Welcome!

COMP 546/598  Computational Perception

Prof:  Michael Langer

See public web page for this course:

Who are you?

(32 students registered)

12 BSc/BArts U3

19 MSc/MEng

1 PhD
Who am I?

- BSc at McGill in early 1980s (Math Major, CompSci Minor) (interest in AI, undergrad summer research in visual neuroscience lab)

- MSc in Computer Science at U of Toronto in late 1980s (thesis: "On the efficient representation of natural images")

- PhD at McGill in early 1990s (thesis: "Shading computations on the radiation manifold")

- postdoc at NEC Research Inst. in NJ, USA in mid-1990s (3 years) - computer vision

- postdoc at Max Planck Inst. in Germany in late 1990s (2 years) - human vision

- professor here since 2000

- I have taught COMP 546 (formerly 646) many times
My Research Interests

- Computational Models of Human Vision

- Applications of Perception in Computer Graphics
  (no course on this)

- Computer Vision
  (COMP 558 not taught this year)
computational models of human vision

human vision

computer vision

applications of perception in computer graphics

computer graphics
How does visual perception work? (concepts of the layman)

- optics (glasses)
- color (color blindness)
- binocular depth perception
- perspective (art class)
- ....
Perception is...

... knowing \textit{what} is \textit{where}

(by seeing, hearing, touching, smelling ....)

... is a process

(and can be modelled as a computation)
<table>
<thead>
<tr>
<th>Physical Stimulus</th>
<th>Sensory Organ</th>
<th>Perceptual System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optics</td>
<td>Eye</td>
<td>Vision (seeing)</td>
</tr>
<tr>
<td>Acoustics</td>
<td>Ear</td>
<td>Audition (hearing)</td>
</tr>
<tr>
<td>Mechanics</td>
<td>Skin</td>
<td>Haptics (touching)</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Mouth, nose</td>
<td>Olfaction (taste, smell)</td>
</tr>
</tbody>
</table>

+ Kinesthesia, balance, pain, ....
Perception is a process.

physical stimulus $\rightarrow$ sensory organ $\rightarrow$ perceptual system (brain)

states of external physical world $\rightarrow$ measurement $\rightarrow$ computation

model of world (perceived)
Visual Perception

physical objects
- shape
- position
- material

perceived objects
- shape
- position
- material
Auditory Perception

- vibrations of physical material
- sound waves
- resonator

sounds
- perceived location
- type e.g. voice, steps, air vent
Scientific Approaches to Perception

Neuroscience: Physiology, Anatomy, Biology
- neurons, nervous system, brain

Behavioral Psychology
- experiments that measure performance (detection and discrimination, recognition, memory, attention)

Computational Neuroscience
- information processing models
Levels of Analysis in computer science

- problem specification
- algorithms
- programs in a high level language
- machine and assembly language
- gates, circuits
- transistors
Levels of Analysis in Perception

- computational model
- behavior / performance
- cortical areas and pathways
- neuron receptive fields
- cell membrane, synapses, spikes
Marr's 3 levels

Computational theory

What computational problem is the nervous system solving?
What is the mapping from input to output?

Representation and algorithm

What is the representation of the inputs and outputs?
How are the inputs transformed?

Hardware implementation

How can the representation and algorithm be realized physically?
Example (Marr): arithmetic

Computational level:
- given two numbers, compute their sum, difference, product

Representation and algorithm:
- base 10 or base 2, grade school method of summing and carrying from least significant to most significant digit
- Roman numerals, "XIV" is the number fourteen. Algorithms exist for arithmetic (but we don't teach them)

Hardware:
- our brains can implement the grade school algorithms
- computers can too
Example: perception

Computational level:

- edge detection
- left / right matching (eyes or ears)
- remembering and recognizing patterns in images (learning)

Representation and algorithm:

- how are input images transformed by the brain?
- what features are extracted and matched (or learned)?

Hardware:

- where and how does this happen in the brain?
Overview of course topics (~22 lectures)

visual image formation (3)
  linear algebra, optics

linear systems (5)
  linear algebra (complex numbers !!) ---> very difficult for some students

measuring and modelling performance (3)
  probability, behavioral psychology

visual system (6)
  computational neuroscience

auditory image formation (2)
  acoustics

auditory system (3)
  computational neuroscience
Why take this course?

- You find the topics interesting

- Applications
  
  - 3D stereo (CG, cinema, TV, games)
  - virtual reality e.g. Oculus Rift
  - augmented reality Google glass, Hololens, aids for visually impaired
    http://esighteyewear.com/
  
  - visualization e.g. infoviz, sciviz

Note: 3D audio is incorporated into many devices
Prerequisites for this course

- COMP 250 (or equivalent)
  we will use MATLAB for assignments

- multivariable calculus (MATH 222)

- linear algebra (MATH 223)

- probability
## Evaluation (credits)

<table>
<thead>
<tr>
<th>Component</th>
<th>Credits (Max)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 assignments</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>midterm 1</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>midterm 2</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>final exam</td>
<td>30 (60)</td>
<td></td>
</tr>
<tr>
<td>oral presentation</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>term paper</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>130</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
How much work do you need to do?

<table>
<thead>
<tr>
<th>GRADE</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture hours</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Exercises</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>3 Assignments</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Study/Review</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>hours per week</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

(Term paper and Oral Presentation are extra.)
Want to get involved in research?

See [www.cim.mcgill.ca/~langer/resources-gradschool.html](http://www.cim.mcgill.ca/~langer/resources-gradschool.html)

Undergraduates:

- COMP 400 Honours Project in CS  
  (Majors, with permission)

- COMP 396 Undergraduate Research Project

  *Either can be done over the summer.*

Graduate students (M.Sc.):

- Project or Thesis