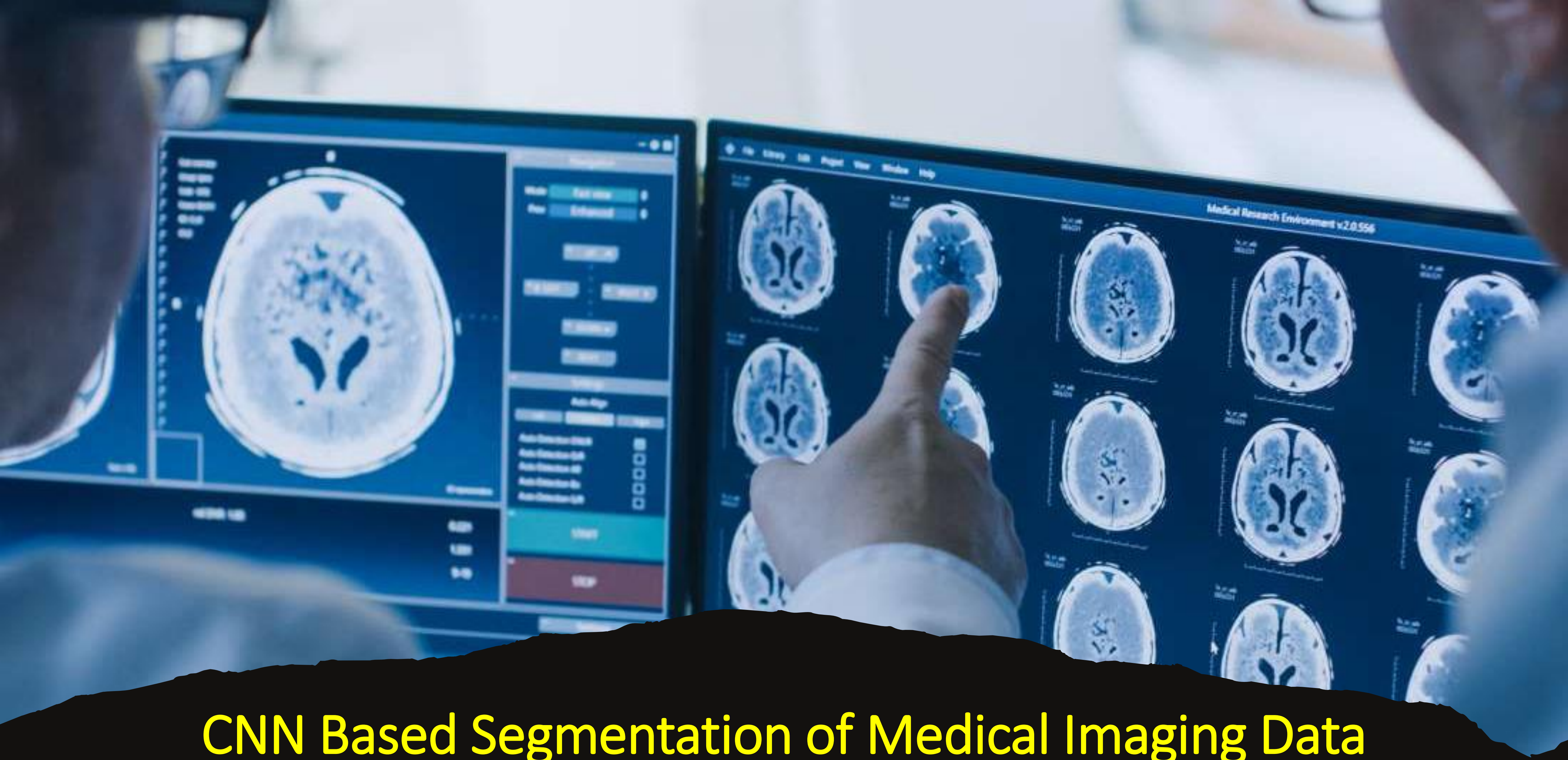

CNN Based Segmentation of Medical Imaging Data

IE643 (Deep Learning: Theory & Practice) Course Project by Team – MetaNet

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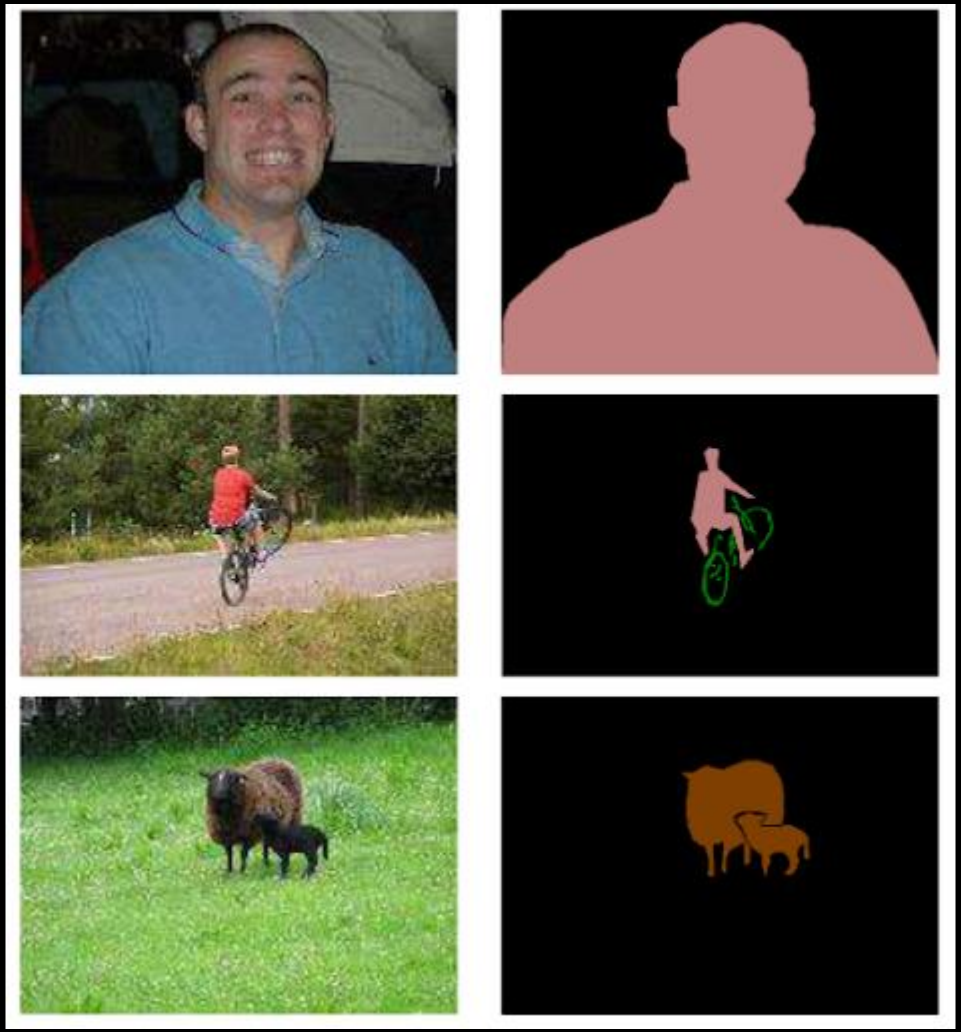
Outline

- Image Segmentation
- Types & Applications
- Techniques
- NN Architectures
- Loss Functions
- Medical Image Segmentation
- Pre-Processing & Training
- Challenges / Issues



Typical Segmentation Maps [3]

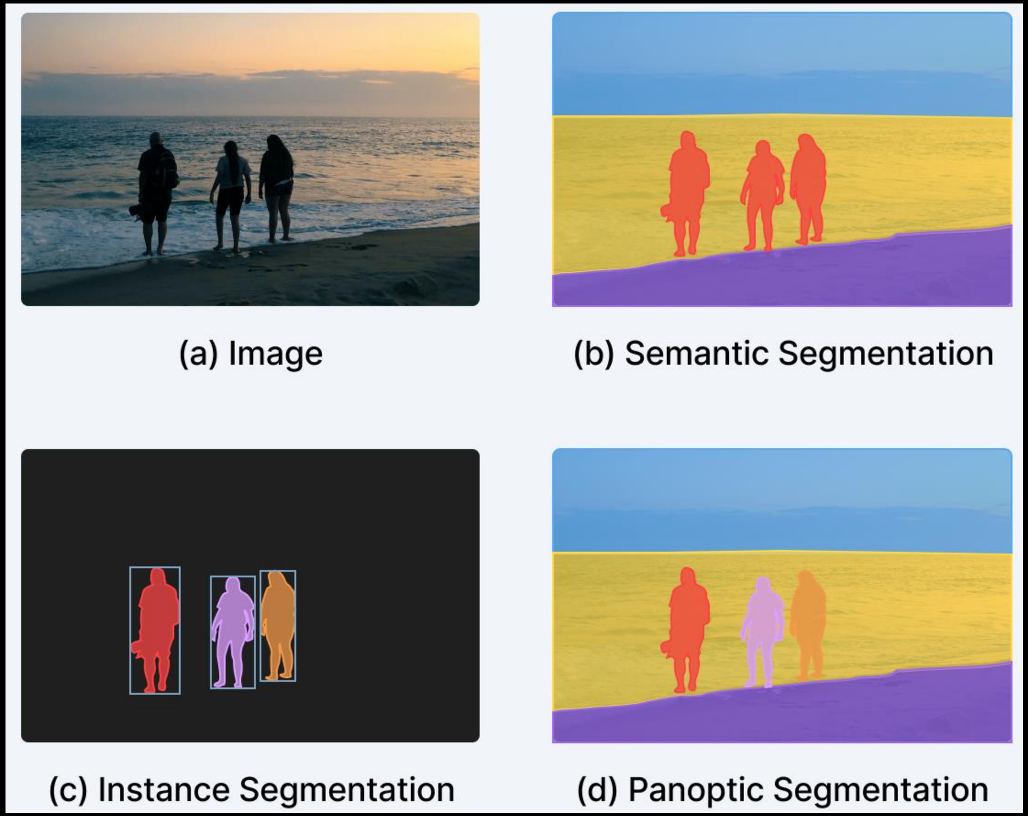
What is Image Segmentation? [4]

- Image segmentation is a method in which a digital image is broken down into various subgroups called Image segments which helps in reducing the complexity of the image to make further processing or analysis of the image simpler
- Segmentation in easy words is assigning labels to pixels. All picture elements or pixels belonging to the same category have a common label assigned to them
- Ex: In an image containing fruit and a flower, an ideal image segmentation model would label every pixel associated with fruit as 'fruit' and similarly with every pixel associated with flower as 'flower'

Types [1,2,3]

- Semantic segmentation – All objects of the same type are marked with the same label
- Instance segmentation – Even instances of the same type will be marked with different label
- Panoptic segmentation - can be expressed as the combination of semantic & instance segmentation where each instance of an object in the image is segregated and the object's identity is predicted

Semantic Segmentation Instance Segmentation



(a) Image (b) Semantic Segmentation (c) Instance Segmentation (d) Panoptic Segmentation

Applications [3]

- Image segmentation finds its way in prominent fields like Robotics, Medical Imaging, Autonomous Vehicles, and Intelligent Video Analytics.
- Robotics - aids machine perception and locomotion by pointing out objects in their path of motion, enabling them to change paths effectively and understand the context of their environment
- Medical Imaging - helps doctors identify possible malignant features in images in a fast and accurate manner
- Smart Cities - AI-based monitoring, crimes can be reported faster, road accidents can be followed up with immediate ambulances, and speeding cars can be easily caught and penalized
- Self-Driving Cars - instance segmentation helps vehicles to identify road patterns and other vehicles, thereby enabling a hassle-free and smooth ride
- Image segmentation is also used by satellites on aerial imagery for segmenting out roads, buildings, and trees.

Image Segmentation Techniques: Traditional

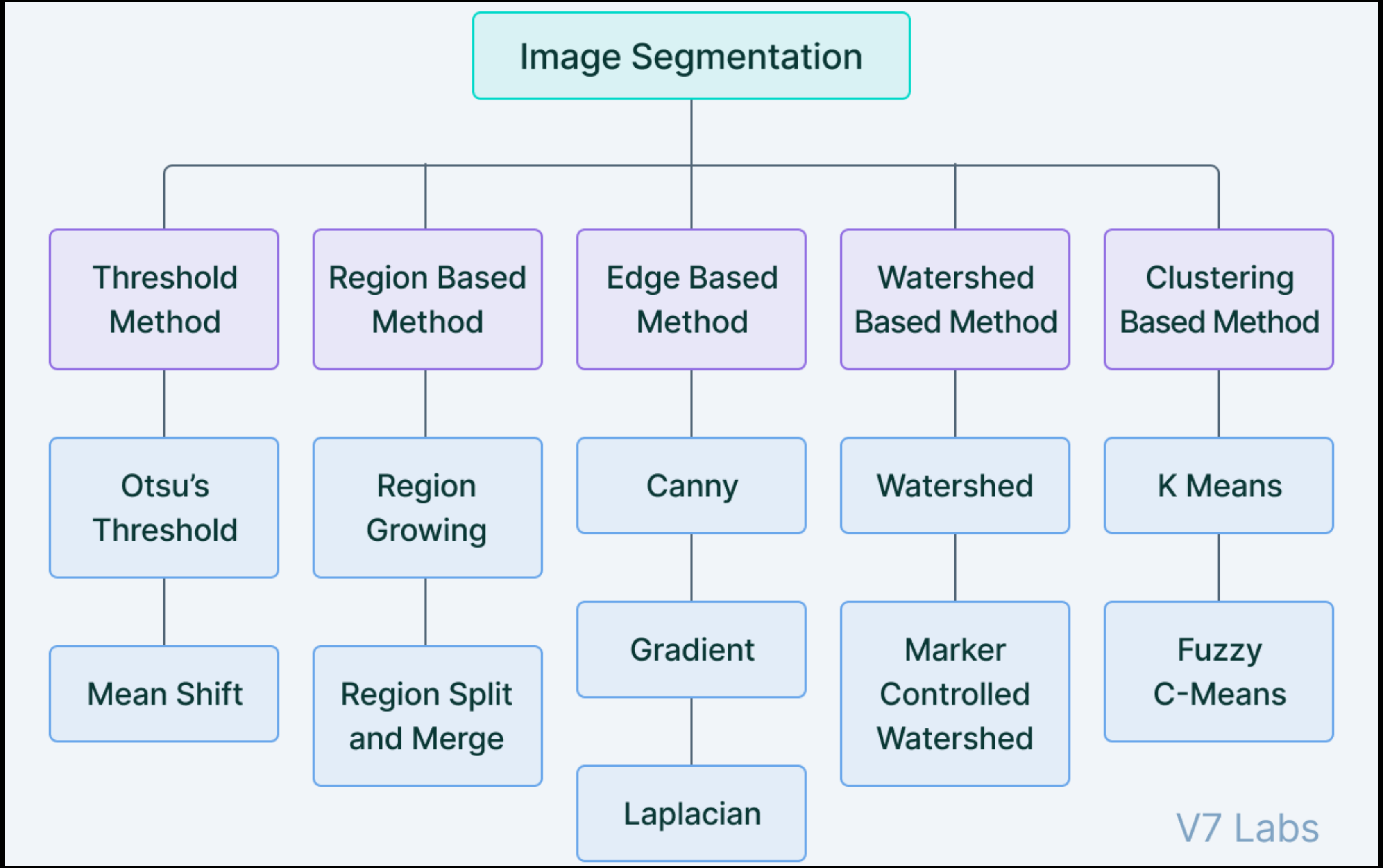
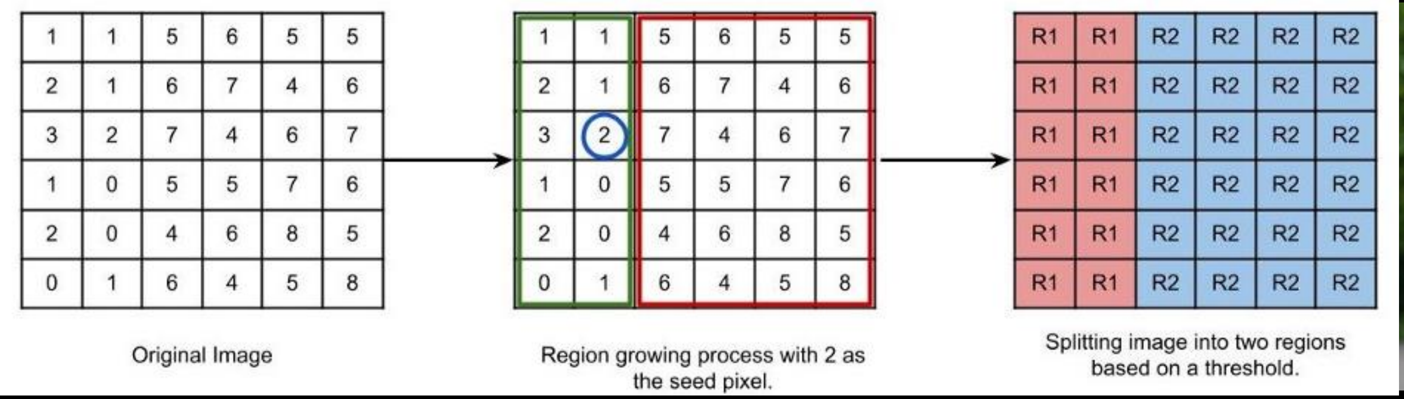
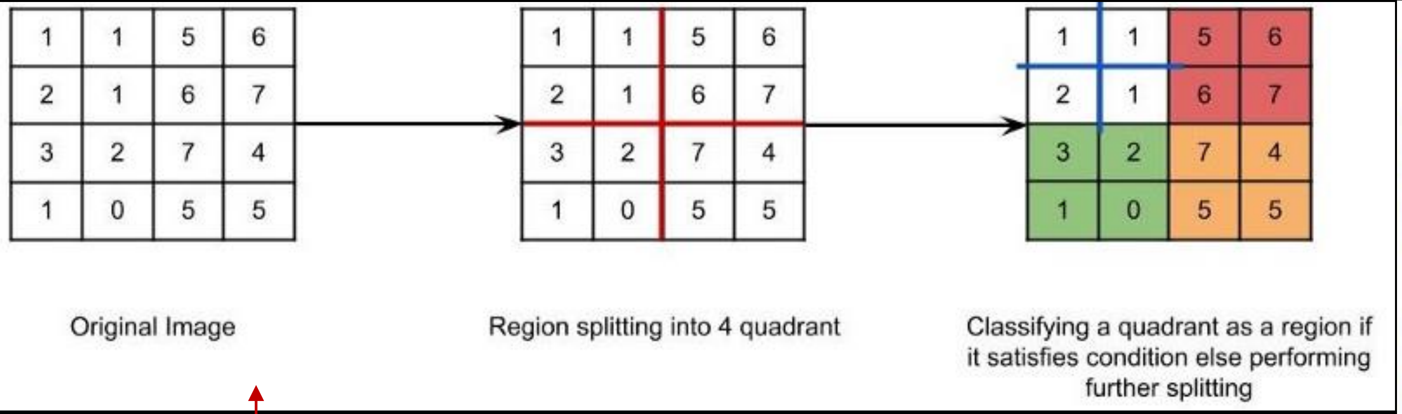


Image Segmentation Techniques: Examples



a) Region Growing Workflow [5]

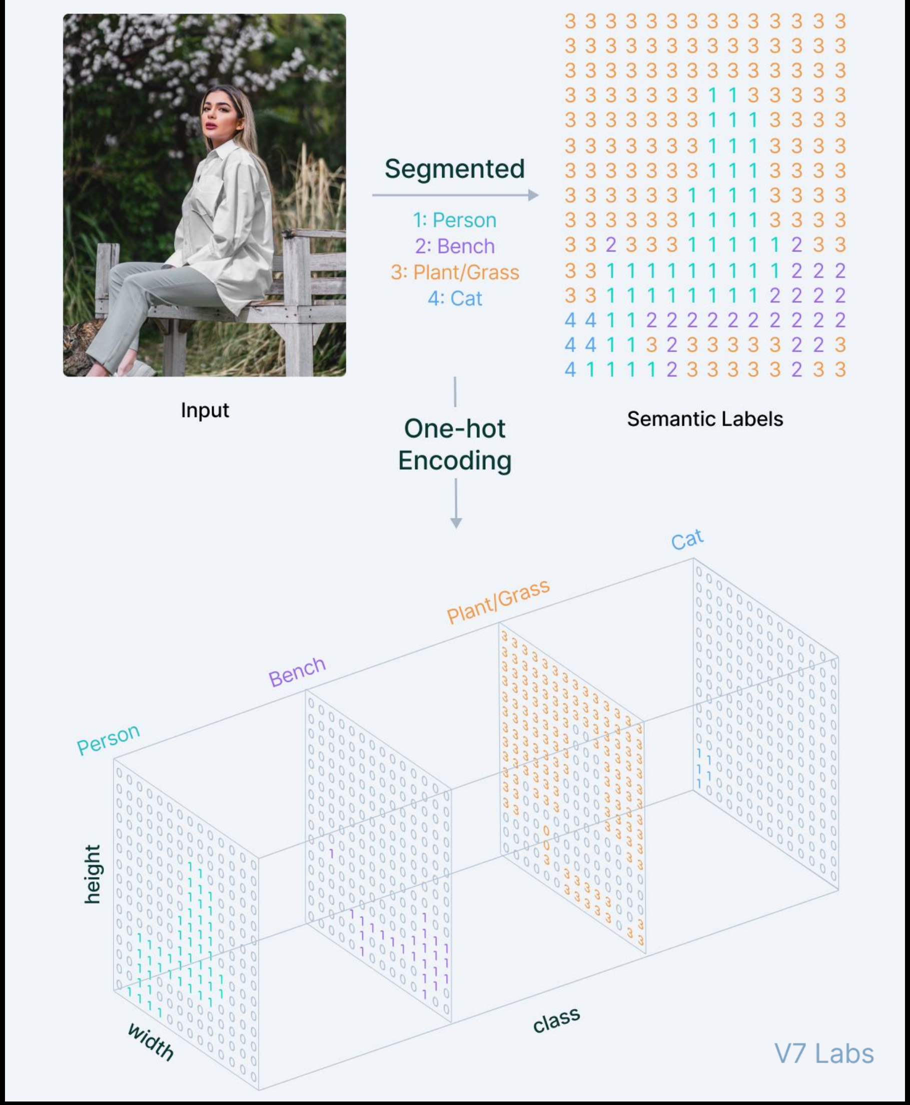
c) Canny Edge Detection [3]

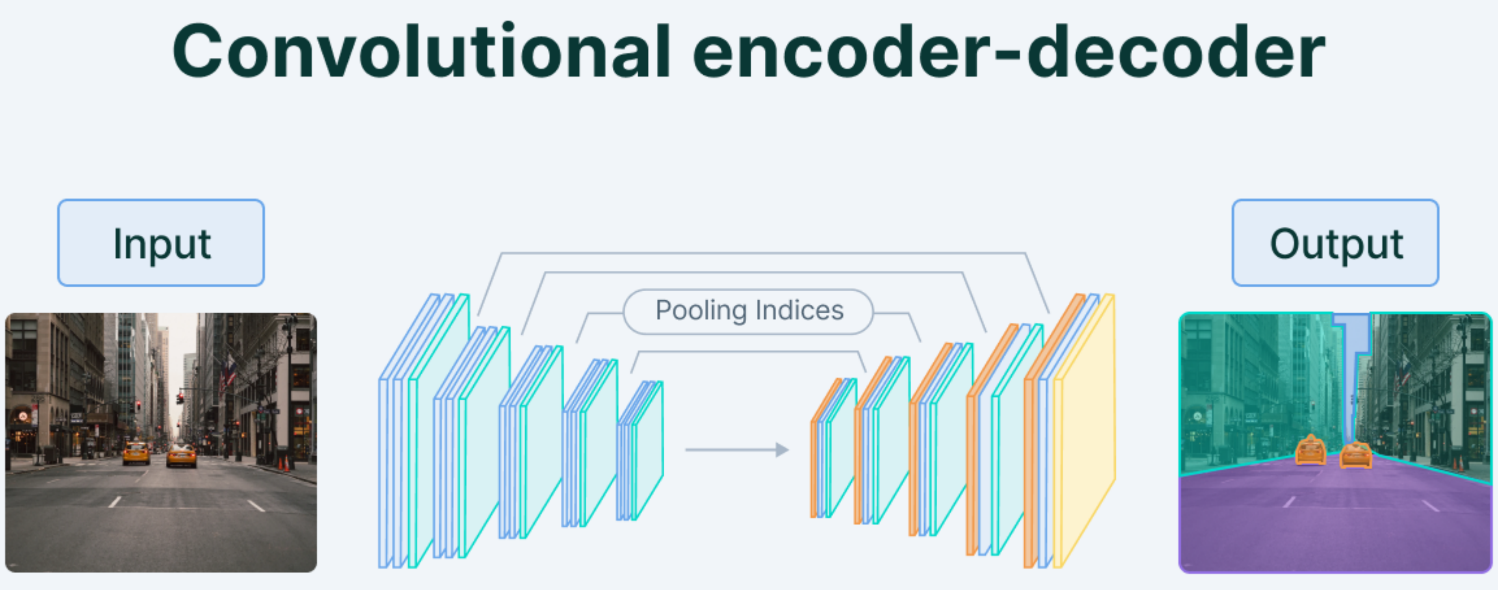


b) Region Splitting & Merging Workflow [5]

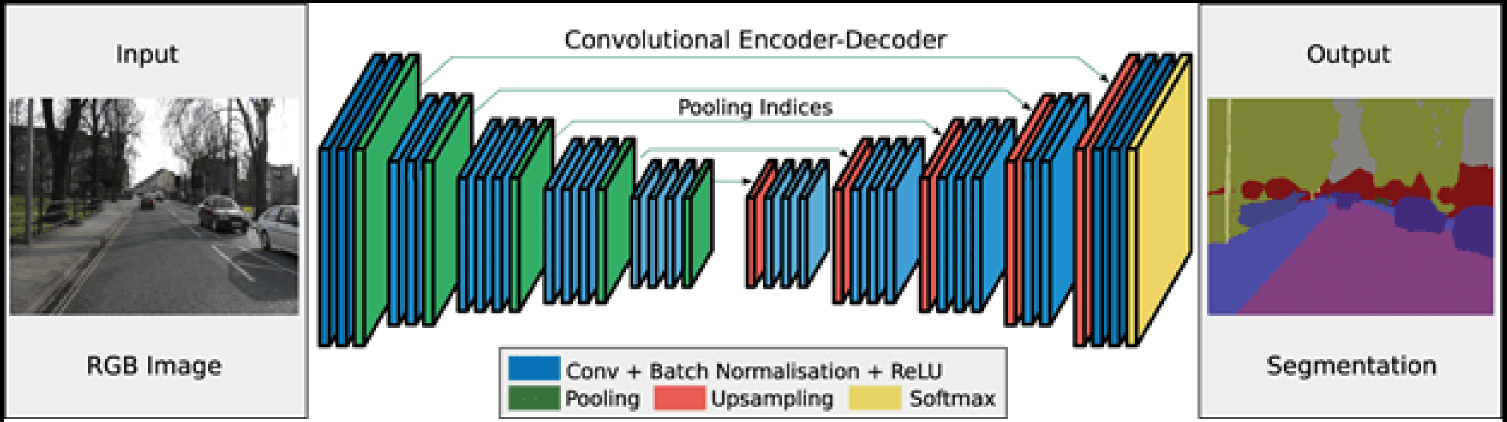
d) Segmentation using K-Means Clustering wrt Colours [5]

Deep Learning Based Image Segmentation





SegNet (by Badrinarayanan *et. al.*) in 2015



Architectures: UNET, Gated SCNN, Mask RCNN, FastFCN

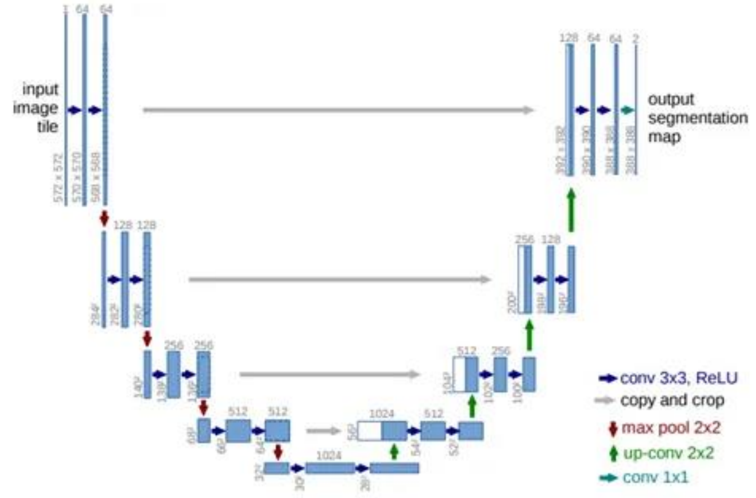


Fig. 1. U-net architecture (example for 32x32 pixels in the lowest resolution). Each blue box corresponds to a multi-channel feature map. The number of channels is denoted on top of the box. The x-y-size is provided at the lower left edge of the box. White boxes represent copied feature maps. The arrows denote the different operations.

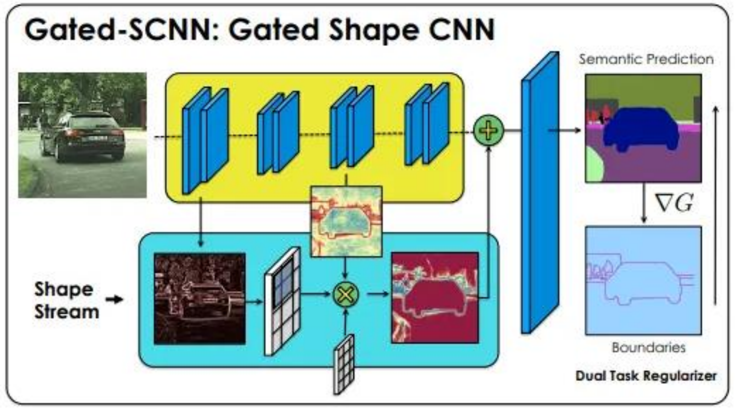


Figure 1: We introduce *Gated-SCNN* (GSCNN), a new two-stream CNN architecture for semantic segmentation that explicitly wires shape information as a separate processing stream. GSCNN uses a new gating mechanism to connect the intermediate layers. Fusion of information between streams is done at the very end through a fusion module. To predict high-quality boundaries, we exploit a new loss function that encourages the predicted semantic segmentation masks to align with ground-truth boundaries.

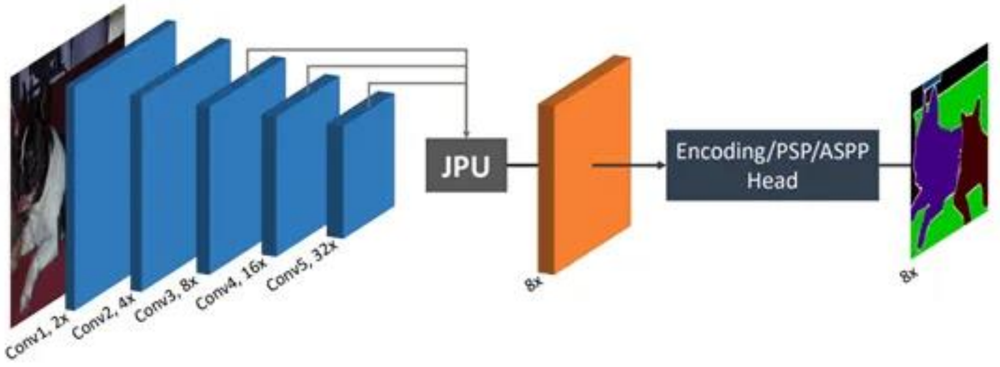


Figure 2: **Framework Overview of Our Method.** Our method employs the same backbone as the original FCN. After the backbone, a novel upsampling module named Joint Pyramid Upsampling (JPU) is proposed, which takes the last three feature maps as the inputs and generates a high-resolution feature map. A multi-scale/global context module is then employed to produce the final label map. Best viewed in color.

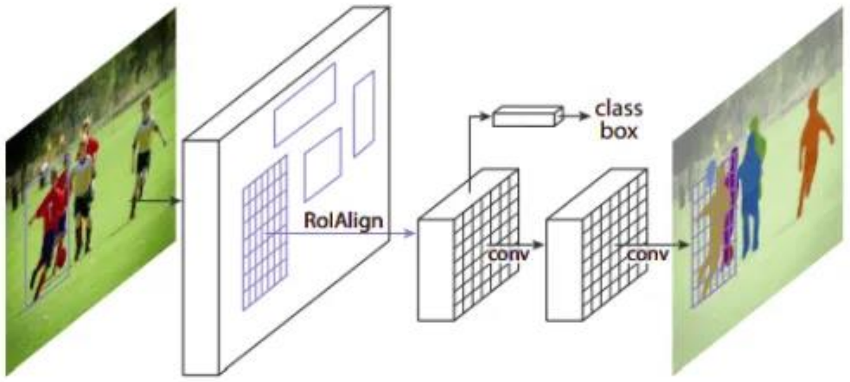
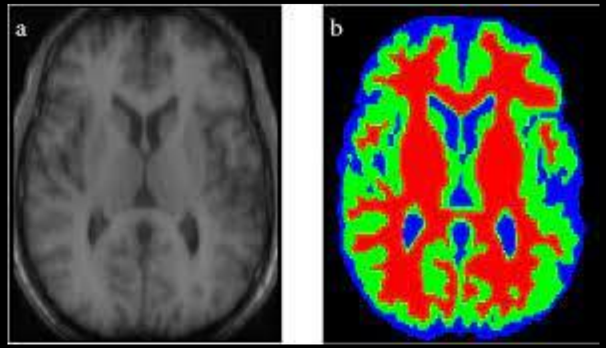


Figure 1. The **Mask R-CNN** framework for instance segmentation.

Loss Functions

- Focal Loss $\mathrm{FL}(p_t) = -(1-p_t)^\gamma \log(p_t).$
  - Improvement to standard cross entropy loss
  - This is done by changing its shape such that the loss assigned to well-classified examples is down-weighted
- Dice Loss $DSC = \frac{2|X \cap Y|}{|X| + |Y|}$
- Intersection over Union (IoU) balanced loss $IoU = TP/(TP + FP + FN)$
- Boundary Loss $\mathrm{Dist}(\partial G, \partial S) = \int_{\partial G} \|y_{\partial S}(p) - p\|^2 dp$
- Weighted Cross Entropy $\mathrm{WCE}(p, \hat{p}) = -(\beta p \log(\hat{p}) + (1-p)\log(1-\hat{p}))$
- Lovász-Softmax loss $\mathrm{loss}(\boldsymbol{f}) = \frac{1}{|\mathcal{C}|}\sum_{c \in \mathcal{C}} \overline{\Delta_{J_c}}(\boldsymbol{m}(c))$

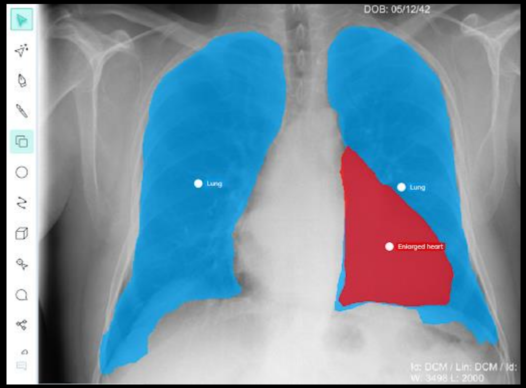
Medical Image Segmentation



- Medical Imaging is an important domain of computer vision that focuses on the diagnosis of diseases from simple visual data & biomedical scans.
- Medical image segmentation involves the extraction of regions of interest (ROIs) from 3D image data, such as from Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans.
- The main goal is to identify areas of the anatomy required for a particular study, for example, to simulate physical properties or virtually positioning CAD-designed implants within a patient. It mainly helps doctors identify possible malignant features in images in a fast and accurate manner.
- Medical image segmentation can be a time-consuming task, and recent advances in AI are making it easier for routine tasks to be completed.

[3, 6]

Pre-Processing & Training



- Data Annotation for Labelling of Images
- Data Augmentation Techniques like:
  a) Identity transformation b) Rotation by random angle
  c) Flipping along random axis d) Generating mirror images
- Image Processing Techniques like:
  - Downsampling = To reduce pixels for easy memory handling
  - Cropping = To get same sizes with principal region of focus
- Network Training Techniques like:
  a) Deeply Supervised b) Weakly Supervised c) Transfer Learning

[3, 7, 8]

Challenges / Issues

- Limited Annotated Data
- Lack of Healthy Brain Images
- Class Imbalance
- Overfitting & Long Training Times
- Vanishing Gradients
- Heterogeneous Nature of Visible Organs
- 3D Images → Computationally Expensive

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