# CHALLENGES AND STRATEGIES FOR DEVELOPING ROBUST AI APPLICATIONS IN ONCOLOGY


**Daniel L. Rubin, MD, MS**

Professor of Biomedical Data Science,
Radiology, Medicine (Biomedical Informatics),
Computer Science (courtesy) and Ophthalmology (courtesy)
Laboratory of Quantitative imaging and AI

Stanford University


## Acknowledgements


**Students, Post-docs, Residents, Staff, and Collaborators**

- Rikiya Yamashita
- Liangqiong Qu
- Anuj Pareek
- Jared Dunnmon
- Okyaz Eminaga
- Darvin Yi
- Xuerong Xiao
- Blaine Rister
- Nandita Bhaskhar
- Khaled Saab
- David Liang
- Siyi Tang
- Emel Alkim
- Mete Akdogan
- Ozge Yurtsever
- Cavit Altindag
- Niranjan Balachandar
- Ted Leng
- Joelle Hallak
- Luis de Sisternes
- Michael Gensheimer
- Christopher Re
- Bao Do
- Sandy Napel
- Chris Beaulieu
- Ann Leung
- Phil Lavori
- Naras Balasubramanian

**Funding Support**

- **NCI grants U01CA142555, 1U01CA190214, 1U01CA187947, 1U01CA242879**

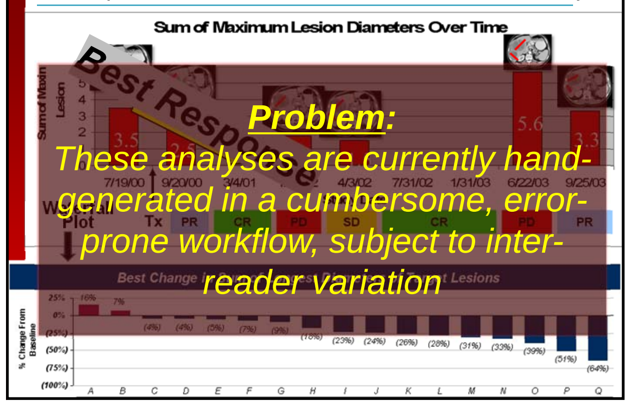
NVIDIA Academic Hardware Grant Program
Stanford Philips and GE BlueSky


## Image assessments of cancer lesions are the basis of evaluating treatment response

- Measurements are made on images
- Recorded as a separate process (spreadsheet, dictated report, etc)
- Disconnected from the image(s)




## Lesion measurements are basis of patient response and cohort treatment efficacy




## Problem: Inter-reader variation:

Sufficiency of information in 167 imaging studies and reports

| No of Observations | Baseline (55) | Follow-up (112) |
|---|---|---|
| **Report** | | |
| Lesion Described | 39 (71%) | 43 (38%) |
| Longest Diameter | 30 (55%) | 31 (28%) |
| **Image Markup** | | |
| Lesion Identified | 40 (73%) | 78 (**70%**) |
| Longest Diameter | 27 (50%) | 29 (26%) |

***Radiologist not aware of measurable disease being tracked by oncologists***

| Number of CT Scans | Baseline (13) | Follow-up (29) | Total (42) |
|---|---|---|---|
| Sufficient to Calculate RECIST Sum of Longest Diameters | 54% | 14% | 26% |

Levy MA, Rubin DL. Tool support to enable evaluation of the clinical response to treatment. AMIA Annu Symp Proc. 2008:399-403.



## Opportunities for AI in cancer imaging

- **Lesion detection**
- **Lesion segmentation**

***Critical for Drug Evaluation***

- Diagnosis
- Treatment selection
- Response assessment
- Clinical prediction (of treatment response or future disease)

***Active research area***

## **Detection** and **segmentation**: General fully connected networks

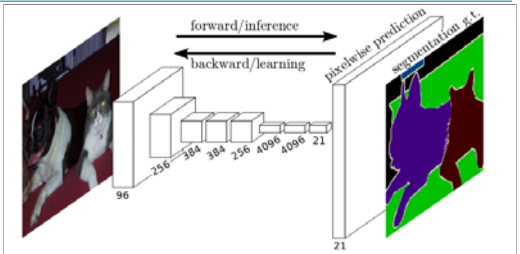



Figure 1. Fully convolutional networks can efficiently learn to make dense predictions for per-pixel tasks like semantic segmentation.

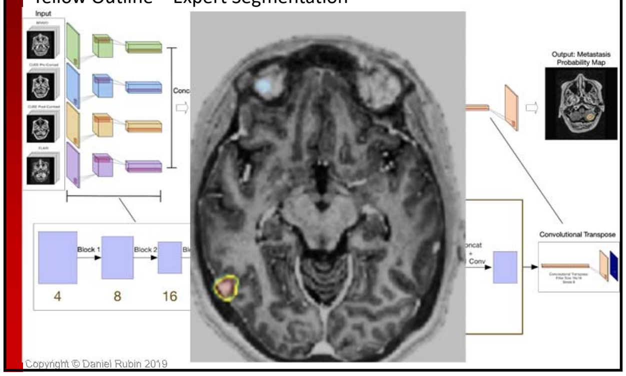
***Detection/segmentation are pixel-based classification tasks***

http://www.cv-foundation.org/openaccess/content_cvpr_2015/papers/Long_Fully_Convolutional_Networks_2015_CVPR_paper.pdf



## Example automated segmentation

Yellow Outline = Expert Segmentation



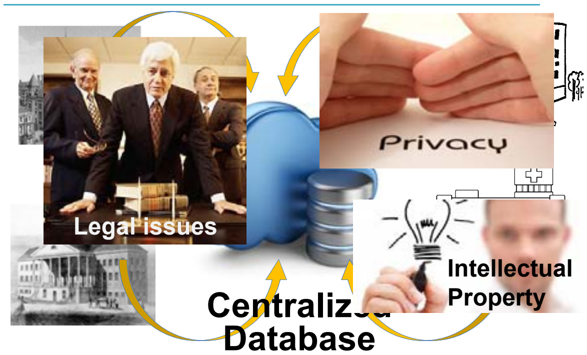



## There are challenges to building robust AI models

- Data among institutions varies
  - Geographic variations in patient populations
  - Differences in imaging parameters
  - Differences in vendor equipment
- Robust AI models require **large amounts of labeled training** data in order to **generalize**
- Difficult/costly to acquire large amounts of data
- There are tremendous amounts of historical data across institutions that could be leveraged



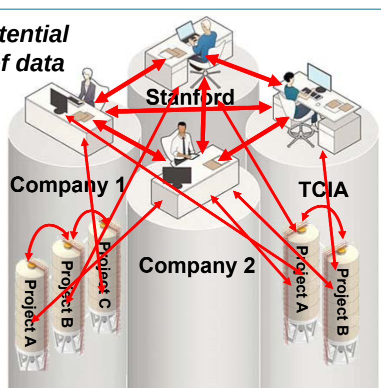
## Acquiring data from multiple sites is challenging






## AI development (and data) is siloed

***Limited potential for reuse of data***

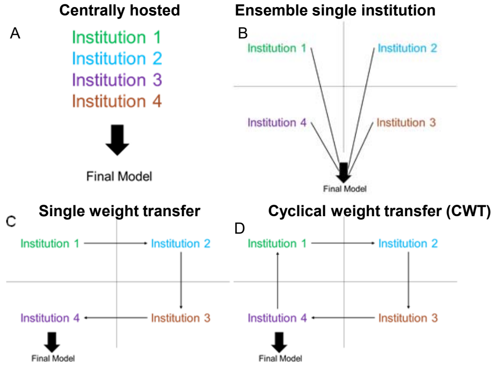





## Overcoming barriers to data sharing

- Bring the **model to the data** instead of bring the data (centralized) to the model
- **Distributed computation** of training deep learning models ("distributed learning")

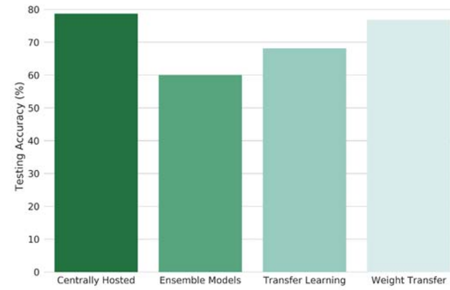
## Alternative models for training distributed deep learning models






J Am Med Inform Assoc 25(8):945-954, 2018

## CWT has similar performance to centrally-hosted training




*Results based on having 4 institutions*



J Am Med Inform Assoc 25(8):945-954, 2018

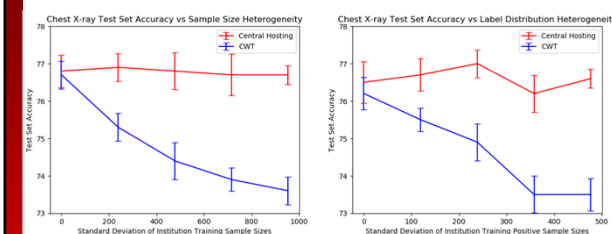
## Challenges to making distributed learning work

***Distributed model performance may be inferior to centrally hosted performance***

- **Heterogeneity in data** across institutions
  - Different patient populations (sample sizes, label distribution)
  - Differences in manifestation of disease
  - Different scanning hardware/parameters
  - Differences in image resolution
  - Differences in image quality
- Differences in **computing hardware** (GPU/CPU) among institutions
- Differences in **network bandwidth** among institutions



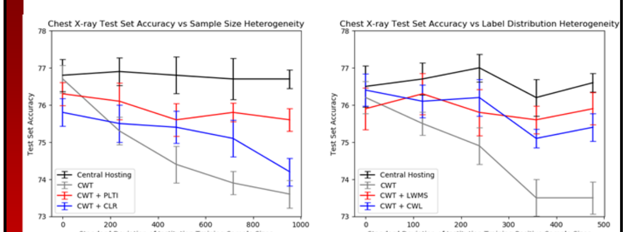
## Variability in sample size and label distribution (NIH Chest X-ray dataset)




- 4 institutions, GoogleNet for classification
- Each point is average across 10 runs
- We generate various institution splits such that there are different levels of variance in sample size and label distribution



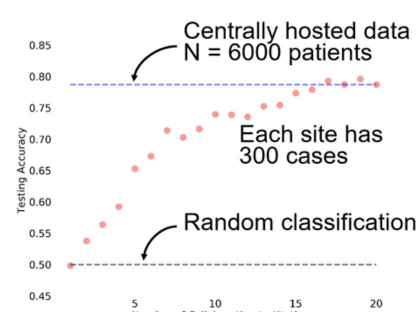
## Overcoming challenges of variability in data (NIH Chest X-ray dataset)




- 4 institutions, GoogleNet for classification
- Each point is average across 10 runs
- We generate various institution splits such that there are different levels of variance in sample size and label distribution



## Importance of sample size



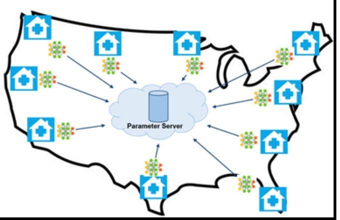

*Accuracy increases with number of collaborating institutions—amount of data (each site has 300 cases)*



J Am Med Inform Assoc 25(8):945-954, 2018

## The future: A collaborative AI ecosystem

- Each site specifies a dataset they wish to make available for building AI
- "Pop-up" collaborations to build AI models using distributed learning
- Full control over data and data use






## Summary

- We need AI in cancer imaging to reduce **variations in assessment of lesions**
- Key AI methods are automated **lesion detection** and **segmentation**
- Building robust AI models requires much data
- Data from multiple institutions can be leveraged through distributed learning
  - Heterogeneities among sites is a challenge
  - Optimizations in distributed computational approaches can overcome challenges



***Thank you.***

**Contact info:**
**dlrubin@stanford.edu**