CS184A/284A
AI in Biology and Medicine

Application: AI in Digital Pathology
AI in healthcare

- Healthcare depends heavily on **data** and **expert knowledge** for lifestyle advice, diagnosis, monitoring, and treatment.
- Medical diagnosis is highly subjective and variable, depending on training and knowledge of medical professionals.
- A.I. has not been widely utilized, although data and expert knowledge are excellent playground for A.I.
- However, many expect that next a few years might witness a major change in adopting A.I. in healthcare.
AI in digital pathology

1. A pathologist’s report after reviewing a patient’s biological tissue samples is often the gold standard in the diagnosis of many diseases.

2. The reviewing of pathology slides is a very complex task, requiring years of training to gain the expertise and experience to do well.

3. Even with this extensive training, there can be substantial variability in the diagnoses given by different pathologists for the same patient, which can lead to misdiagnosis. For example, agreement in diagnosis for some forms of breast cancer can be as low as 48%, and similarly low for prostate cancer.

4. There can be many slides per patient, each of which is 10+ gigapixels when digitized at 40X magnification.
AI in digital histopathology

Breast cancer metastases in lymph nodes
Given a set of whole slide images, performance binary classification and tumor detection

Image courtesy of https://camelyon16.grand-challenge.org/data/
Deep learning in digital pathology

Work by Google AI
Distinguishing tumors from macrophages

Work by Google AI
A general methodology is to formulate the problem as a patch-based classification problem.
Segmentation formulation

Ground Truth

Predicted annotations
Can also be used for survival analysis

A. Whole-slide imaging
   - Resection / biopsy
   - Whole-slide image

B. Region of interest selection
   - Web viewer
   - Regions of interest

C. Survival Convolutional Neural Network (SCNN)
   - Prediction error (negative log-likelihood)
   - Convolutional layers
   - Fully connected layers
   - Cox model
   - Patient survival
Computational Pathology Datasets

- Paige.AI Prostate Biopsy Complete Diagnosis 15,000 Slides
- Camelyon Challenge 400 Slides
- First Computational Pathology Paper [Fuchs et al. 2008] 1 Slide (Tissue Microarray)
- GLASS challenge 200 slides
Performance on Binary WSI classification

AUC: 0.942, compared 0.96 by experienced pathologists.
Classify H&E stained microscopy images one of four classes: *normal*, *benign*, *in situ carcinoma*, and *invasive carcinoma*
Performance on 4-class classification

<table>
<thead>
<tr>
<th>Normalization</th>
<th>Accuracy</th>
<th>Validation Set</th>
<th>Test Set</th>
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<td>MV</td>
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<td>Ensemble with refinement</td>
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Image-wise accuracy: 87.5% compared to 75% in previous state-of-the-art
Colon Polyp Classification
Samples with different colorectal polyps: (a) hyperplastic, (b) sessile serrated, (c) traditional serrated, (d) tubular, (e) tubulovillous/villous, and (f) normal, (H&E)
Cell Nuclei Detection

Potential Applications: Cytology
Cell Nuclei Detection