U-Net: Convolutional Networks for Biomedical Image Segmentation

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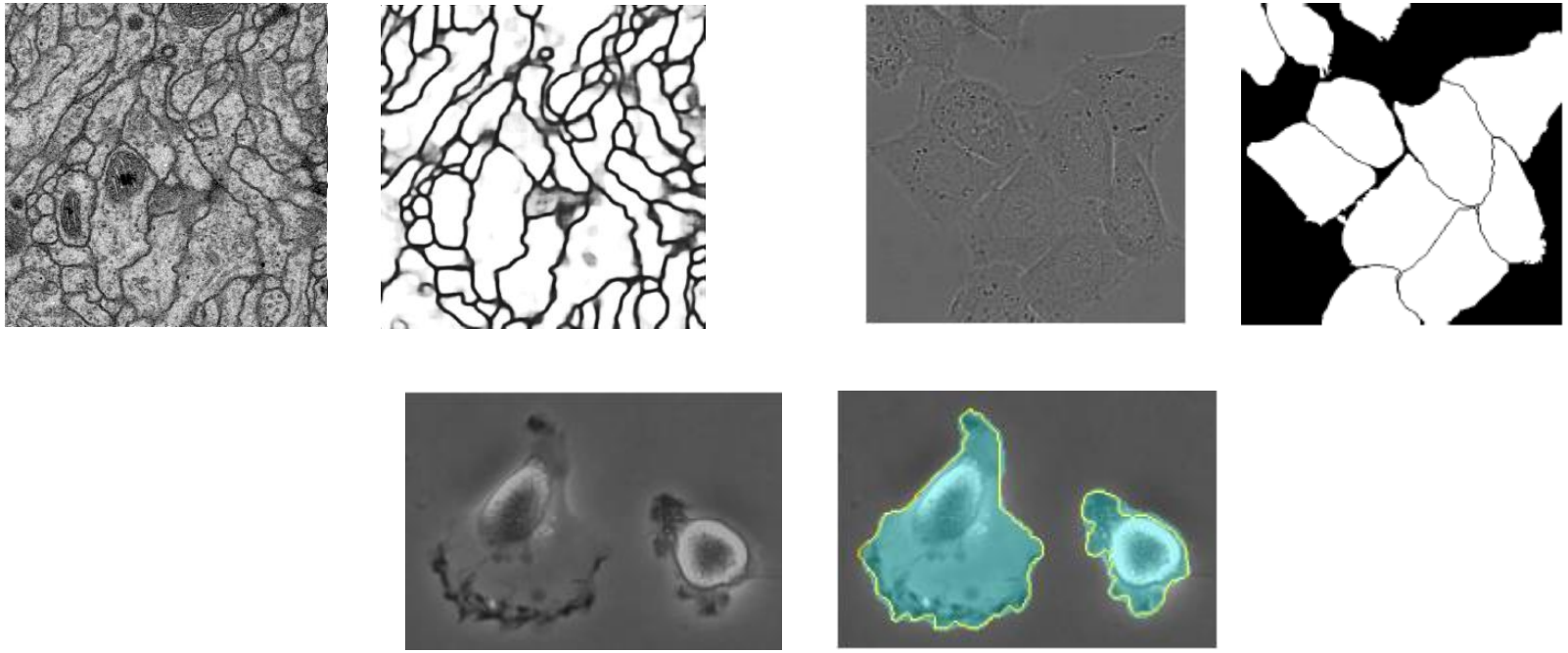
Slide by Dong Nie

Problem Definition

- Biomedical Image Segmentation



Outline

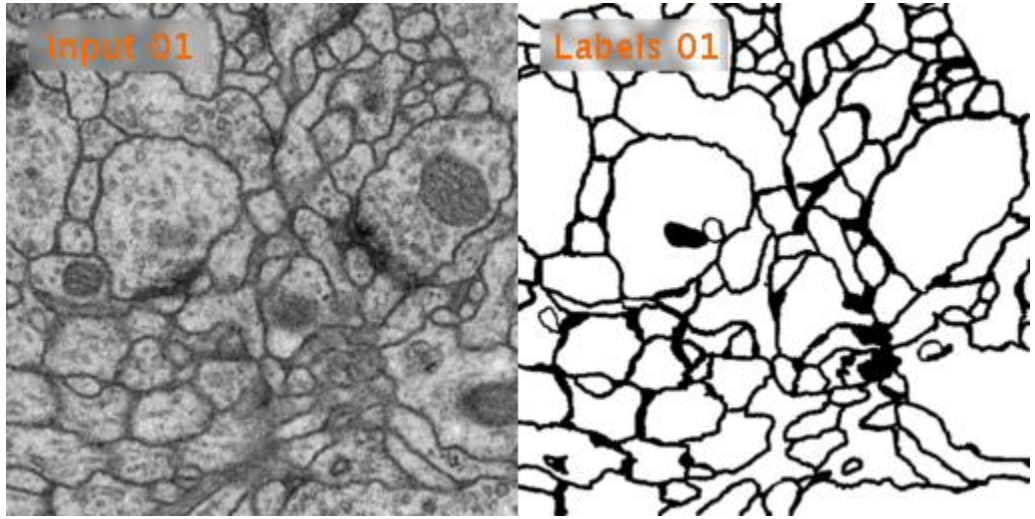
- Background/Motivation
- Method
- Experiments
- Conclusion

Challenging

- Visual complexity
  - Manual analysis is difficult
- Intensity differences are not notable
- Structure boundaries are not correlated with high image gradients
- Dataset is small

ISBI Challenge: Segmentation of neuronal structures in EM stacks

- Tissue segmentation is very important

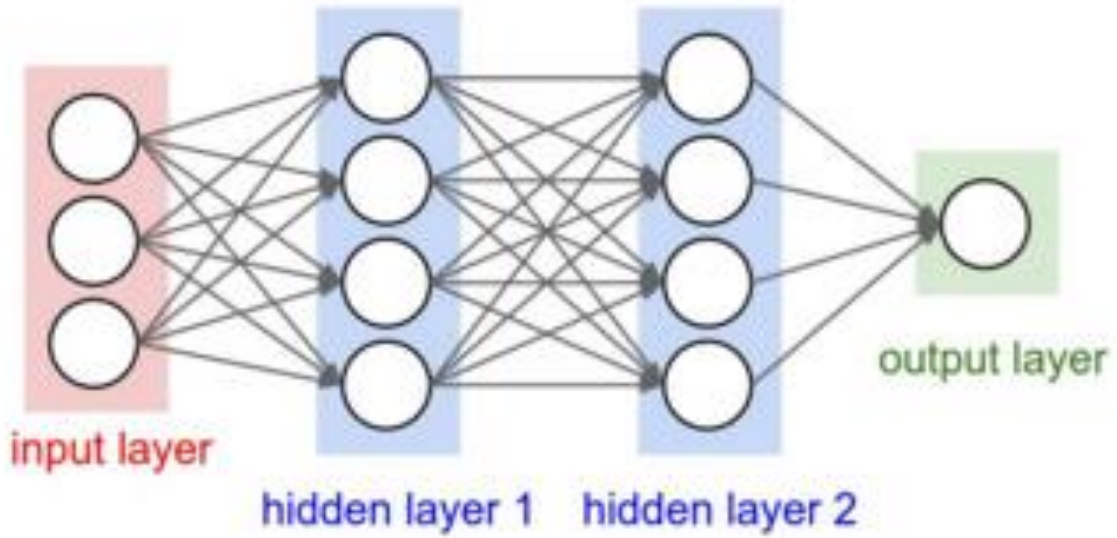


ISBI Challenge Rankings

Rank	Group name	Warping Error	Rand Error	Pixel Error
	** human values **	0.000005	0.0021	0.0010
1.	u-net	**0.000353**	0.0382	0.0611
2.	DIVE-SCI	0.000355	0.0305	0.0584
3.	IDSIA [1]	0.000420	0.0504	0.0613
4.	DIVE	0.000430	0.0545	**0.0582**
⋮				
10.	IDSIA-SCI	0.000653	**0.0189**	0.1027

Most are deep learning based methods

Neural Network Example



Conventional Deep Models

- For patch: convolutional neural networks (CNN)
  - Classify a patch to label (FG/BG)
- For image: sliding-window based
  - Localization
  - Classification

Networks

- Slow!
- Highly depend on patch size

Existing problems

- Still slow to segment an image
- Cannot well tradeoff localization accuracy and use of context
- Dataset is still small

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  - FCN Introduction
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Method

- Form this problem as 2-category classification
- Use fully convolutional networks (FCN) to do pixel-wise segmentation
- Novelty in helping localization

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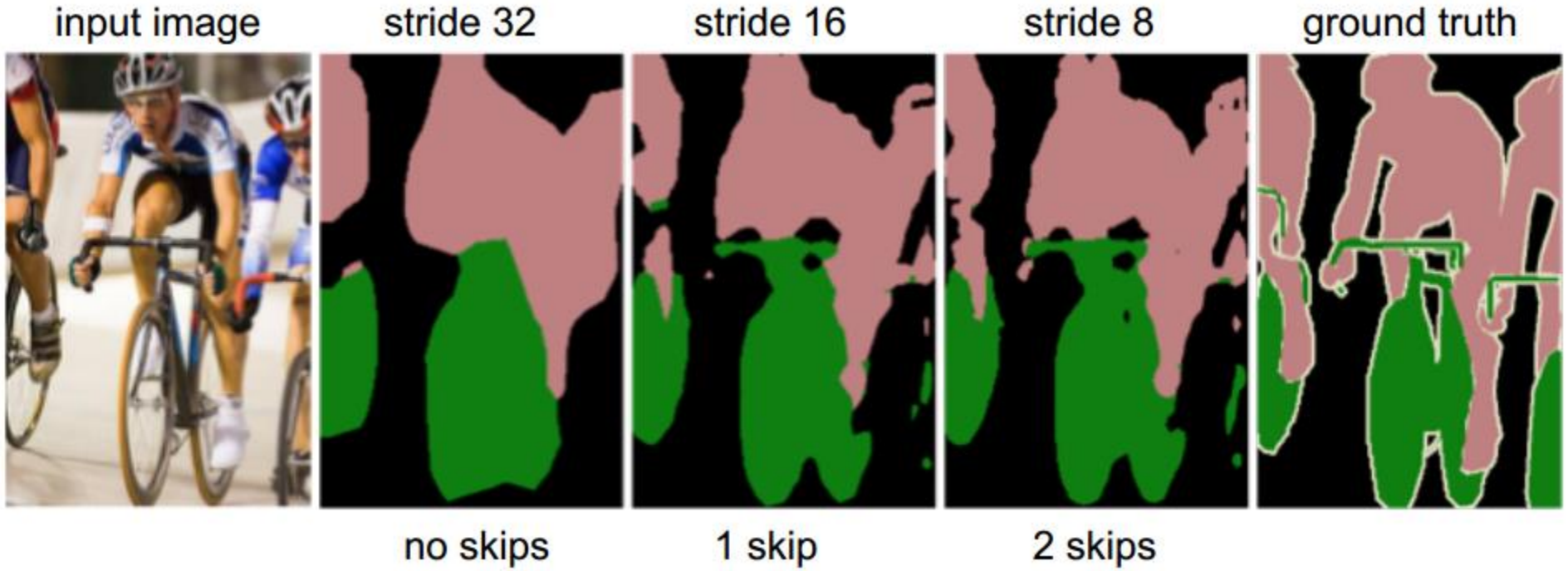
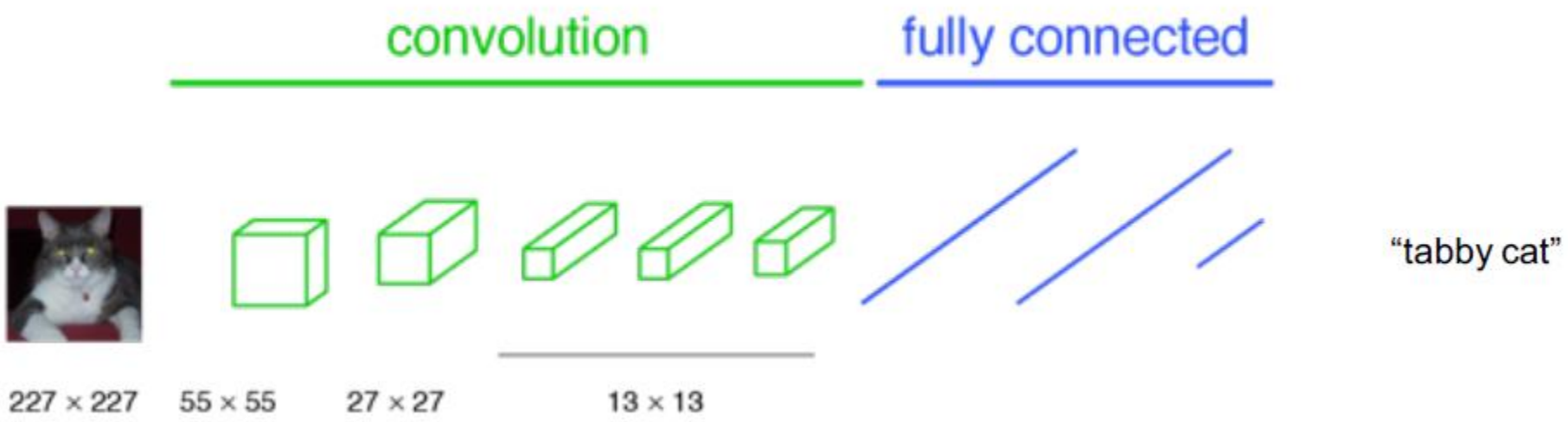
Fully Convolutional Networks (FCN)

- Currently, FCN is widely used to do semantic segmentation and image prediction, and achieves excellent performance

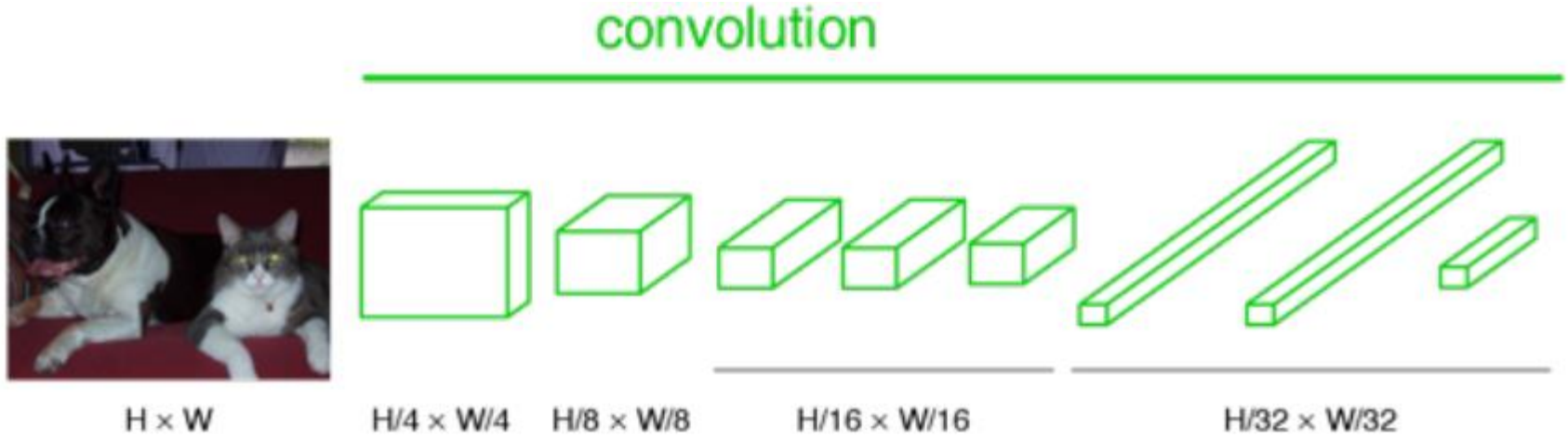


A classification network



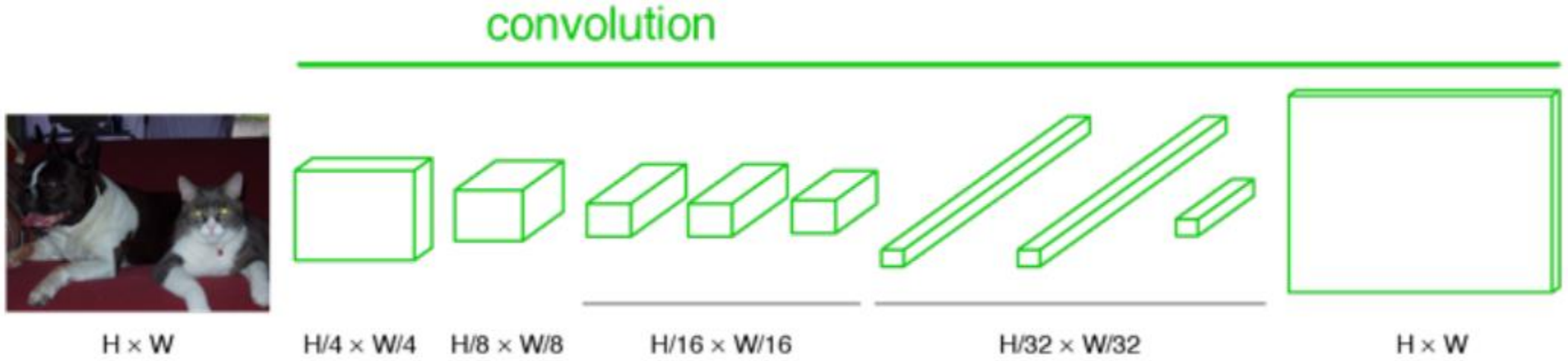
Slide credit: Jonathan Long

Becoming fully convolutional



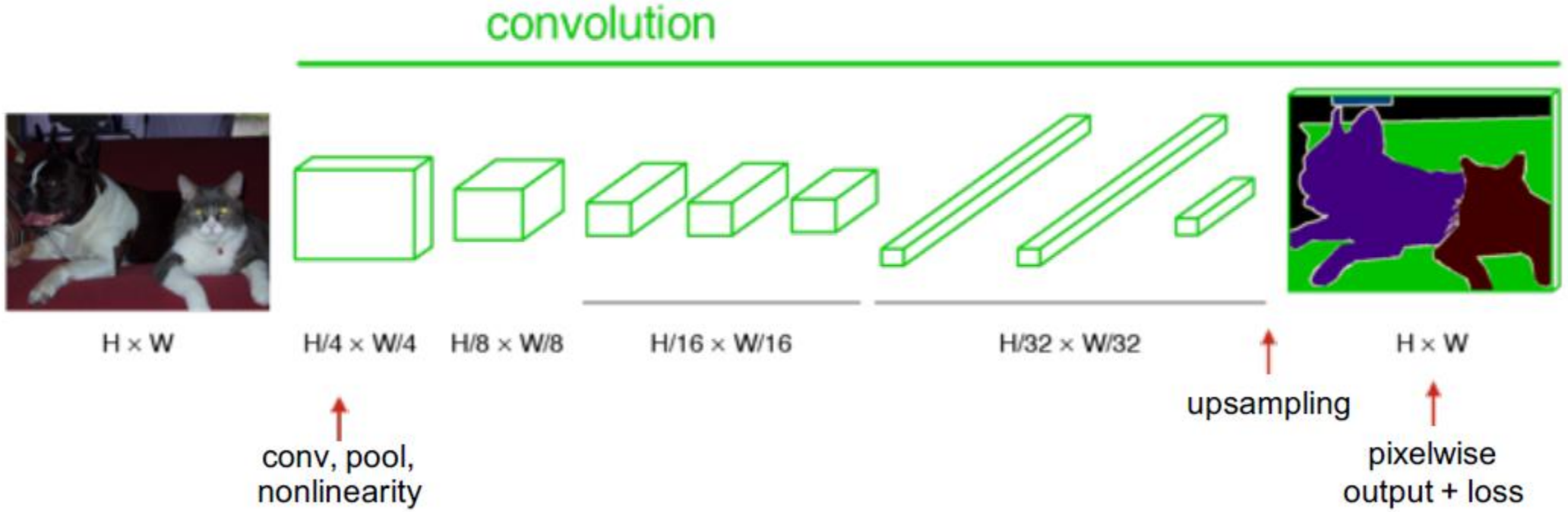
Slide credit: Jonathan Long

Upsampling Output



Slide credit: Jonathan Long

Pixel-wise Prediction



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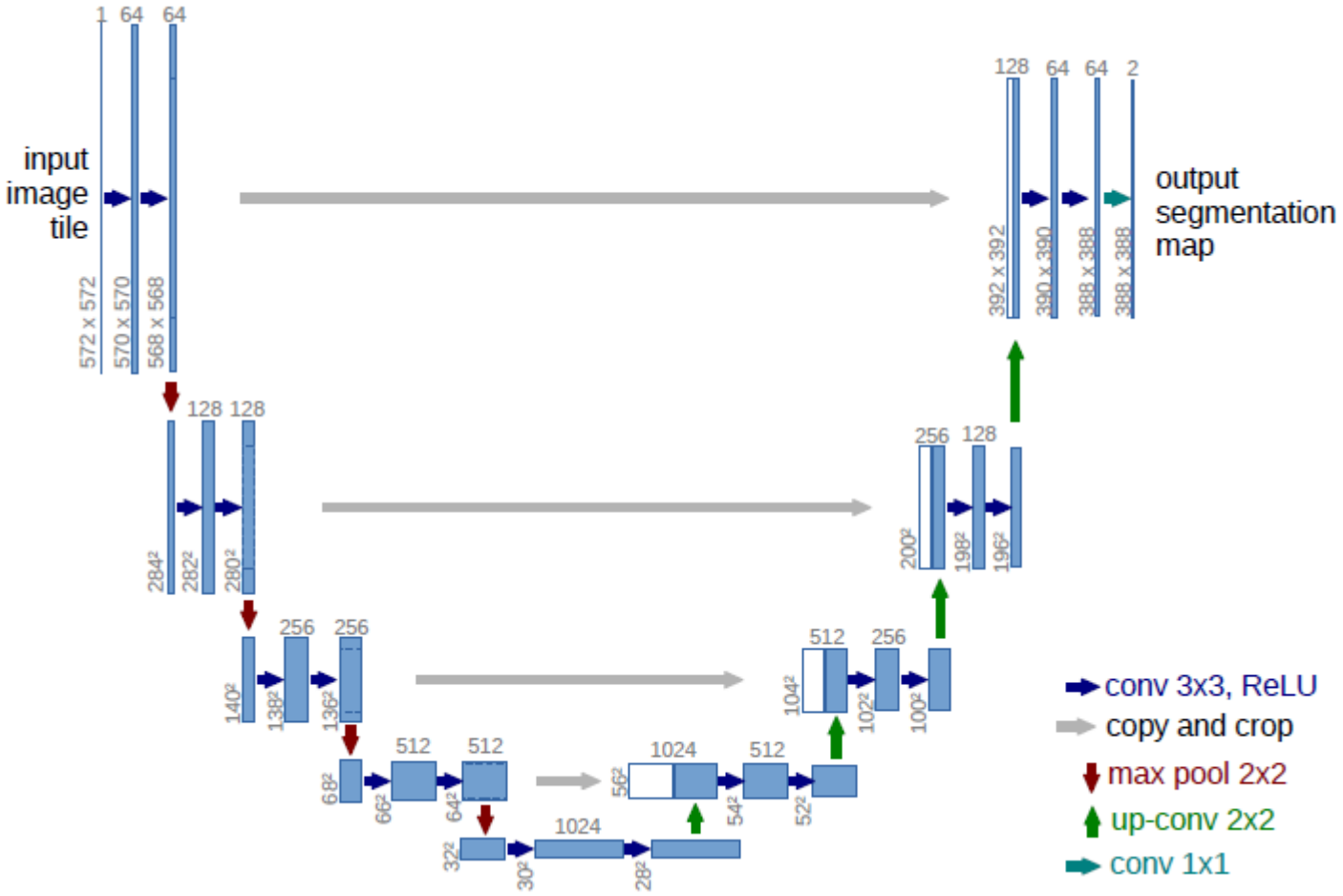
FCN-based Segmentation

- Can be faster
- Can see broader view

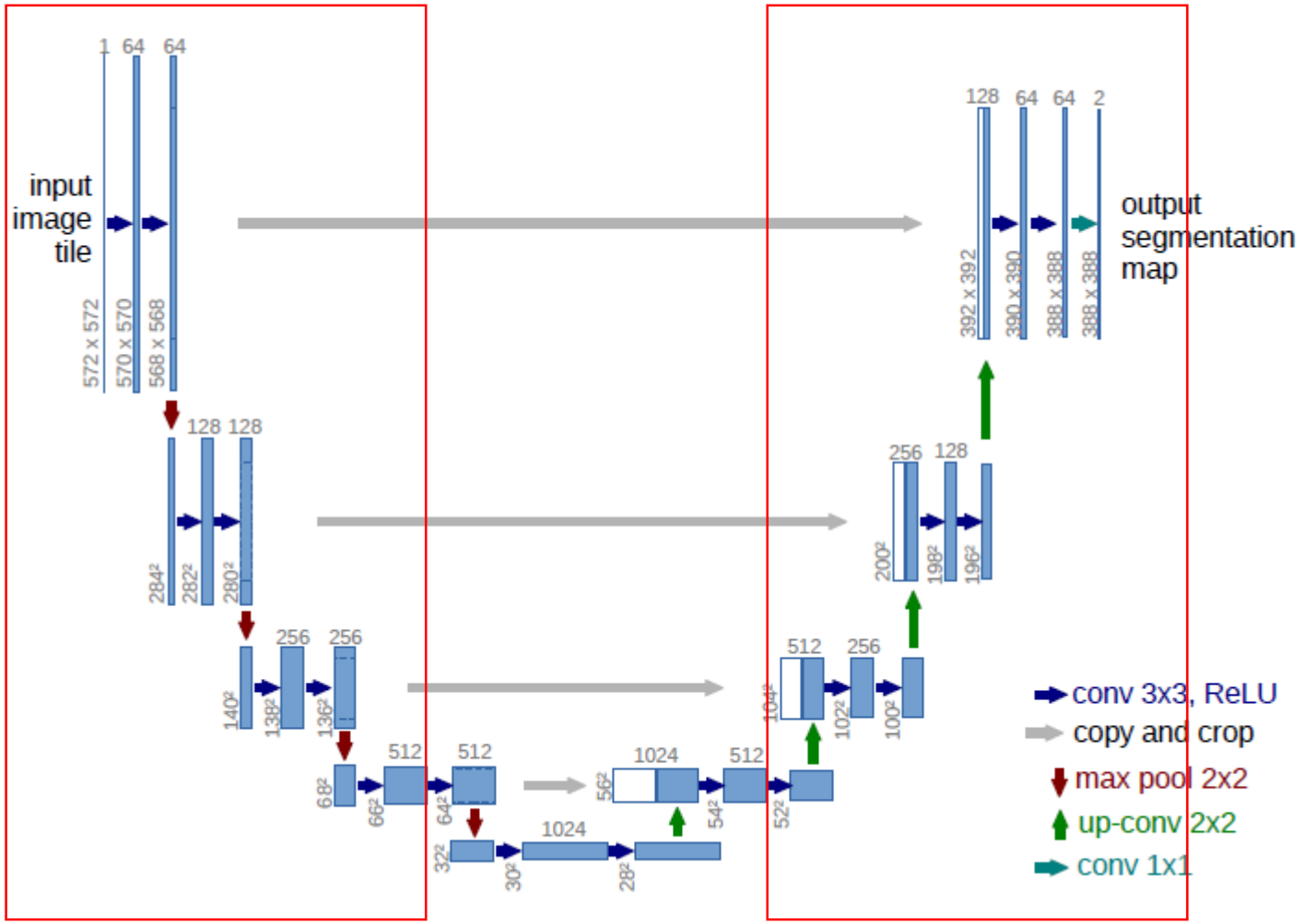
Networks

Localization may be not good!!!

Proposed Model



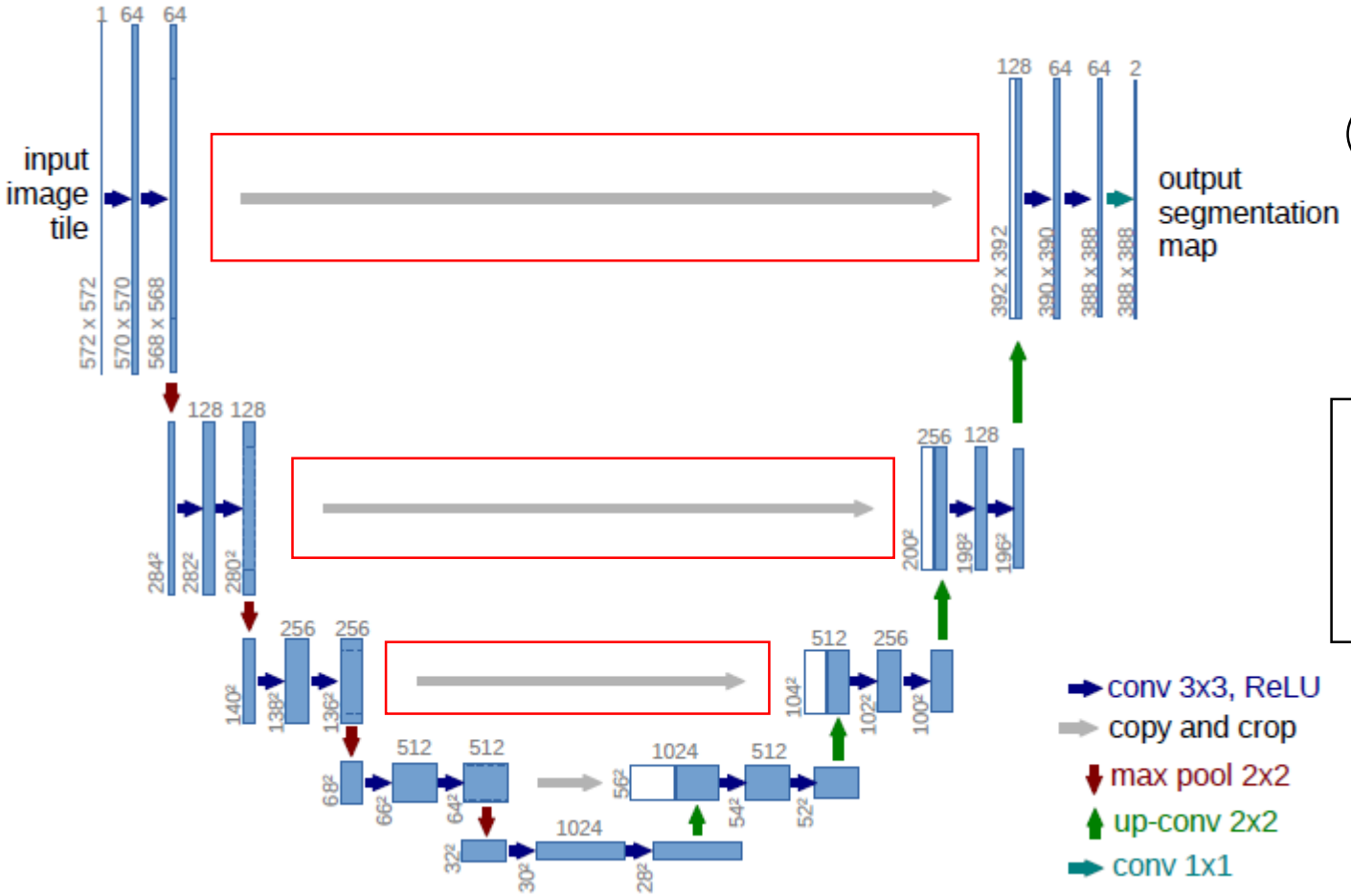
Proposed Model



Contracting path

Expansive path

Proposed Model



Claim from the paper: Help localize!

I guess: features in contracting path are more precise to indicate location

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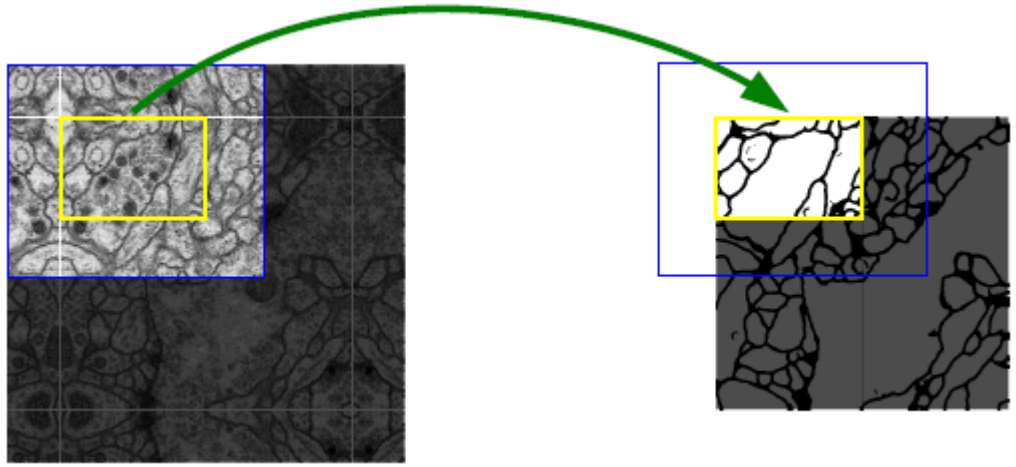
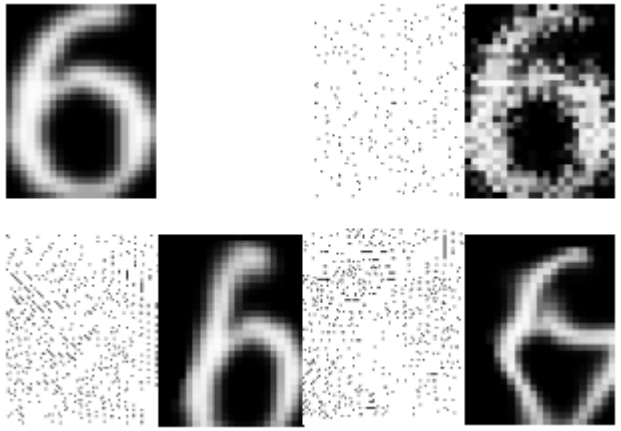
Overlap-tile Strategy



Data Augmentation

- Elastic deformation
- Smooth deformation with random displacement vectors on a coarse 3x3 grid



[1]. Best Practices for Convolutional Neural Networks Applied to Visual Document Analysis

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  - Neuronal Structure Segmentation in Electron Microscopic Images
  - Cell Segmentation in Light Microscopic Images: PhC-U373
  - Cell Segmentation in Light Microscopic Images: DIC-HeLa
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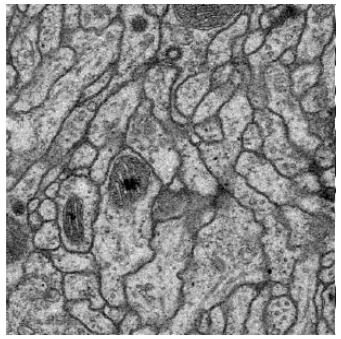
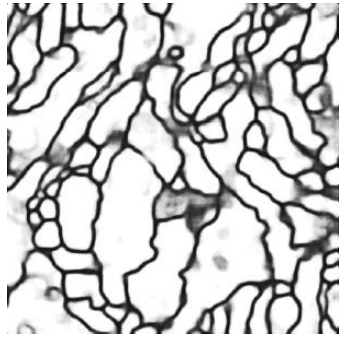
Dataset

- EM segmentation challenge
- 30 images (512×512 pixels) with corresponding fully annotated ground truth segmentation map





- http://brainiac2.mit.edu/isbi_challenge/

Metrics

- Warping error
  - a segmentation metric designed to account for topological disagreements [1]; it accounts for the number of neuron splits and mergers required to obtain the candidate segmentation from ground truth.
- Rand error
  - Rand error is the frequency with which the two segmentations disagree over whether a pair of pixels belongs to same or different objects

$$R(S,T) = \binom{N}{2}^{-1} \sum_{i \neq j} \left| \delta(S_i, S_j) - \delta(T_i, T_j) \right|,$$

- Pixel error
  - Defined as $1 - F_{pixel}$, where F_{pixel} represents the F_1 score of pixel similarity

[1]. Boundary Learning by Optimization with Topological Constraints

Experimental Results

Table 1. Ranking on the EM segmentation challenge [14] (march 6th, 2015), sorted by warping error.

Rank	Group name	Warping Error	Rand Error	Pixel Error
	** human values **	0.000005	0.0021	0.0010
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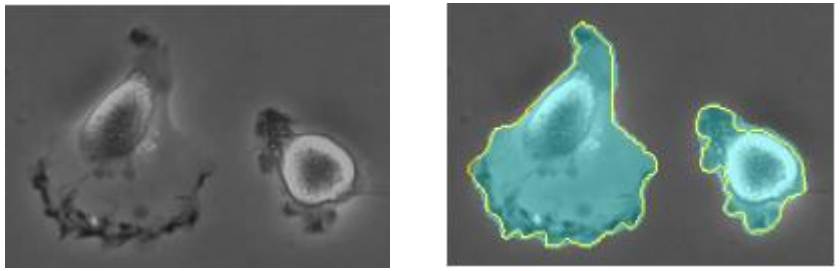
Dataset

- ISBI cell tracking challenge 2014/2015
- 35 annotated images



Glioblastoma-astrocytoma U373 cells

Experimental Results

Table 2. Segmentation results (IOU) on the ISBI cell tracking challenge 2015.

Name	PhC-U373	DIC-HeLa
IMCB-SG (2014)	0.2669	0.2935
KTH-SE (2014)	0.7953	0.4607
HOUS-US (2014)	0.5323	-
second-best 2015	0.83	0.46
u-net (2015)	**0.9203**	**0.7756**

Metric
IOU: intersection over union

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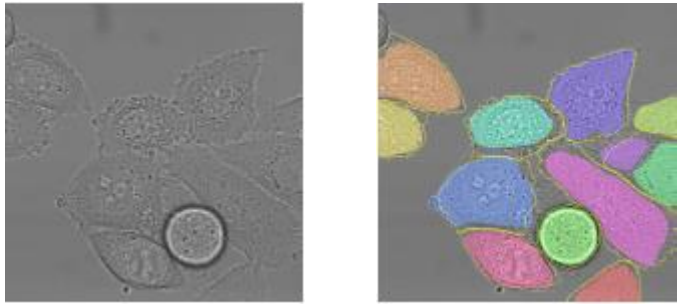

HeLa cells

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Conclusion

- U-net architecture achieves very good performance on several biomedical segmentation tasks
- Elastic deformation for data augmentation is helpful

Thanks