[2020 KOHI]
Semantic segmentation

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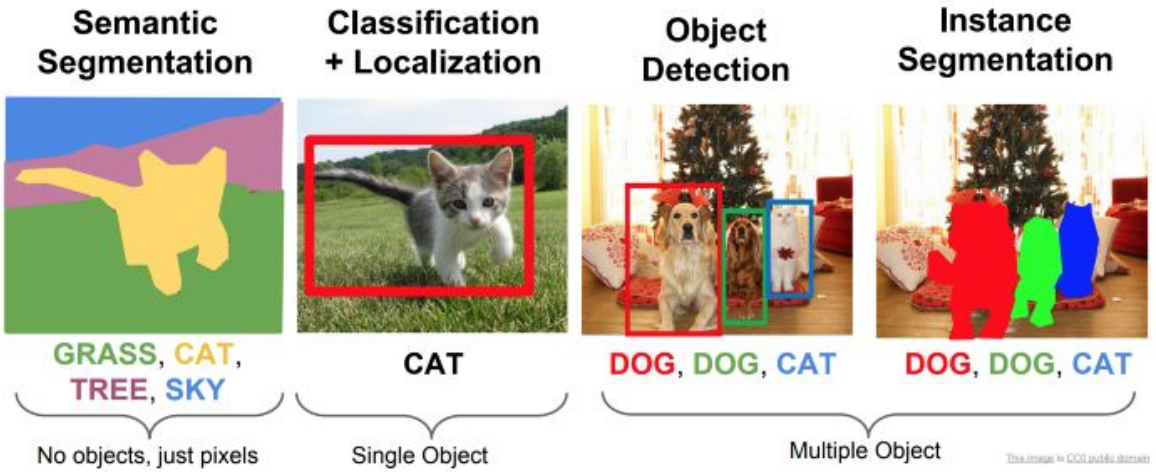
What is semantic segmentation?

Definition : Segmentation

Simple & easy to label →



For a given **image**, areas or structures are displayed as output by analyzing information such as **color, edge, pattern, and orientation**.

from Fei-Fei Li Stanford Course — Detection And Segmentation

What is semantic segmentation?

Definition : Segmentation

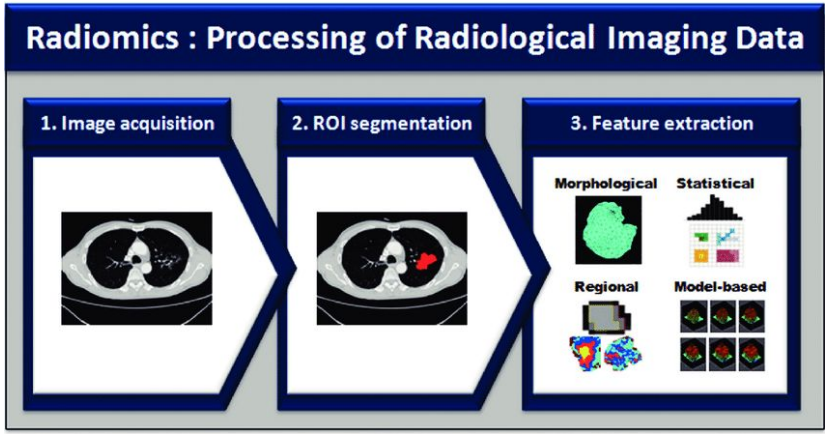
- **Image Classification**: Classify the main object category within an image.
- **Object Detection**: Identify the object category and locate the position using a bounding box for every known object within an image.
- **Semantic Segmentation**: Identify the object category of each pixel for every known object within an image. **Labels are class-aware.**
- **Instance Segmentation**: Identify each object instance of each pixel for every known object within an image. **Labels are instance-aware.**

What is semantic segmentation?

Why do we need semantic segmentation?

1. **Precision analysis**
2. **Necessary but annoying**

Ex) Radiomics

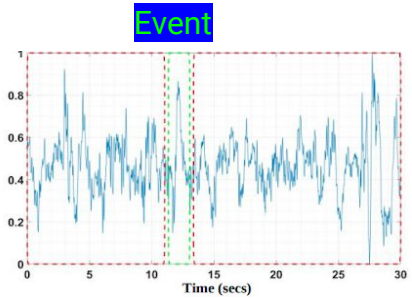


- Our criteria are based on spatial information
- There are numerous amounts of information in the image. (ex 512 * *512* * 1 = 2^{18})
- CNN finds features well, but if you give key local information, the performance increases.
- Good for quantitative analysis and quantification.

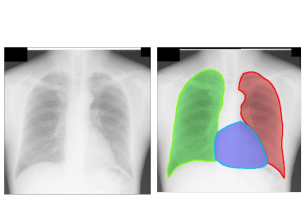
What is semantic segmentation?

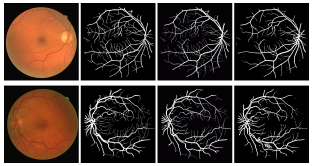
Segmentation in medicine

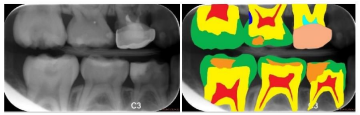
1D : Signal (N x s x C)



2D : image (N x H x W x C)

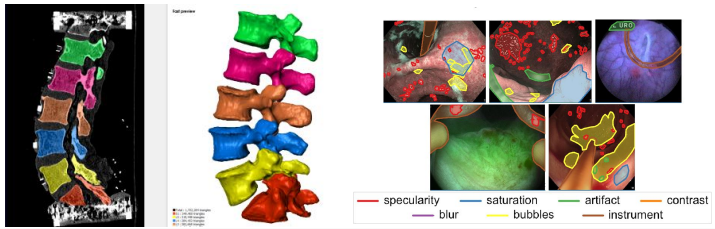




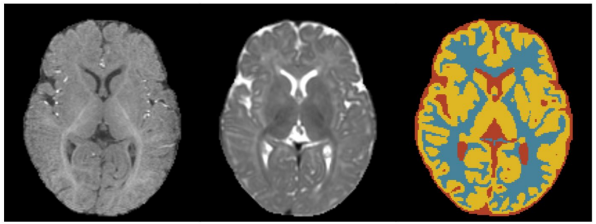


3D : 3D image (N x D x H x W x 1)

image with time (N x T x H x W x 1)

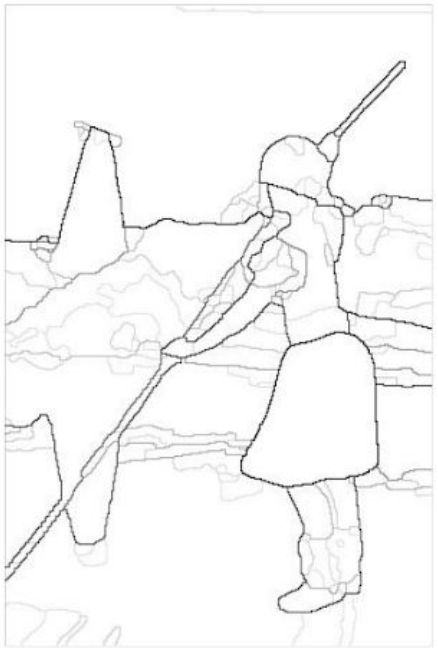


4D : Multi modal 3D image (N x D x H x W x **C**)



What is semantic segmentation?

Traditional segmentation



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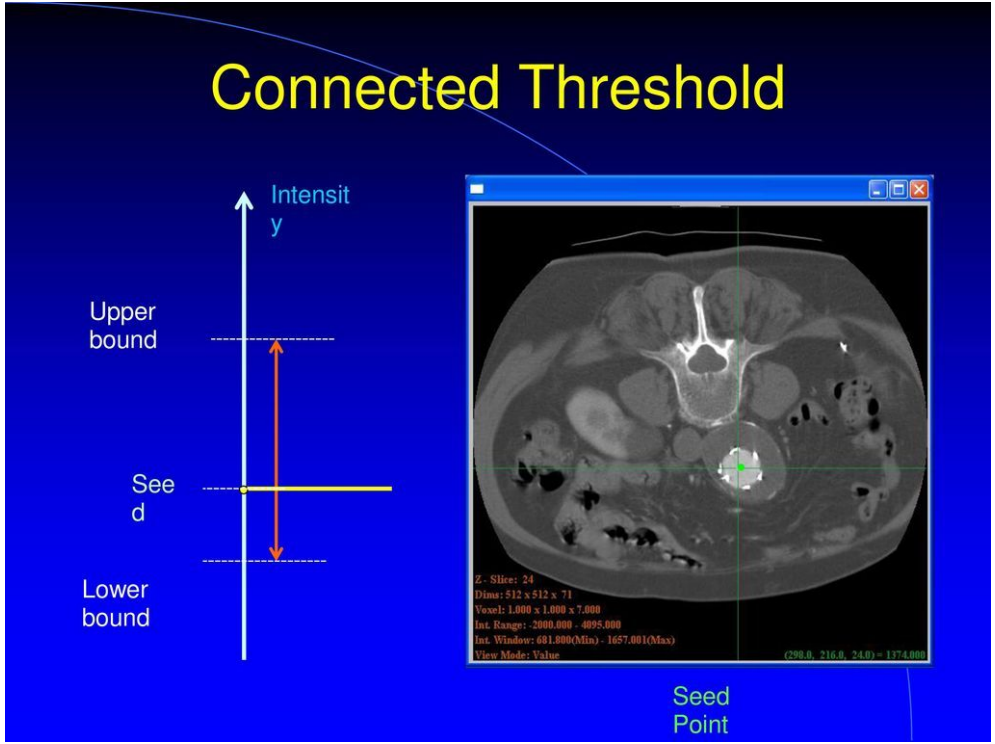
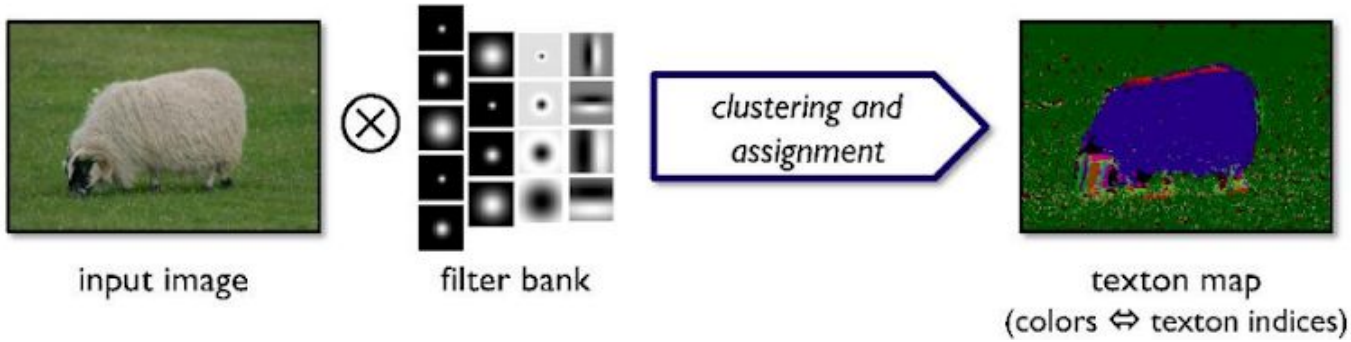
Traditional segmentation



from “ITK Segmentation Methods"

What is semantic segmentation?

Traditional segmentation



Tingwu Wang et al. [2]

Workflow of segmentation using deep learning

1. **Dataset** — class, size, shape imbalanced?
   Different protocol, kernel, slice thickness?
   Sensitive label, multi labeler?
2. **Preprocessing** — bit? Modality? Resample?
3. **Metric** — Dice, IoU, distance, FROC?
4. **Loss function** — CE, Dice, Tversky, Boundary?
5. **Model** — U-net, Pyramid?
6. **Evaluation** — False positive, False Negative?

Metric

1. **Dice**
2. **IoU(Intersection over Union)**
3. Jaccard
4. **Hausdorff Distance**
5. **FROC**
6. **...**

$$Dice\ Coefficient = \frac{2 * TP}{FN + (2 * TP) + FP}$$

$$Jaccard\ Index = \frac{TP}{TP + FN + FP}$$

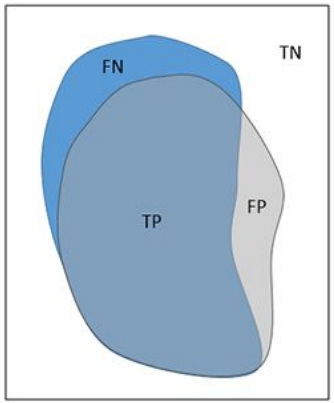
$$Sensitivity = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

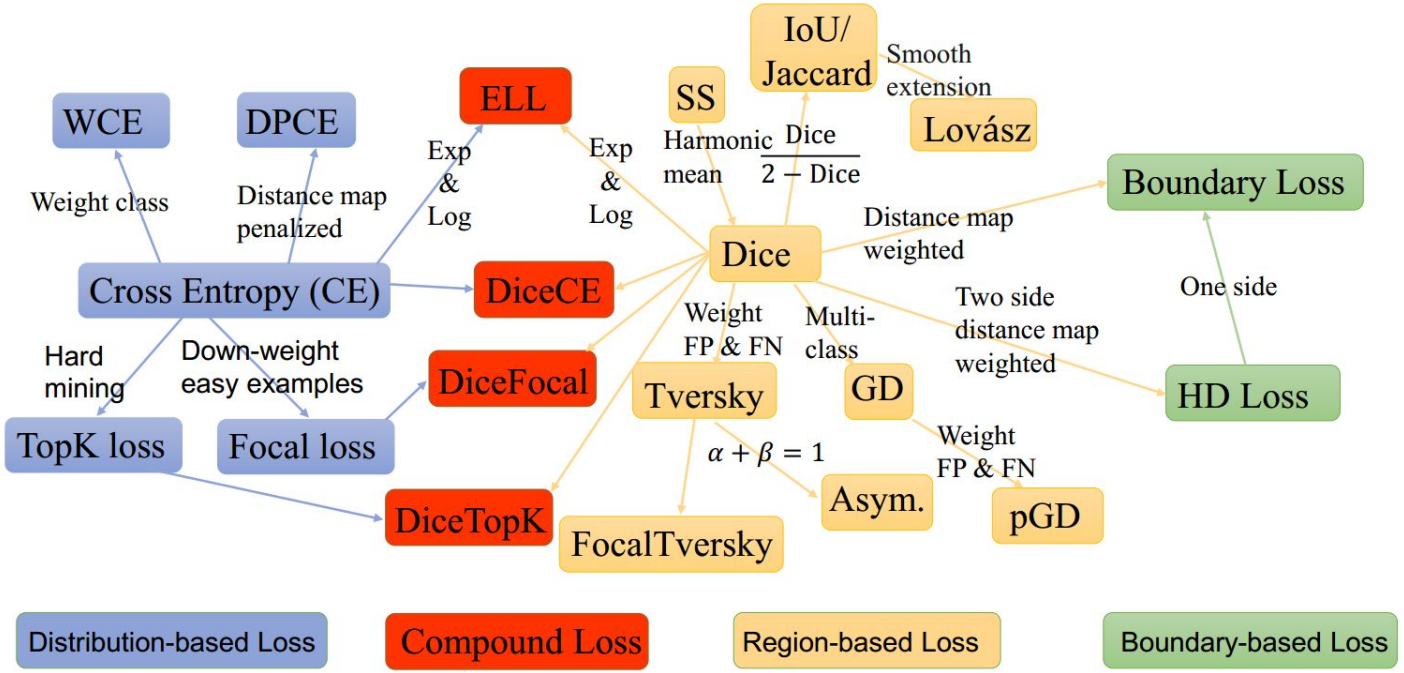
TP - true positive
TN - true negative
FP - false positive
FN - false negative

Manual Segmentation

Automated Segmentation



Loss function



Images from [5] https://github.com/JunMa11/SegLoss

Segmentation using Deep learning

Dataset

Input

segmented

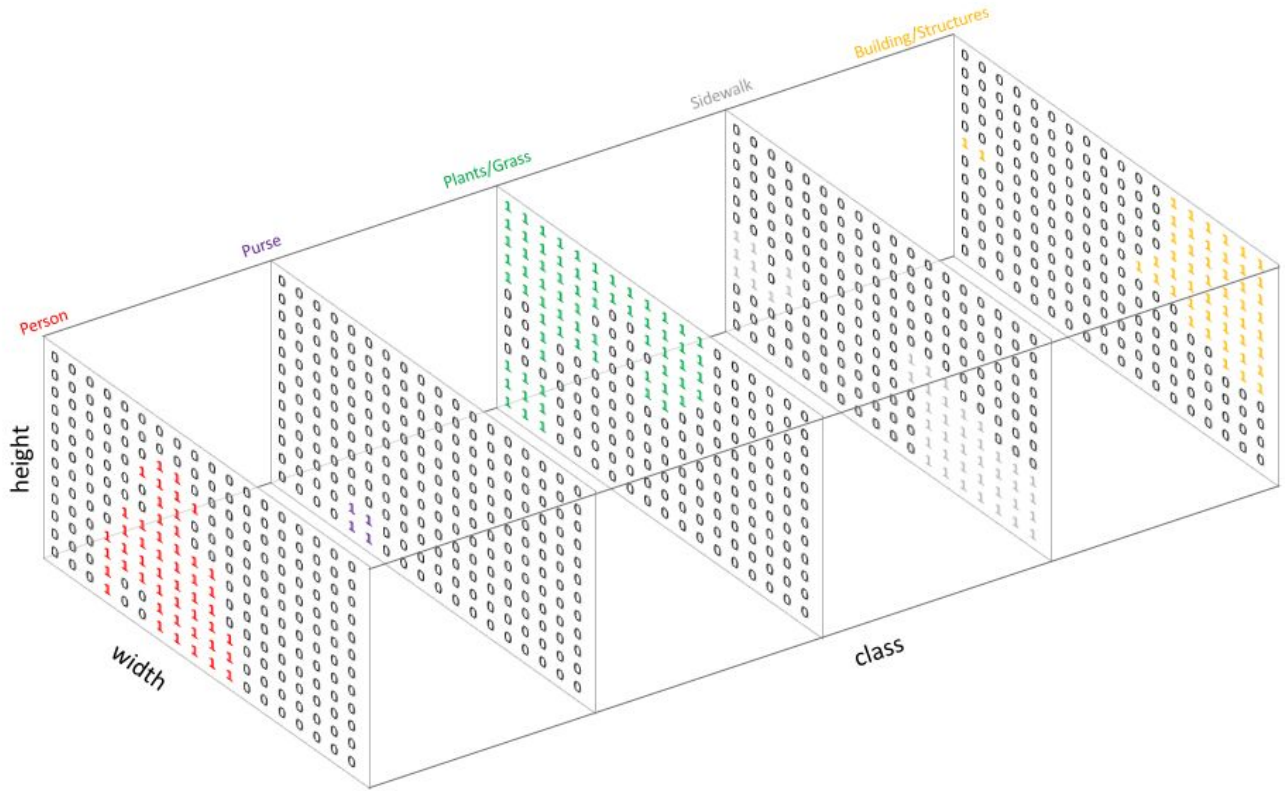
1: Person
2: Purse
3: Plants/Grass
4: Sidewalk
5: Building/Structures

3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5
3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	5	5	5
3	3	3	3	3	3	1	1	3	3	3	3	5	5	5	5	5	5
3	3	3	3	3	1	1	1	1	3	3	3	5	5	5	5	5	5
3	3	3	3	3	3	1	1	3	3	3	5	5	5	5	5	5	5
5	5	3	3	3	3	1	1	3	3	5	5	5	5	5	5	5	5
4	4	3	4	1	1	1	1	1	1	4	4	4	5	5	5	5	5
4	4	3	4	1	1	1	1	1	1	4	4	4	4	4	5	5	5
4	4	4	1	1	1	1	1	1	1	1	4	4	4	4	4	4	4
3	3	3	1	1	1	1	1	1	1	1	4	4	4	4	4	4	4
3	3	3	1	2	2	1	1	1	1	1	4	4	4	4	4	4	4
3	3	3	1	2	2	1	1	1	1	1	4	4	4	4	4	4	4

Semantic Labels

Segmentation using Deep learning

Dataset



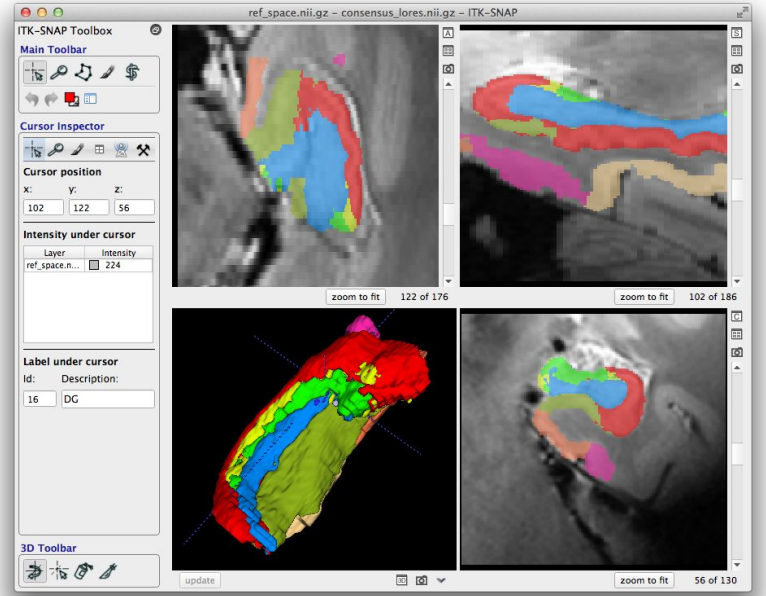
Segmentation using Deep learning

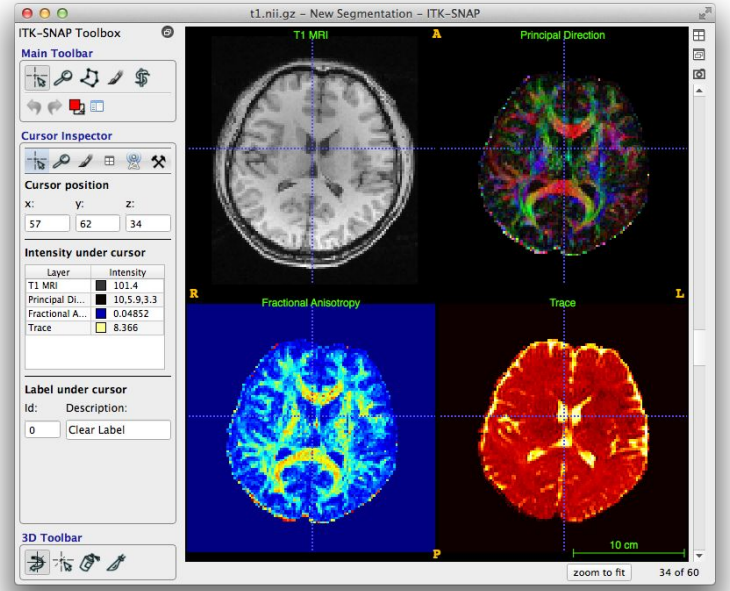
Dataset

0: Background/Unknown
1: Person
2: Purse
3: Plants/Grass
4: Sidewalk
5: Building/Structures

Segmentation using Deep learning

Medical labeling tool (ITK-SNAP)

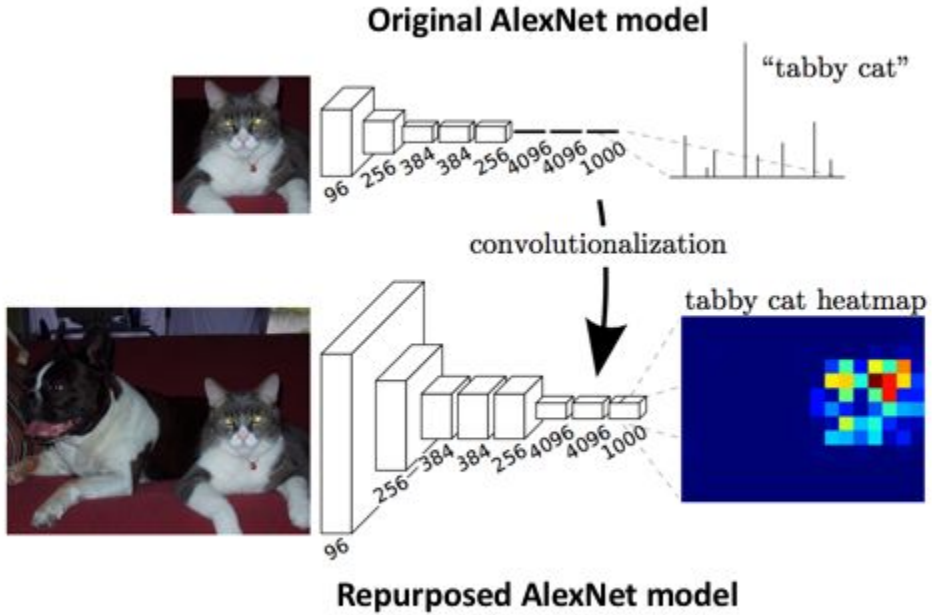




http://www.itksnap.org/pmwiki/uploads/Train/RSNA2016-Handout-Exercises.pdf

Segmentation using Deep learning

Fully Convolutional Network

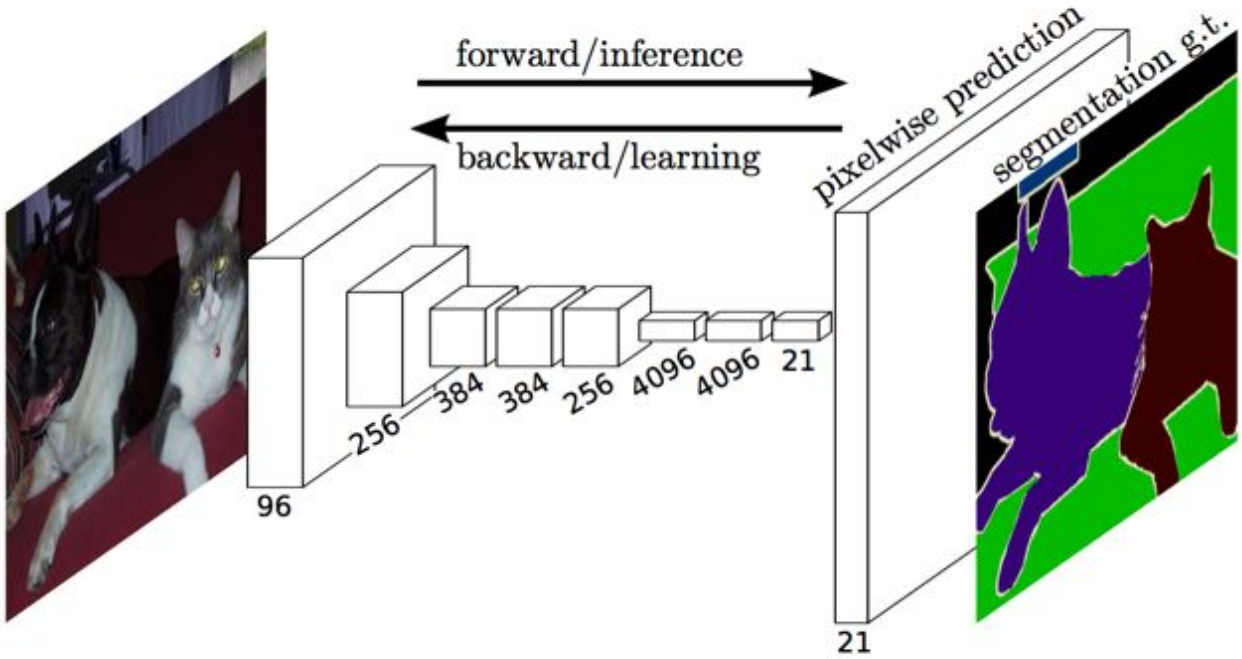


The encoder produces a ***coarse*** feature map which is then refined by the decoder module.

Images from Fully Convolutional Networks for Semantic Segmentation

Segmentation using Deep learning

Fully Convolutional Network



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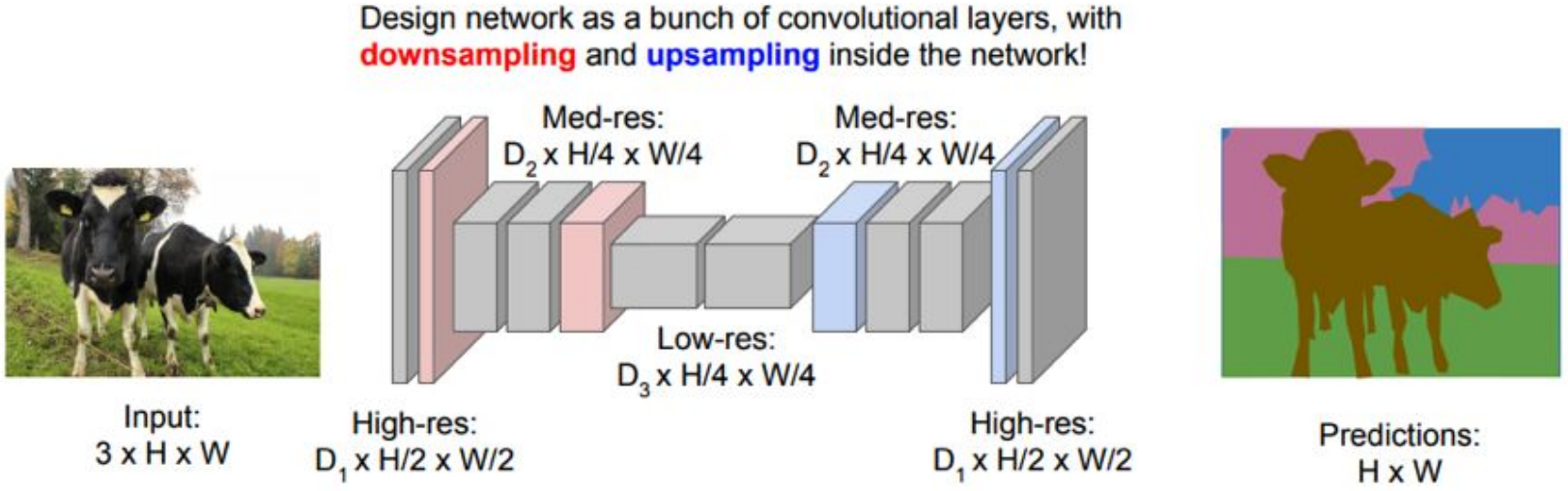
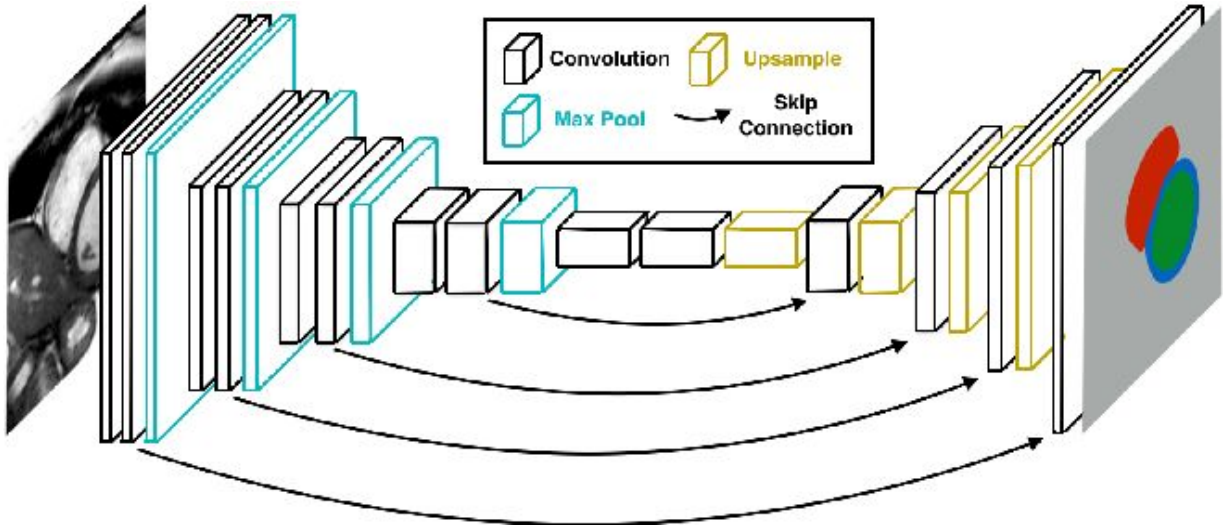
Fully Convolutional Network



Solution: Make network deep and *work at a lower spatial resolution* for many of the layers.

Segmentation using Deep learning

U-Net



Images from [5] groundai.com/

Hands on

[1] Lung segmentation (2D) : FCN to U-Net

https://colab.research.google.com/github/kevinkwshin/Handson_segmentation/blob/main/SemanticSegmentation_KOHI_2D.ipynb

[2] Sleen segmentation (3D) with MONAI Project (https://github.com/Project-MONAI/MONAI)

https://colab.research.google.com/github/Project-MONAI/tutorials/blob/master/3d_segmentation/spleen_segmentation_3d.ipynb

Discussion

- SOTA model and method

  : https://paperswithcode.com/task/medical-image-segmentation
- False positive reduction
  - post-processing
  - cascaded network
  - Set false positive as 2nd label
  - learning post-processing
- Open source?

  : nnU-Net (Official) : https://github.com/MIC-DKFZ/nnUNet

  : MONAI (Official) : https://github.com/Project-MONAI/MONAI
- Multi-organ segmentation

  : http://medicaldecathlon.com/

Reference

[1] https://www.jeremyjordan.me/semantic-segmentation/

[2] Semantic Segmentation, Tingwu Wang, Machine learning group, University of Toronto

[3] Fully Convolutional Networks for Semantic Segmentation, Jonathan Long, et al.

[4] CS231n: Convolutional Neural Networks for Visual Recognition, Stanford University,

[5] https://www.groundai.com/project/fastventricle-cardiac-segmentation-with-enet/

[6] https://glassboxmedicine.com/2020/01/21/segmentation-u-net-mask-r-cnn-and-medical-applications/

[7] https://github.com/JunMa11/SegLoss