AUTOMATIC CATHETER DETECTION IN PEDIATRIC X-RAY IMAGES USING A SCALE-RECURRENT NETWORK AND SYNTHETIC DATA

Yi X., Adams S., Babyn P., Elnajmi A.
Department of Medical Imaging, University of Saskatchewan

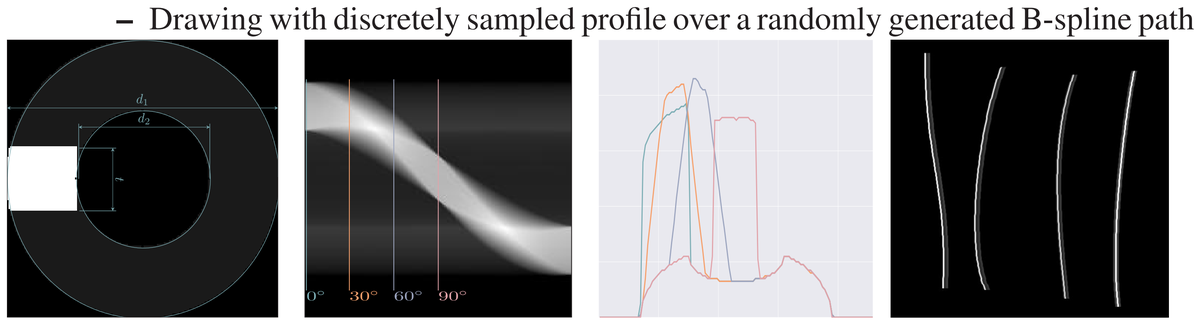
UNIVERSITY OF SASKATCHEWAN

ABSTRACT

Catheters are commonly inserted life supporting devices. X-ray images are used to assess the position of a catheter immediately after placement as serious complications can arise from malpositioned catheters. Previous computer vision approaches to detect catheters on X-ray images either relied on low-level cues that are not sufficiently robust or only capable of processing a limited number or type of catheters. With the resurgence of deep learning, supervised training approaches are begining to showing promising results. However, dense annotation maps are required, and the work of a human annotator is hard to scale. In this work, we proposed a simple way of synthesizing catheters on X-ray images and a scale recurrent network for catheter detection. By training on adult chest X-rays, the proposed network exhibits promising detection results on pediatric chest/abdomen X-rays in terms of both precision and recall.

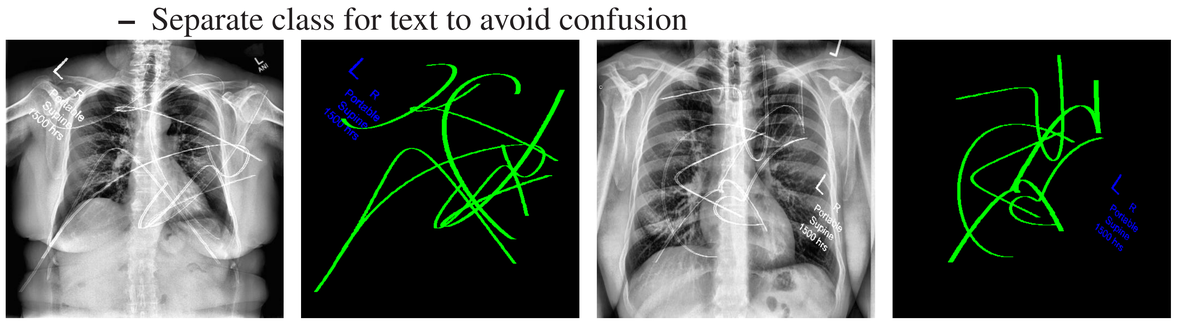
METHODS

- Synthesizing training dataset
  - Single sided cross-section profile for NGT, ETT and double sided cross-section profile for UVC, UAC
  - Projected sinogram with parallel beam geometry
  - Drawing with discretely sampled profile over a randomly generated B-spline path



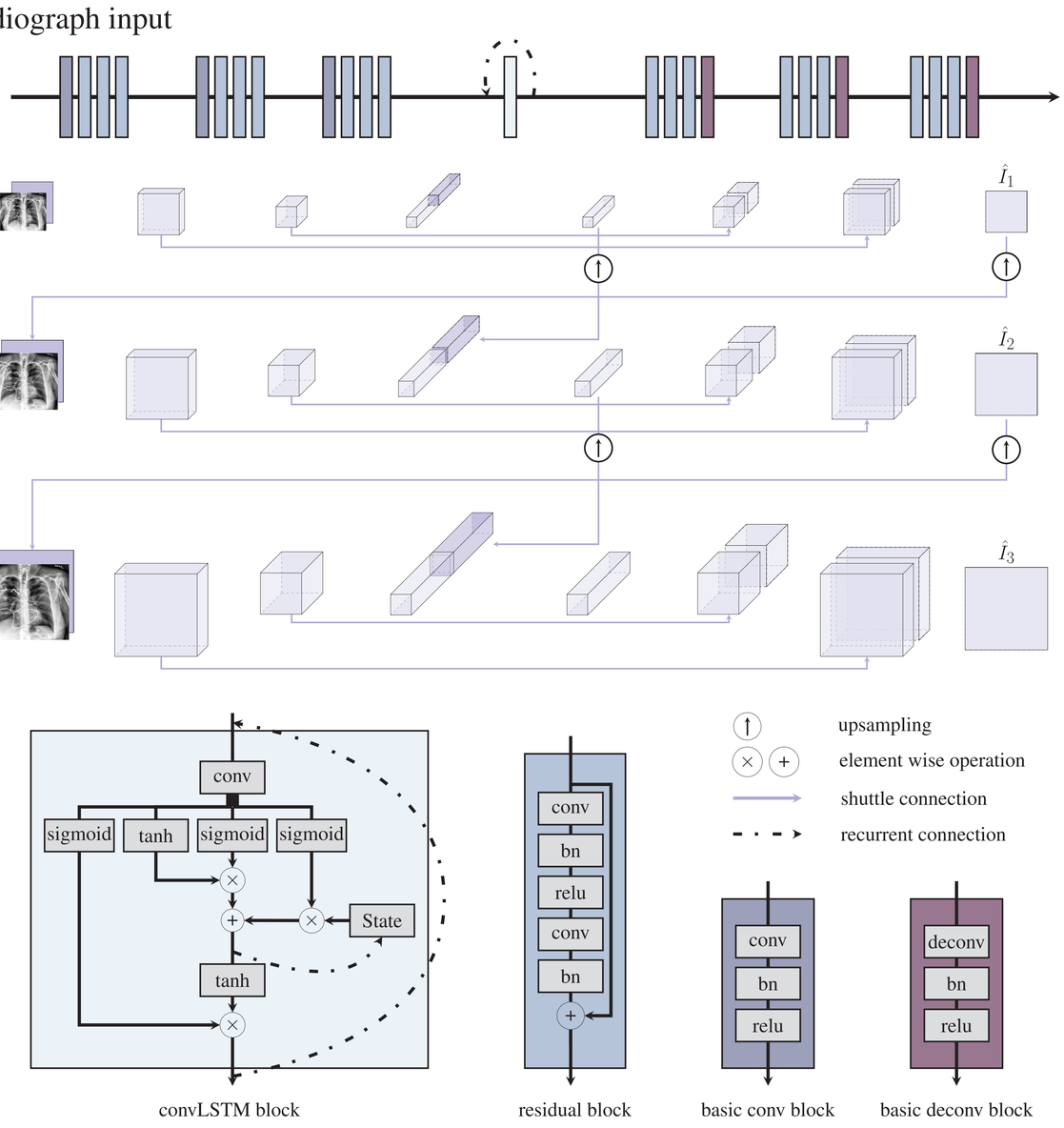
(a) (b) (c) (d)

- Generated training samples
  - 2515 frontal adult chest-Xrays from NIH Open-i dataset [1] of size 512×512
  - Separate class for text to avoid confusion



(a1) (b1) (a2) (b2)

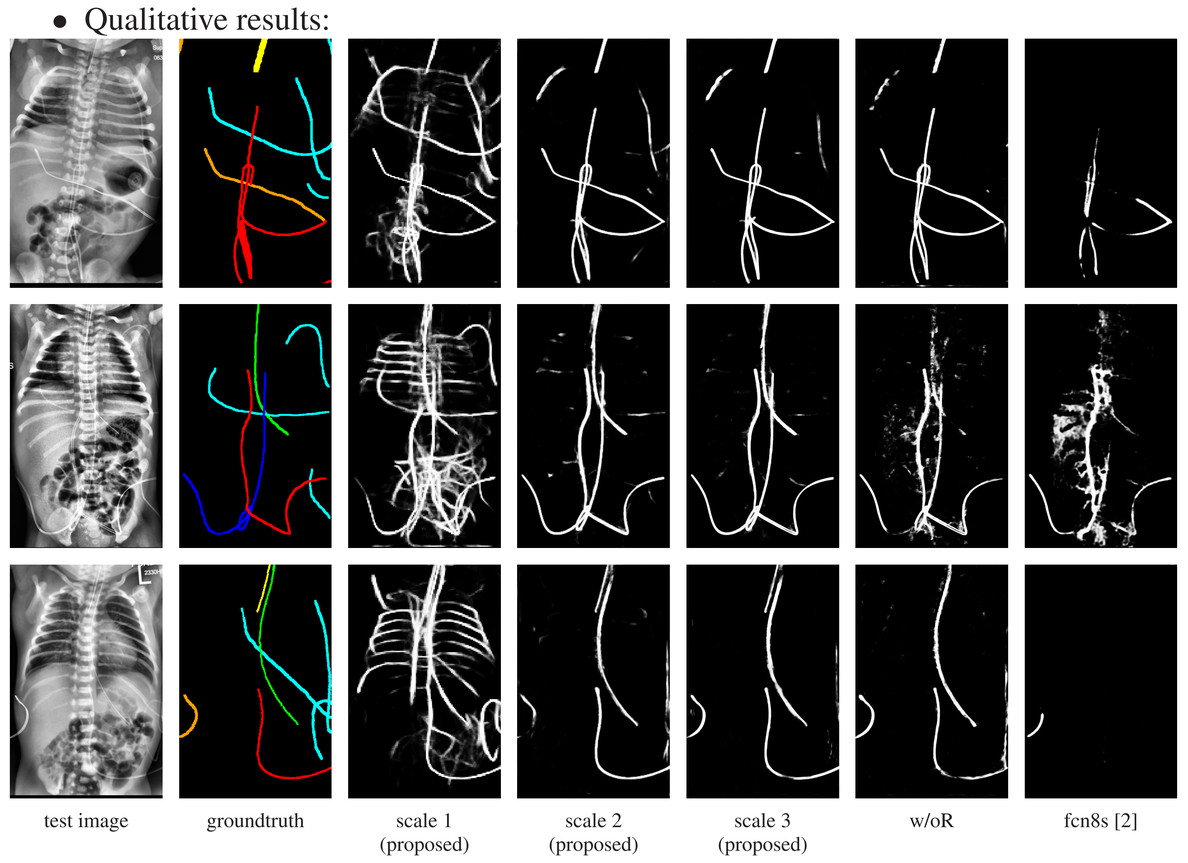
- Test dataset
  - Collected locally and only contains frontal chest-abdominal X-rays from patients < 4 weeks old (35 annotated images)
  - All images preprocessed by contrast limited adaptive histogram equalization
- Scale recurrent neural network [3] that exploits the multi-scale information of the radiograph input



convLSTM block residual block basic conv block basic deconv block

RESULTS

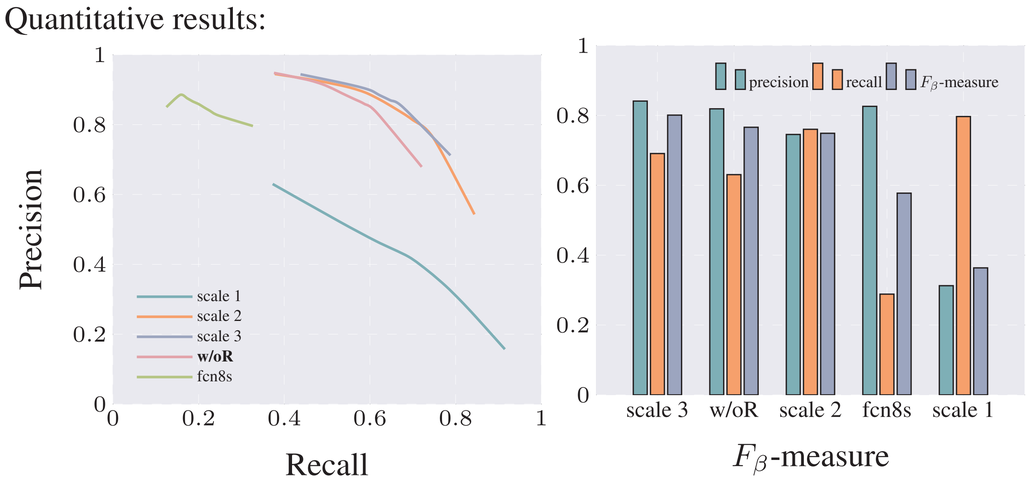
- Qualitative results:



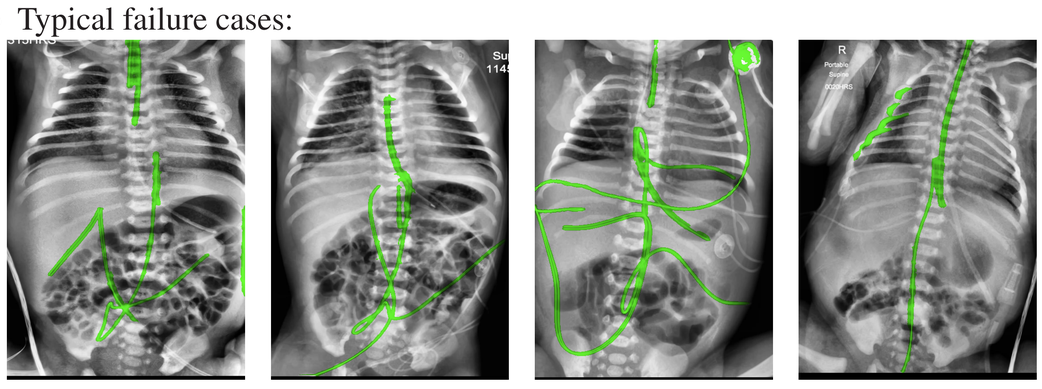
test image groundtruth scale 1 (proposed) scale 2 (proposed) scale 3 (proposed) w/oR fcn8s [2]

Umbilical venous catheter (UVC) Umbilical arterial catheter (UAC) Nasogastric tube (NGT)
Endotracheal tube (ETT) ECG leads (ECG) Other tubes (OTT)
Background (BK)

- Quantitative results:



- Typical failure cases:



DISCUSSION AND CONCLUSION

- By training on adult chest X-rays with synthetic catheters, the detection network achieved promising results on real pediatric chest/abdomen X-rays.
- The likelihood map from the smallest scale contains almost all line-like structures, including not only catheters but also ribs and ECG leads. The segmentation recall was improved by iterating through the scale space of the radiograph input as compared to baselines.
- Catheters are represented as thin lines of just a few pixels wide on X-ray images. Therefore, a slight pixel shift in the ground truth annotation could adversely impact the quantitative results.
- Detection could fail for catheters with decreased visibility of the radiopaque strip; occluded by the abdomen; indistinguishable from the lateral aspect of the rib cage or unidentified line
- The approach described in this work may contribute to the development of a system to detect and assess the placement of catheters and tubes on X-ray images, thus providing a solution to triage and prioritize X-ray images which have potentially malpositioned catheters for a radiologists urgent review, and ensuring patient safety by alerting the clinician in a timely manner.

REFERENCES

[1] Dina Demner-Fushman, Marc D Kohli, Marc B Rosenman, Sonya E Shooshan, Laritza Rodriguez, Sameer Antani, George R Thoma, and Clement J McDonald. Preparing a collection of radiology examinations for distribution and retrieval. *Journal of the American Medical Informatics Association*, 23(2):304–310, 2015.

[2] Hyunkwang Lee, Mohammad Mansouri, Shahein Tajmir, Michael H Lev, and Synho Do. A deep-learning system for fully-automated peripherally inserted central catheter (picc) tip detection. *Journal of digital imaging*, pages 1–10, 2017.

[3] Xin Tao, Hongyun Gao, Yi Wang, Xiaoyong Shen, Jue Wang, and Jiaya Jia. Scale-recurrent network for deep image deblurring. *arXiv preprint arXiv:1802.01770*, 2018.