Course Staff

Teacher :
Ofir Pele

TA:
Oded Horowits
Communications

WWW: moodel

Forums:
- Q & A – ask the staff about material.
- Exercises forums.
Course

- programming exercises in Matlab,
  It might be possible to use c++ with ceemple
- Some of the exercises will be checked also in a frontal test
Books & Resources

Book:
Richard Szeliski:
“Computer Vision Algorithms and Applications”
http://szeliski.org/Book

Additional papers are in the syllabus
What are we going to learn?
Topics

- Computer Vision: Image $\rightarrow$ Model
- Image Processing: Image $\rightarrow$ Image
- Computational Photography: Image $\rightarrow$ Image
Different techniques from Image Processing,
Can use Computer Vision as an ingredient.
Can use modify the camera.
Isn’t it easy?
THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".
THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".
THE SUMMER VISION PROJECT
Computer vision seems easy, but it is not

- We see “effortlessly”:
  - “Seeing” seems simpler than thinking.
  - Everyone (including toddlers) can “see” but only few can perform really “hard” stuff like playing Chess or solving a mathematical problem.
- We use 50%-70% of our brain in order to “see”!
- We presume that our “seeing” reflects the physical world, but it is not always the case.
Examples
Photo Tourism overview

Input photographs → Scene reconstruction → Photo Explorer
Photo Tourism overview

Photo Tourism
Exploring photo collections in 3D

Noah Snavely  Steven M. Seitz  Richard Szeliski
University of Washington  Microsoft Research

SIGGRAPH 2006
Optical character recognition (OCR)

Technology to convert scanned docs to text

Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition
Face detection

Many new digital cameras now detect faces
Smile detection?

Sony Cyber-shot® T70 Digital Still Camera
Face recognition

Who is she?
Vision-based biometrics

“How the Afghan Girl was Identified by Her Iris Patterns”  Read the story
Special effects: motion capture

*Pirates of the Caribbean*, Industrial Light and Magic

[Click here for interactive demo](#)
Special effects: motion capture

*Pirates of the Caribbean*, Industrial Light and Magic

[Click here for interactive demo](#)
Smart cars

Mobileye

- Vision systems currently in high-end BMW, GM, Volvo models
Smart cars

Mobileye Vision systems currently in high-end BMW, GM, Volvo models
OrCam – Helping the Visually impaired
Vision in space

NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read “Computer Vision on Mars” by Matthies et al.
Robotics

NASA's Mars Spirit Rover

http://www.robocup.org/
Medical imaging

3D imaging
MRI, CT

Image guided surgery
Grimson et al., MIT
BriefCam
High Dynamic Range
High Dynamic Range
Human Vision
Visible light

We “see” electromagnetic radiation in a range of wavelengths
Bees and humming birds see differently
Bees and humming birds see differently
Mantis Shrimp: Extraordinary Eyes
Mantis Shrimp: Extraordinary Eyes

Spectral Sensitivity

Wavelength (nm)

UV
IR

1

300
400
500
600
700

300
400
500
600
700

1

Wavelength (nm)
The Human Eye

(A) Iris – changes the amount of light entering the eye

(B) Lens – can change shape to focus

(C) Retina – where an image is formed
The Human Eye – Color Perception

Light hits the retina which contains photosensitive cells:
- Rods (~ 120M)
- Cones (~7M)
Density of rods and cones

Rods and cones are *non-uniformly* distributed on the retina

- Rods responsible for intensity, cones responsible for color
- **Fovea** - Small region (1 or 2°) at the center of the visual field containing the highest density of cones (and no rods).
- Less visual acuity in the periphery—many rods wired to the same neuron
Color filter array In a Camera

Bayer grid

Estimate missing components from neighboring values (demosaicing)

Source: Steve Seitz
Color filter array In a Camera

Bayer grid

Estimate missing components from neighboring values (demosaicing)

Why more green?
Color filter array In a Camera

Bayer grid

Estimate missing components from neighboring values (demosaicing)

Why more green?
Optical Illusions
Measuring light vs. measuring scene properties

Edward H. Adelson
Measuring light vs. measuring scene properties
Assumptions can be wrong
Camera - Image Formation
Let’s design a camera –
Idea 1: Put film in front of an object
Let’s design a camera –
Idea 2: “pinhole camera”
If we treat pinhole as a point, only one ray from any given point can enter the camera.
Effect of pinhole size - aperture

(A) Source

(B) Source

Reduced pinhole
Pinhole sizes –

Too big  OK  Too small = Diffraction
Lens – gather more light
Lens – gather more light

sensor  lens

Point in focus
SLR Lens – contains several “lens elements”
Focal length: pinhole optics

\[ f \quad d \]

s

Film/ sensor
pinhole

scene
Lenses

24mm

50mm

135mm
Focal length: pinhole optics

What happens when the focal length is doubled?

- Projected object size
- Amount of light gathered
Focal length: pinhole optics

What happens when the focal length is doubled?

- Projected object size - Bigger
- Amount of light gathered - Smaller
Focal length: pinhole optics

What happens when the scene is twice as far?

Is **getting closer** and **zooming in** equivalent?
Perspective vs. viewpoint

Focal lens does NOT ONLY change subject size
Same size by moving the viewpoint
Different perspective (e.g. background)
Perspective vs. viewpoint

Telephoto makes it easier to select background (a small change in viewpoint is a big change in background.)
Perspective vs. viewpoint

Martin Scorcese, Good Fellas
Moves camera as you zoom in
Better known as the Hitchcock Vertigo effect
Perspective vs. viewpoint

Portrai: distortion with wide angle
Why?

Wide angle  Standard  Telephoto
Sensor / film size

What happens when the film is half the size?
Sensor / film size

Crop Factor

Medium format (Kodak KAF 39000 sensor)

35 mm "full frame"

APS-H (Canon)

APS-C (Nikon DX, Pentax, Sony)

APS-C (Canon)

Foveon (Sigma)

Four Thirds System

CX (Nikon)

2/3"

1/1.7"

1/2.3"
Shutter – sets the time the sensor “sees”

- Most of the time, the film/sensor is protected from light.
- When we take a picture, the shutter opens and closes, thereby exposing the film.
- Exposure is proportional to the time the shutter is open.
- Expressed in fraction of a second (1/60s, 1/125s, 1/250s, 1/500s, etc.).

Two types of shutter
The two-blind system (right) is most common
Shutter distortion
Effect of shutter speed

Longer shutter speed ➔
more light & motion blur

Faster shutter speed ➔
freezes motion
Effect of shutter speed

Longer shutter speed ➔ more light & motion blur

Faster shutter speed ➔ freezes motion
Freezing motion – how fast should the shutter be?

Walking people: 1/125
Running people: 1/250
Car: 1/500
Fast train: 1/1000
Shutter speed and focal length

Because telephoto “magnifies” ➔
It also magnifies your hand shaking ➔
Telephotos therefore require faster shutter speed

Rule of thumb:
- The slowest shutter speed where normal human can hand-
hold and get a sharp picture is 1/f
  E.g., a 500mm requires 1/500 s or higher.
Solutions for shaky hands blur

- **Image stabilization:**
  mechanically compensates for vibration
  Can gain 2 or 3 shutter speeds
  (1/125 or 1/60 for a 500mm)

- **Put the camera on something solid**
  (table, floor, tripod, …)
Aperture

Diameter of the lens opening (controlled by diaphragm) Expressed as a fraction of focal length, in f-number
- f/2.0 on a 50mm means that the aperture is 25mm
- f/2.0 on a 100mm means that the aperture is 50mm

Small f number = big aperture

What happens to the area of the aperture when going from f/2.0 to f/4.0?

Full aperture  Medium aperture  Stopped down
### Aperture

Diameter of the lens opening (controlled by diaphragm)
Expressed as a fraction of focal length, in f-number
- f/2.0 on a 50mm means that the aperture is 25mm
- f/2.0 on a 100mm means that the aperture is 50mm

Small f number = big aperture

What happens to the area of the aperture when going from f/2.0 to f/4.0?

\[
\text{Area} = \pi \left( \frac{\text{focal length}}{2(f \text{ number})} \right)^2
\]
Aperture – real lens
Sensitivity to light

- Sensor’s ISO sensitivity to light ➔
  Higher = more sensitive, also more noise

- Double the ISO ➔
  camera needs half as much light for the same exposure
Sensitivity to light

- Higher ISO and same light with shutter speed / aperture
  ➔ More noise (there might be movement blur or out-of-focus-bur on the other hand)
Sensitivity to light

Higher ISO, same aperture and shutter speed. different cameras, different amount of noise – why?
Sensitivity to light

Higher ISO, same aperture and shutter speed. different cameras, different amount of noise – why? Mostly because of sensor size.
Depth of Field
Depth of Field

Changing the aperture of a camera also changes the amount of the image that is in focus – this amount is called the depth of field.
DoF depends on aperture
DoF depends on aperture
DoF depends on focusing distance
DoF depends on focal length
Only light at the focus depth is exactly in focus, the rest has varying circles of confusion.
Only light at the focus depth is exactly in focus, the rest has varying circles of confusion.
Depth of Field – shallow and deep

Large aperture = small f numbers ➞ Shallow depths of field
Small aperture = Large f number ➞ Deep depths of field
Depth of Field – can be changed by focal length

NORMAL FOCAL LENGTH In this sequence, focus distance and aperture are fixed at 5m and f/5.6. Here a 70mm lens is used to widen depth of field.

SHORT TELEPHOTO LENS Switching to 135mm lens has visibly reduced the depth of field, causing significantly more blurring of the houses behind the statue.

TELEPHOTO LENS Switching to a 300mm lens has dramatically reduced depth of field to the point where the buildings are reduced to soft, abstract shapes.
Depth of Field – can be changed by focus

**FOREGROUND FOCUS** In this sequence the lens is fixed (105mm, F4.5) and the focus distance altered. Here, focused on the nearest house, depth of field is minimised.

**MIDDLE DISTANCE FOCUS** With the lens focused on the middle house, depth of field now extends about five times further than it did in example one.

**BACKGROUND FOCUS** Focused on the farthest house, depth of field is increased again and now extends almost as far back to the lens as it did in example two.
Creative Use of DOF

Separate your subject from the background

Give a feeling of space or distance to a scene

Highlight a area of the image
Creative Use of DOF
Perspective effects
Perspective effects
Perspective effects

Far away objects appear smaller
Perspective effects
Perspective effects

Parallel lines in the scene intersect in the image
Converge in image on horizon line
Perspective effects
Perspective effects
Perspective effects
Perspective effects
Beyond Pinholes: Radial Distortion

No Distortion  
Barrel Distortion

Corrected Barrel Distortion

Pincushion Distortion