Rethinking Computer-aided Tuberculosis Diagnosis

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http://mmcheng.net/tb/

What is tuberculosis (TB)?

- The **second leading cause of death** by infectious disease (after HIV)
- Induced by Mycobacterium TB
- Typically infects the **lungs**
- 8,000,000 - 10,000,000 new TB patients every year
- 2,000,000 - 3,000,000 deaths every year

What is the significance of TB diagnosis?

- Early diagnosis of TB
  - improves the chances of survival greatly
  - helps control the spread of infection
  - tracks the process of clinical treatment

  - is **the key** to the prevention and treatment of TB

How to diagnose TB?

- Golden standard: diagnostic microbiology for the identification of Mycobacterium TB
  - Biosafety level-3 lab (**BSL-3**) is needed
  - It requires **several months** for this process
- Early TB screening through X-rays
  - **Common** and data-intensive
  - **Low accuracy** (68.7% in our study)
- **Motivation: Adopt deep learning for computer-aided TB diagnosis/screening with X-ray images**

- **Challenges**
  - Deep learning is always **data-hungry**
  - The publicly available TB data are **very limited**

Datasets	Year	Class	Label	Sample
MC [1]	2014	2	Image-level	138
Shenzhen [1]	2014	2	Image-level	662
DA [2]	2014	2	Image-level	156
DB [2]	2014	2	Image-level	150
TBX11K	2020	4	Bounding box	11200

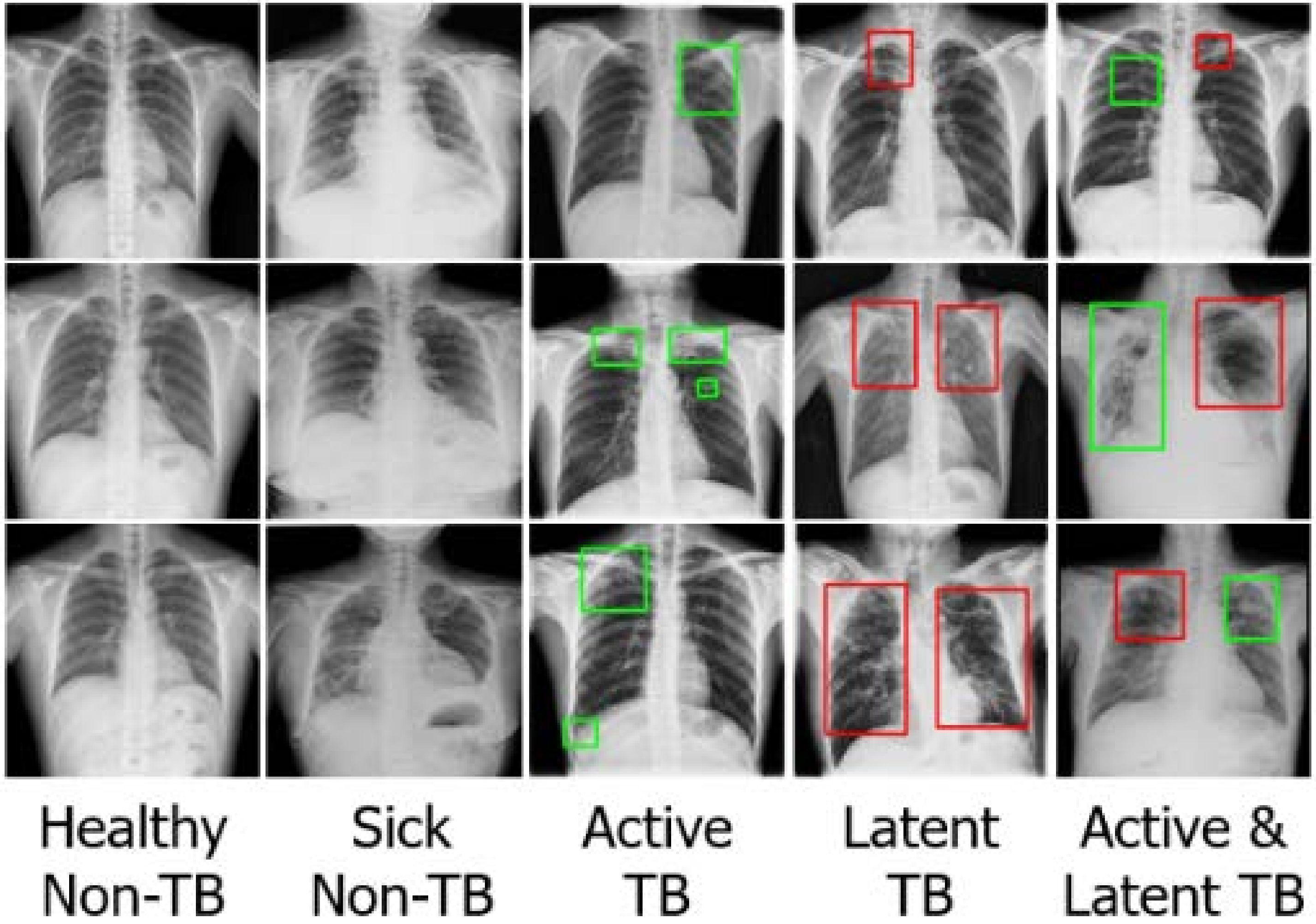
Summary of publicly available TB datasets, among which TBX11K is ours.

[1] Jaeger S, Candemir S, Antani S, et al. Two public chest X-ray datasets for computer-aided screening of pulmonary diseases[J]. QIMS, 2014, 4(6): 475.
[2] Chauhan A, Chauhan D, Rout C. Role of Gist and PHOG features in computer-aided diagnosis of tuberculosis without segmentation[J]. PloS One, 2014, 9(11).

Tuberculosis X-ray (TBX11K) Dataset

- We contribute to the community with a large-scale Tuberculosis X-ray (**TBX11K**) dataset which
  - is **17×larger** than the existing largest dataset
  - annotates TB areas using **bounding boxes**
    - gold standard, double-check
  - includes **four categories** of healthy, sick but non-TB, active TB, and latent TB

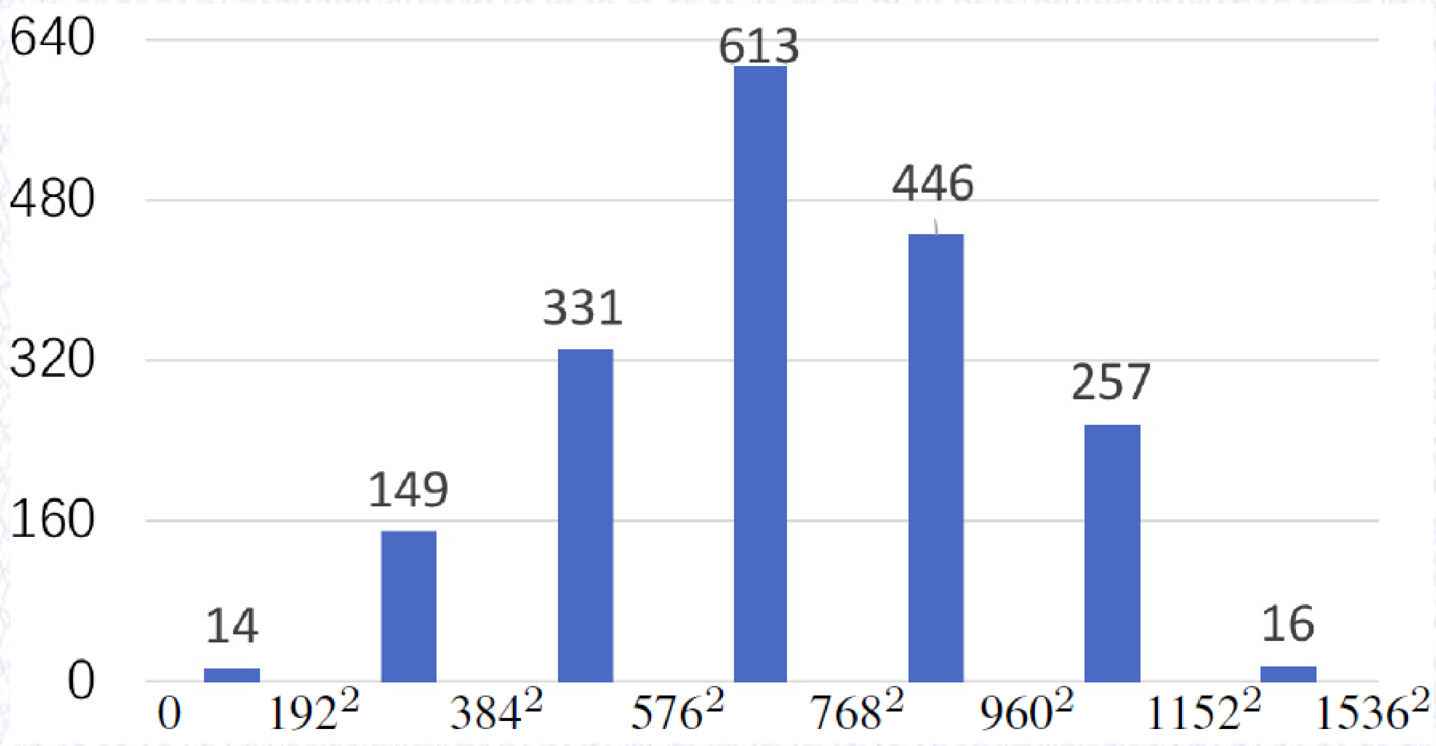
TBX11K


Healthy
Non-TB
Sick
Non-TB
Active
TB
Latent
TB
Active &
Latent TB

- Split for the proposed TBX11K dataset

	Class	Train	Val	Test	Total
Non-TB	Healthy	3000	800	1200	5000
	Sick & Non-TB	3000	800	1200	5000
TB	Active TB	473	157	294	924
	Latent TB	104	36	72	212
	Active & Latent TB	23	7	24	54
	Uncertain TB	0	0	10	10
Total		6600	1800	2800	11200

- Distribution of the areas of TB bounding boxes



Experiments

- Task: Simultaneous X-ray image classification and TB area detection
- Baselines: SSD[1], RetinaNet[2], Faster R-CNN[3], FCOS[4]
  - Adding an image classification branch
  - Two-stage training

[1] Liu W, Anguelov D, Erhan D, et al. SSD: Single shot multibox detector[C]//ECCV. Springer, Cham, 2016: 21-37.
[2] Lin T Y, Goyal P, Girshick R, et al. Focal loss for dense object detection[C]//IEEE ICCV. 2017: 2980-2988.
[3] Ren S, He K, Girshick R, et al. Faster R-CNN: Towards real-time object detection with region proposal networks[C]//NIPS. 2015: 91-99.
[4] Tian Z, Shen C, Chen H, et al. FCOS: Fully convolutional one-stage object detection[C]//IEEE ICCV. 2019: 9627-9636.

Method	Pretrained	Backbone	Accuracy	AUC (TB)	Sensitivity	Specificity	Ave. Prec.	Ave. Rec.
SSD	Yes	VGGNet-16	84.7	93.0	78.1	89.4	82.1	83.8
RetinaNet		ResNet-50 w/ FPN	87.4	91.8	81.6	89.8	84.8	86.8
Faster R-CNN		ResNet-50 w/ FPN	**89.7**	**93.6**	**91.2**	**89.9**	**87.7**	**90.5**
FCOS		ResNet-50 w/ FPN	88.9	92.4	87.3	**89.9**	86.6	89.2
SSD	No	VGGNet-16	**88.2**	**93.8**	**88.4**	89.5	**86.0**	**88.6**
RetinaNet		ResNet-50 w/ FPN	79.0	87.4	60.0	**90.7**	75.9	75.8
Faster R-CNN		ResNet-50 w/ FPN	81.3	89.7	72.5	87.3	78.5	79.9

X-ray image classification results on the proposed TBX11K test data

Method	Data	Pretrained	Backbone	CA TB		Active TB		Latent TB	
				AP_{50}^{bb}	AP^{bb}	AP_{50}^{bb}	AP^{bb}	AP_{50}^{bb}	AP^{bb}
SSD	ALL	Yes	VGGNet-16	52.3	22.6	50.5	**22.8**	8.1	**3.2**
RetinaNet			ResNet-50 w/ FPN	52.1	22.2	45.4	19.6	6.2	2.4
Faster R-CNN			ResNet-50 w/ FPN	**57.3**	**22.7**	**53.3**	21.9	**9.6**	2.9
FCOS			ResNet-50 w/ FPN	46.6	18.9	40.3	16.8	6.2	2.1
SSD		No	VGGNet-16	**61.5**	**26.1**	**60.0**	**26.2**	**8.2**	**2.9**
RetinaNet			ResNet-50 w/ FPN	20.7	7.2	19.1	6.4	1.6	0.6
Faster R-CNN			ResNet-50 w/ FPN	21.9	7.4	21.2	7.1	2.7	0.8
SSD	TB	Yes	VGGNet-16	68.3	**28.7**	**63.7**	**28.0**	**10.7**	4.0
RetinaNet			ResNet-50 w/ FPN	**69.4**	28.3	61.5	25.3	10.2	**4.1**
Faster R-CNN			ResNet-50 w/ FPN	63.4	24.6	58.7	23.7	9.6	2.8
FCOS			ResNet-50 w/ FPN	56.3	22.5	47.9	19.8	7.4	2.4
SSD		No	VGGNet-16	**69.6**	**29.1**	**67.0**	**29.0**	**9.9**	**3.5**
RetinaNet			ResNet-50 w/ FPN	40.5	13.8	37.8	12.7	3.2	1.1
Faster R-CNN			ResNet-50 w/ FPN	37.4	11.8	35.3	11.3	3.9	1.1
FCOS			ResNet-50 w/ FPN	42.1	14.4	38.5	13.6	4.3	1.1

TB area detection results on the proposed TBX11K test set

Thank you!