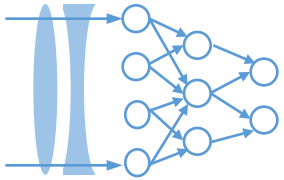


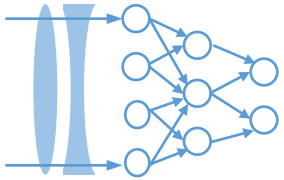
Lecture 0: Class outline and motivation

Machine Learning and Imaging

BME 590L

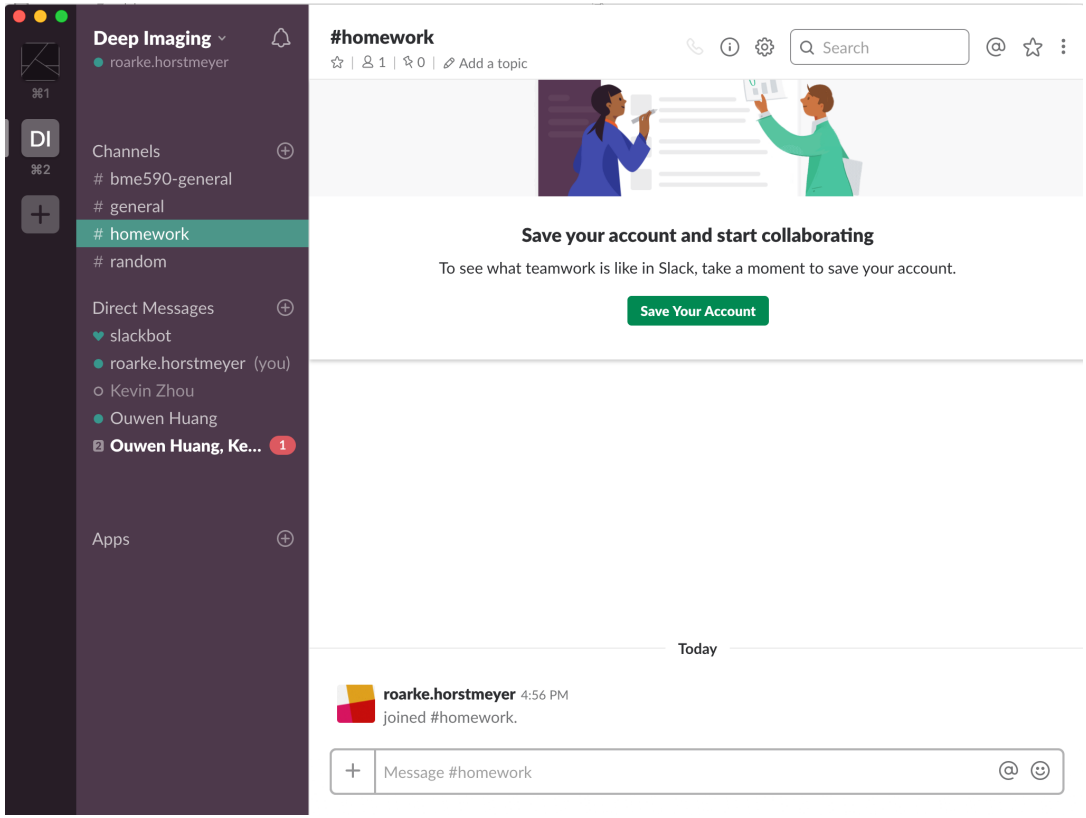
Roarke Horstmeyer

Organizational stuff

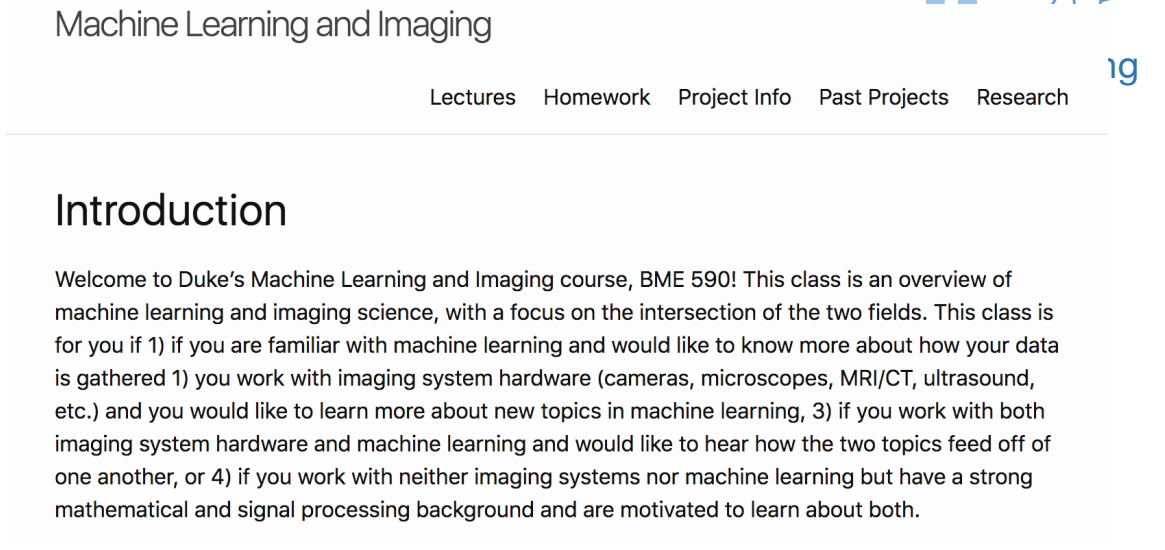


- Course website: deepimaging.github.io (and deepimaging.io)
- Slack channel: deepimaging.slack.com
- Homeworks will be posted on Slack (and Github)
- Homeworks will be a mix between “hand-written” problems and code
- “Hand-written” problems can be written up and turned in at class, or turned in via Github
- Coding assignments will be shared via Github
- Code should be written up with Jupyter notebooks
- Coding assignments should be submitted via Github

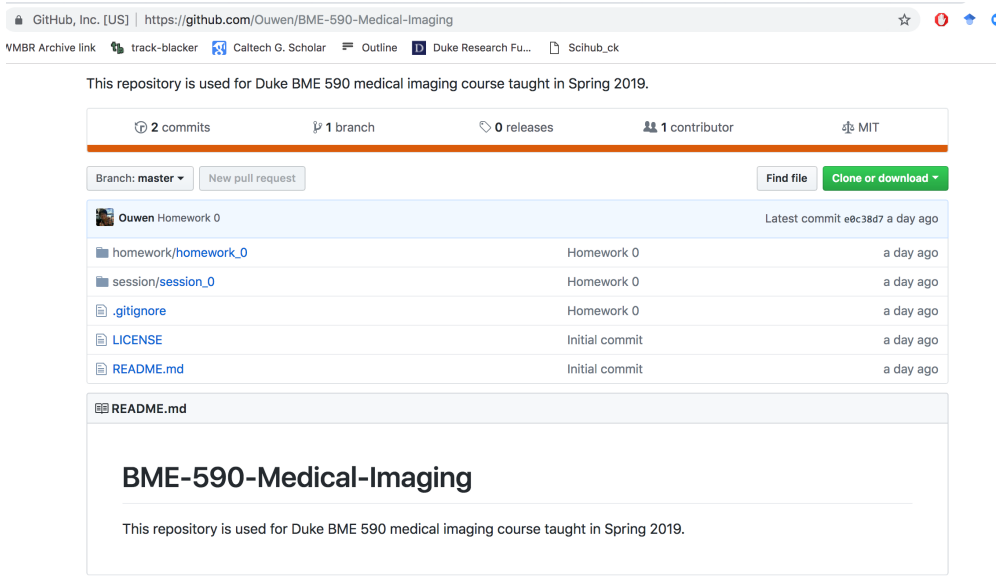
Slack



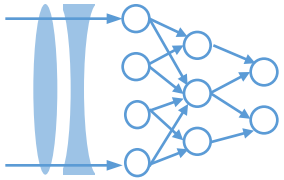
Course webpage



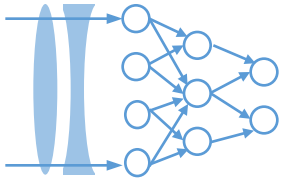
Github



Organizational stuff – Lab Sessions



- Monday and Wednesday 4:55pm-6pm
- Please bring your laptop to the lab sessions (I assume you have one, if not please come speak with me)
- Try your best to show up to the lab session that you signed up for, but you can attend alternate ones if you really have a conflict
- First lab sections will go over basics of code setup (Python, Jupyter, Github, CoLab, GCS)
- Then we'll get into classification & Tensorflow, also homework help
- Please try out Jupyter/Github on your machines before lab sections next week – we may send out a survey



Organizational stuff - Grading

- 5 homework assignments, maybe 2-3 short quizzes, 1 final project
- -20%/day for late homework
- Final project is important, mostly for you!
- Participation: come to lecture & lab & office hours if needed, self-scored
- Collaboration encouraged, but please write up your *own code* and *own solutions*

Grading:
Homework: 45%
Project proposal: 7%
Final project: 40%
Participation: 8%

(maybe quizzes: 15%)

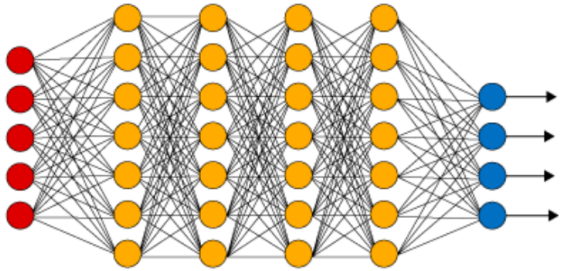
What is this class about?

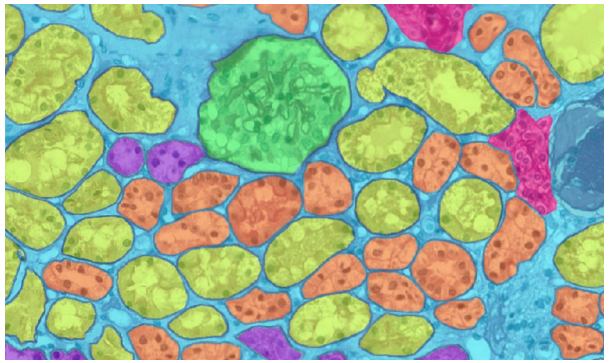
Historically, hardware has been optimized to create images for humans

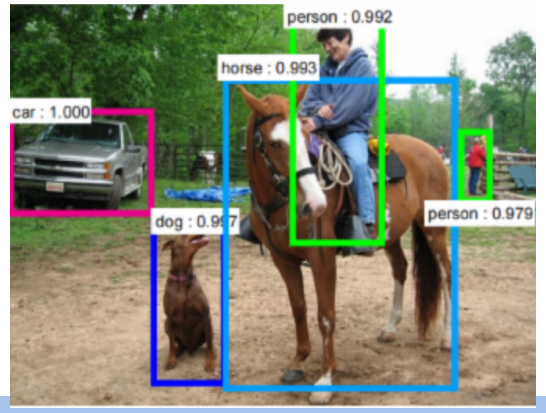
What is this class about?

deep imaging

Over the last 10 years, computers have become “really good” at automatically processing image data

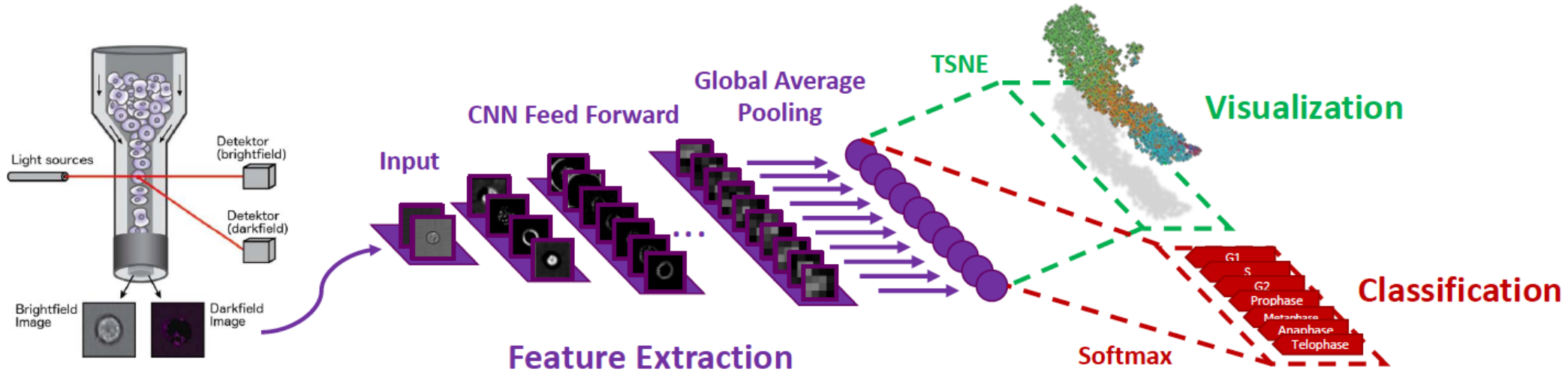


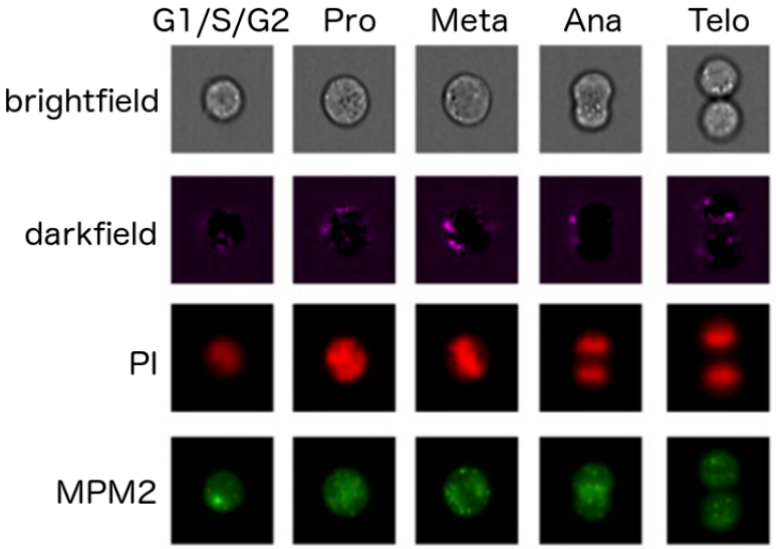


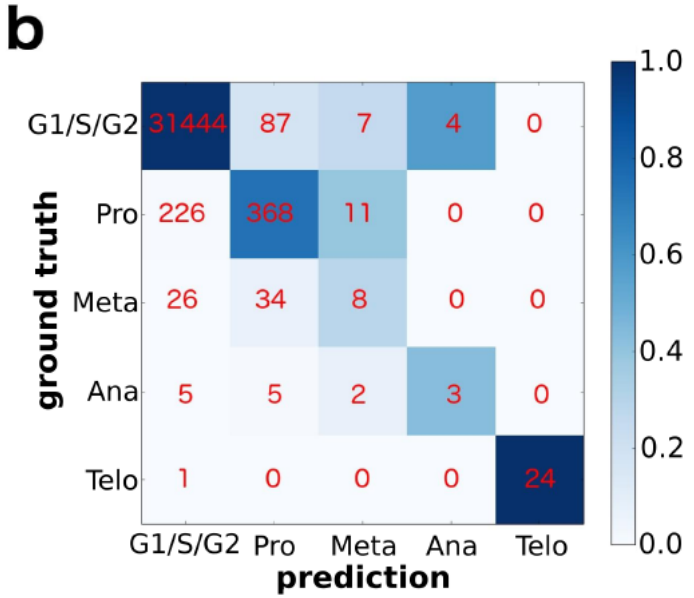


Nearly all new advances enabled by deep neural networks

P. Eulenberg et al., “Reconstructing cell cycle and disease progression using deep learning”



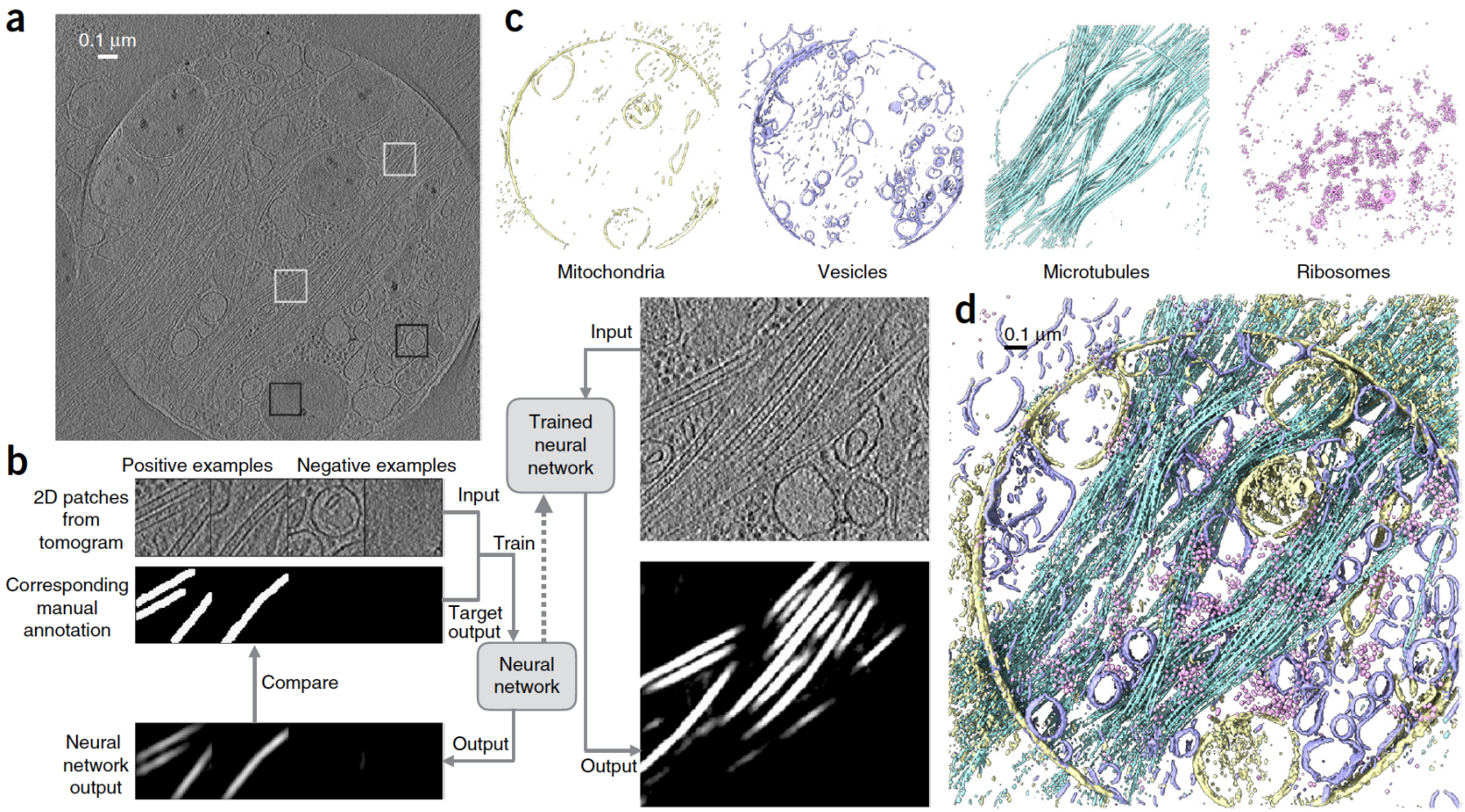




Convolutional neural networks for automated annotation of cellular cryo-electron tomograms

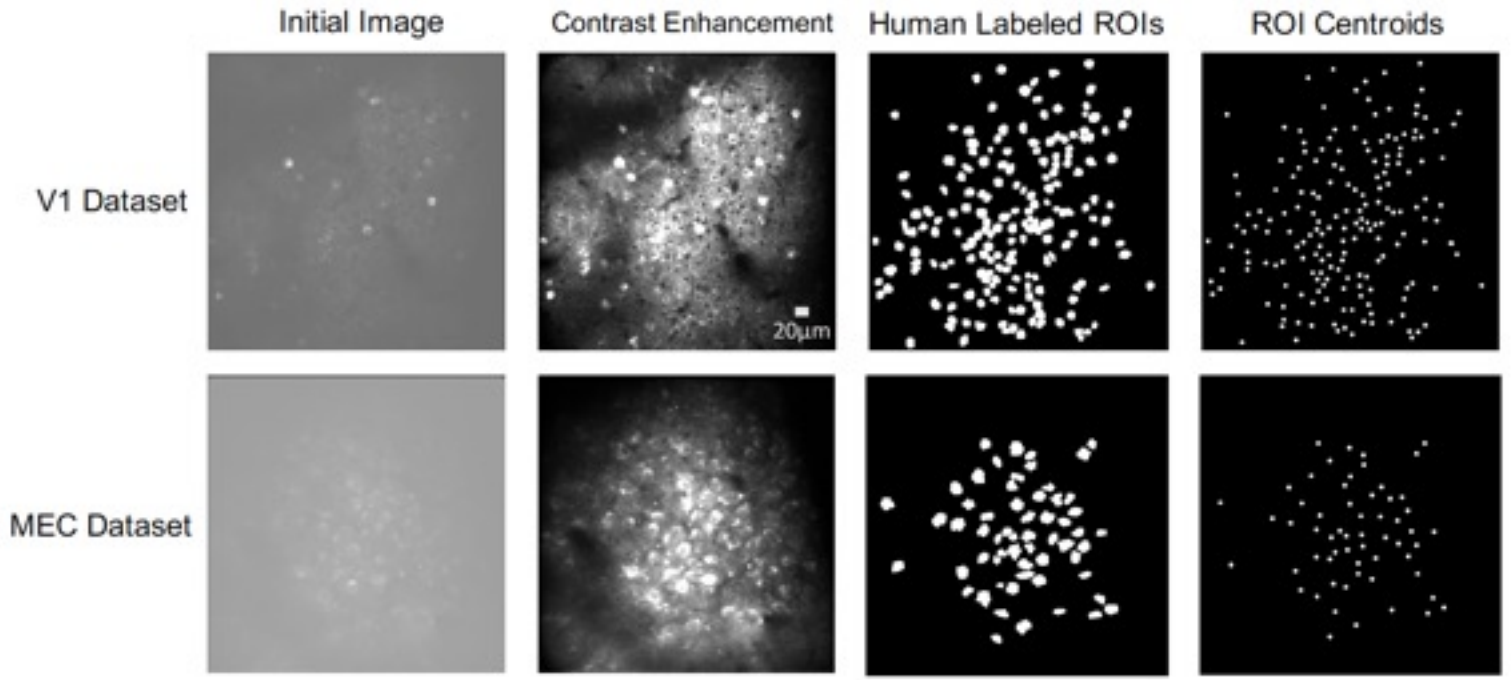
Muyuan Chen[1,2], Wei Dai[2,4], Stella Y Sun[2], Darius Jonasch[2], Cynthia Y He[3], Michael F Schmid[2], Wah Chiu[2] & Steven J Ludtke[2]

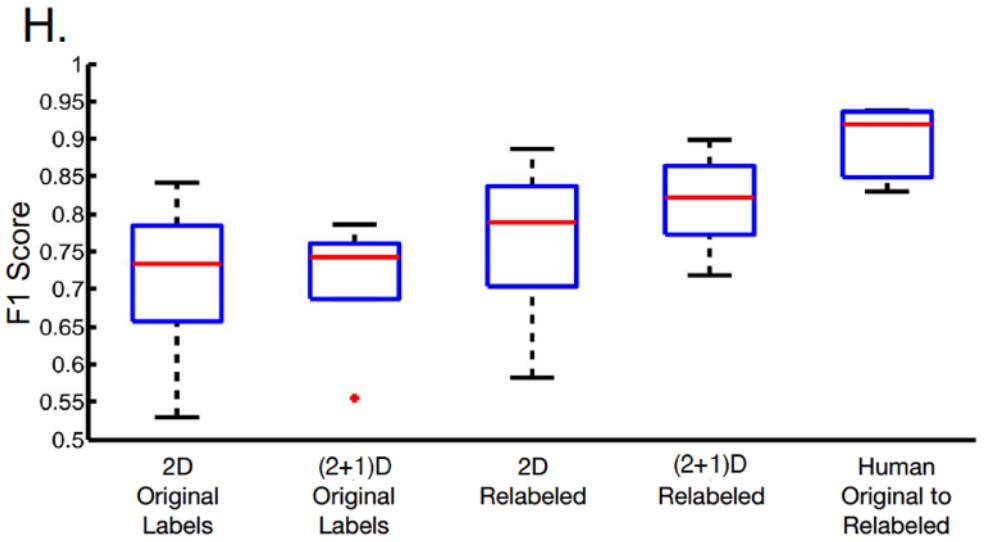
deep imaging

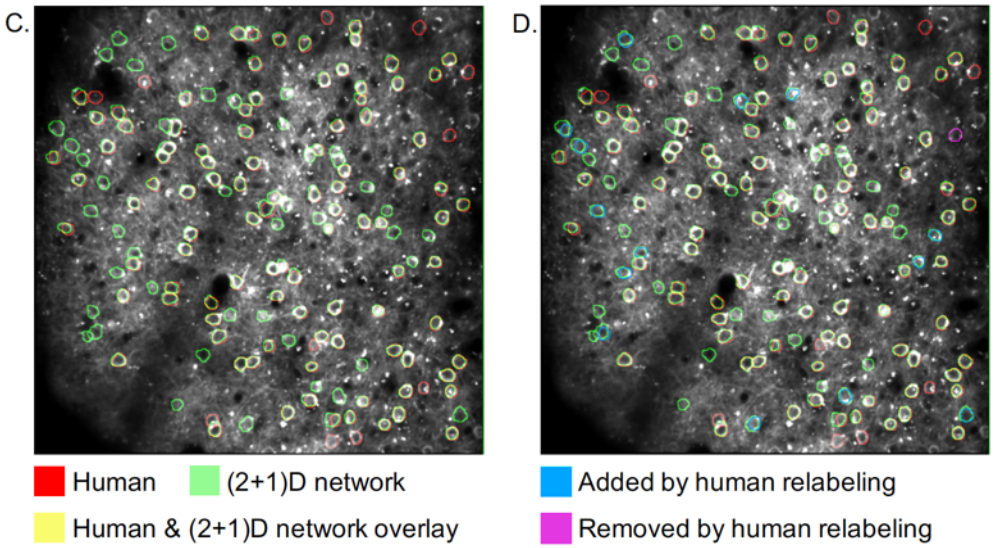


Automatic Neuron Detection in Calcium Imaging Data Using Convolutional Networks

Noah J. Apthorpe[1*] Alexander J. Riordan[2*] Rob E. Aguilar[1] Jan Homann[2]
Yi Gu[2] David W. Tank[2] H. Sebastian Seung[12]
[1]Computer Science Department [2]Princeton Neuroscience Institute
Princeton University



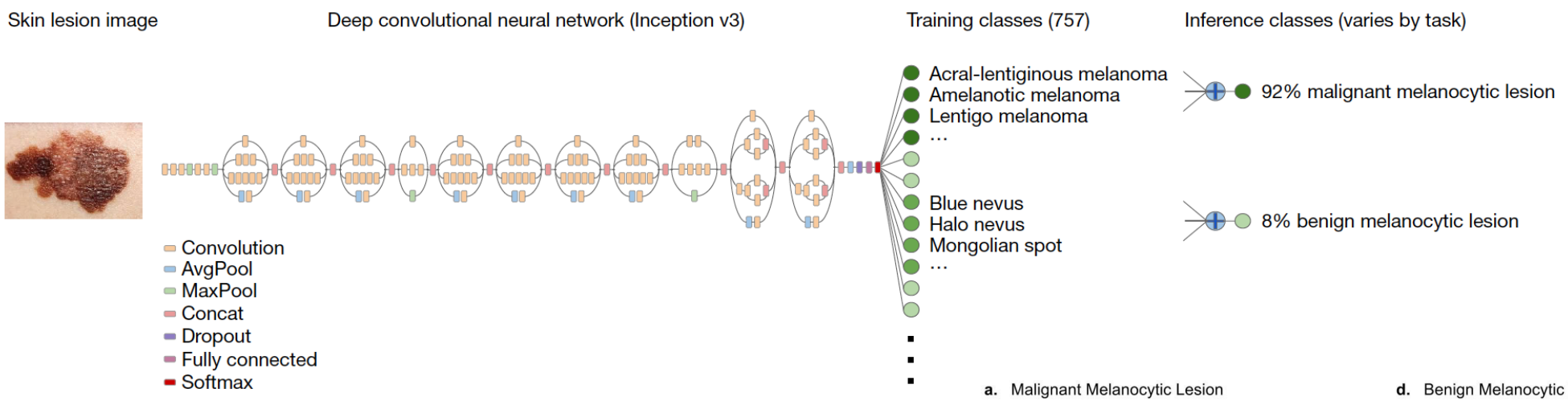


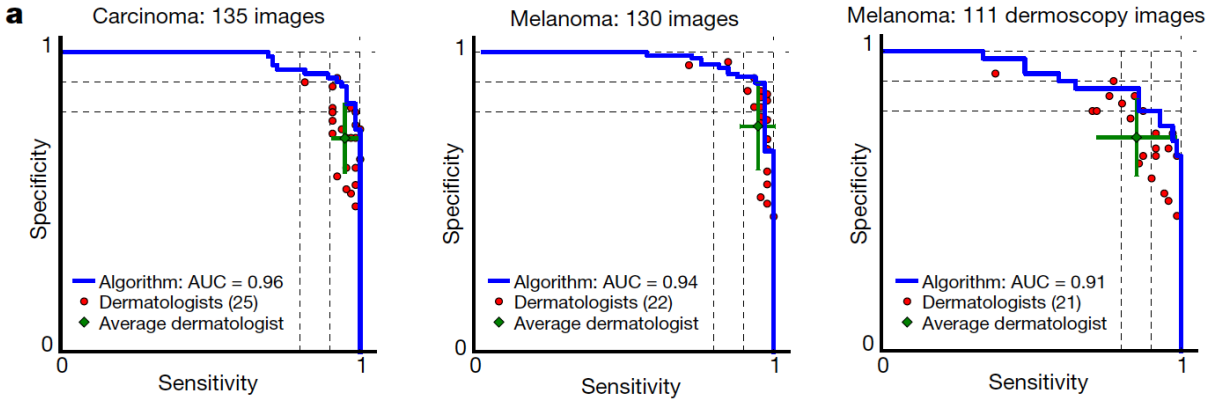


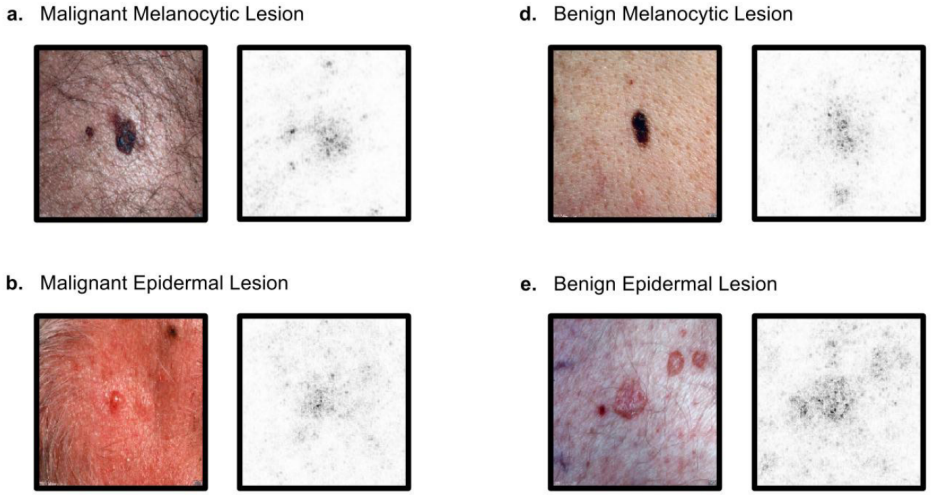
Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva[1]*, Brett Kuprel[1]*, Roberto A. Novoa[2,3], Justin Ko[2], Susan M. Swetter[2,4], Helen M. Blau[5] & Sebastian Thrun[6]

deep imaging





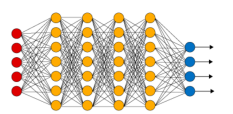


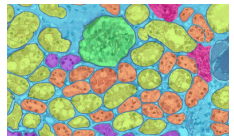
What is this class about?

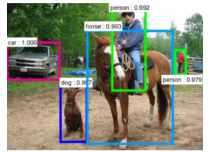
deep imaging

We will figure out what is going to be right here

*Computer-*centered hardware + software



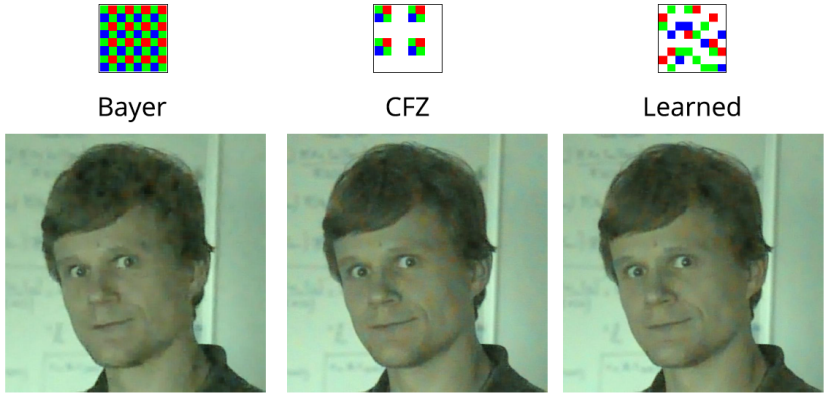




Human-centered hardware design

Computer-centered software design

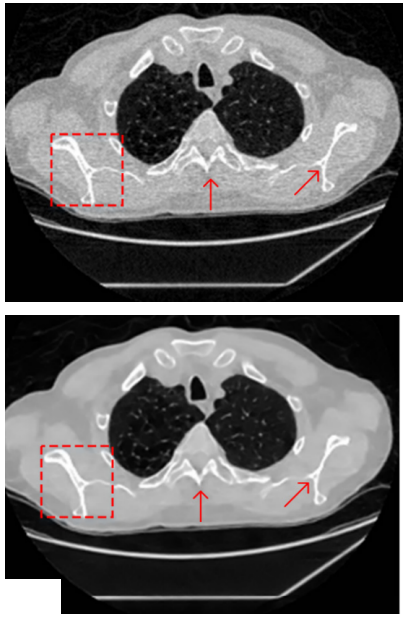
Some examples of computer-centered hardware?



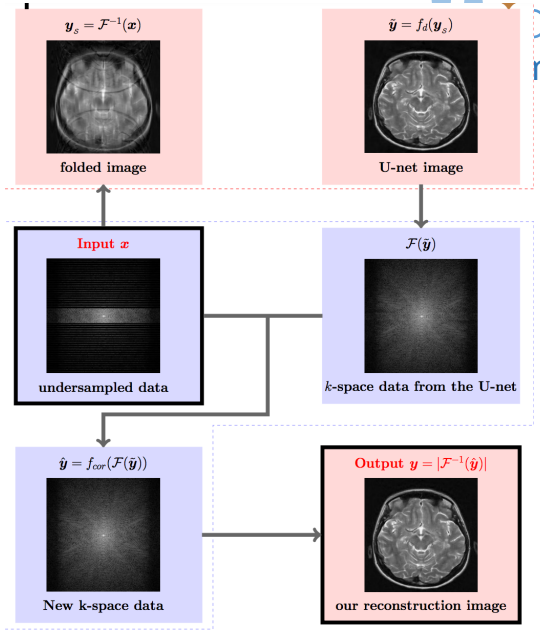
A. Chakrabarti

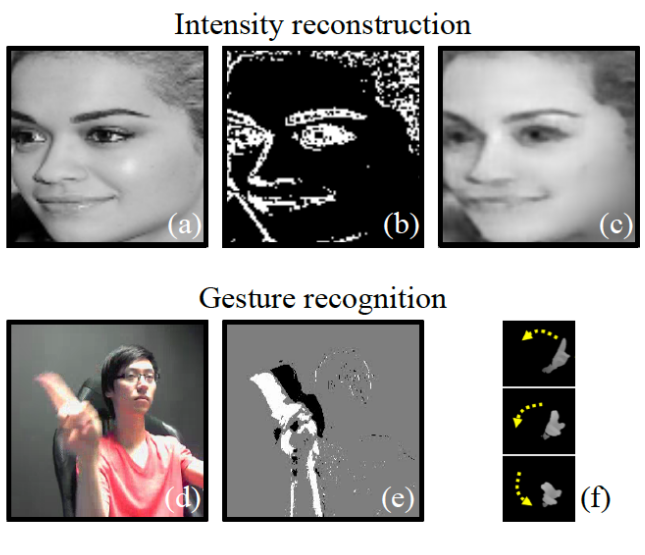
Butterfly

Low-dose CT – Chen et al.

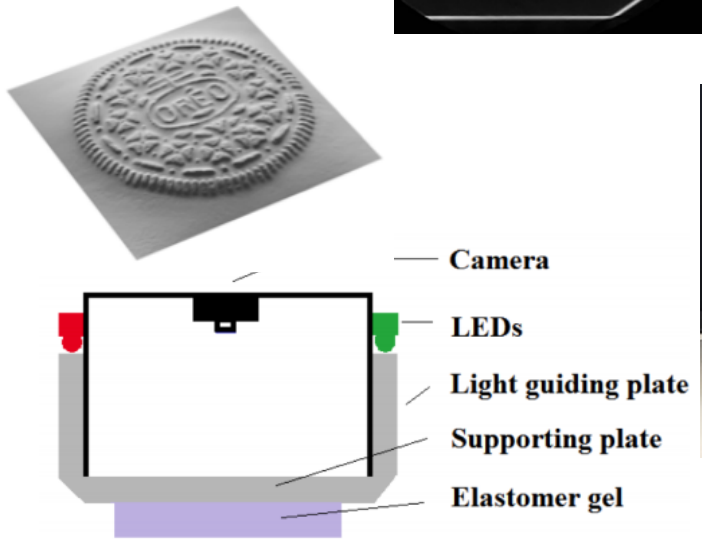


Under-sampled MRI – Hyun et al.

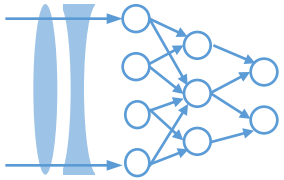




Nvidia



https://youtu.be/BIW_jq3dOEE



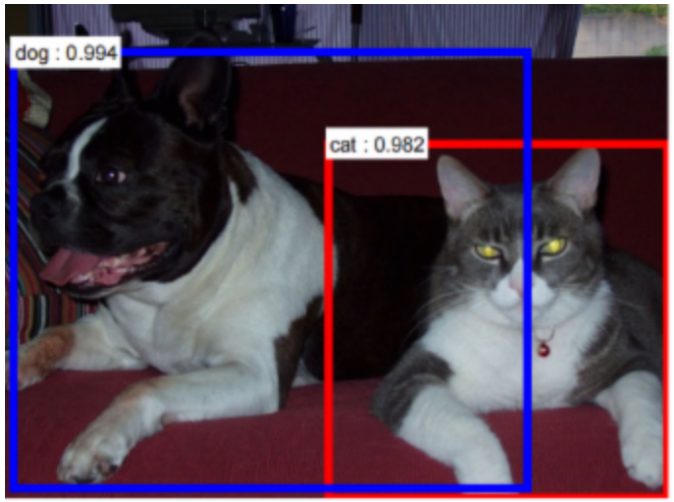
General layout for this class:

- Here is what I plan to cover:
  - Fundamental concepts behind machine learning
  - Current methods in machine learning for image analysis
    - Deep neural neworks & CNN's
    - Classification, segmentation, translation, super-resolution
  - How to model *simplified* imaging systems (cameras, microscopes, ultrasound, CT, etc.)
  - How to optimize imaging system hardware with machine learning

What is this class *not* about?

deep imaging

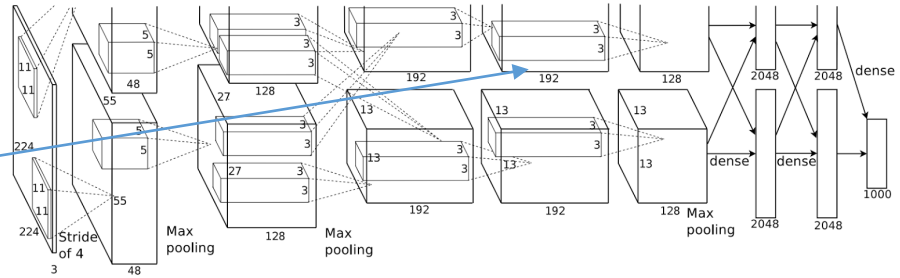
"I want to get this score from 0.982 up to 0.999"



"Can we create a comprehensive mathematical framework to understand how deep learning algorithms work?"

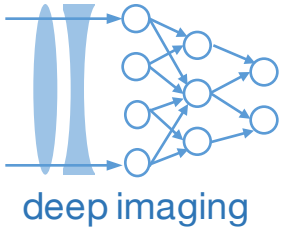
"I'd like an in-depth explanation of how my (fill-in-the-blank) imaging system works"

"I want to really understand this one operation here"



"I want to program something to make cool pictures like this"

What do I need to know about beforehand to succeed in this class?



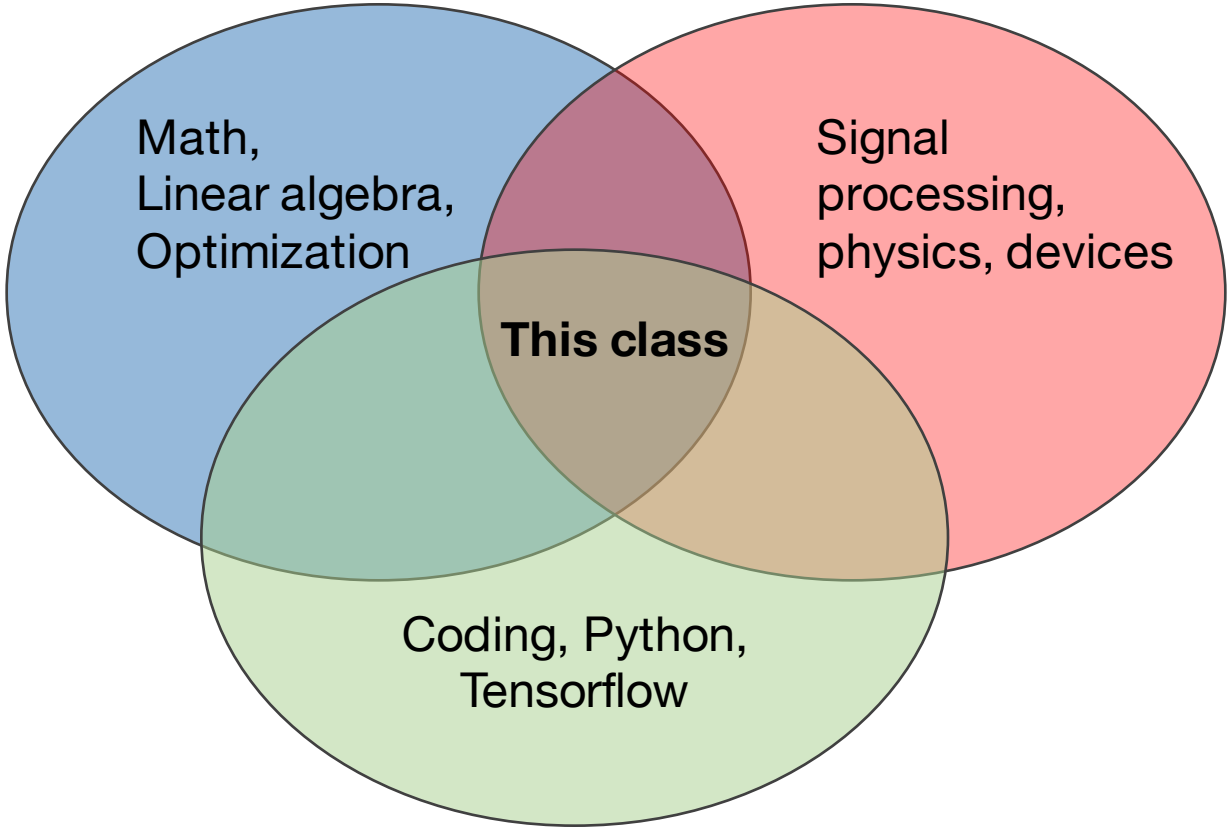
- Python coding experience ideally, but MATLAB programming experience will probably be ok

- Linear algebra & Calculus
  - Vector/matrix operations
  - Matrix inversion, pseudo-inverse
  - Gradients, partial derivatives

- Signal processing
  - Complex-valued signals
  - Fourier transforms
  - Convolutions

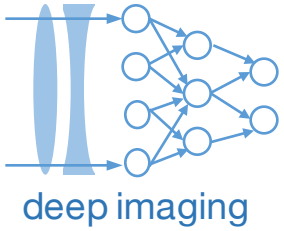
- Optimization
  - Differences between Linear, convex, non-linear optimization
  - Gradient descent

This class is interdisciplinary (by design)



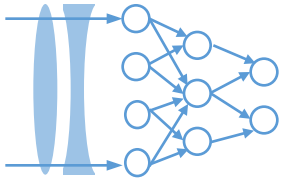
- We will move pretty fast
- We will jump between subjects I assume most have had “some” exposure to
- End goal: Meaningful project with Tensorflow
- This is the second time, so we have some proof it works…

What should I expect to gain from this class?



- Comfort with general mathematical principles behind machine learning
- Comfort with how to simply model generalized imaging systems (math and simulation)
- Ability to program in Python and Tensorflow
- Hands on experience with current “deep” ML algorithms (convolutional neural networks, GANs maybe)
- An ability to reason thought architecture choices for deep CNNs
- Coding experience with adding imaging system hardware optimization into a CNN or other NN structure

Projects from BME590: Machine Learning in Imaging



Finding Ultrasound Sub-apertures for Liver Vessel Segmentation
Single-Pixel, Single-Frequency Hand Gesture Recognition with a Dynamic Metasurfaces
Going Deeper: Depth Image Classification via simulated SPAD array images
Trained Blur Kernel for histology slide segmentation using a Deep Neural Network
Classification of Tuberculosis Bacilli With and Without Staining
A deep learning approach to improving ultrasonic plane wave imaging
Automated Image Focus Detecting Algorithm for Low-Cost Handheld Microscope
Optimal shift-variant point-spread function for improved classification
Deep Learning for Motion Tracking on the Micron Scale with Ultrasound
Sensor Multiplexing and Reconstruction for Color Images
Noise Reduction in Optical Coherence Tomography using a Deep Image Prior
Optimization of illumination for Unet-Base Cervix Segmentation
HDR image reconstruction with filters over pixels – What is the optimal design?
Detection of Lesions in Variably Noisy Ultrasound Images Using Machine Learning
Methods for Segmentation of Fine Structure in Rodent Histological Specimens
Direct reconstruction network for photoacoustic imaging with fewer measurements
Machine Learning for Ultrasound Lesion Mapping with Apodization Optimization
Resolution versus Precision in X-ray detection of Pneumonia
Optimizing illumination for overlapped image classification