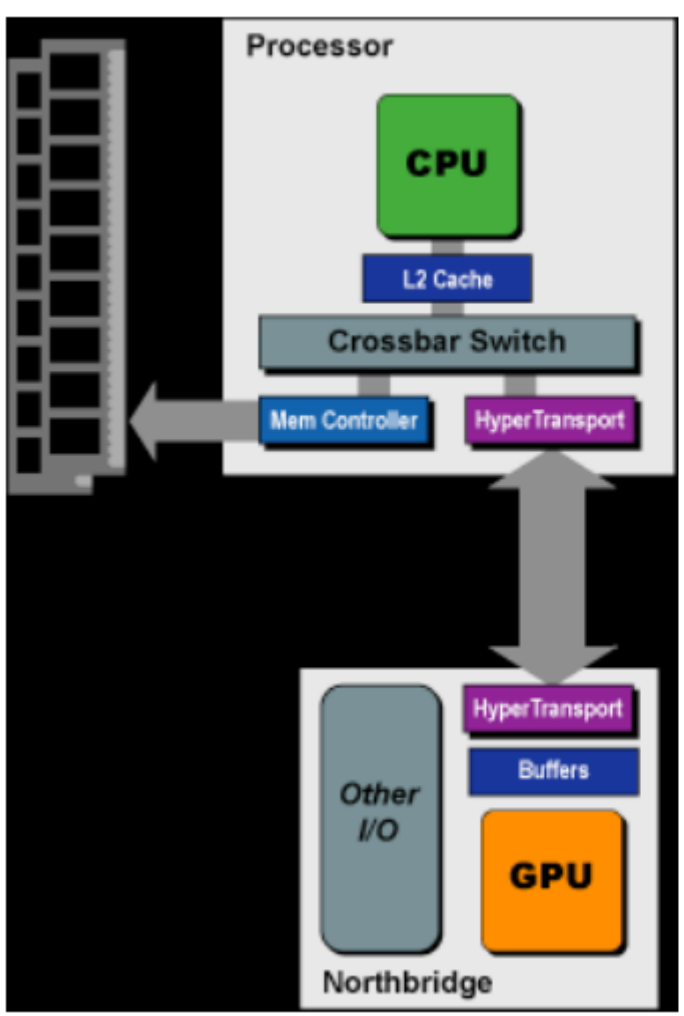
Frame Buffer

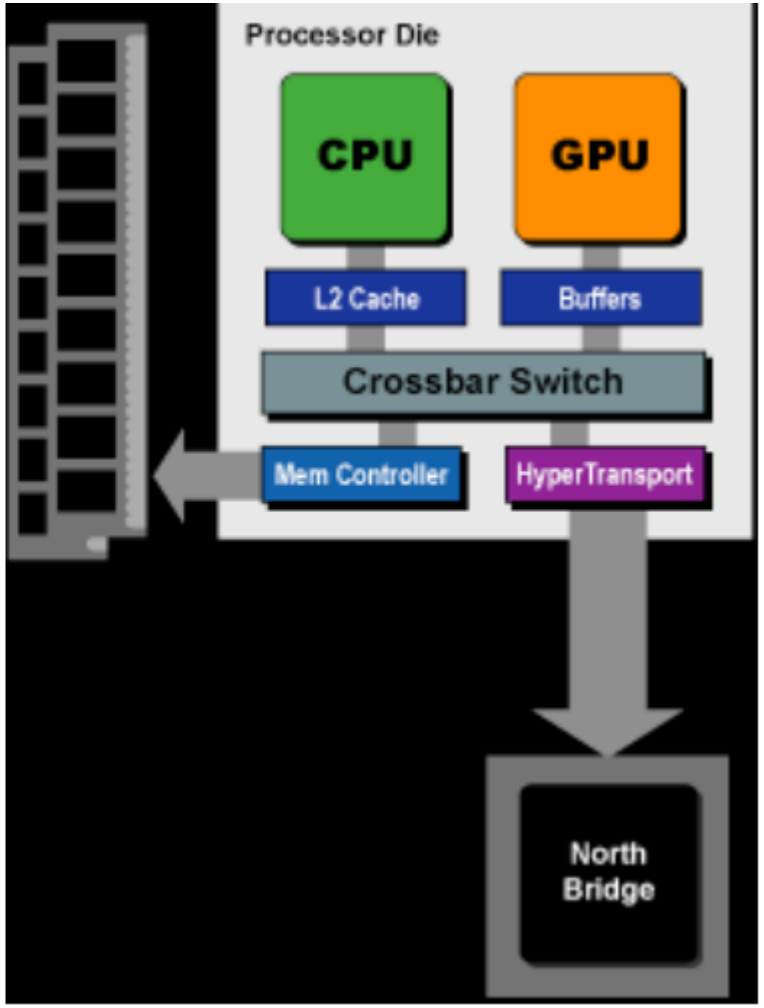
- The frame buffer is a part of RAM in a computer allocated to hold the graphics information for one frame of image.
- Frame buffer (FB) size determines the maximum resolution and color depth of the image
  - FB size = resolution × color depth,
  - E.g. 640X480X8 bit = 2,457,600 bits = 307,200 Bytes
  - E.g. 1024x768x24 bit = 18,874,368 bits = 2,359,296 Bytes
  - 4K image: 3840x2160x32 = ~33.2 MB
- 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 GPU
  - 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)

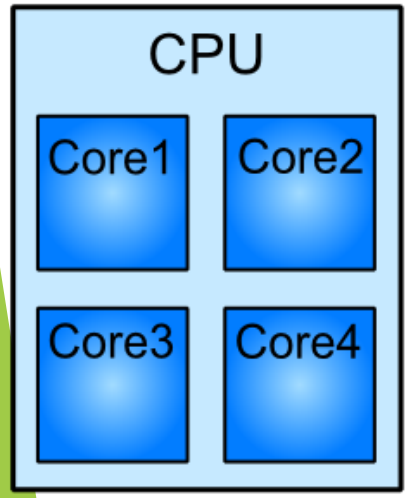


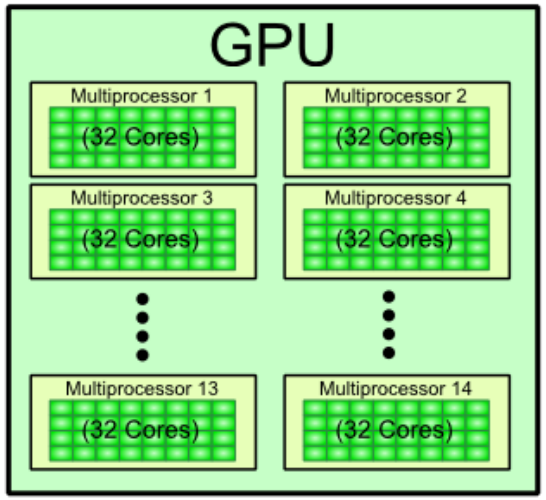


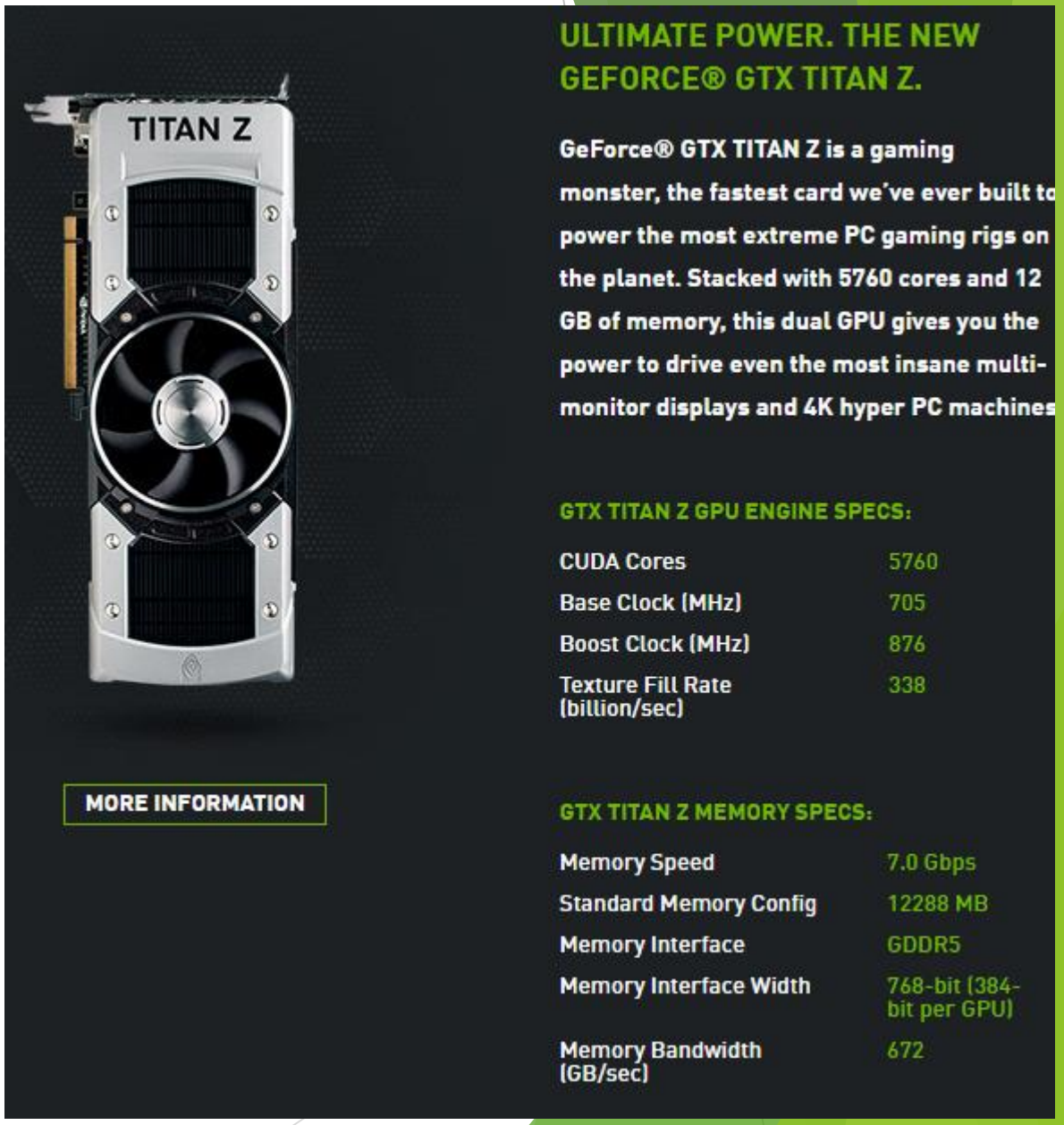
GPU vs CPU

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

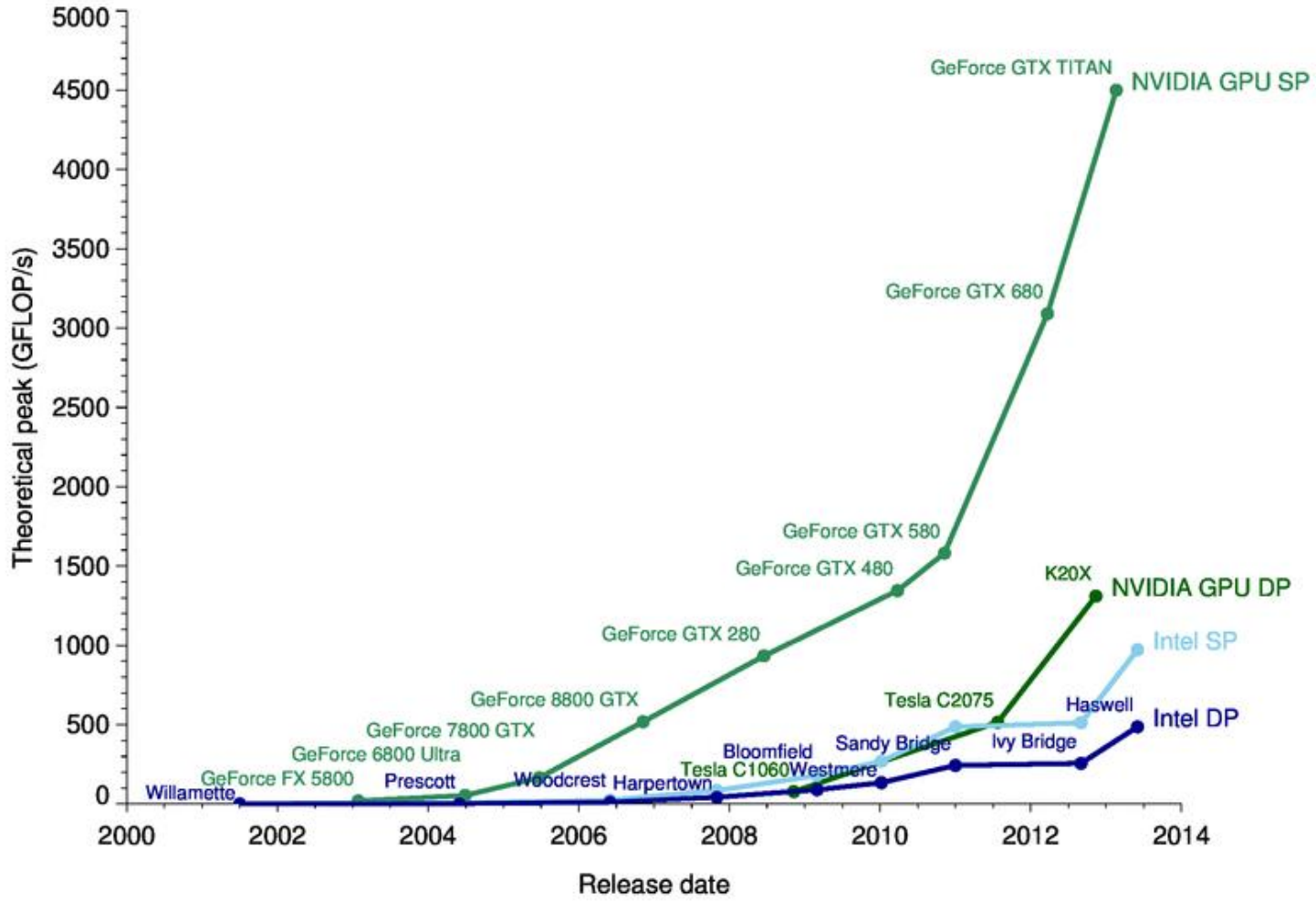
CPU/GPU Architecture Comparison



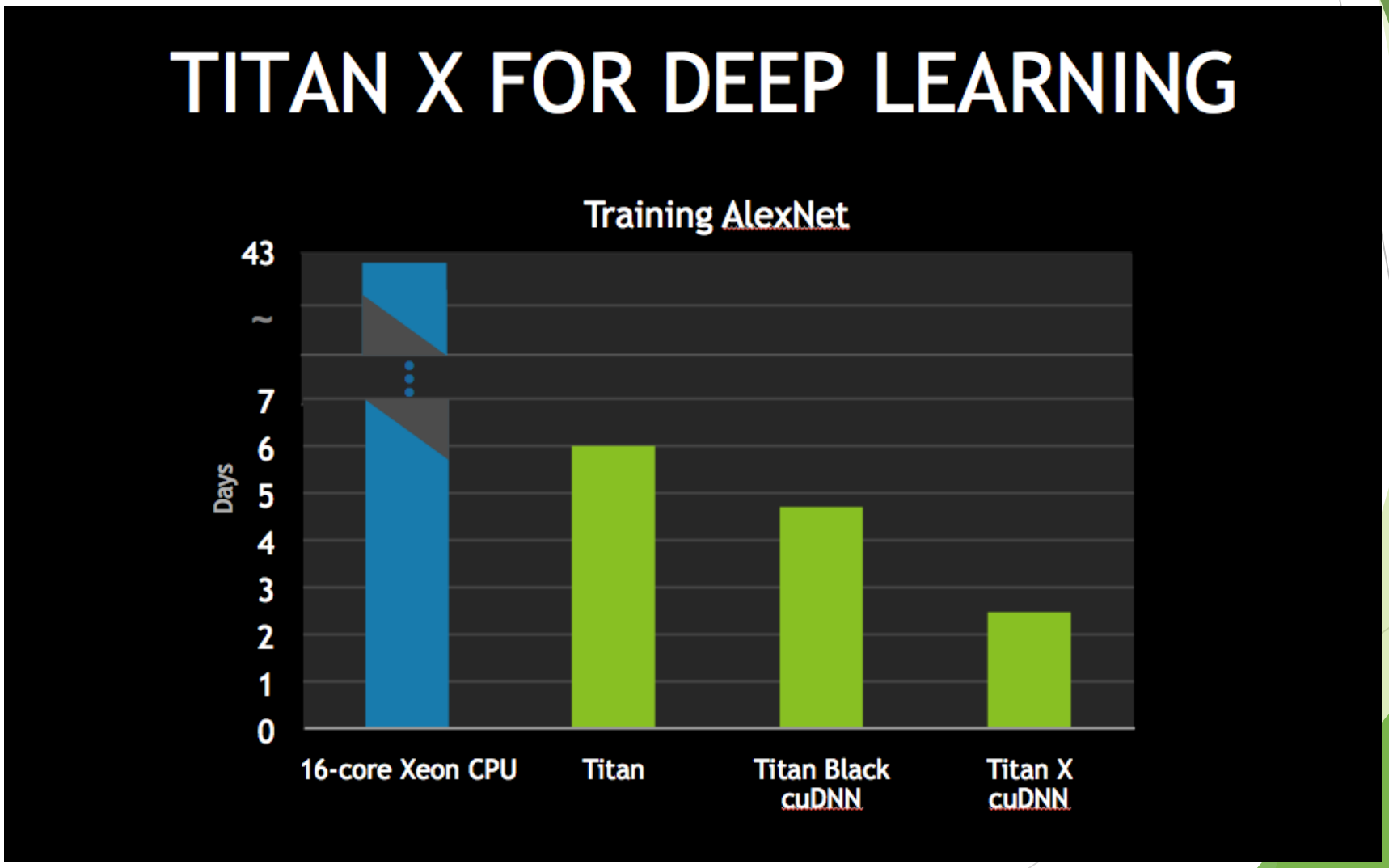




GPU vs CPU


Theoretical peak (GFLOP/s)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2000
2002
2004
2006
2008
2010
2012
2014
Release date
GeForce GTX TITAN
NVIDIA GPU SP
GeForce GTX 680
GeForce GTX 580
GeForce GTX 480
GeForce GTX 280
GeForce 8800 GTX
GeForce 7800 GTX
GeForce 6800 Ultra
GeForce FX 5800
Willamette
Prescott
Woodcrest
Harpertown
Bloomfield
Tesla C1060
Westmere
Sandy Bridge
Ivy Bridge
Haswell
Tesla C2075
K20X
NVIDIA GPU DP
Intel SP
Intel DP

GPU vs CPU


TITAN X FOR DEEP LEARNING
Training AlexNet
Days
43
~
7
6
5
4
3
2
1
0
16-core Xeon CPU
Titan
Titan Black cuDNN
Titan X cuDNN

Refresh rates and Resolution

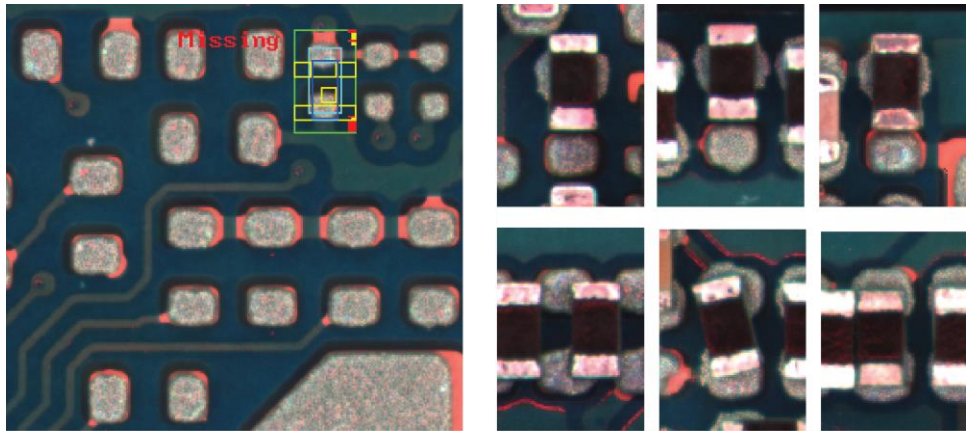
- Frequency:
  - How many frames per second
  - Typically with CRT, was 60 frames per second
  - What's the update frequency with 4K TV
    - https://www.cnet.com/uk/news/ultra-hd-4k-tv-refresh-rates/

Computer Vision

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

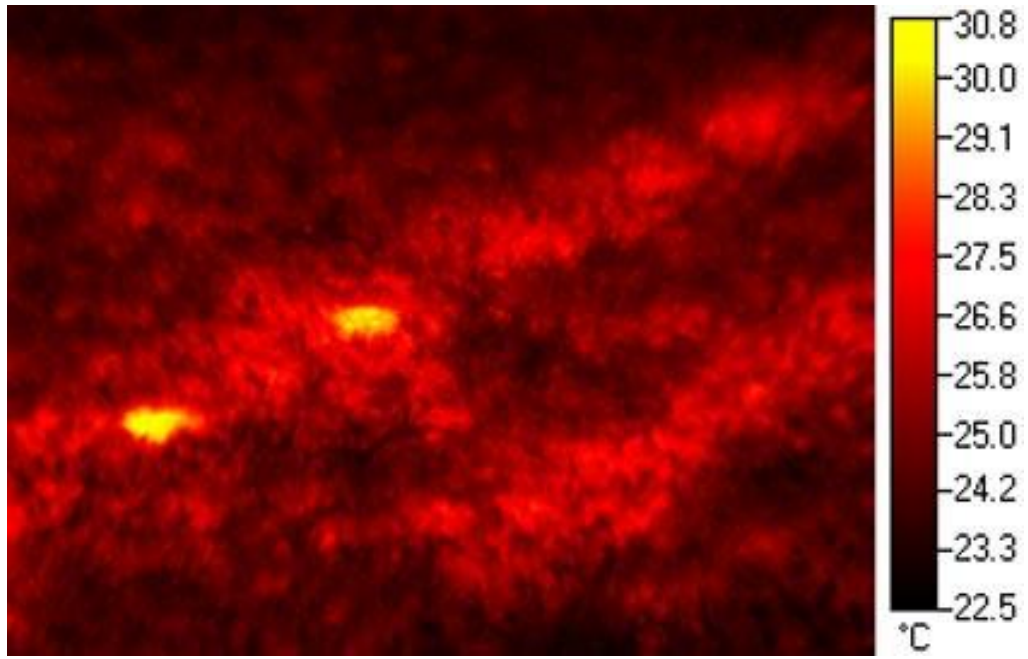


Applications – Surveillance / Forensics

- 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



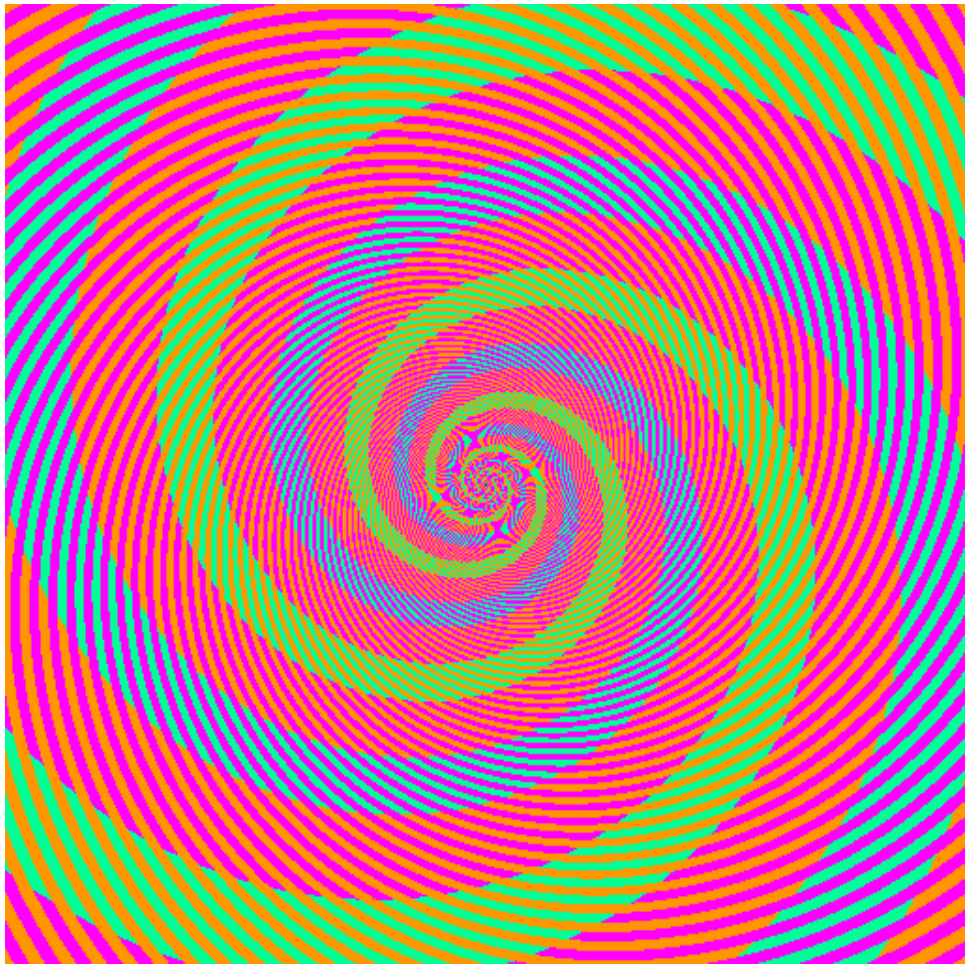
Vision is hard

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

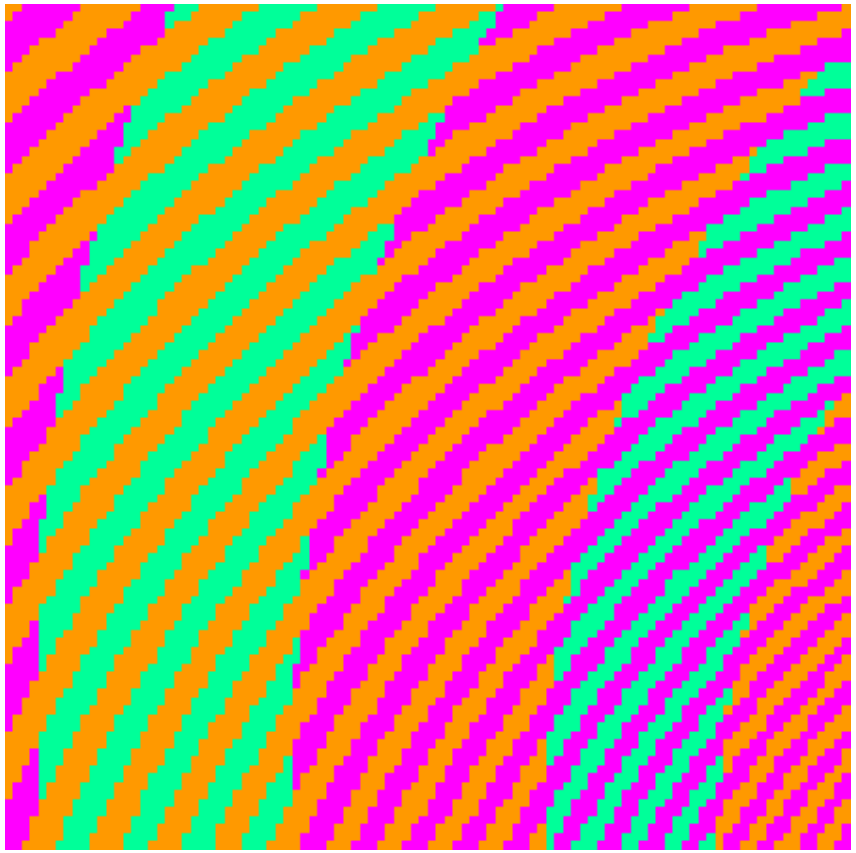
[Perception: From Sense to Object by J. Wilding]


Cuisinart
WÓDKA
VODKA
SNOW CRYSTALS
FOTOGRAFIE UND DAS UNSICHTBARE
DER KLEINE STOWASSER
LATEINISCH-DEUTSCHER SCHULWÖRTERBUCH
MATHEMATICS
MAN AND SPACE
DRUGS
STACK-ON


Cuisinart
WÓDKA
VODKA
MATHEMATICS
MAN AND SPACE
DRUGS
STACK-ON



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

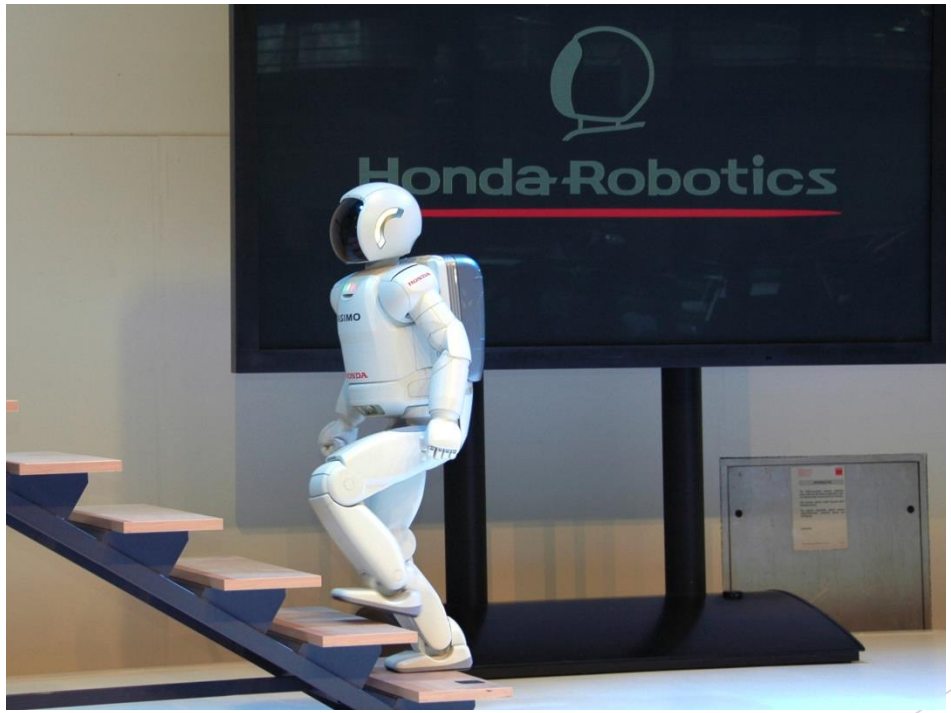
"If our long-sought quest to create autonomous anthropomorphic automata is to succeed, we must first impart perceptual abilities to machines".

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

Applications – Robot Vision

Ultimately emulating this…

So, how are we doing?



Where we are now:

- https://www.theverge.com/circuitbreaker/2017/11/17/16671328/boston-dynamics-backflip-robot-atlas
- Google image search
  - Demo – Search by image

Process of Edge Detection

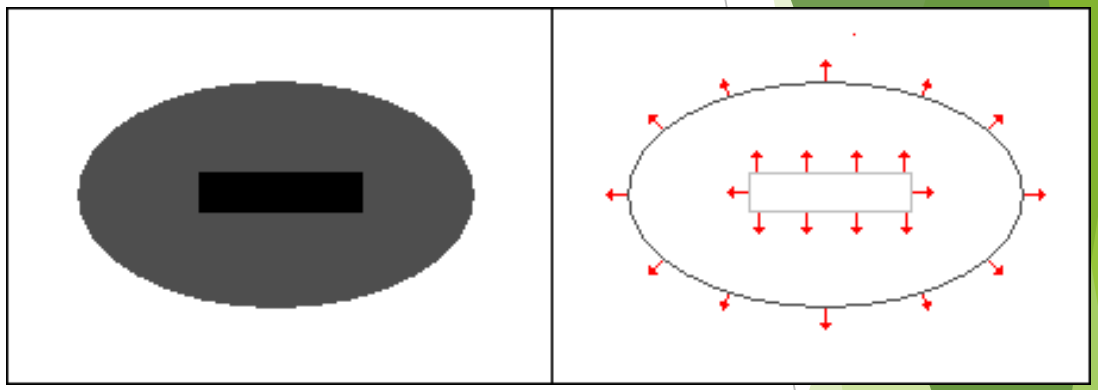
- Edge detection is the most common approach for detecting meaningful discontinuities.
  - An edge is a set of connected pixels that lie on the boundary between two regions.
  - Edge detection is commonly used for image segmentation in computer vision tasks (e.g. face recognition)
- The magnitude of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

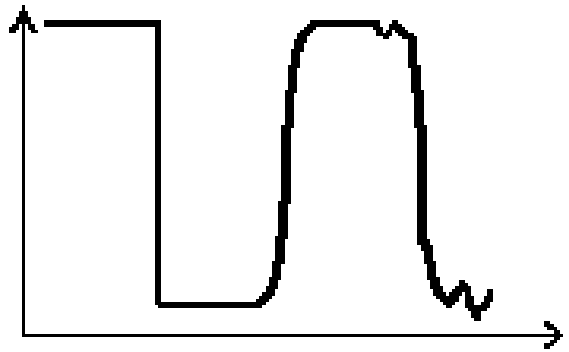
Edge Detection – Topics

- 1st derivative edge detection - Sobel
- 2nd derivative edge detection - Canny
- Overview of Multispectral edge detection
- Application: Image sharpening

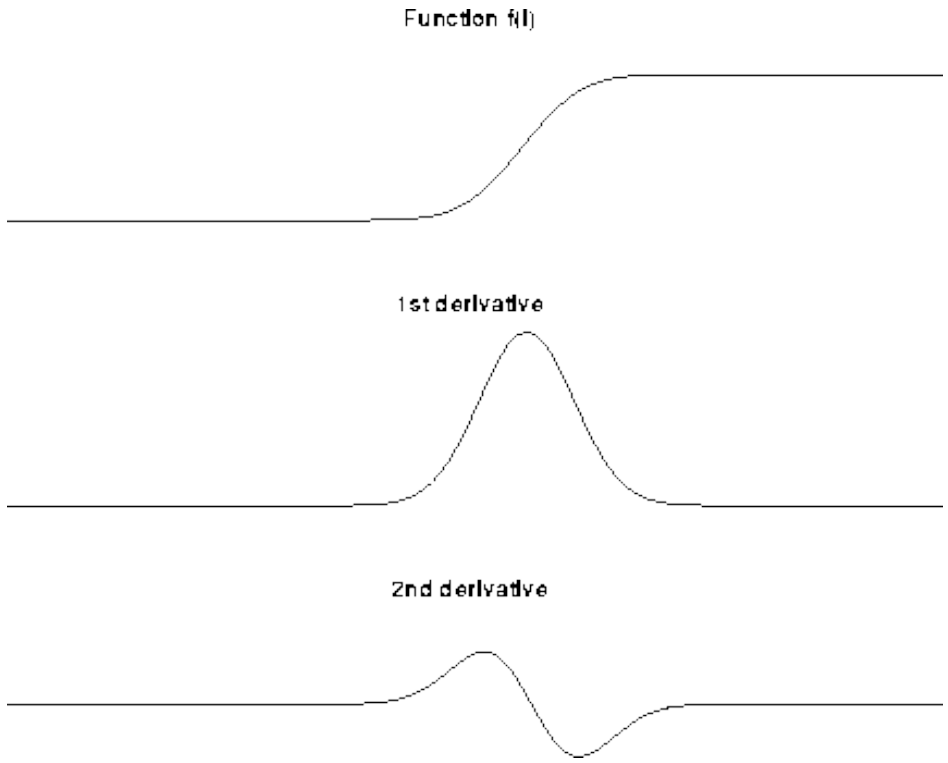
Edge Detection – What is an edge?

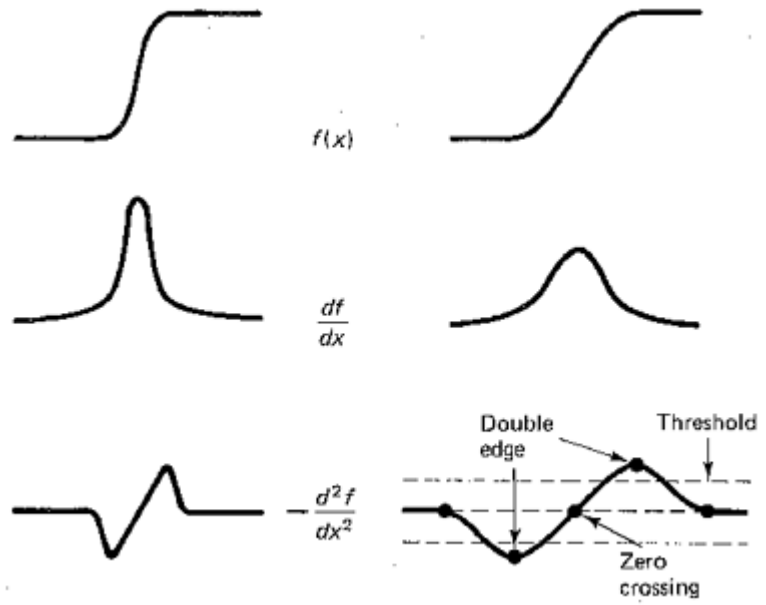
- Where brightness changes abruptly
- Edges have
  - Magnitude (Gradient)
  - Direction (Orientation)
- Edge Profiles
  - Step
  - Real
  - Noisy



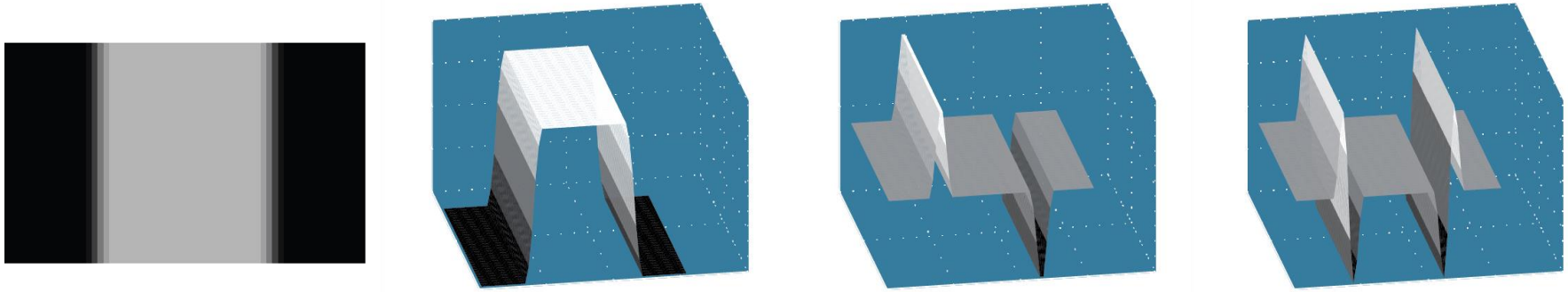


Edge Detection - derivatives

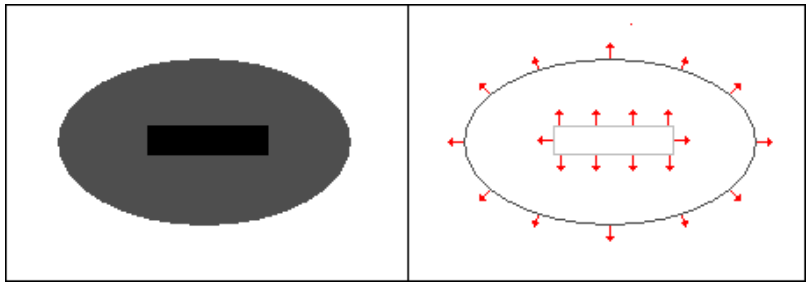




Edge Detection – 1st derivative definitions



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



Edge detection – 1st derivative – Sobel

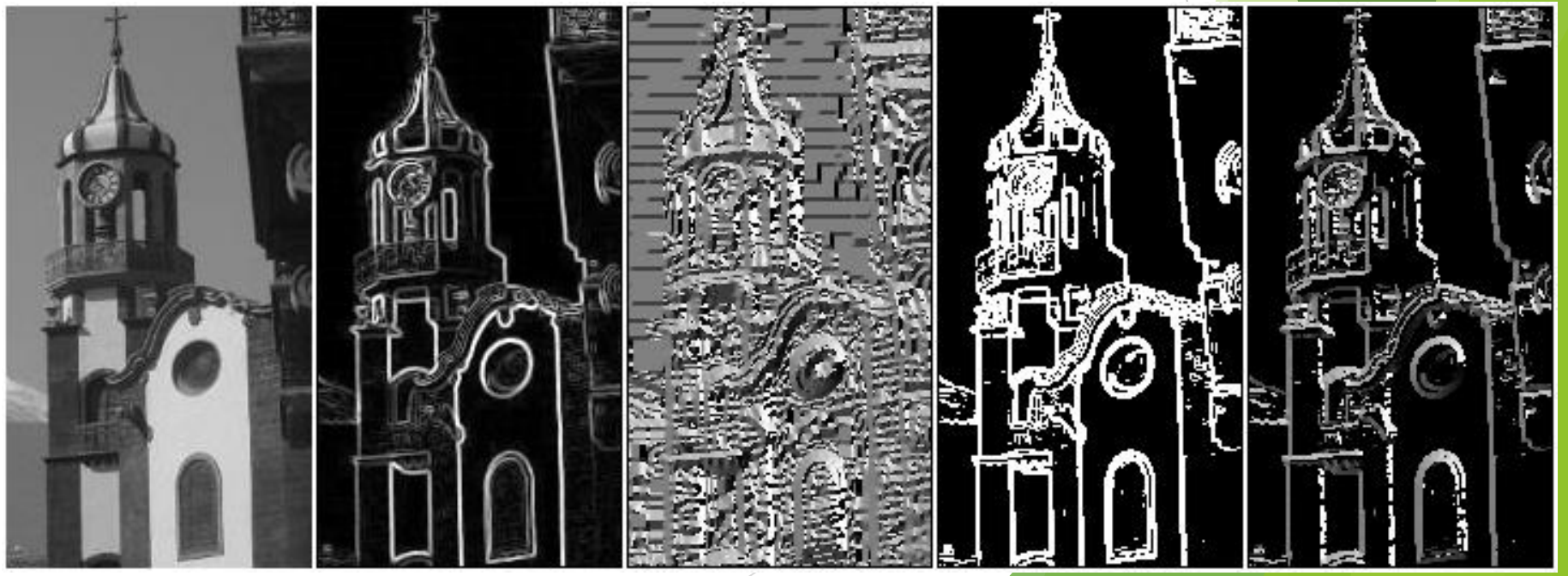
- The Sobel operator is used to find the approximate absolute gradient magnitude **at each point** in an input gray-scale image.
- **Sobel detection** uses these two below 3*3 convolution kernels to find edge in an image.

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

G_x

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

G_y

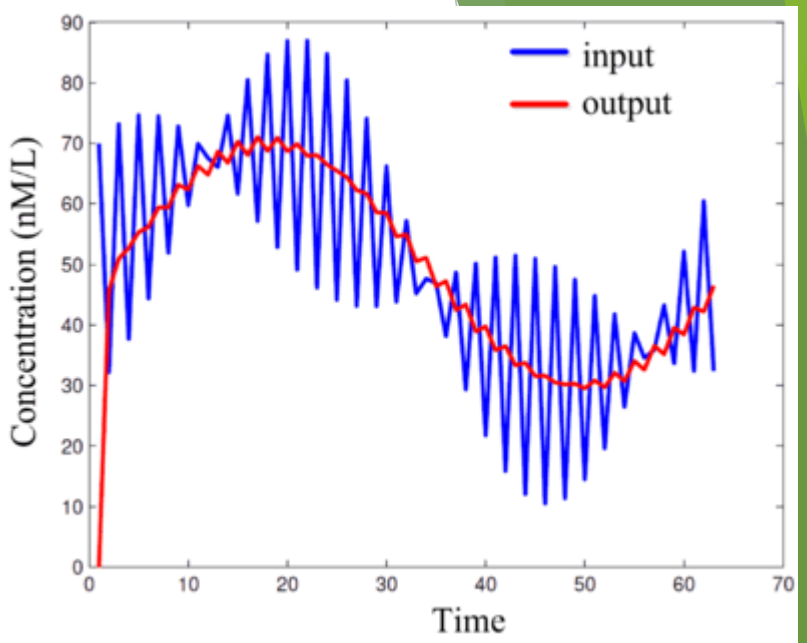


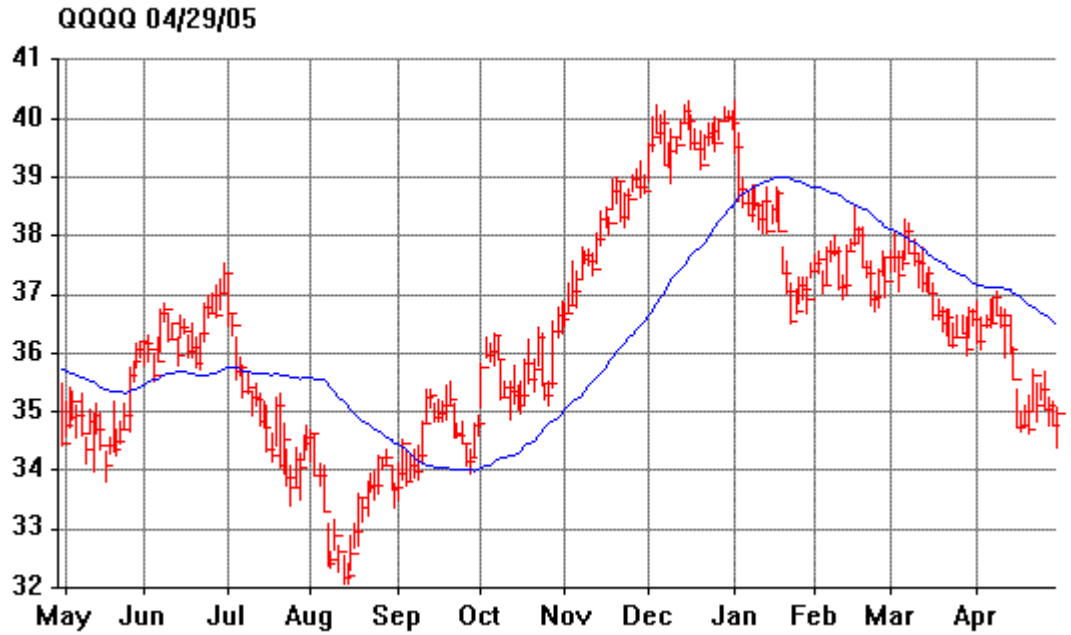
Edge detection – 2nd derivative – Canny algorithm

- 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**

Low Pass Filter

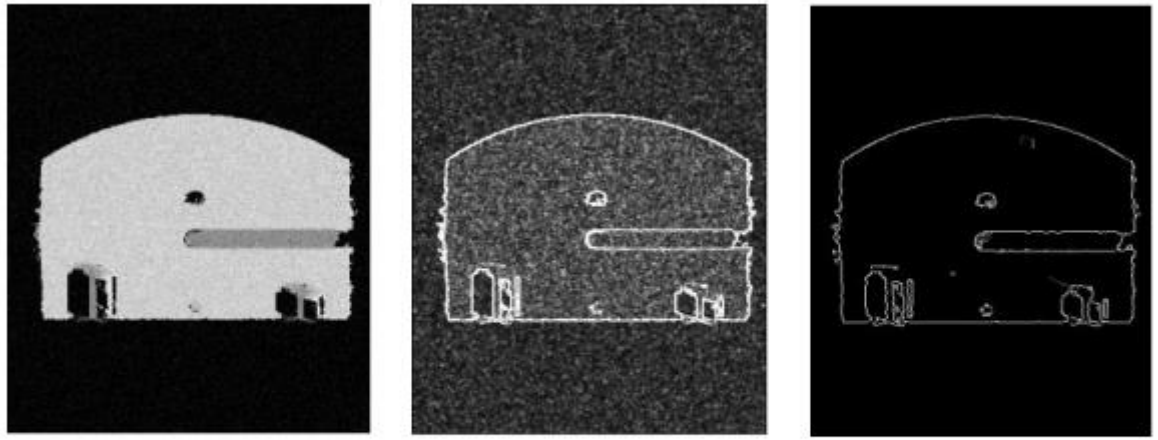
- E.g. Moving average filter
  - https://www.youtube.com/watch?v=ZoaEDbivmOE





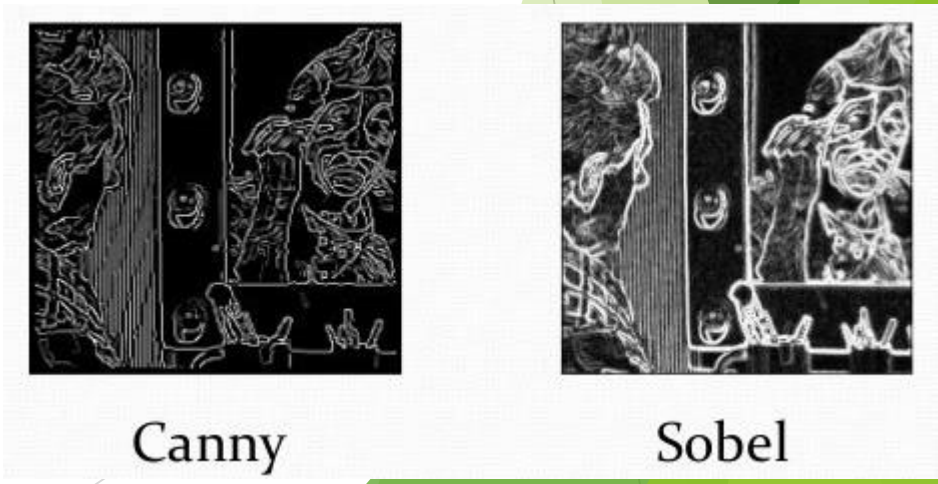
(a) (b) (c)

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



(a) (b) (c)

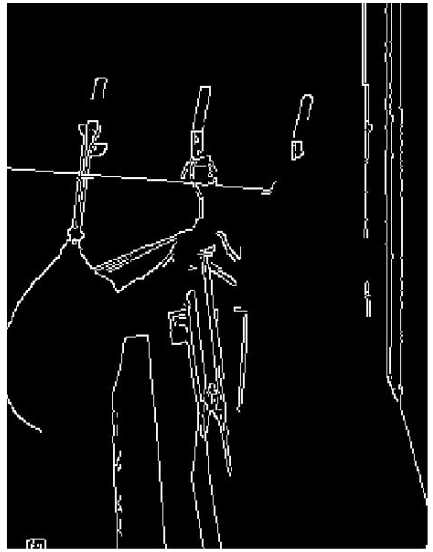
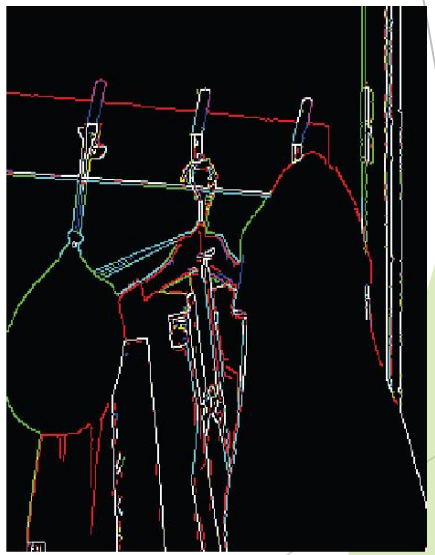
Figure 7: (a) Original image. Sobel (b). Canny (c)



Overview: Multispectral edge detection

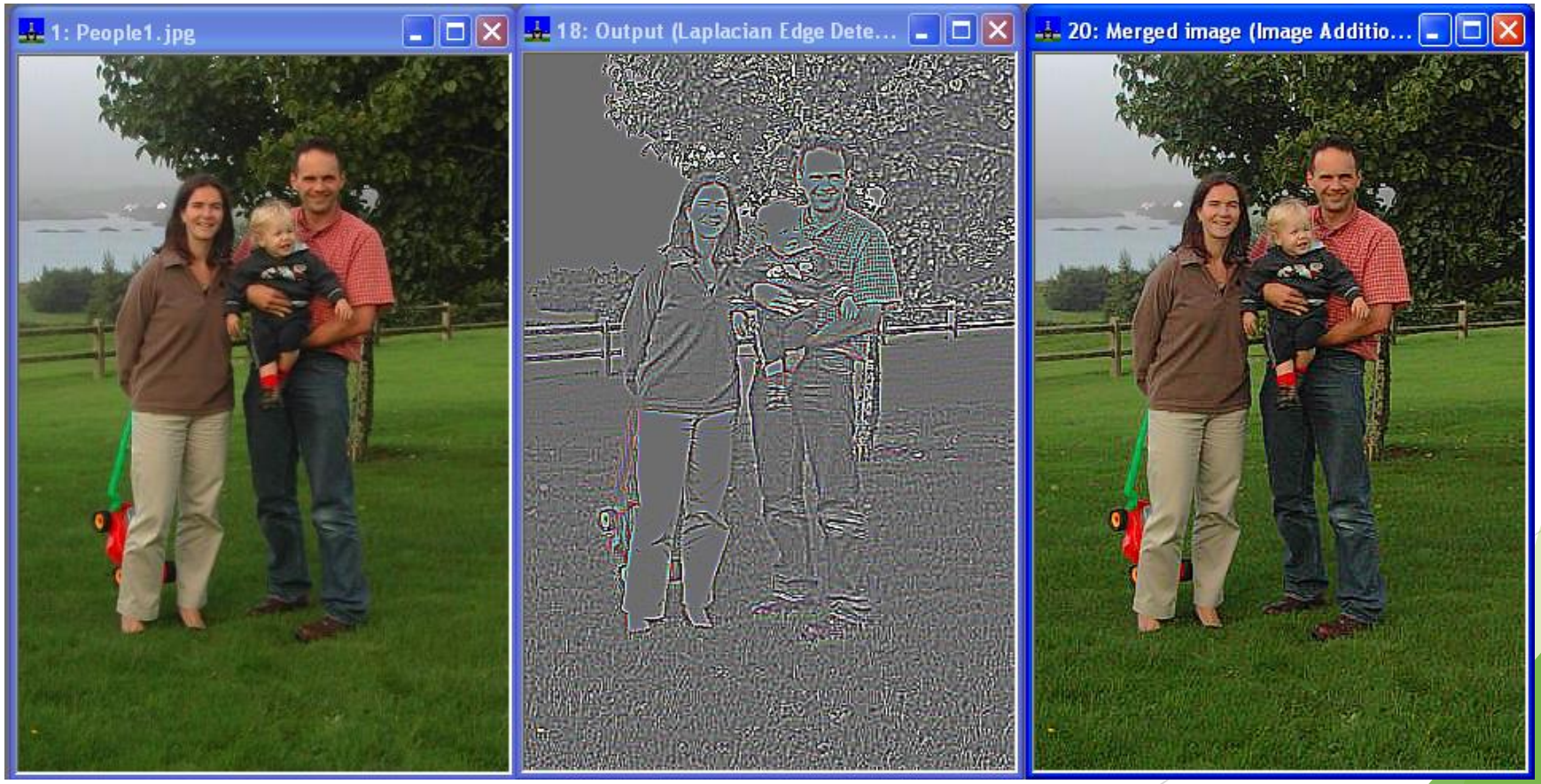
- Detect edges separately in each spectral band
  - Use maximal value OR some linear combination



Application: Image sharpening

- Making edges steeper.

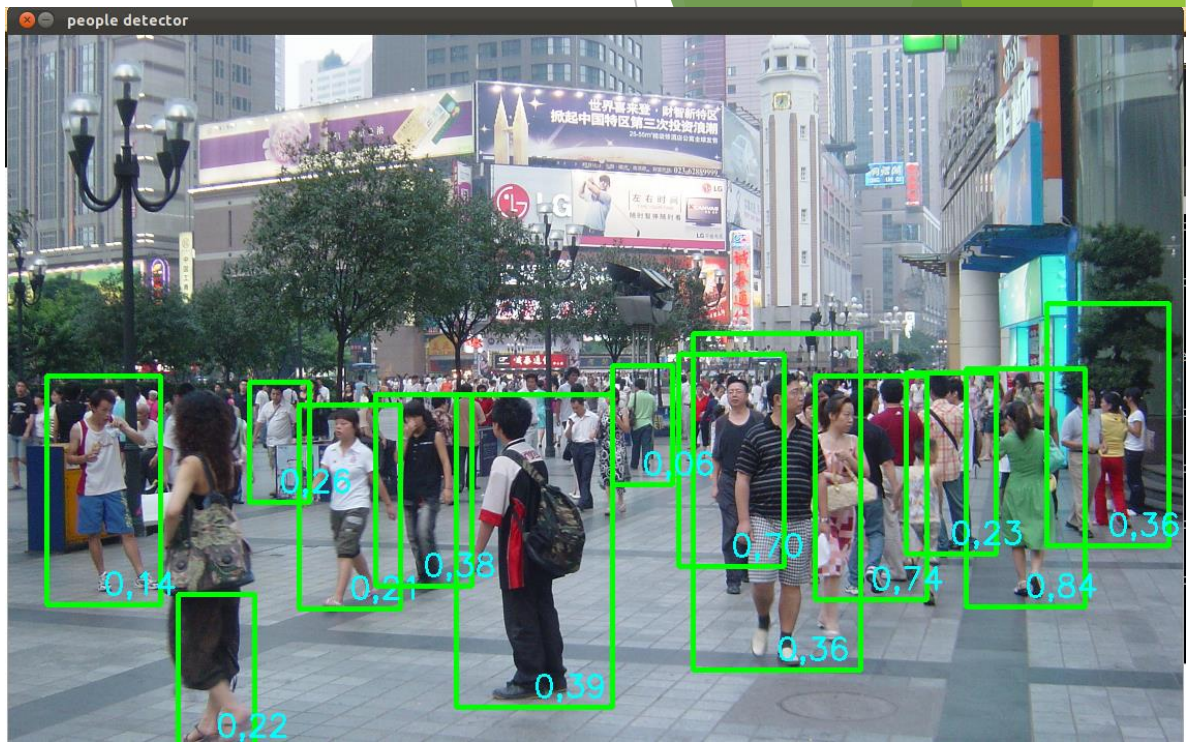


Application: Image sharpening

- 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.



OpenCV

python™

Lab this week

- Intro to OpenCV
- Edge detection with Sobel and Canny