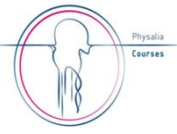


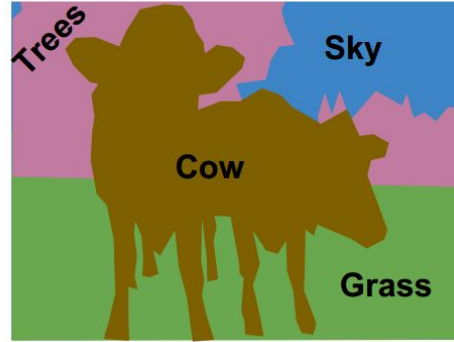
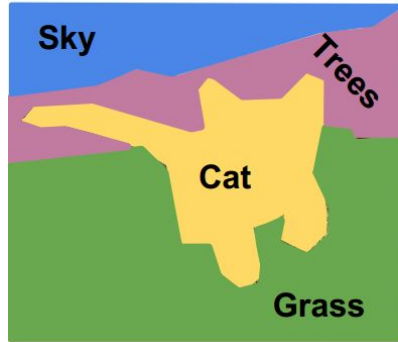
Image Segmentation



What is semantic segmentation?



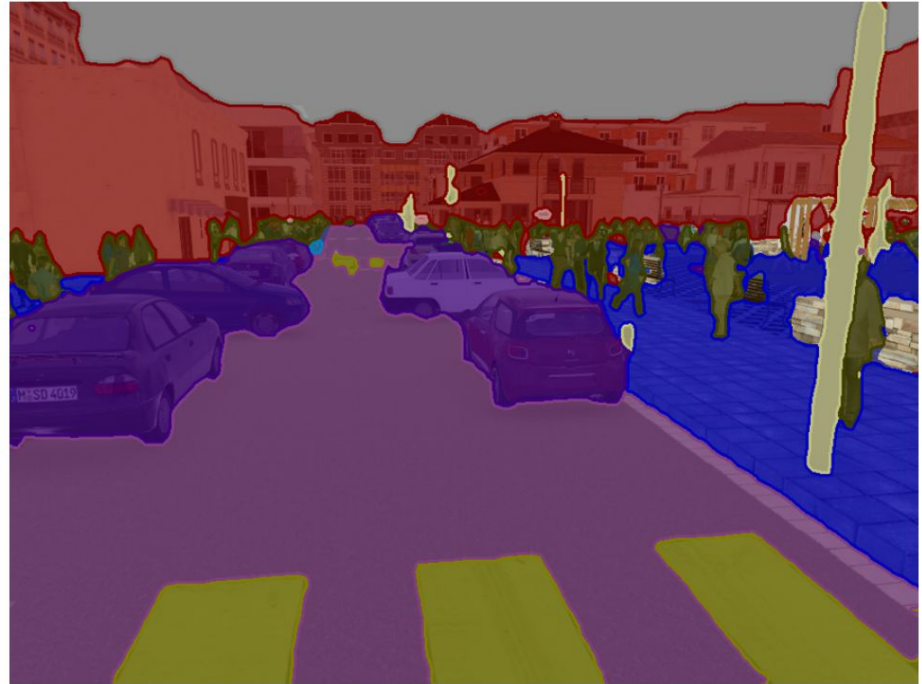
[This image is CC0 public domain](#)



Source: <https://tariq-hasan.github.io/concepts/computer-vision-semantic-segmentation/>



Application: car vision

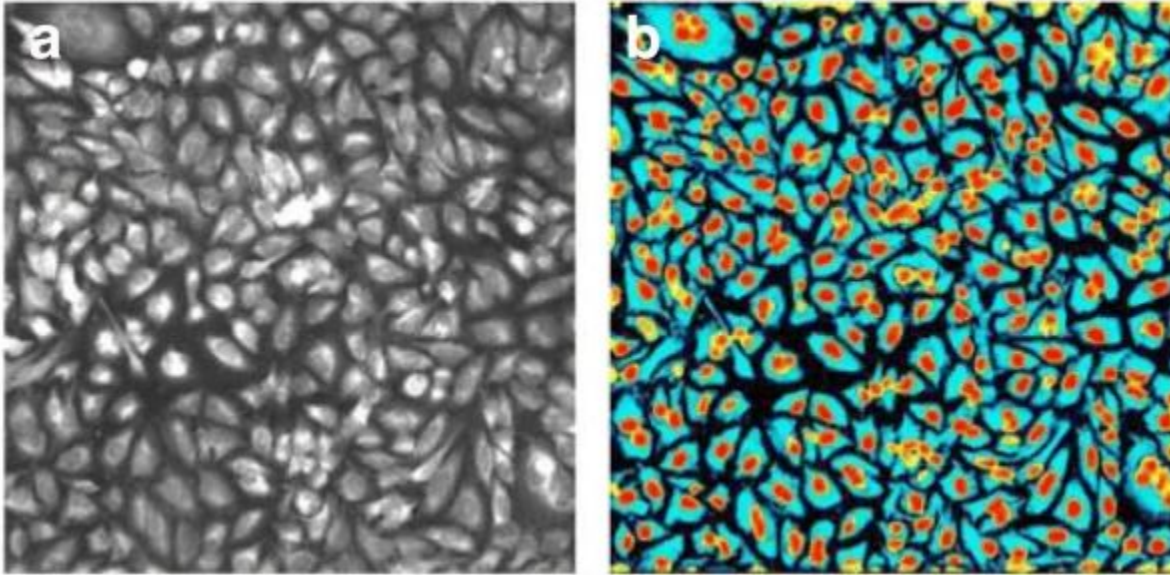


■ Sky ■ Building ■ Road ■ Sidewalk ■ Fence ■ Vegetation ■ Pole ■ Car ■ Sign ■ Pedestrian ■ Cyclist

Source: <https://developer.nvidia.com/blog/image-segmentation-using-digits-5/>



Application: cell images

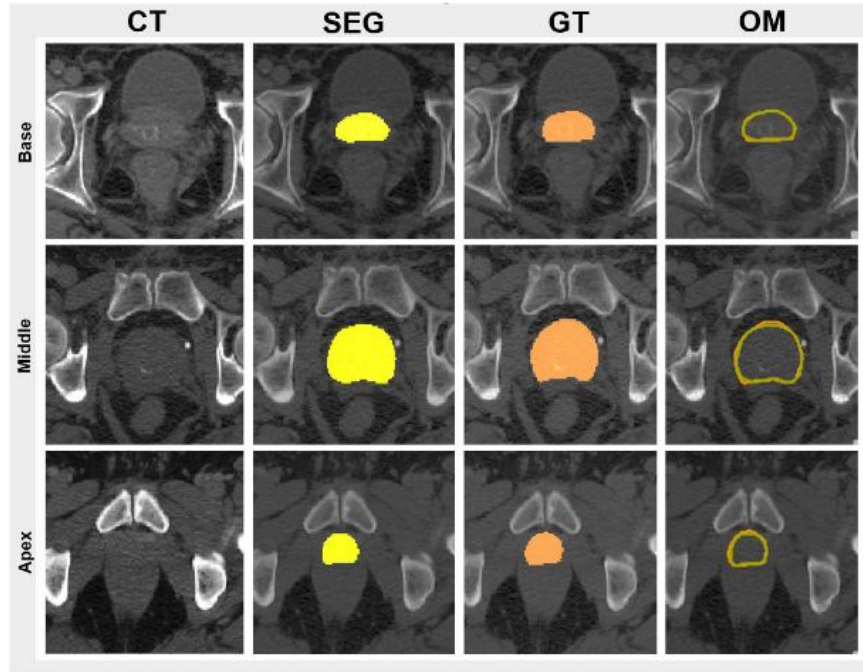


- a) Input image
- b) Nuclei (Yellow-Red) and Cells (Blue-Cyan) prediction map.

Source: Yousef Al-Kofahi et al., A deep learning-based algorithm for 2-D cell segmentation in microscopy images. BMC Bioinformatics, 2018



Application: organs contouring



CT: original CT scan image
SEG: U-Net segmentation
GT: ground truth
OM: overlay map of ground truth and segmented images.

Source: Kazemifar et al., Segmentation of the prostate and organs at risk in male pelvic CT images using deep learning. Biomedical Physics & Engineering Express, 2018



Application: plant detection

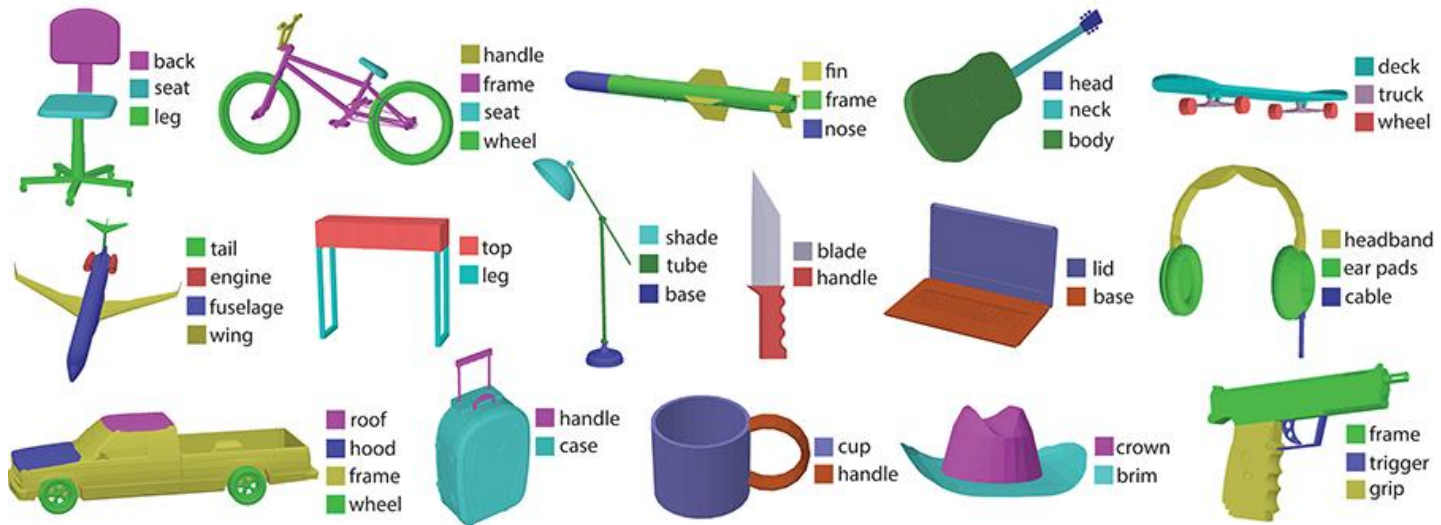


Source: Plant Images Segmentation with Deep Learning

<https://medium.com/zaka-ai/plant-images-segmentation-with-deep-learning-ff1ed67e80e6> (nice tutorial!)



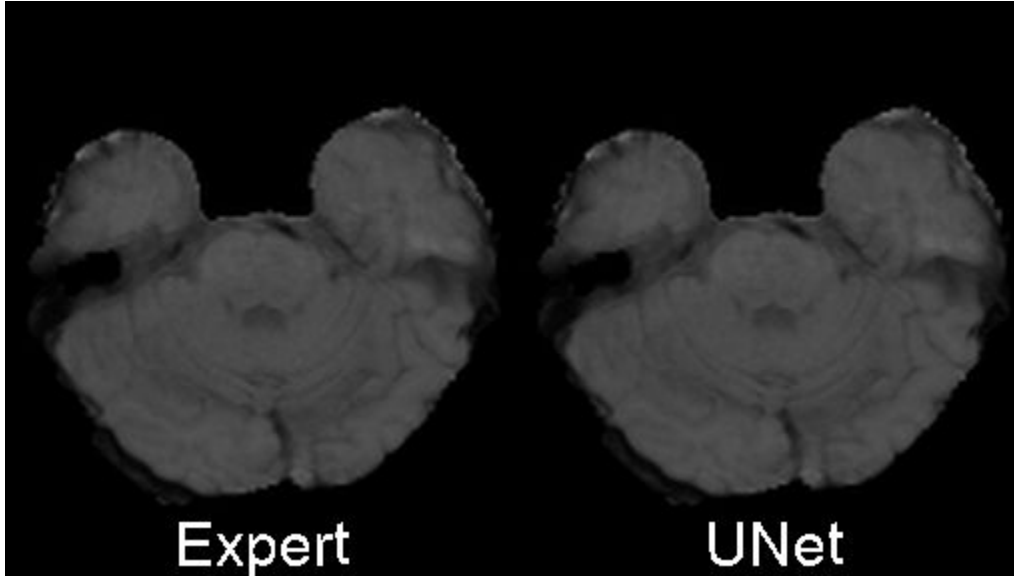
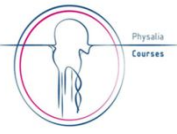
Beyond bidimensional images: 3D



Source: Kalogerakis et al., 3D Shape Segmentation with Projective Convolutional Networks. Proceedings of the IEEE Computer Vision and Pattern Recognition (CVPR) 2017



Application: tumor recognition



A CT scan is a set of (usually equally spaced) slices

Source:

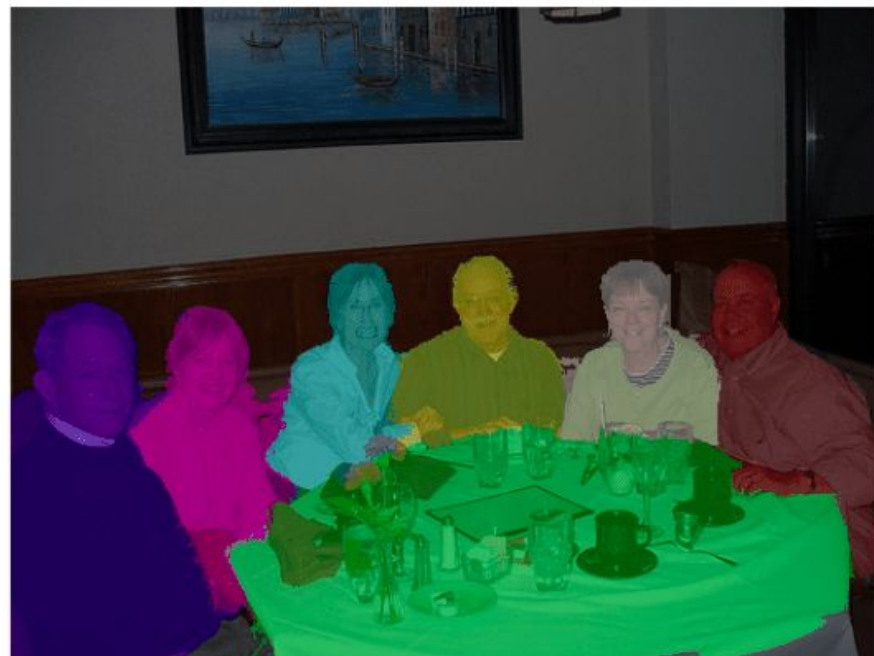
<https://pythonawesome.com/keras-3d-u-net-convolution-neural-network-designed-for-medical-image-segmentation/>



Semantic vs. Instance



Semantic Segmentation



Instance Segmentation

Source: Anurag Arnab, Shuai Zheng et. al 2018 “Conditional Random Fields Meet Deep Neural Networks for Semantic Segmentation”



Classification vs. Segmentation

INPUT	
Image (2d, 3d...)	Image (2d, 3d...)
Ground Truth: CLASS	Ground Truth: MASK
OUTPUT	
Predicted class	Predicted mask
LOSS	
Accuracy, Binary cross entropy, ...	???



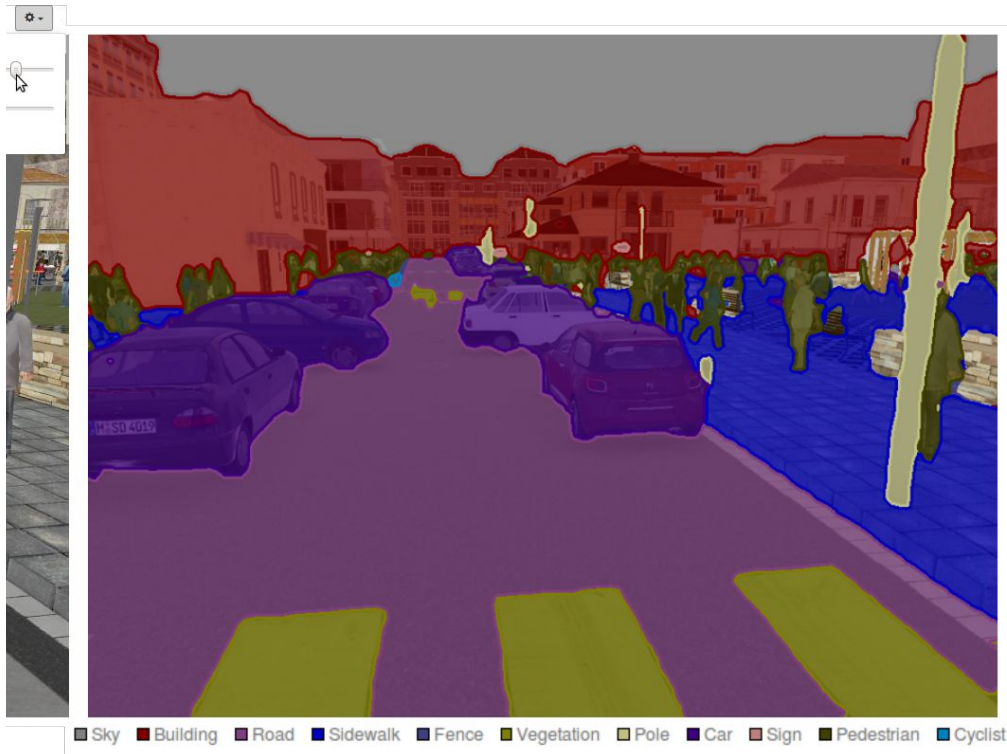
Metric proposal: pixel accuracy



$$\text{Pixel Accuracy} = \frac{\text{Number of pixel correctly classified}}{\text{Total number of pixels in the image}}$$



Metric proposal: pixel accuracy

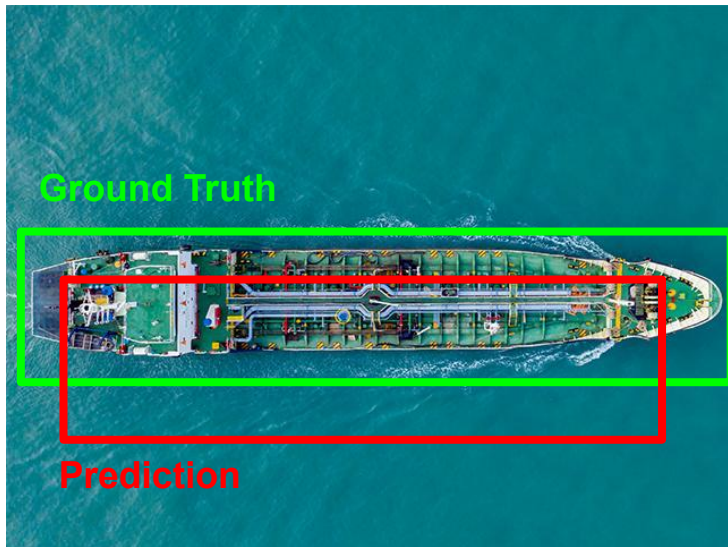


Other metrics

- PA - Pixel accuracy
 - MPA - Mean Pixel Accuracy
- Intersection over Union (IoU) - Jaccard Index
- Dice coefficient
- (Precision/Recall/F1 index)



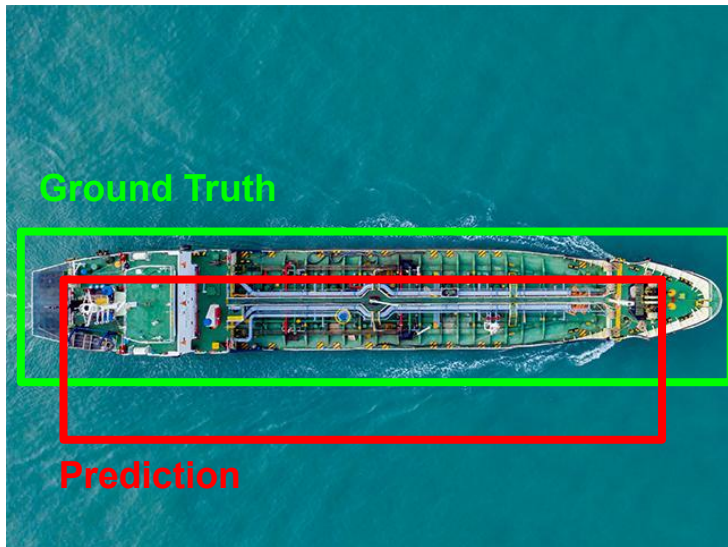
Intersection Over Union



$$\text{IoU} = \frac{\text{Number of pixel correctly classified}}{\text{Union(Ground Truth, Prediction)}}$$



Dice coefficient



$$DC = \frac{2 \times \text{Number of pixel correctly classified}}{\text{Ground Truth} + \text{Prediction}}$$



Metrics summary

$$\text{Pixel Accuracy} = \frac{\text{Number of pixel correctly classified}}{\text{Total number of pixels in the image}}$$

$$\text{IoU} = \frac{\text{Number of pixel correctly classified}}{\text{Union(Ground Truth, Prediction)}}$$

$$\text{Dice Coefficient} = \frac{2 \times \text{Number of pixel correctly classified}}{\text{Ground Truth} + \text{Prediction}}$$

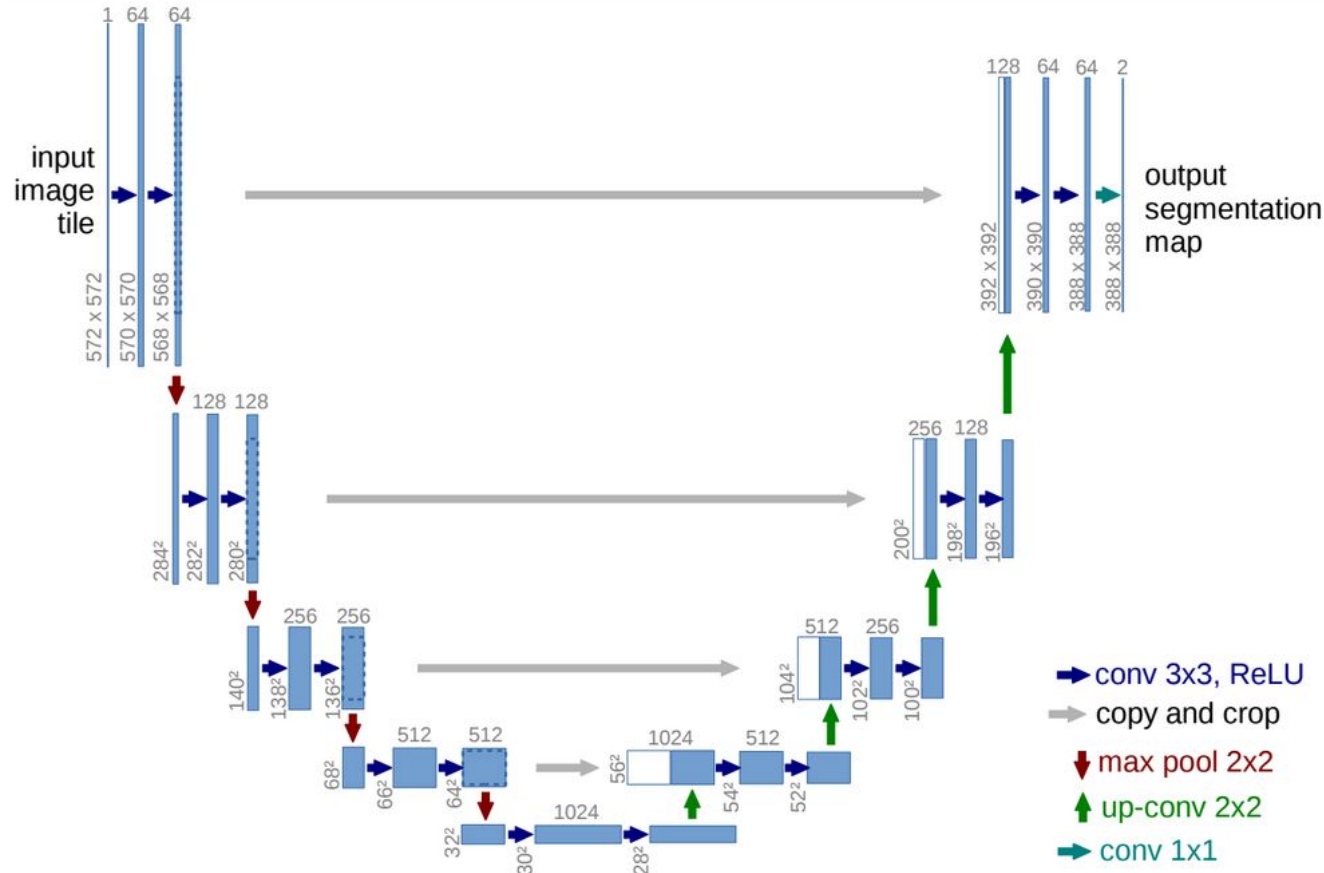


Let's do that





U-Net



Source: Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." *International Conference on Medical image computing and computer-assisted intervention*. Springer, Cham, 2015.

Let's also do that



Tips

- Expensive to generate training set
- Less standard than classification
- Actively developed...
- ...but you need to follow the architecture authors
- Transfer learning is your friend

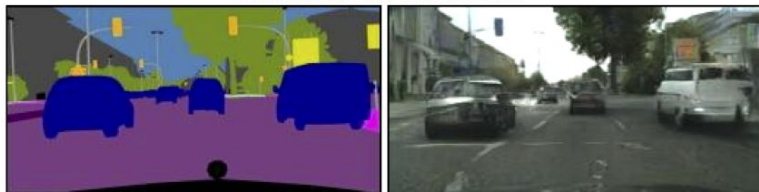


What if we use the net in reverse?



CycleGAN and pix2pix (in PyTorch)

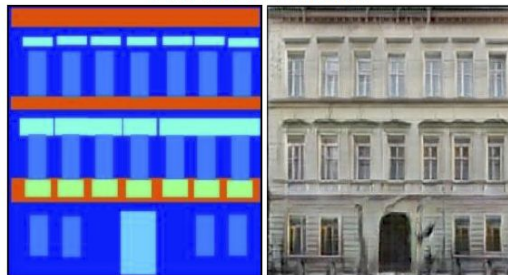
Labels to Street Scene



input

output

Labels to Facade



input

output

BW to Color



input

output

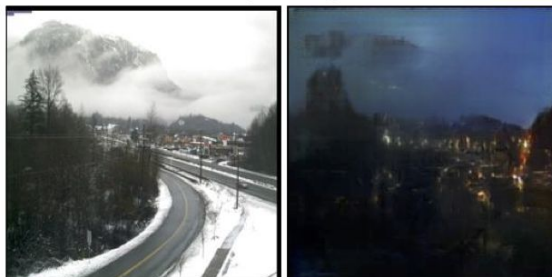
Aerial to Map



input

output

Day to Night



input

output

Edges to Photo



input

output

Sources:

- Zhu et al., "Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks"

[REF] Architectures

- **U-Net**
 - Olaf Ronneberger et. al 2015 “U-net architecture image segmentation”
 - <https://arxiv.org/abs/1505.04597>
- **FastFCN**
 - Huikai Wu et.al 2019 “FastFCN: Rethinking Dilated Convolution in the Backbone for Semantic Segmentation”
 - <https://arxiv.org/abs/1903.11816>
- **Gated-SCNN**
 - Towaki Takikawa et. al 2019 “Gated-SCNN: Gated Shape CNNs for Semantic Segmentation”
 - <https://arxiv.org/abs/1907.05740>
- **DeepLab**
 - *Liang-Chieh Chen et. al 2016 “DeepLab: Semantic Image Segmentation with Deep Convolutional Nets, Atrous Convolution, and Fully Connected CRFs”*
 - <https://arxiv.org/abs/1606.00915>
- **Mask R-CNN**
 - Kaiming He et. al 2017 “Mask R-CNN”
 - <https://arxiv.org/abs/1703.06870>



[REF] Databases

- **[2D] Pascal Visual Object Classes (VOC)**
 - <http://host.robots.ox.ac.uk/pascal/VOC/index.html>
 - 21 object classes (vehicle, household, animal, airplane...)
- **[2D] Microsoft COCO: Common Objects in Context**
 - <https://paperswithcode.com/dataset/coco>
 - “91 objects types that would be easily recognizable by a 4 year old”
- **[2D] Cityscapes**
 - <https://www.cityscapes-dataset.com/>
 - 5 000 images with high quality annotations · 20 000 images with coarse annotations · 50 different cities
- **[2.5D] Sun RGB-D**
 - <https://rgbd.cs.princeton.edu/>
 - four different sensors and contains 10,000 RGB-D images
- **[3D] Stanford 2D-3D-Semantics Dataset**
 - <http://buildingparser.stanford.edu/dataset.html>
 - It covers over 6,000 m2 and contains over 70,000 RGB images, along with the corresponding depths, surface normals, semantic annotations, global XYZ images
- **[2D] CycleGAN training set for segmentation**
 - <https://github.com/junyanz/pytorch-CycleGAN-and-pix2pix#cyclegan-traintest>



[REF] Useful stuff



- **Image Segmentation Using Deep Learning: A Survey**
 - Minaee, Shervin, et al. "Image segmentation using deep learning: A survey." IEEE Transactions on Pattern Analysis and Machine Intelligence (2021).
- **Data preprocessing and augmentation using Torch.IO**
 - (take away the message, even if using pyTorch)
 - https://colab.research.google.com/github/fepegar/torchio-notebooks/blob/main/notebooks/Data_preprocessing_and_augmentation_using_TorchIO_a_tutorial.ipynb

