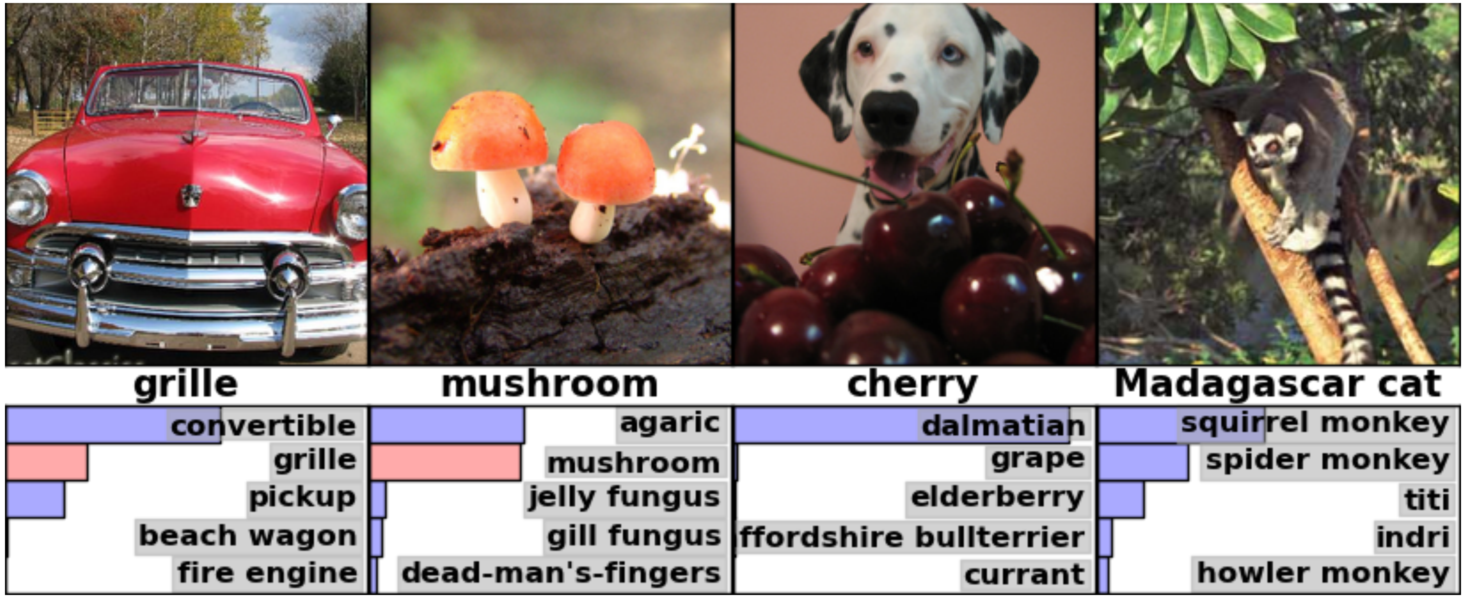
CNNs in Medicine: Beyond Classification

June 8, 2019

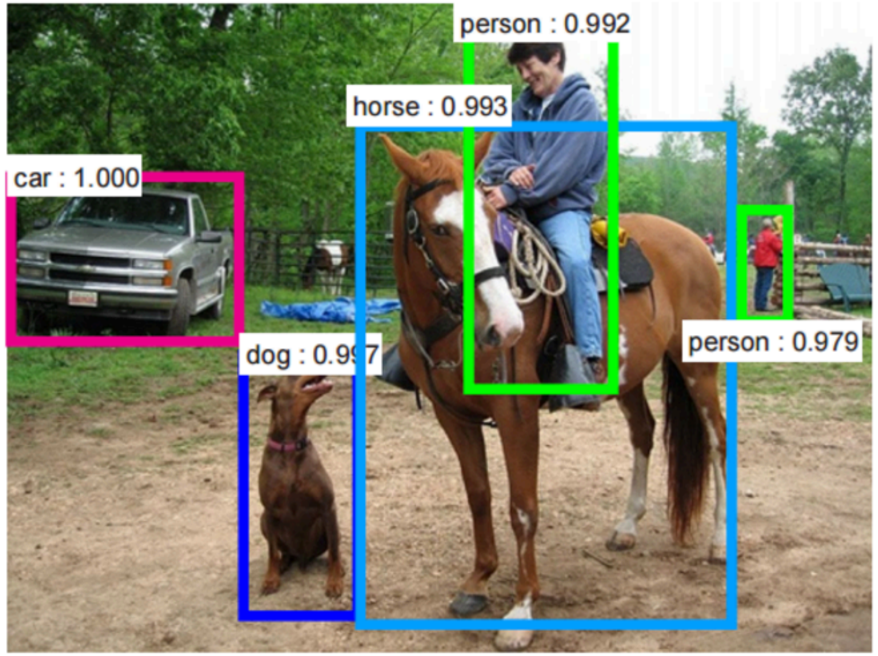
Block 2, Lecture 3
Applied Data Science
MMCi Term 4, 2019

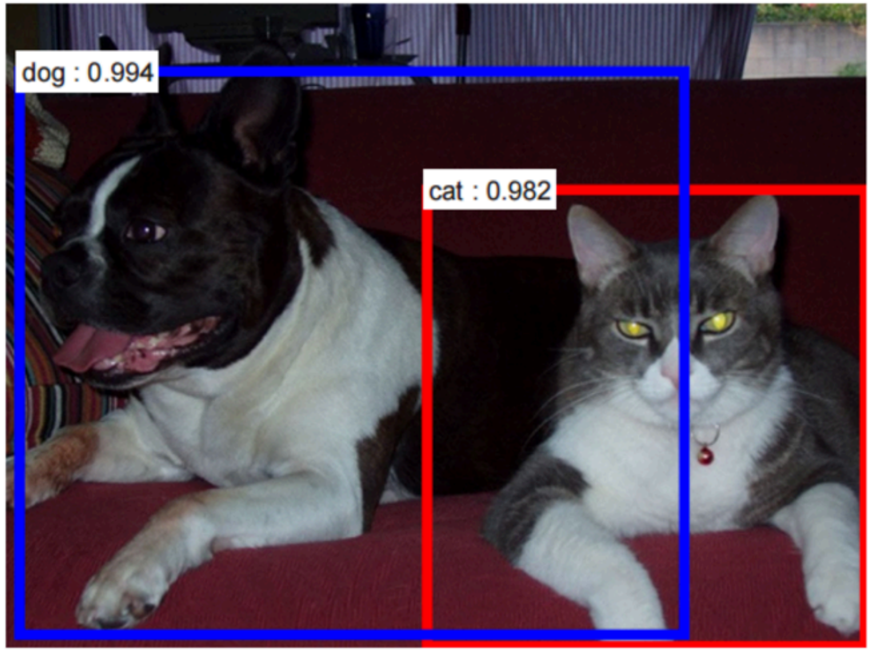
Matthew Engelhard

Which label is best?



Detection: propose regions and predict their labels





Detection Output

Number of classes C

Rows sum to 1

Variable Number of Detected Regions of Interest

(index omitted)

p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}

$$p_{ij} = p(y_i = j | x_i)$$

Detection Output

Number of classes C

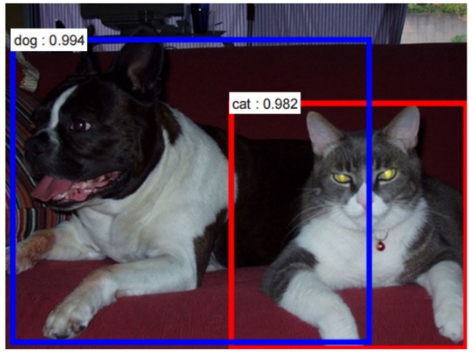
Rows sum to 1

2 detected ROIs

(index omitted)

p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}

$$p_{ij} = p(y_i = j | x_i)$$



Detection Output

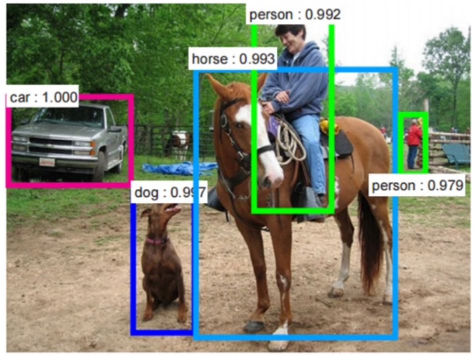
Number of classes C

Rows sum to 1

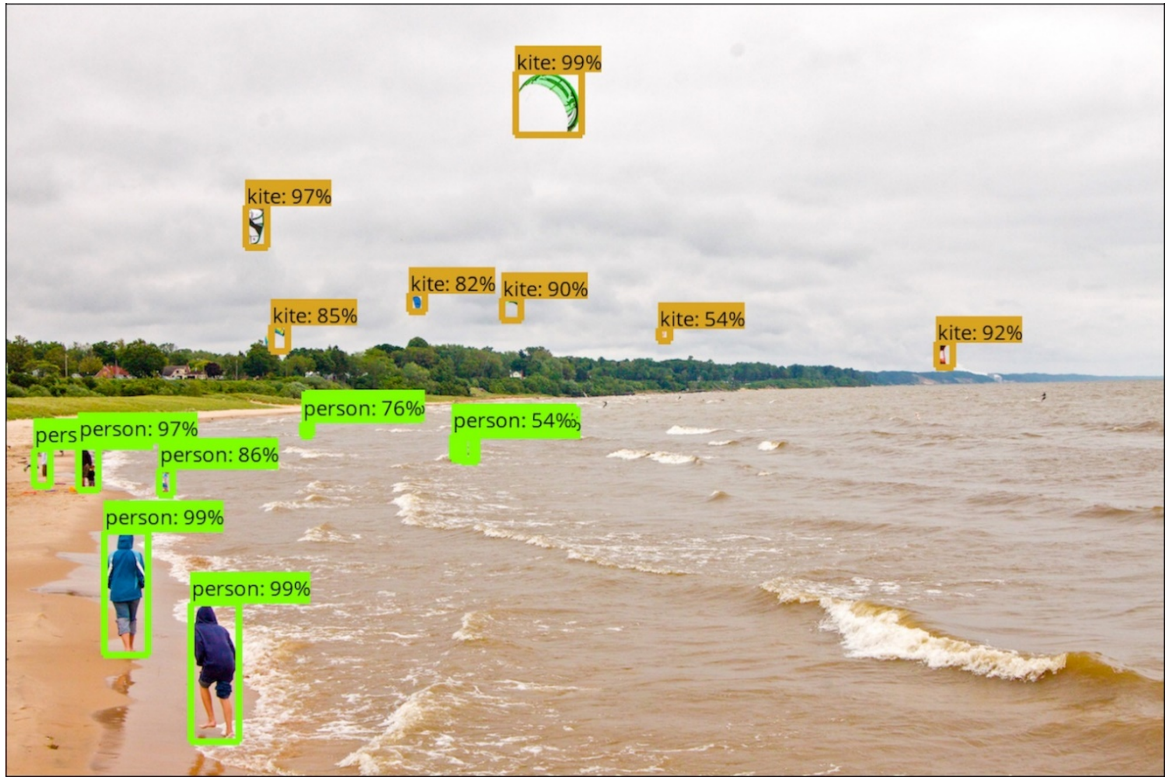
5 detected ROIs

(index omitted)

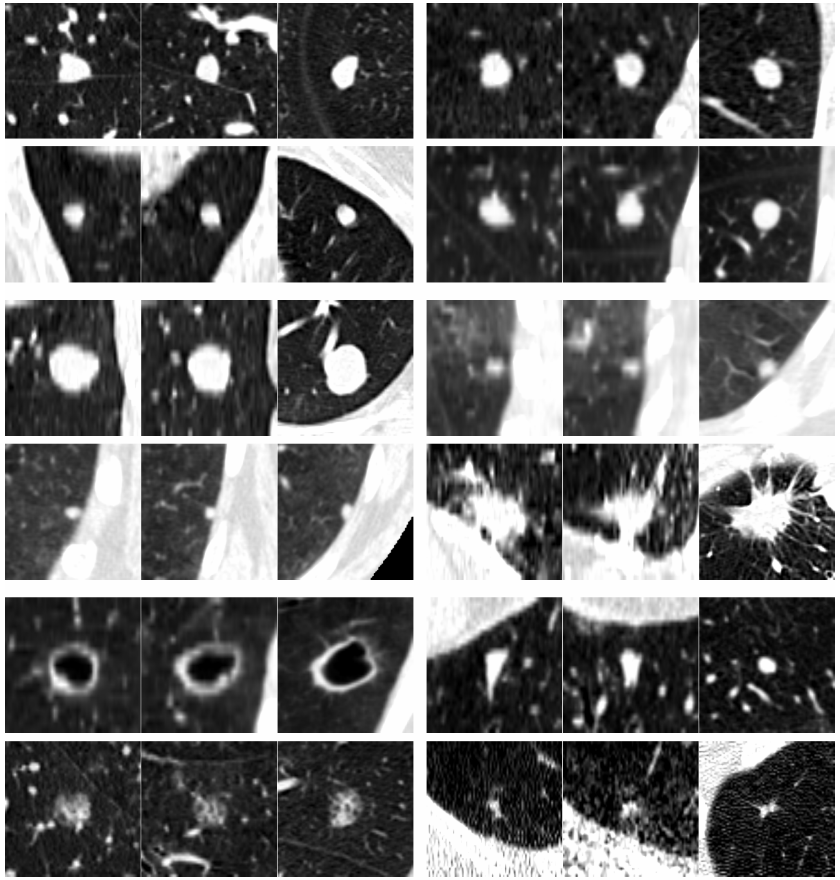
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}
p_{i1}	p_{i2}	p_{i3}	p_{i4}	p_{i5}	…	p_{iC}



Numerous real-world and medical applications

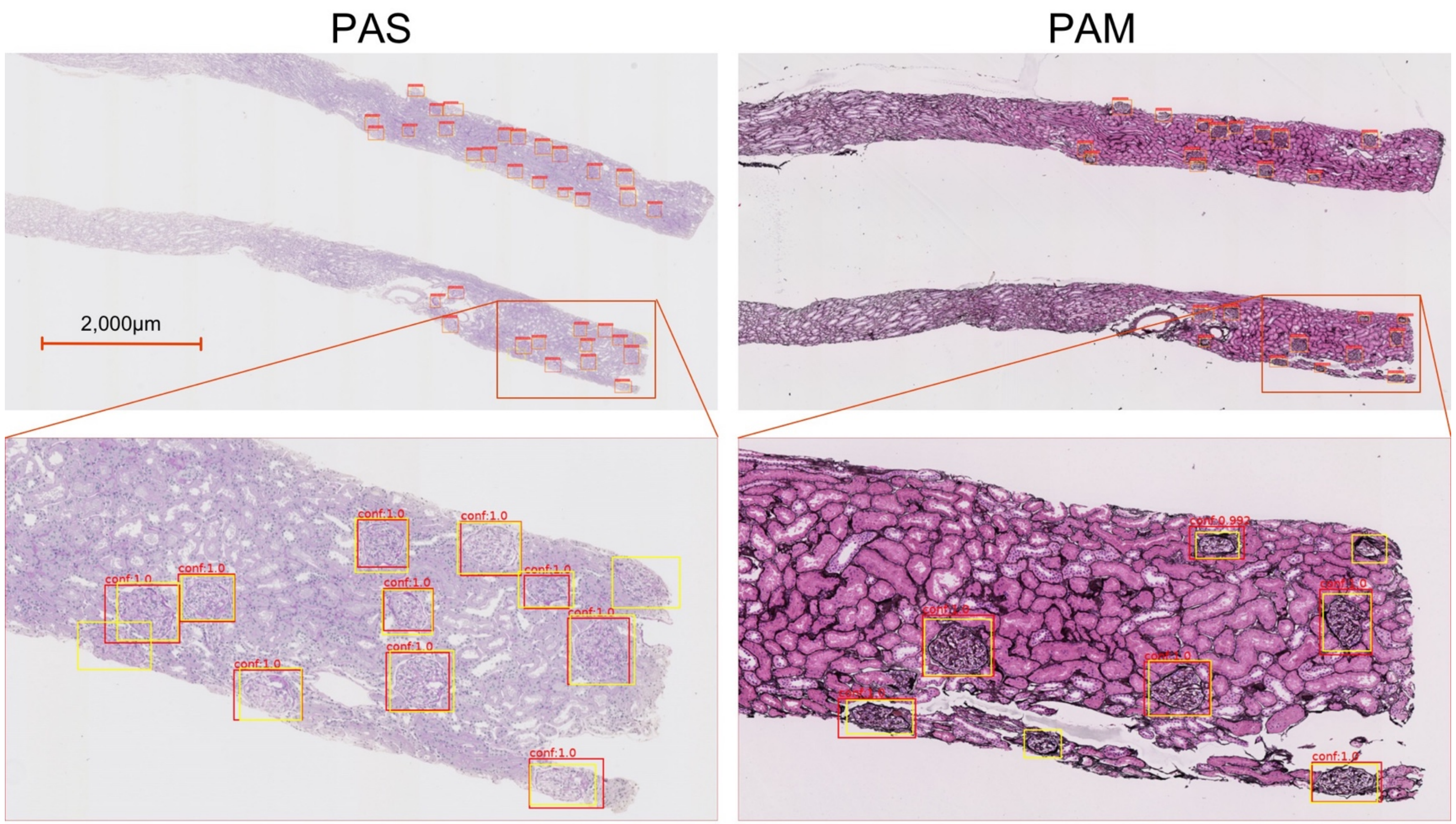


https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/img/kites_detections_output.jpg



van Ginneken B, Setio AA, Jacobs C, Ciompi F. Off-the-shelf convolutional neural network features for pulmonary nodule detection in computed tomography scans. InBiomedical Imaging (ISBI), 2015 IEEE 12th International Symposium on 2015 Apr 16 (pp. 286-289). IEEE.

Glomerular Detection with Faster-RCNN

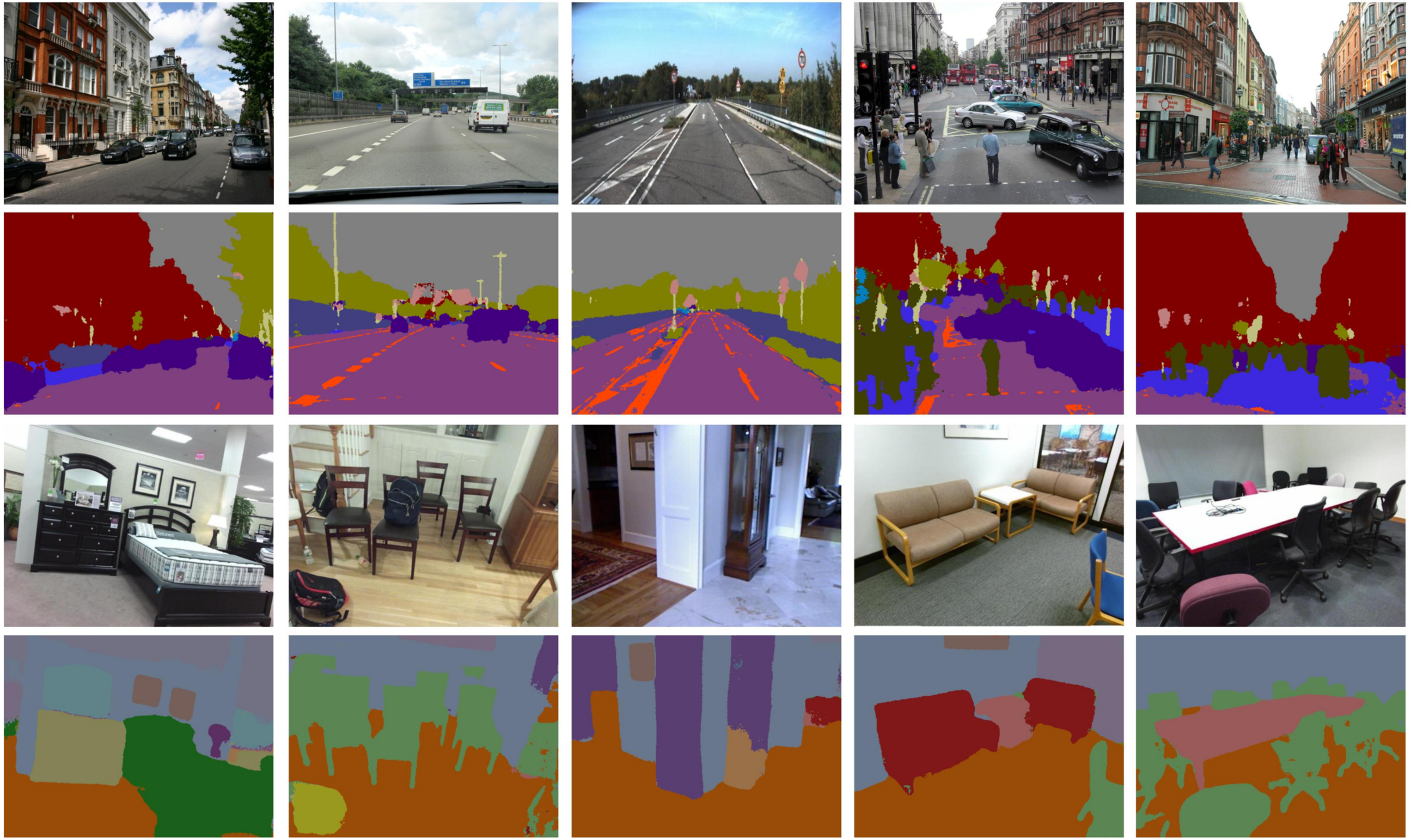


Kawazoe, Y., Shimamoto, K., Yamaguchi, R., Shintani-Domoto, Y., Uozaki, H., Fukayama, M., & Ohe, K. (2018). Faster R-CNN-Based Glomerular Detection in Multistained Human Whole Slide Images. *J. Imaging, 4*, 91.

Highlighting colon polyps or cerebral vasculature

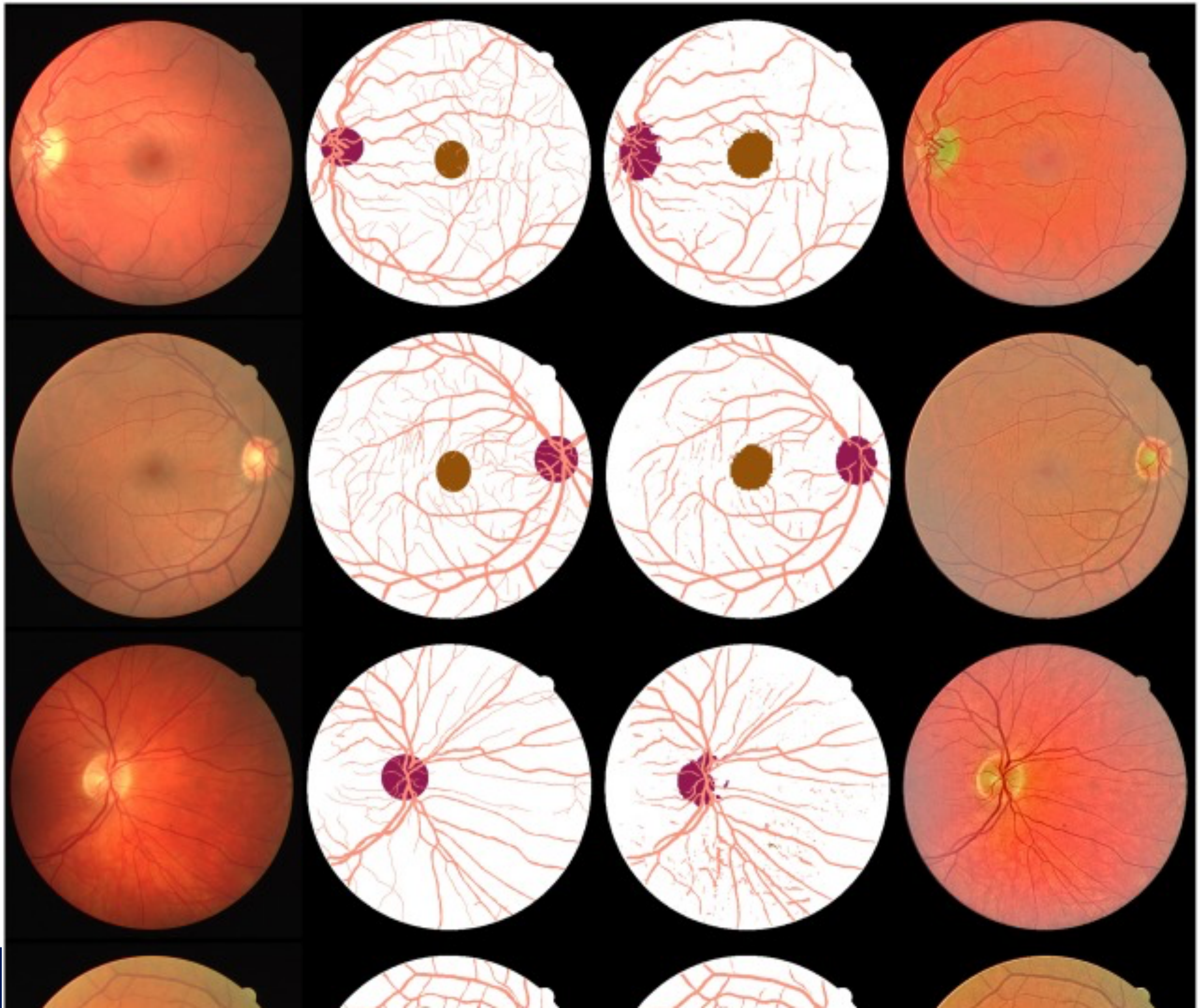
SEGMENTATION

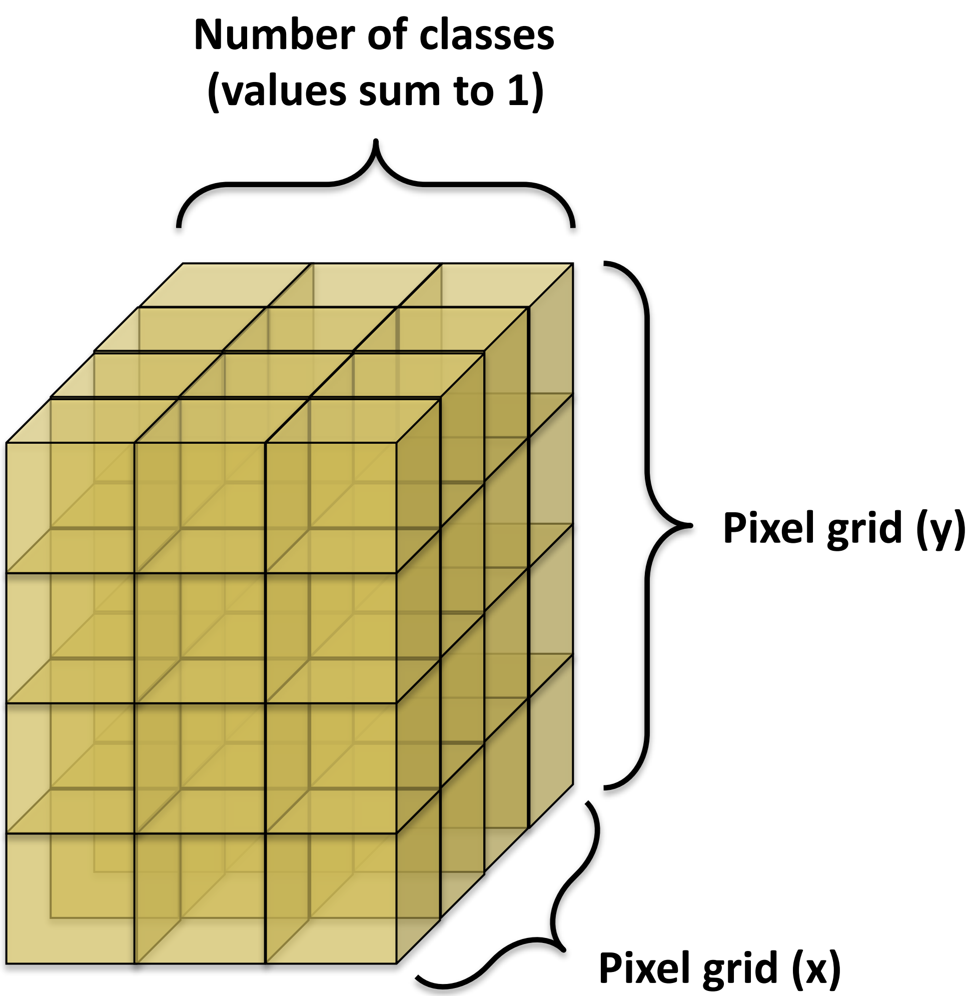
Segmentation: pixel-wise classification



Segmentation of optic disc, fovea and retinal vasculature

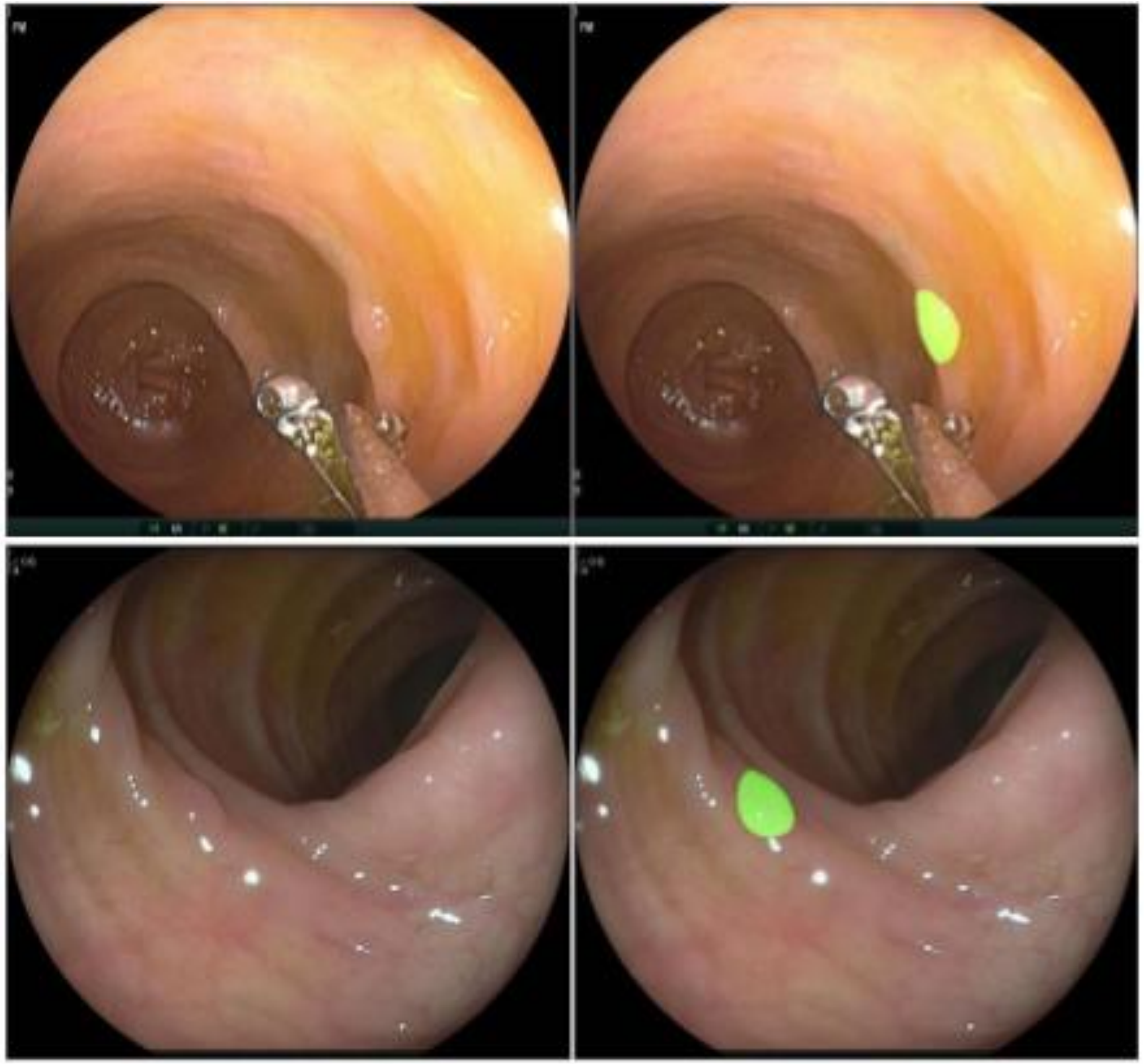
Journal of Computational Science, *20*, 70-79 (2017).



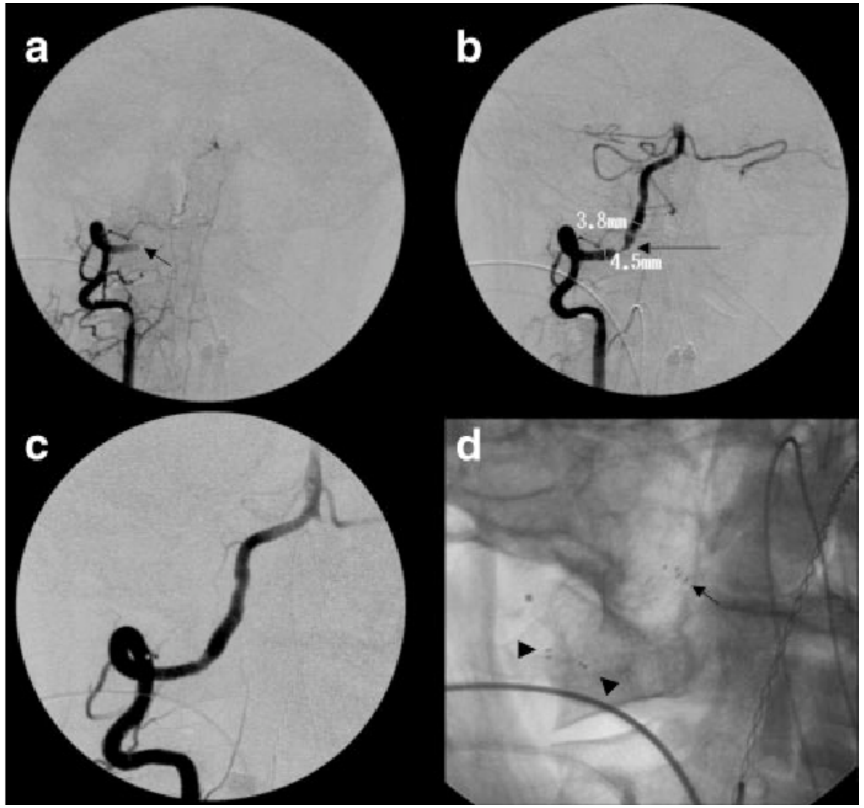


Segmentation Output: Distribution over Classes *for each pixel*

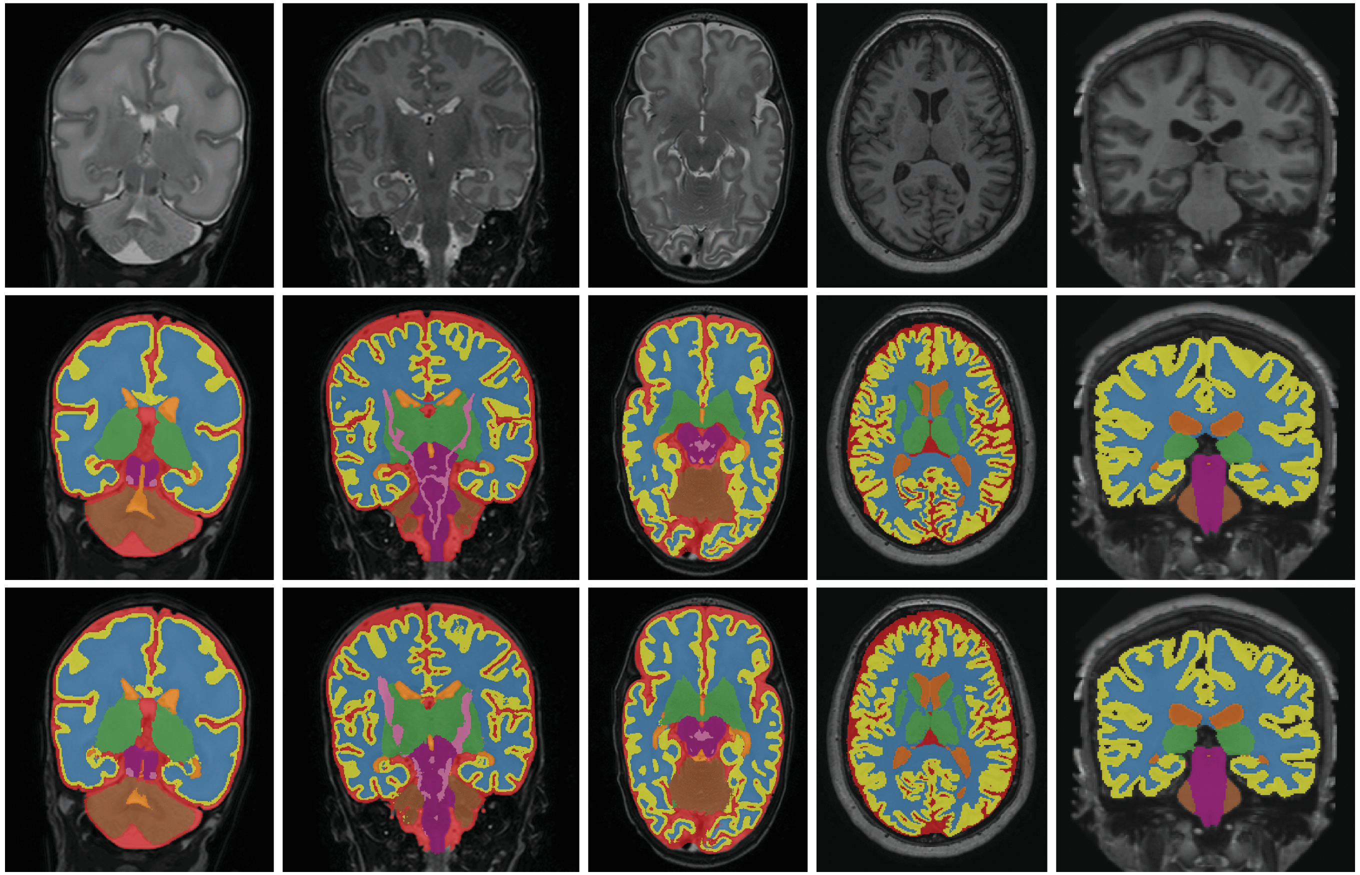
Precisely Identify Boundaries



Precisely Identify Boundaries



Calculate Areas or Volumes



Within-Structure Measures

International Workshop on Machine Learning in Medical Imaging
MLMI 2018: Machine Learning in Medical Imaging pp 205-213 | Cite as

Reproducible White Matter Tract Segmentation Using 3D U-Net on a Large-scale DTI Dataset

Authors | Authors and affiliations

Bo Li, Marius de Groot, Meike W. Vernooij, M. Arfan Ikram, Wiro J. Niessen, Esther E. Bron

Tract-specific diffusion measures, as derived from brain diffusion MRI, have been linked to white matter tract structural integrity and neurodegeneration. As a consequence, there is a large interest in the automatic segmentation of white matter tract in diffusion tensor MRI data. Methods based on the tractography are popular for white matter tract segmentation. However, because of the limited consistency and long processing time, such methods may not be suitable for clinical practice. We therefore developed a novel convolutional neural network based method to directly segment white matter tract trained on a low-resolution dataset of 9149 DTI images...

Segmentation-based features when end-to-end classification is not feasible

Segment Bones → Calculate lengths and areas → Simple Classifier for Genetic or Growth Disorder

EXAMPLE: SEGMENTATION OF COLON POLYPS

nature
biomedical engineering

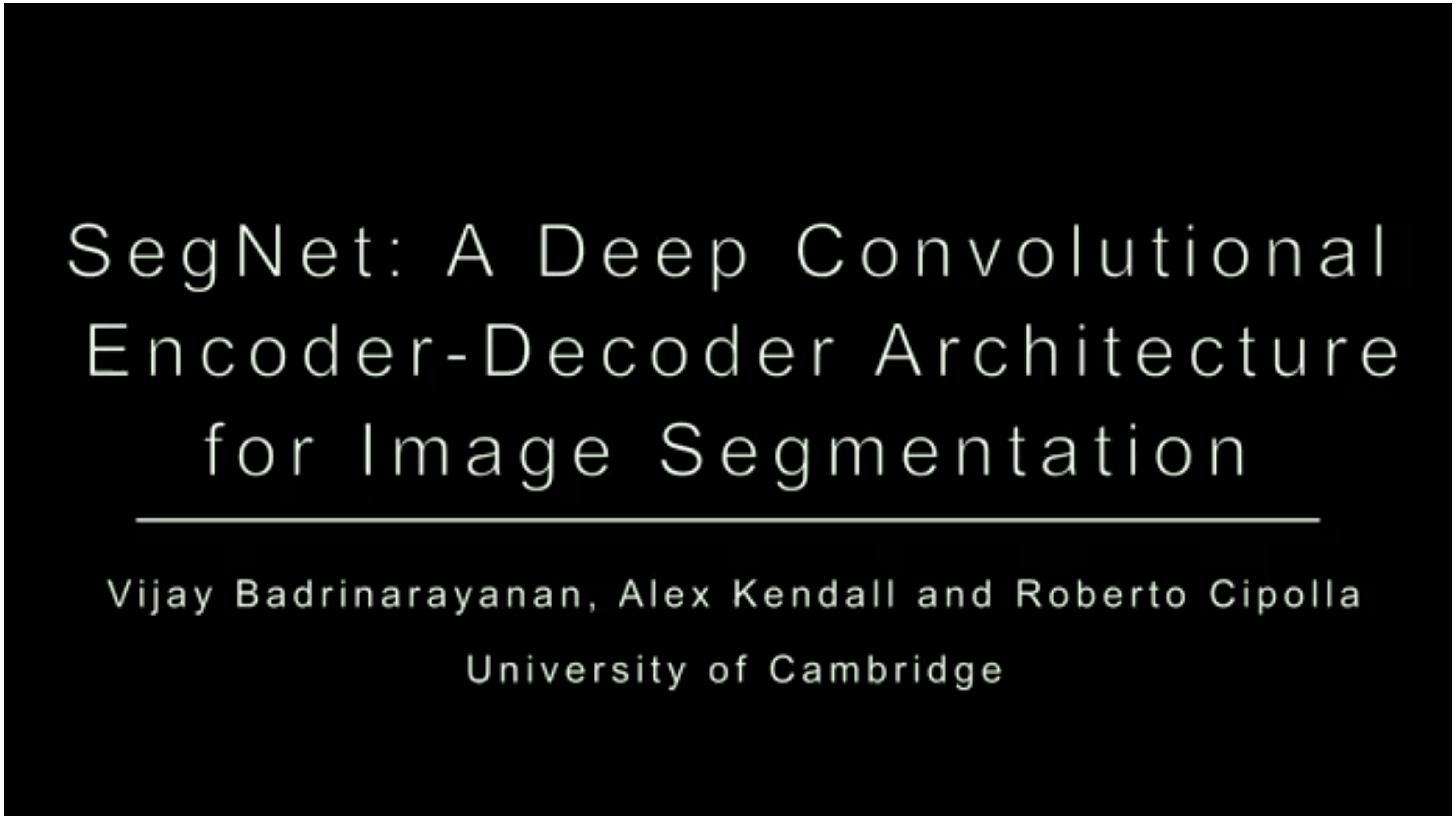
Article | Published: 10 October 2018

Development and validation of a deep-learning algorithm for the detection of polyps during colonoscopy

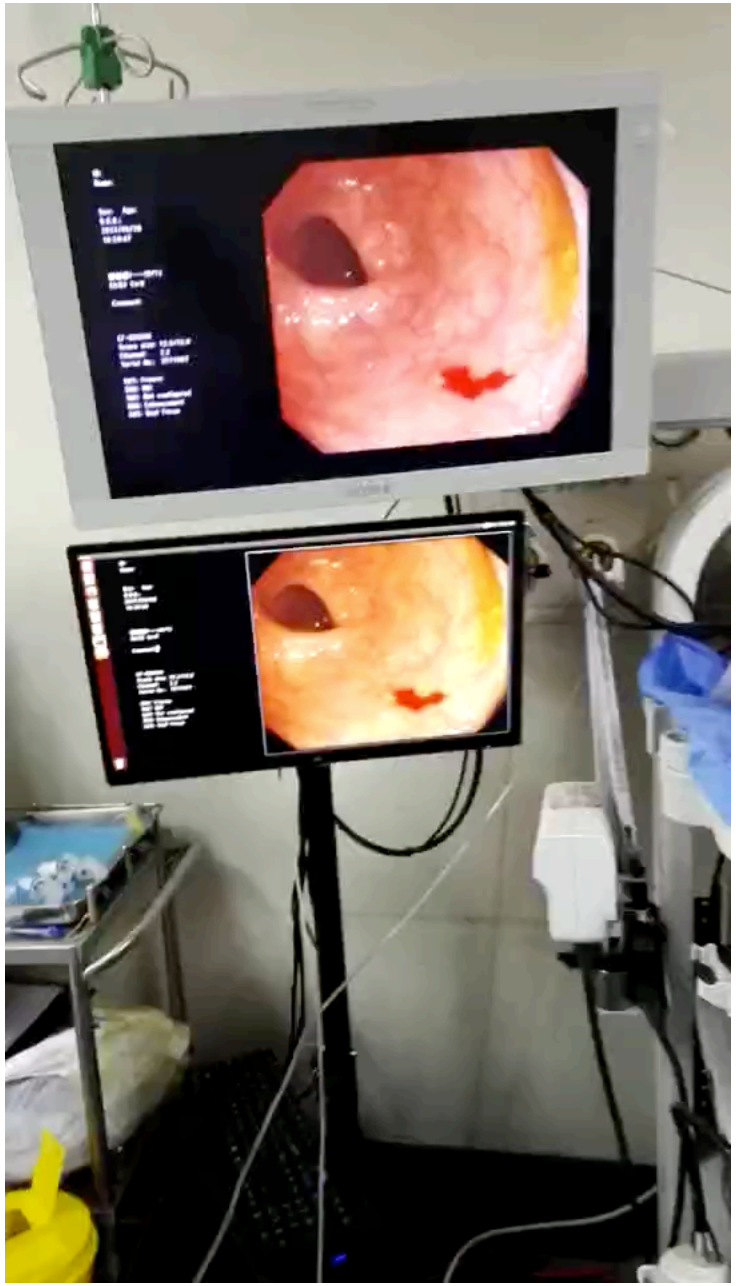
Pu Wang, Xiao Xiao, Jeremy R. Glissen Brown, Tyler M. Berzin, Mengtian Tu, Fei Xiong, Xiao Hu, Peixi Liu, Yan Song, Di Zhang, Xue Yang, Liangping Li, Jiong He, Xin Yi, Jingjia Liu & Xiaogang Liu

Nature Biomedical Engineering **2**, 741–748 (2018) | Download Citation

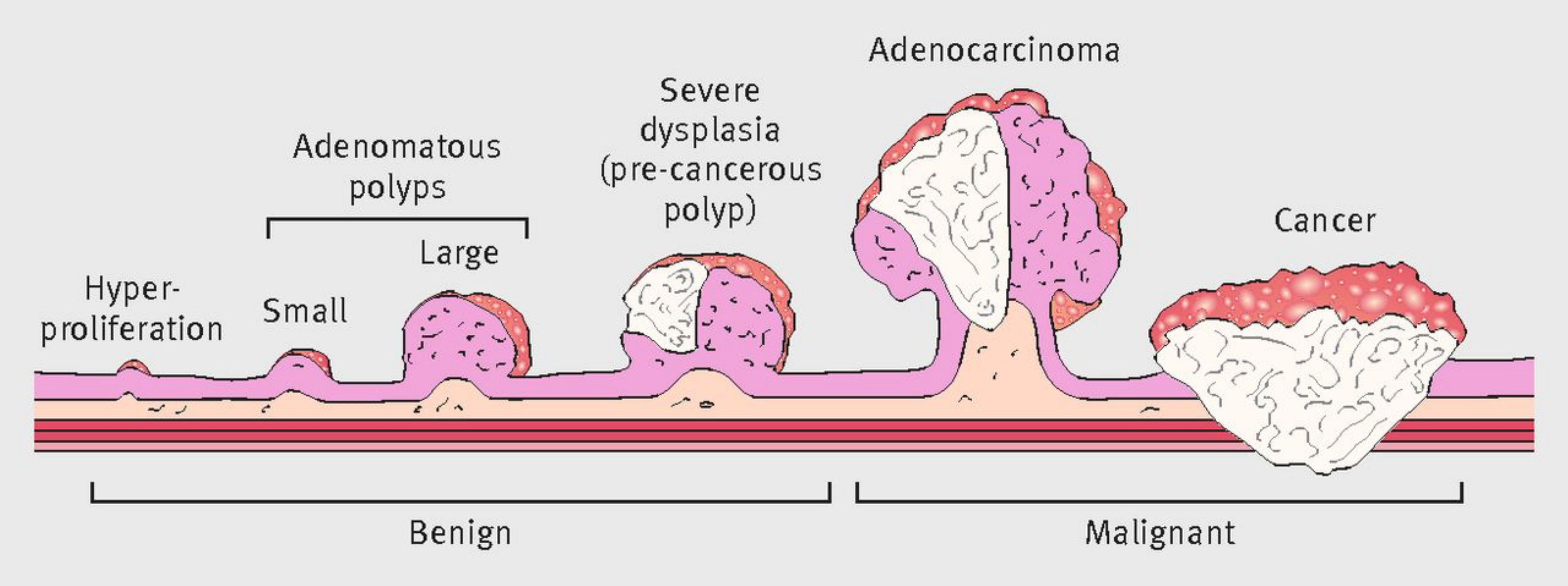
Approach: Start with SegNet (2015)



Retrain to segment polyps in real time



Focus on Adenomatous Polyps



BMJ 2016;354:i3590

Why are polyps missed?

1. Never in the visual field

2. In the field, but not recognized

-> Segment polyps in real time to act as an "extra set of eyes" during colonoscopy

Strength of this paper: 4 validation datasets

A: new imageDB

Sichuan Provincial People's Hospital of China, 01-12/16

27,113 images from 1,138 consecutive patients who had polyps

20% of images had polyps

Confirmed histology

Excluded poor-quality images (by panel) and >2cm masses

B: public imageDB

Hospital Clinic of Barcelona (public CVC-ClinicDB)

612 image frames from 29 colonoscopy videos

Images

C: polyp videos

Sichuan Provincial People's Hospital of China, 05-07/16

videos of 138 consecutively encountered polyps from 110 polyp patients

Confirmed histology

Used to assess **sensitivity**

D: complete videos

Sichuan Provincial People's Hospital, 01-02/18

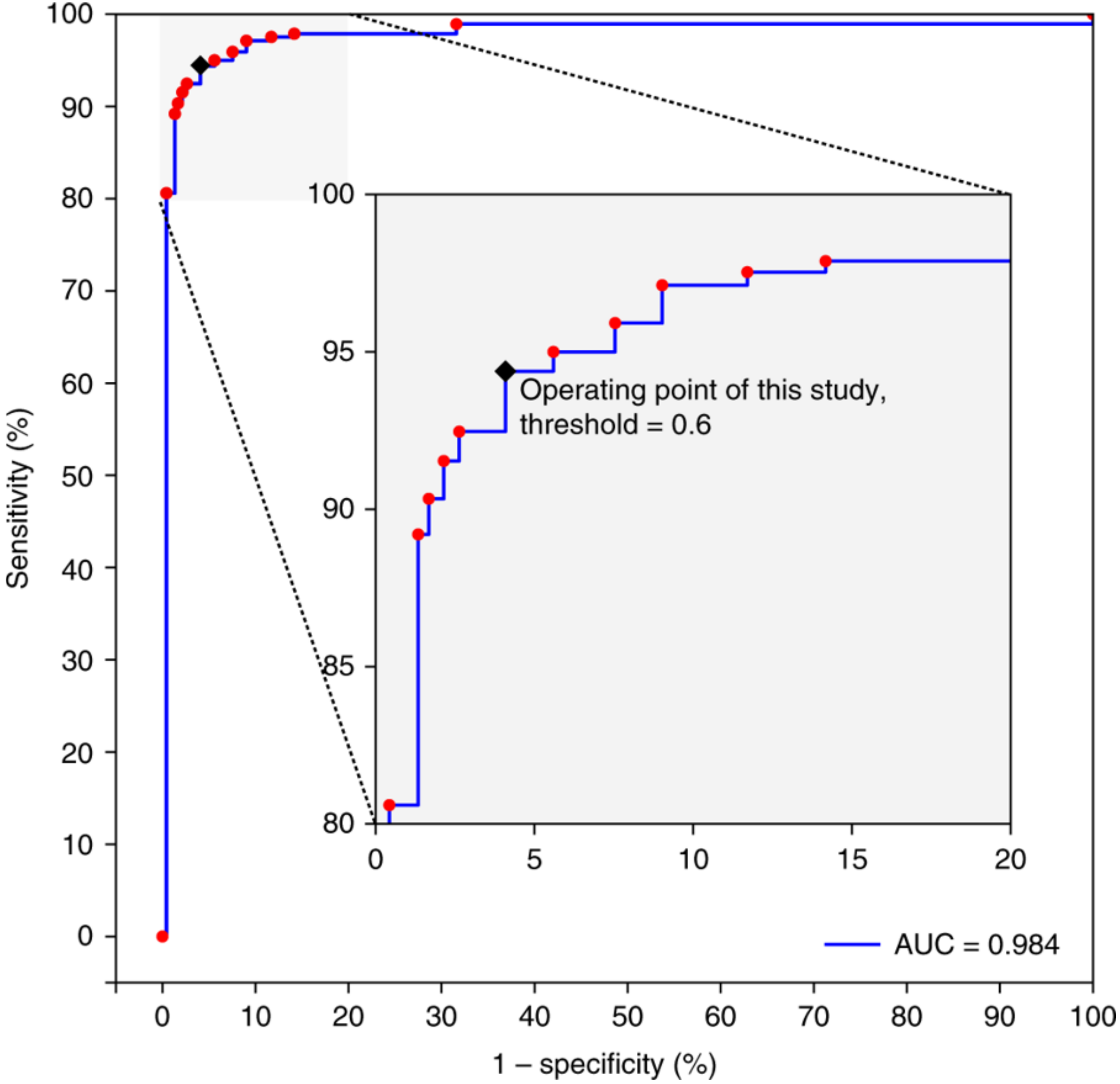
54 unaltered full-length colonoscopy videos from 54 patients

Used to assess **specificity**

Video

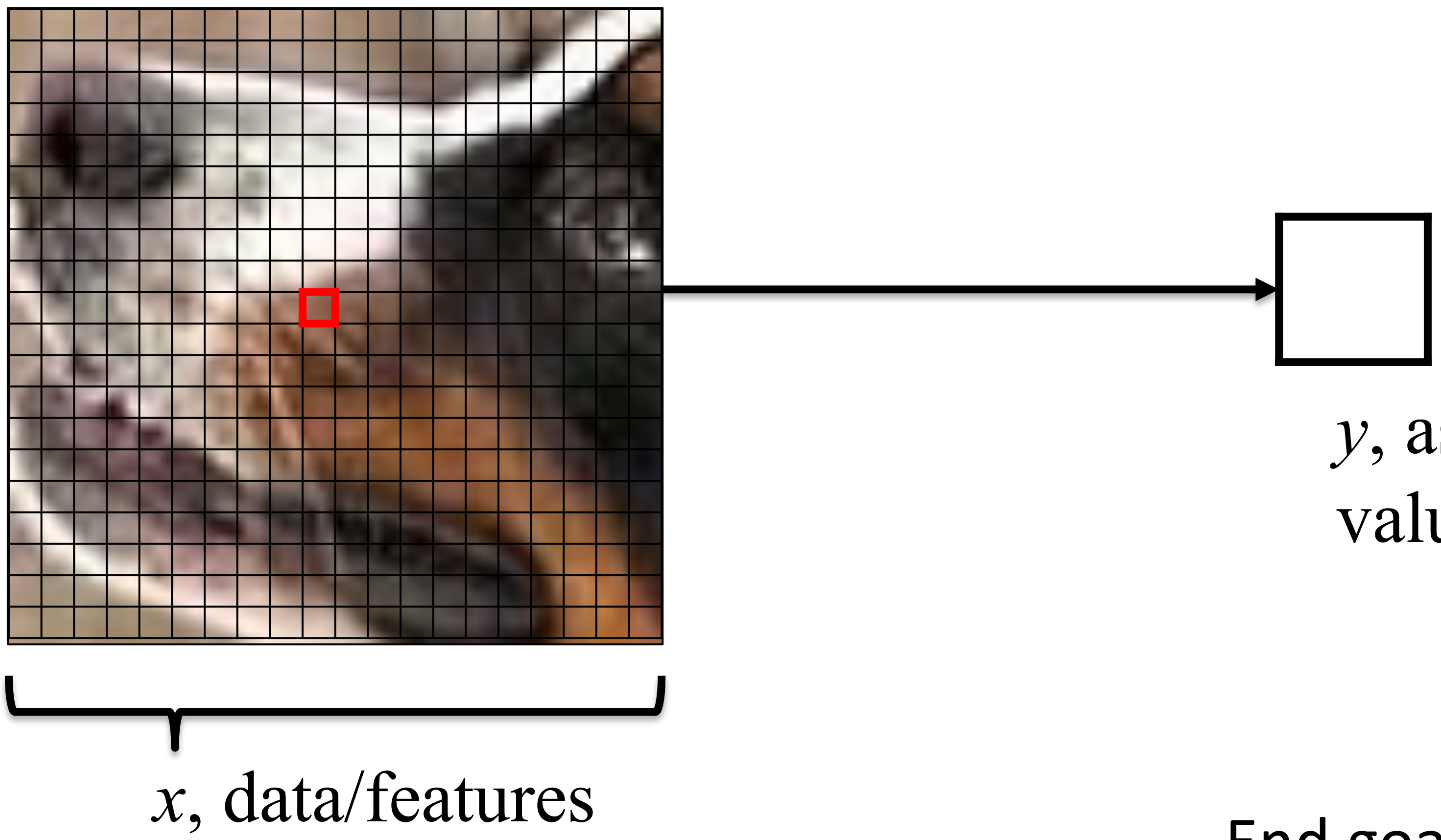
Performance (dataset A)

no straightforward way to compare to experts



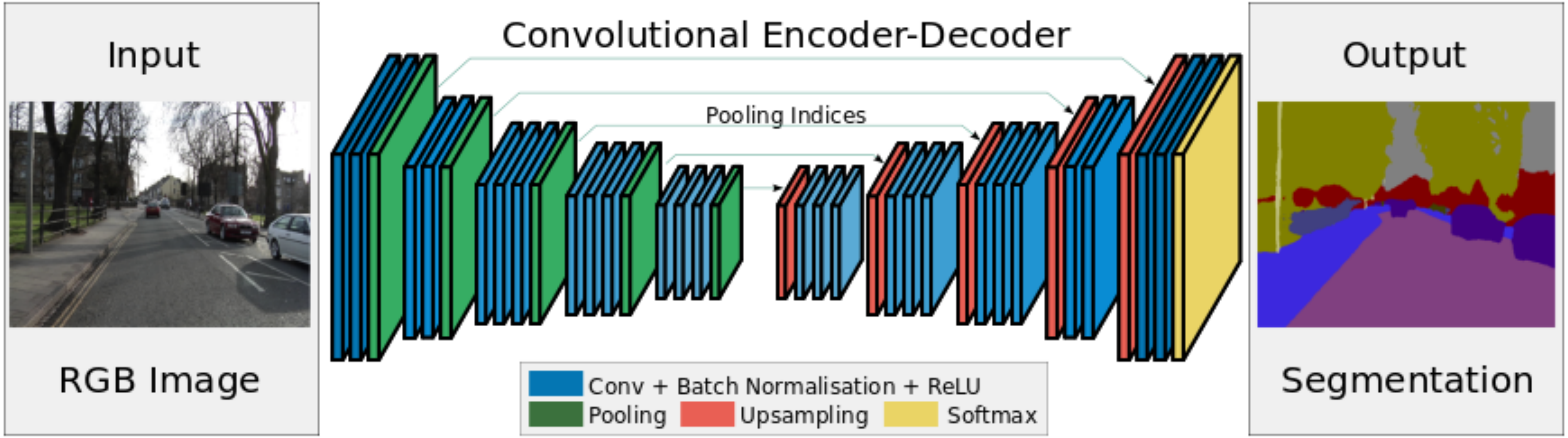
HOW DOES SEGMENTATION WORK?

A separate classifier for each pixel?



End goal: predict y from x

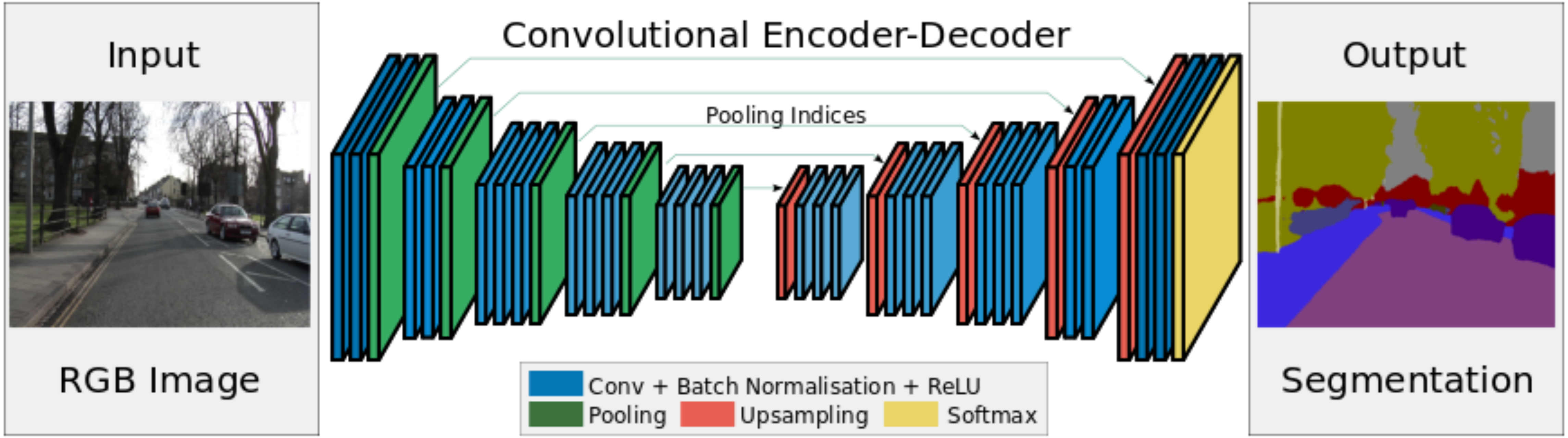
Segmentation Architecture



SegNet (2015): fully convolutional architecture

Stage 1: Encoder identifies features

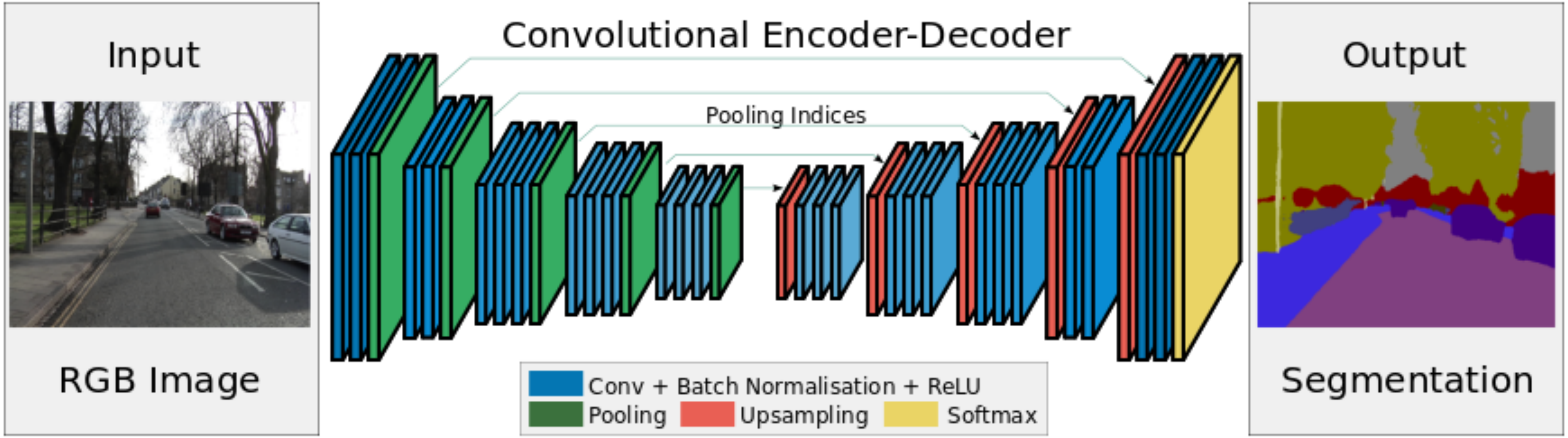
Stage 2: Decoder reconstructs the spatial map



Alternative architectures differ in their approach to the spatial reconstruction process

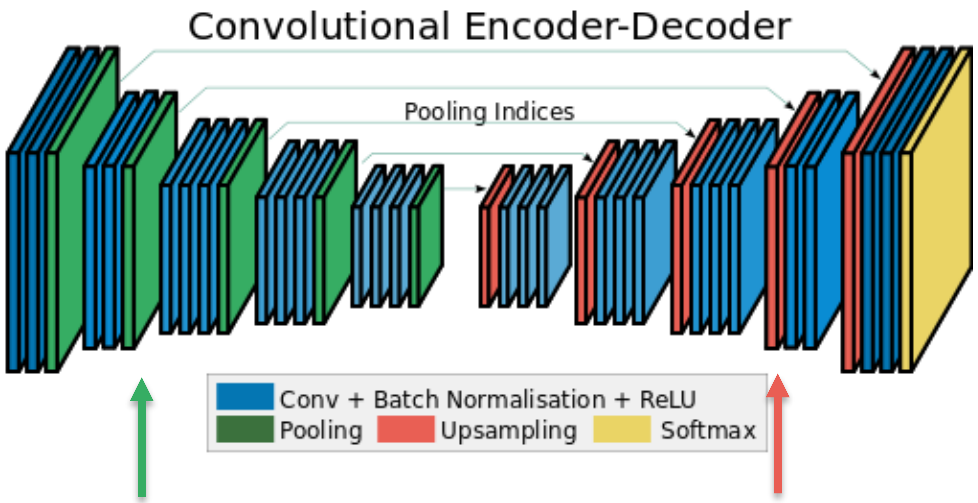
Stage 1: Encoder identifies features

Stage 2: Decoder reconstructs the spatial map



Segnet's approach to reconstruction: <u>remember</u> max-pooling indices

SegNet decoder overview



Remember max pooling indices

Use max pooling indices