Computational Methods for Medical Imaging

1. Introduction

UCLA – CS 168 – Spring 2019

Fabien Scalzo, Ph.D.
Brief Bio

2008 - Ph.D. in Machine Learning – Computer Vision (Liège, Belgium)
2009 - Post-doc (UCLA, Neurosurgery - Neurology)
2015 - Assistant Professor at UCLA, Neurology – Computer Science and Electrical and Computer Engineering
UCLA Medical Center

- 520 beds, 1,145 nurses, >40,000 ER visits each year
- Ranked one of the best hospital of the West

- Translational research in Biomedical Engineering
- Opportunities for innovation
AI in Imaging and Neuroscience

• We develop Machine Learning and Computer Vision algorithms to improve our understanding of neurological disorders.
Outline

• Introduction to physics of medical imaging, image processing, computer vision, and machine learning

• **Medical image acquisition**: basic theory of techniques (X-ray, MRI)

• **Image processing**: representation, transformation, filtering, and interpolation

• **Computer vision**: feature extraction, description, reconstruction

• **Machine learning**: standard algorithms and evaluation methods
Approach

• Focus on your Learning Experience
  • Build a knowledge foundation
  • Acquire skills needed today in the real world
  • Get inspired by lectures from top Professors in the field

• Develop Problem Solving Skills
  • Work in a team
  • Provide a new solution to an existing problem

• Communicate

*Excellence is to do a common thing in an uncommon way*
Image processing: Detect and Track

Detect and Track all objects in a scene

Illustration by U.S. Army
Image processing: Enhance
Snapchat & Facebook
The future is now
Why Medical Imaging?

• Refers to technologies used to view the human body in order to diagnose, monitor, or treat medical conditions
## Schedule and Topics

<table>
<thead>
<tr>
<th>Week 1</th>
<th>1-Apr</th>
<th>Introduction</th>
<th>3-Apr</th>
<th>Projects</th>
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<tbody>
<tr>
<td>Week 2</td>
<td>8-Apr</td>
<td>Basics of X-rays</td>
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What is an image?

• An image is a visual representation of something.
  • An abstraction that can be seen in 2D/3D.
  • It has inherent limitations and provides a limited (usually distorted) view of the object of interest.
  • “It is an artifact that depicts visual perception that has a similar appearance to some subject, thus providing a depiction of it.”
What is a digital image?

- A digital image is an array that associate a value (e.g. color) to a location. (2D: pixels, 3D: voxels)
Digital images
Acquisition
Each sensor creates an electrical current when exposed to the light. The strength of the current is (~proportional) to the brightness of the light.
Resolution

500 pixels  125 pixels  62 pixels  25 pixels
# Electromagnetic Spectrum

<table>
<thead>
<tr>
<th>Wavelength (μm)</th>
<th>10^12</th>
<th>10^11</th>
<th>10^10</th>
<th>10^9</th>
<th>10^8</th>
<th>10^7</th>
<th>10^6</th>
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<th>10^3</th>
<th>10^2</th>
<th>10^1</th>
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</thead>
<tbody>
<tr>
<td>Wavenumber (cm^-1)</td>
<td>10^12</td>
<td>10^11</td>
<td>10^10</td>
<td>10^9</td>
<td>10^8</td>
<td>10^7</td>
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<td>10^3</td>
<td>10^2</td>
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<tr>
<td>Electron Volt (eV)</td>
<td>10^12</td>
<td>10^11</td>
<td>10^10</td>
<td>10^9</td>
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<td>10^7</td>
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<td>Frequency (Hz)</td>
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<td>10^6</td>
<td>10^11</td>
<td>10^12</td>
<td>10^13</td>
<td>10^14</td>
<td>10^15</td>
<td>10^16</td>
<td>10^17</td>
<td>10^18</td>
<td>10^19</td>
<td>10^20</td>
<td>10^21</td>
</tr>
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## Bands

- **Radio Spectrum**
  - AM radio 600kHz-1.8MHz
  - FM radio 88-108 MHz
  - Mobile Phones 900MHz-2.4GHz
  - Radar 1-100 GHz
  - TV Broadcast 54-700 MHz
  - Wireless Data ~ 2.4 GHz
  - Microwave Oven 2.4 GHz

- **Visible light**
  - Wavelength: 0.39-0.75 μm
  - Frequency: 4.25-8.75 THz
  - Energy: 3.4-2.8 eV

- **Infrared (IR)**
  - Wavelength: 0.7-1000 μm
  - Frequency: 0.7-10 THz
  - Energy: 1.4-2.8 eV

- **Ultra Violet (UV)**
  - Wavelength: 0.01-0.39 μm
  - Frequency: 3.1-4.25 THz
  - Energy: 3.4-4.28 eV

- **X-ray**
  - Wavelength: 0.001-0.01 μm
  - Frequency: 31-310 THz
  - Energy: 4.28-42.8 eV

- **Gamma rays**
  - Wavelength: <0.001 μm
  - Frequency: >310 THz
  - Energy: >42.8 eV

## Sources and Uses

- **Sound Waves**
  - Wavelength: ~20Hz-10kHz

- **Ultrasound**
  - Wavelength: 1-20 MHz

- **TV Broadcast**
  - Wavelength: 54-700 MHz

- **Microwave Oven**
  - Wavelength: 2.4 GHz

- **Visible light**
  - Wavelength: 0.2-0.7 μm
  - Frequency: 750-3800 THz
  - Energy: 2.8-3.4 eV

- **X-ray**
  - Wavelength: 0.01-0.001 μm
  - Frequency: 10-310 THz
  - Energy: 4.2-42.8 eV

- **Gamma rays**
  - Wavelength: <0.001 μm
  - Frequency: >310 THz
  - Energy: >42.8 eV

## Equations

- **λ** = \(3 \times 10^8 \text{ cm/s} \times \text{freq} = \text{freq} \times 10^8 \text{ Hz} = 1.24 \times 10^{-6} \text{ eV} \)
Medical imaging

CT

MRI / fMRI

Nuclear

PET

SPECT

Ultrasound

X-ray

magnetic spin

metabolic tracer X-ray emission

sound waves
Brain image processing
Image processing: Face Detection
Retina is recognized by means of scanning blood vessel patterns of the retina and the pattern of flecks on the iris.

It is difficult to fake a retinal scan because no technology exists that allows the forgery of a human retina, and the retina of a deceased person decays fast to be used to fraudulently bypass a retinal scan.
Interpretation and Semantic
Image processing

Low-level

Image processing
Image processing/Computer Vision

High-level

Computer vision

Low-level

Image processing
Image Processing
Brewster-type stereoscope, 1870
Vision in 3D
Built-in 3D -> the human visual system
Augmented and Virtual Reality

3D Imaging
Human Learning – How do we learn to process images?
Machine Learning

- Gives computers the ability to learn without being explicitly programmed
- Find patterns in the data
- Example:
  - Finding a mapping between input and output

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<th>X2</th>
<th>Y</th>
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“Biologically” inspired Machine Learning
Processing Images

- Artificial Intelligence
- Machine Learning
- Machine Vision
- Image Coding
- Visual Perception
- Display Technology

- Computer Graphics
- Computational Photography

- Imaging

- Robotics, Inspection, Photogrammetry
- M-d Signal Processing
“Star” Lectures

Yair Rivenson

William Hsu

Wesley Chun

Shantanu Joshi

Leonardo Christov-Moore

Achuta Kadambi

Kyung Sung
Schedule and Topics

<table>
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<tr>
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<td>6-May</td>
<td>Quanquan Gu</td>
<td>8-May</td>
<td>Shantanu Joshi</td>
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<td>Week 6</td>
<td>13-May</td>
<td>Google Cloud</td>
<td>15-May</td>
<td>ML Toolboxes</td>
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<td>Week 7</td>
<td>20-May</td>
<td>Leonardo Christov-Moore</td>
<td>22-May</td>
<td>Yair Rivenson</td>
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<td>Week 8</td>
<td>27-May</td>
<td>Memorial Day</td>
<td>29-May</td>
<td>Achuta Kadambi</td>
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<tr>
<td>Week 9</td>
<td>3-Jun</td>
<td>William Hsu</td>
<td>5-Jun</td>
<td>Kyung Sung</td>
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<tr>
<td>Week 10</td>
<td>7-Jun</td>
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Project

- **Team**
  - Find teammates - teams of 3
  - Add your name/uid to the sheet on google drive (to be posted on ccle)

- **Topic**
  - Choose a research project topic related to medical imaging
  - Review medical imaging challenges, ex: https://grand-challenge.org/All_Challenges/

- **Teamwork - Communication**
  - Use a collaborative platform (Trello, Atlassian, Gitlab)
  - Track your progress
  - Share your code, ideas, problems, findings
  - Centralize your resources
Example of topic: heart rate estimation

1. Face Region Extraction
2. Feature Extraction
3. Self-Adaptive Matrix Completion
4. Heart Rate Estimation

Signal estimated using SAMC

Power spectral density estimation

Input Video
Amplified Video

Pulse From Head Motion: 54.1 bpm
Deep learning and radiomics: the utility of Google TensorFlow™ Inception in classifying clear cell renal cell carcinoma and oncocytoma on multiphasic CT

Authors
Heidi Coy  Kevin Hsieh, Willie Wu  Mahesh B. Nagarajan, Jonathan R. Young, Michael L. Douek, Matthew S. Brown, Fabien Scalzo, Steven S. Raman
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Final: June 11, 2019 - 3 pm
Grading

- **Project** (65%)
- **Final** (25%)
- **Homework** (10%)
Grading

- **Project** (65%)
  - Introduction/Literature review (10%)
  - Final report (30%)
    - Methods/Evaluation/Results/Discussion
  - Video (15%)
  - Code (10%)

- **Final** (25%)

- **Homework** (10%)
Organization

• Assistants
  • Ali Hatamizadeh, ahatamiz@ucla.edu
  • Weinan Song, wsong@g.ucla.edu

• Questions
  • Contact Assistant: homework, final, data, project
  • Otherwise, contact me: fab@cs.ucla.edu

• Office hours
  • Friday 11:30am – 12:30pm, 1:30pm – 2:30pm
  • Neuroscience Research Building (NRB), room 116

• Home page
  • https://ccle.ucla.edu/course/view/19S-COMSCI168-1