

Improving Tuberculosis(TB) Diagnostics using Deep Learning and Mobile Health Technologies among Resource-poor and Marginalized Communities

Yu Cao¹, Chang Liu¹, Benyuan Liu¹, Maria J. Brunette¹, Ning Zhang¹, Tong Sun¹,
Peifeng Zhang¹, Jesus Peinado², Epifanio Sanchez Garavito³, Leonid Lecca
Garcia³, Walter H. Curioso⁴

¹University of Massachusetts, Lowell

²Partners in Perú

³National Hospital Sergio E.Bernales Perú,

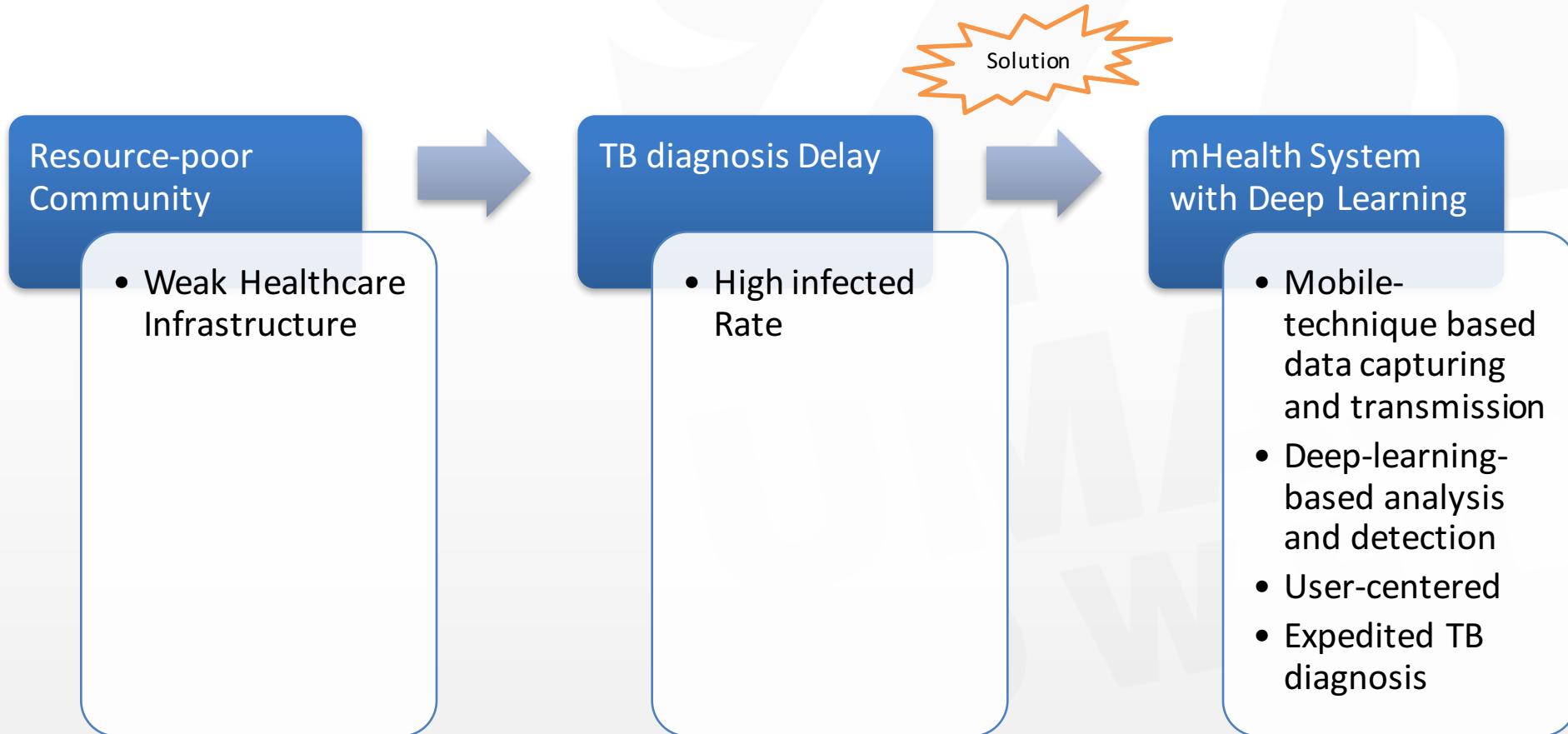
⁴University of Washington, Seattle



Tuberculosis(TB)

- ▶ A **chronic and infectious** disease
- ▶ Affects the **most disadvantaged populations** and involves complex treatment regimes
- ▶ More than **9 million** estimated new case and **1.5 million** deaths every year
- ▶ Over 80% were in South-East Asia, Western Pacific and African(2013)
- ▶ Majority of the infected populations was from **resource-poor** and **marginalized** communities.

Tuberculosis Diagnostics



Related Work

- ▶ mHealth in developing country for TB diagnosis
 - “Mobile health for public health in Peru: lessons learned”, 2015, E. F. Ruiz et al.
 - “Emerging technologies for monitoring drug-resistant tuberculosis at the point-of-care”, 2014, V. Mani et al.
- ▶ Develop Chest X-ray image database
 - Most of TB screen dataset have less than 200 images
 - ImageCLEF, JSRT Digital Image Database, ANODE Grand Challenge Database etc.. , but only contains one or two TB manifestation
- ▶ Computer-aided system to screen the chest radiography image for TB diagnosis
 - Computer-aided screening and scoring algorithms using chest radiographic features for TB diagnosis
 - X-ray image categorization on organ and pathology level



mHealth

Challenge

Lack of large scale, well-annotated, real-world X-ray Image Dataset

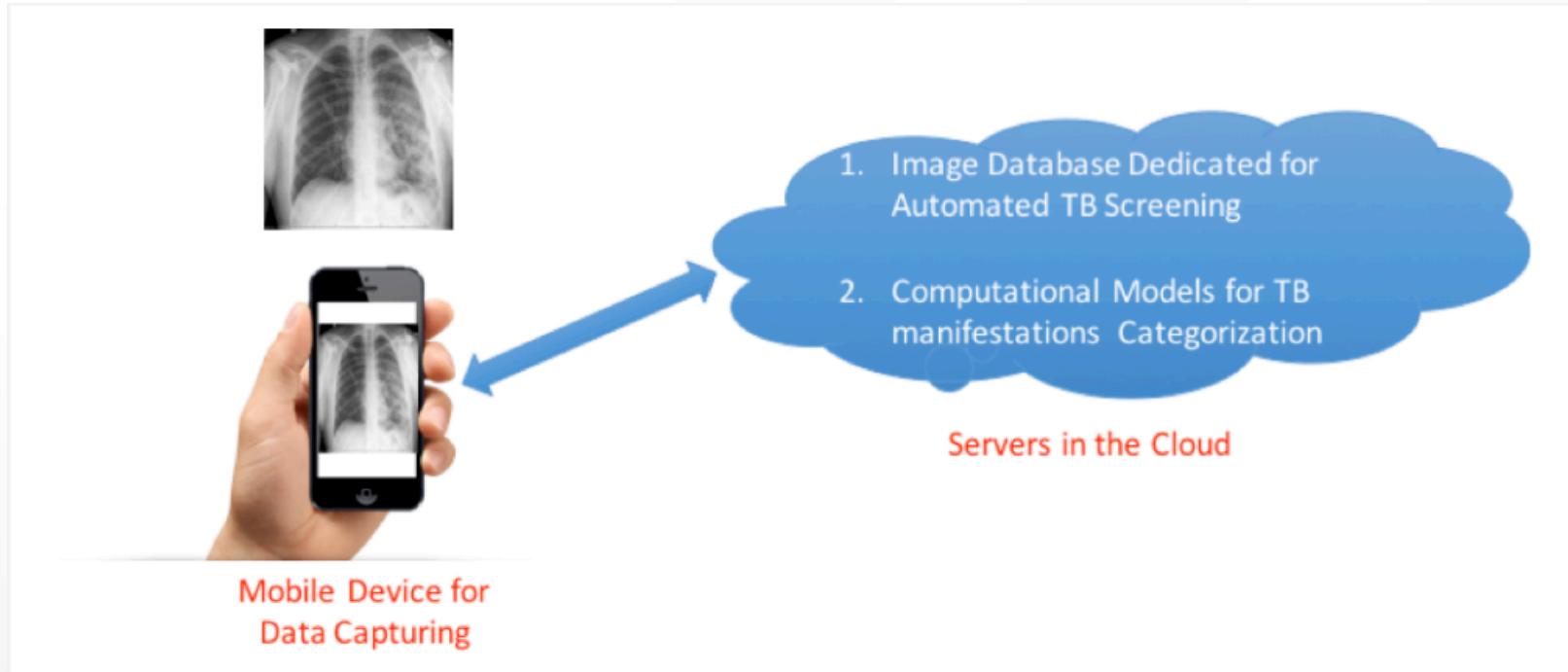
Lack of mobile device-based computing system

Solution!

- * International research team
 - * Clinical and research collaborators
 - * Develop Annotation software

- * Develop a Mobile-cloud system
 - * Deep learning model Training in cloud server

System Overview



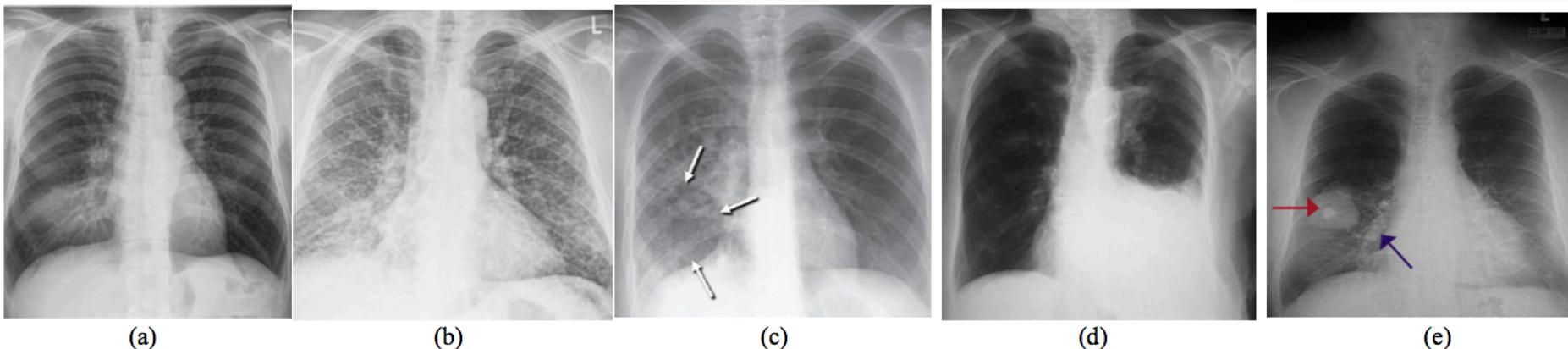
▶ Mobile Application

- Image Capturing and Data Transmission

▶ Cloud Server

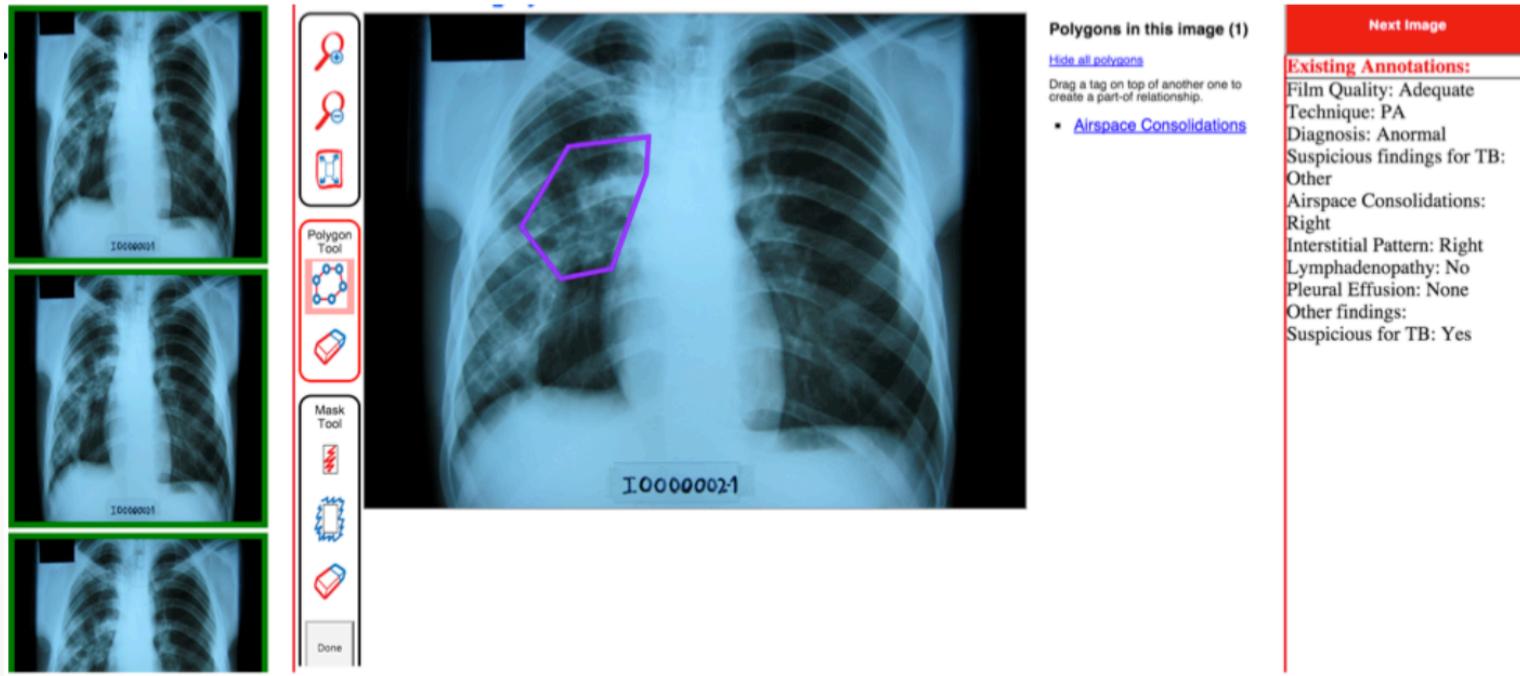
- X-ray Image Annotation
- Deep Learning(CNN)-based Data Analytics

TB Manifestation



- ▶ (a) Air space consolidation which showing glass opacity with consolidation in the right middle lobe;
- ▶ (b) Miliary pattern with seed-like appearance;
- ▶ (c) Cavity located at the lower lobe (annotated by arrows);
- ▶ (d) Pleural effusion, which is excess fluid that accumulates in the pleural cavity;
- ▶ (e) Calcified granulomata: The red arrow indicates a large 5 cm diameter squamous cell carcinoma of the right lower lobe and there is 1.5 cm bright opacity in the middle of the mass (which is a calcified granuloma). Additional calcified granulomatous areas are medial to the mass, as indicated by blue arrow.

Annotation Software

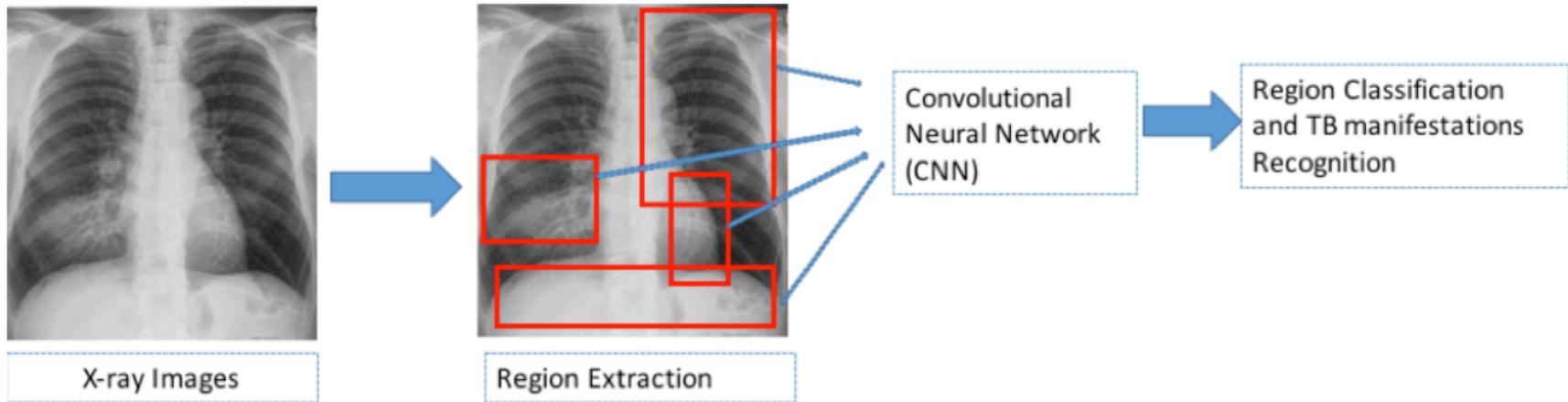


* Modified from open source software

- ▶ Left Panel: Lists of Images
- ▶ Middle Panel: Annotation tools
- ▶ Right Panel: existing annotation details



Proposed Computational Model



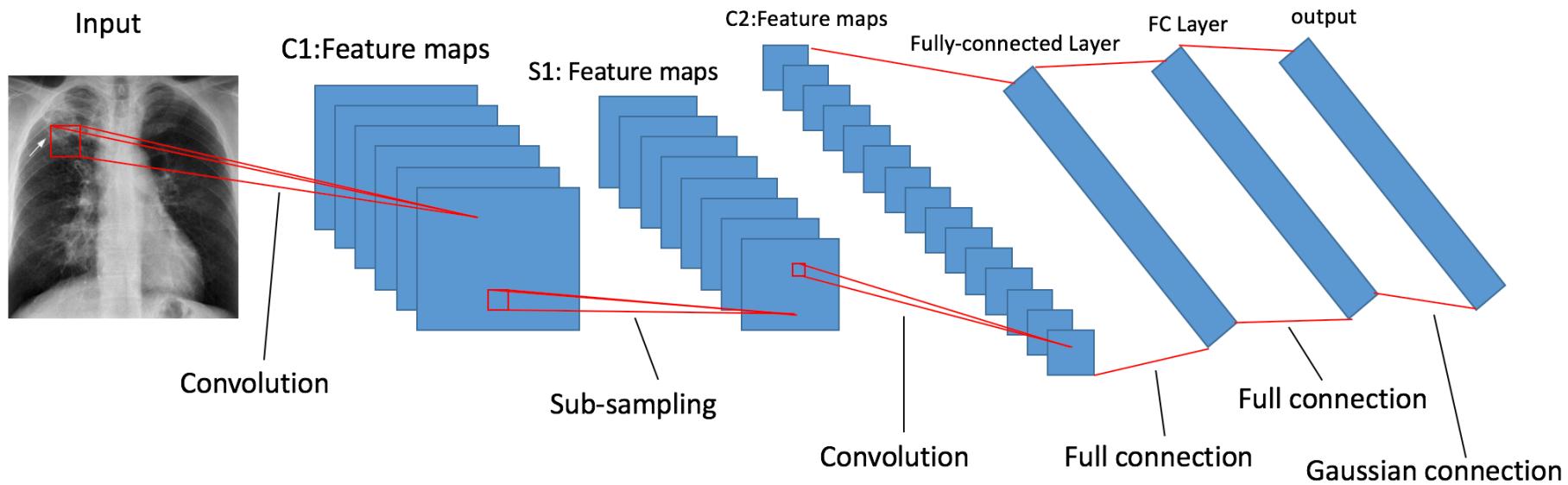
- ▶ Extraction of region proposal
- ▶ Compute CNN features
- ▶ Region Classification
- ▶ TB manifestation recognition

Proposed Approach: Deep Learning

- ▶ A branch of *machine learning*
- ▶ Attempts to model *high-level abstractions* in data by using *model architectures*
- ▶ Multiple layers of *nonlinear* processing units
- ▶ The unsupervised or supervised learns ***feature representations*** in each layer, with the layers forming a hierarchy from *low-level* to *high-level* features
- ▶ Among various techniques, **Convolutional Neural Network(CNN)** has achieved most promising result in *classification* and *object detection* for images.



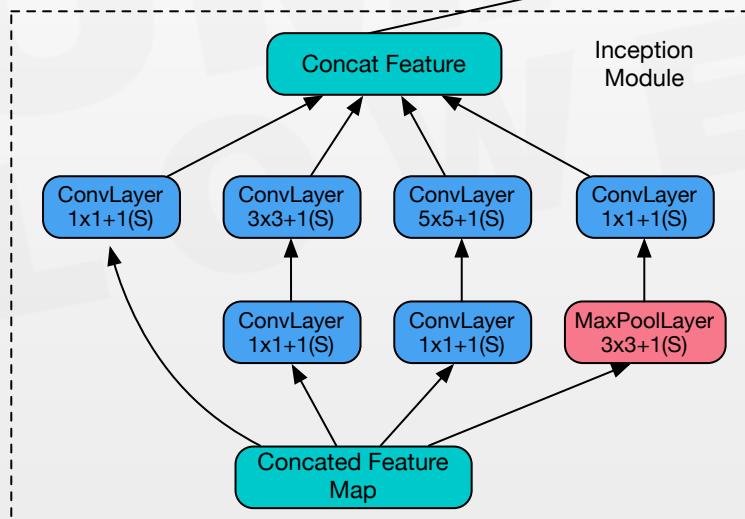
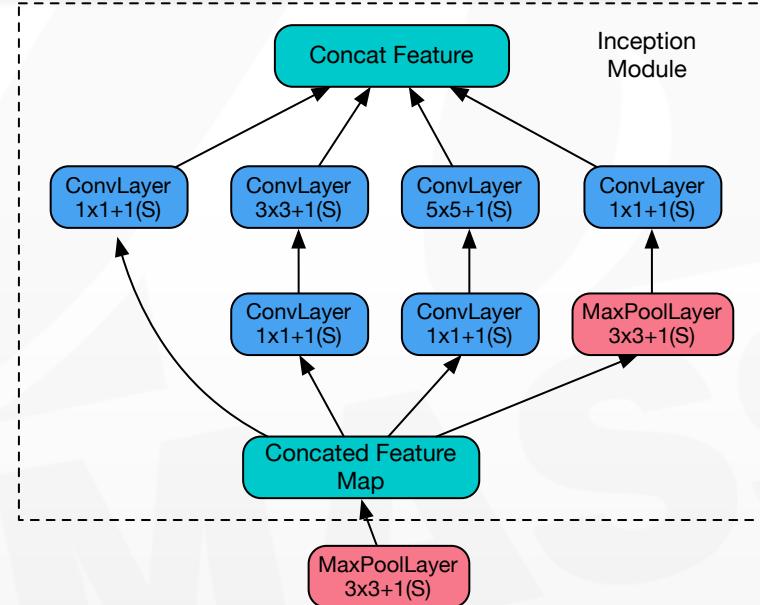
Proposed Approach: Deep Learning (CNN) Model Structure



- ▶ Input
- ▶ Convolutional Layer
- ▶ Sub-sampling/Pooling Layer
- ▶ Fully-connected Layer
- ▶ Output

Proposed Approach: Model Optimization

- ▶ Proposed approach for model optimization
 - Hinted by two recent advances
 - Network in Network
 - GoogLeNet
 - 22 Layers
 - Inception Model
 - Repeated inceptions
 - Smaller convolution size



Proposed Approach: Training Strategy

Dataset

- ImageNet (millions of images)
- X-ray TB image datasets(~ 4700 images)

Caffe + Cuda 6.5

- Model Zoo(publicly released)
- GPU accelerating, Nvidia K80

Pretrain + finetune

- GoogLeNet Model on ImageNet
- Finetune on our TB datasets



Experimental Result(1)

- ▶ Dataset: 4701 images from Peru
- ▶ Two categories: Abnormal(4248 images) vs Normal (453 images)
- ▶ Convolutional Neural Network(CNN)
 - GoogLeNet Model
 - Pre-trained on ImageNet, fine-tuned on our X-ray dataset
 - Binary classification: 4/5 of the images for training, 1/5 of the images for testing

# of iteration	10,000	30,000	50,000	80,000	100,000
Average precision	82.8%	88.6%	89.0%	89.5%	89.6%

Table1: Average Precision for binary classification

Experimental Result(2)

- Dataset: 4701 images from Peru
- Four categories, Same training strategy

Category(TB Manifestation)	Total Image #	Image # Used for Training	Image # Used for Testing
Cavitation	1182	946	246
Lymphadenopathy	202	162	40
Infiltration	2252	1802	450
Pleural Effusion	560	448	112

Table2: Data distribution for different TB manifestation

# of iteration	10,000	30,000	50,000	80,000	100,000
Average precision	43.48%	61.68%	61.92%	62.05%	62.07%

Table3: Average Precision for multi-class classification

Conclusion

- ▶ Mobile technologies have the potential to reduce the burden of TB for better diagnosis.
- ▶ Deep learning technology, especially CNN, can further improve the classification accuracy of X-ray images.
- ▶ Our integrated system can reduce the diagnosis time, within resource-poor and marginalized communities.



Future Work

- ▶ Continue to develop the large scale, real-world X-ray TB database.
- ▶ Improve the classification accuracy for the deep learning computational models.
- ▶ Implement a scalable solution by making the mobile device based system available as an open source platform
- ▶ Conduct field-testing in tuberculosis clinics in Peru.



Acknowledgement

- ▶ *This project is supported in part by*
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Q&A

Thank you!

