Introduction to Semantic Segmentation

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Outline

- Introduction to segmentation
- Practical examples and applications
- Various types of segmentation
- Accuracy metrics
- Computational requirements
- Resources

Introduction to Segmentation

- Image Segmentation is a process that subdivides an image into its constituent parts or objects.
- Key task in computer vision and image processing
- It can be formulated as a pixel classification problem with three different approaches (***semantic***, ***instance*** and ***panoptic***)

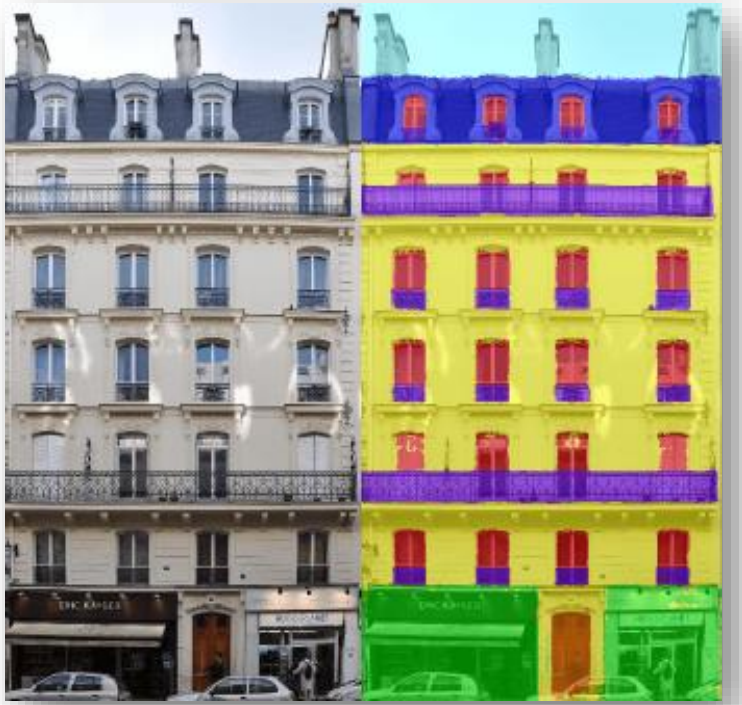
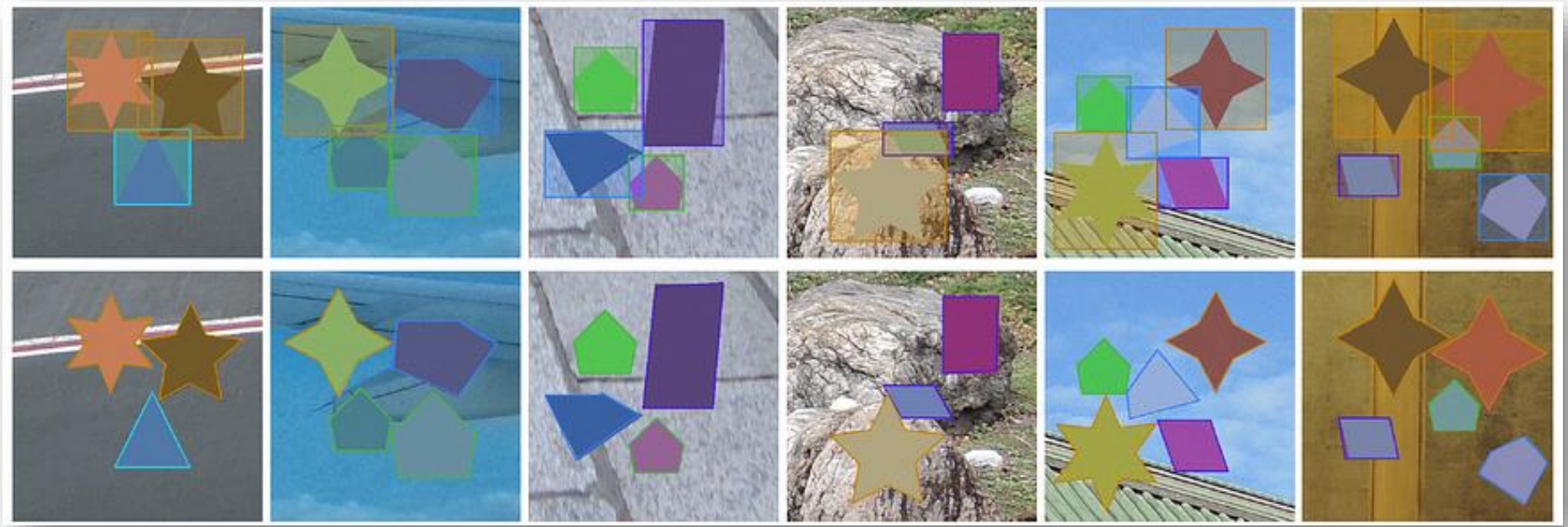
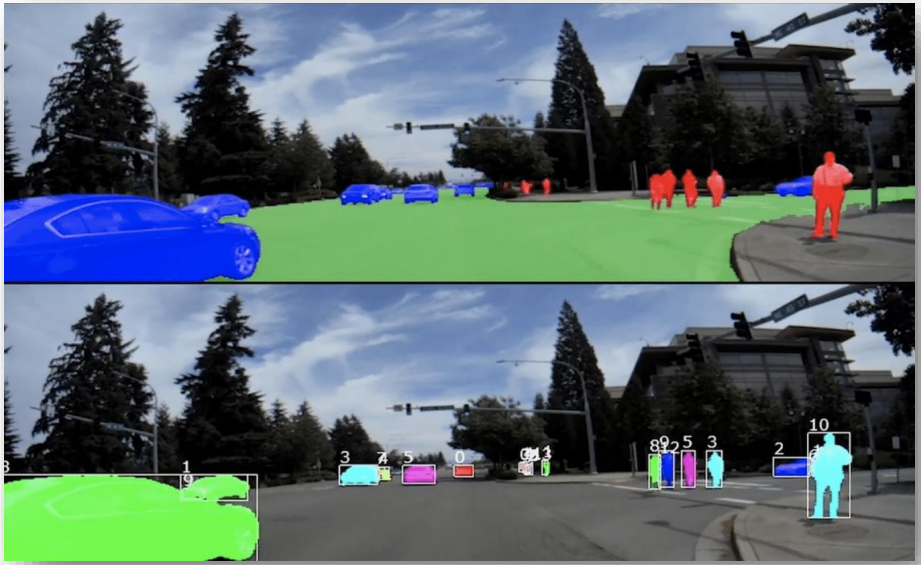


Image Segmentation vs. Object Detection



Practical Examples

- Autonomous vehicles
- Smart agriculture
- Drones and aerial imaging
- Medical image diagnosis
- Image editing
- Dataset augmentation

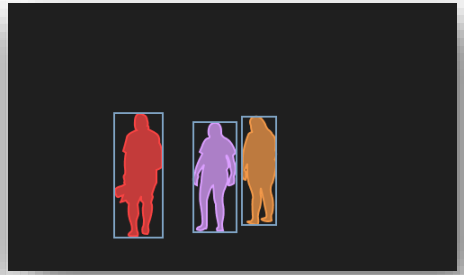


Instance, Semantic and Panoptic Segmentation

- **Semantic segmentation:** produces a contextual description of the “stuff” in the image. Classes are isolated but not objects within the same class. We don’t have access to a single object.
- **Instance segmentation**: produces a better description that can list objects as individual instances of “things” but lower generalization on the environment and background “stuff”.
- **Panoptic segmentation**: Combines semantic and instance segmentation. We have access to the environmental context but also to the individual objects. So, we see both “stuff” and “things”.

Image

Semantic Segmentation

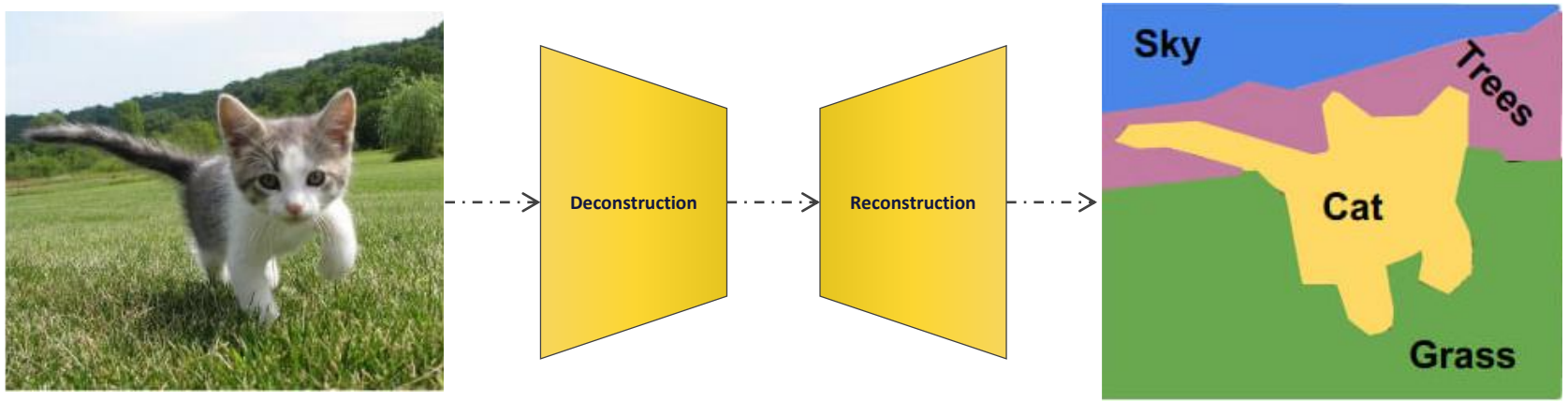


Instance Segmentation

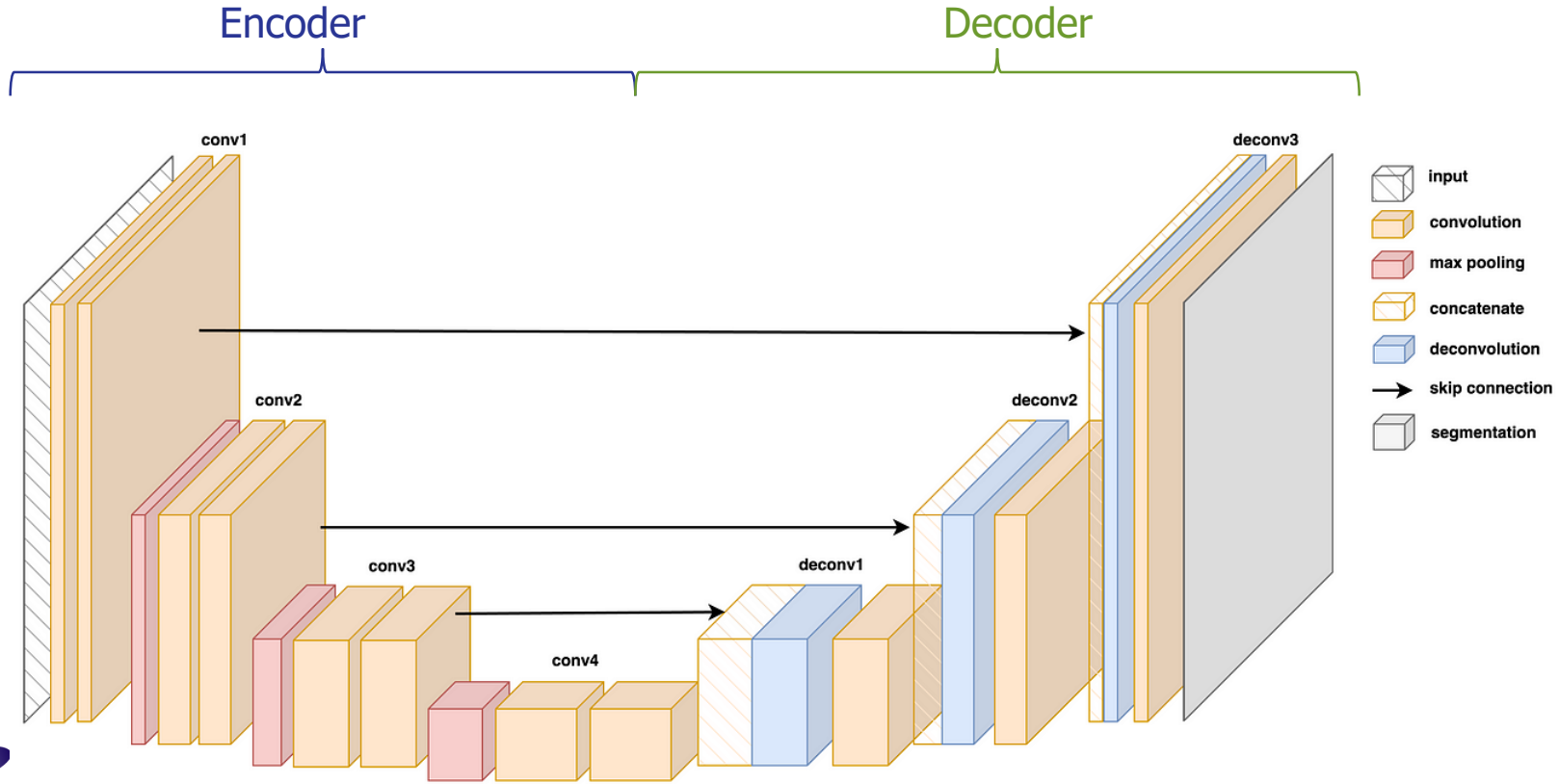
Panoptic Segmentation

Image Segmentation Using Deep Learning

- Deconstruction: Feature extraction (backbone, encoder)
- Reconstruction: Upsampler (decoder)

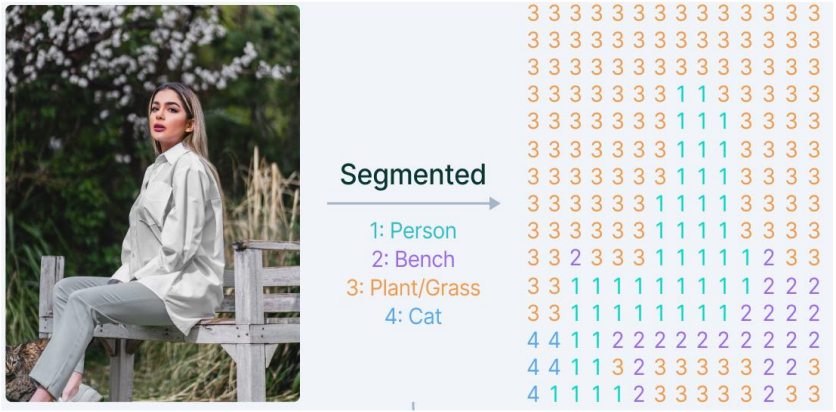


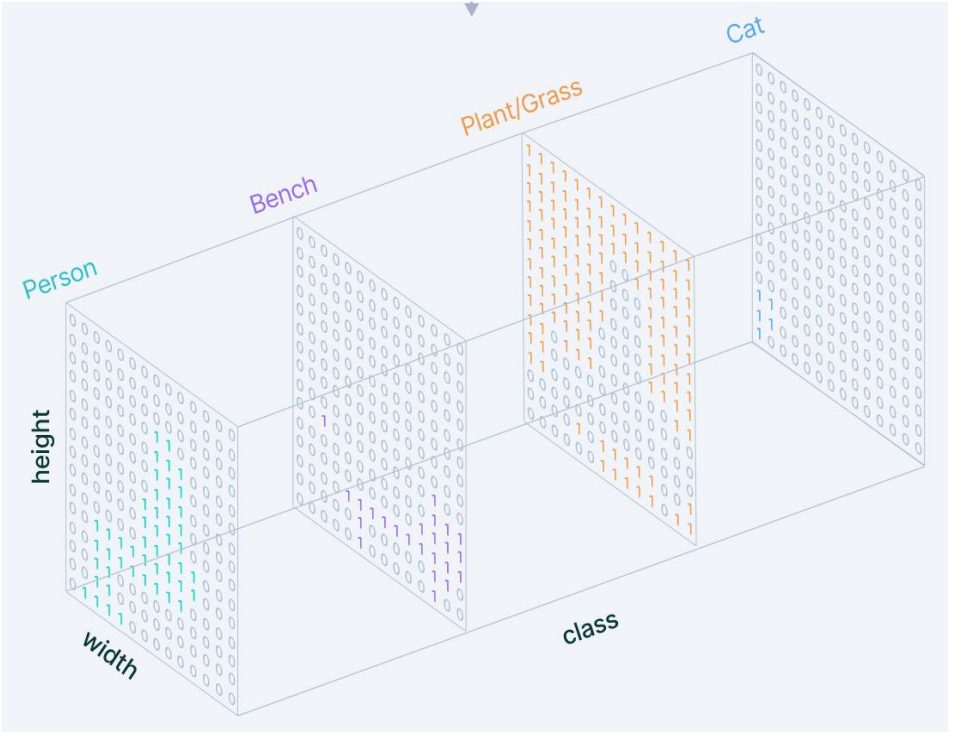
Deep Learning Segmentation Architecture



Semantic Segmentation Output

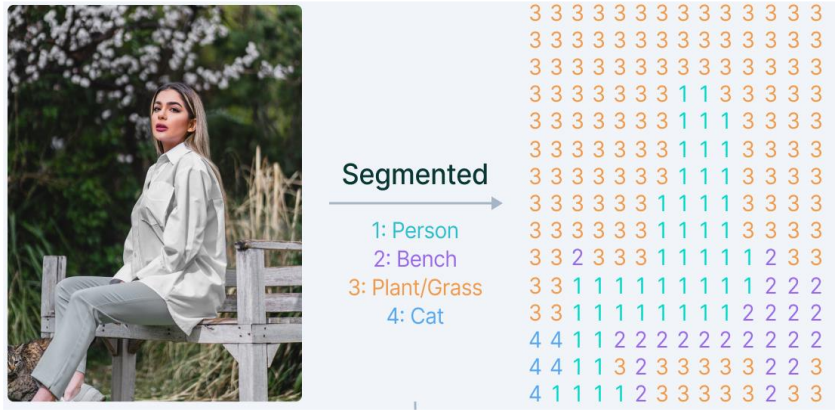
- 1-hot encoding, just like classification
- Score applied to each pixel
- Class with highest score sets the pixel





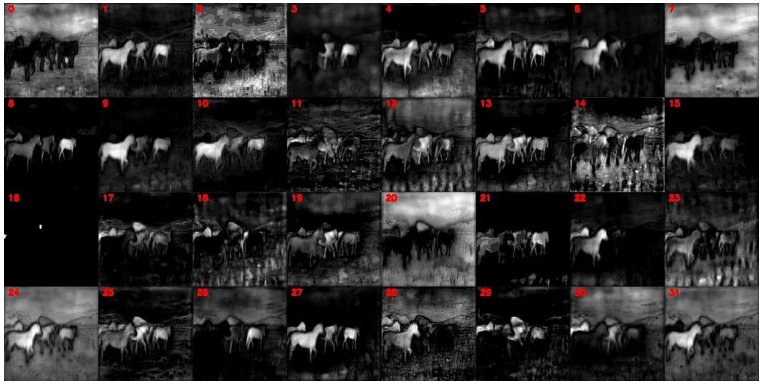
Instance Segmentation – Naïve

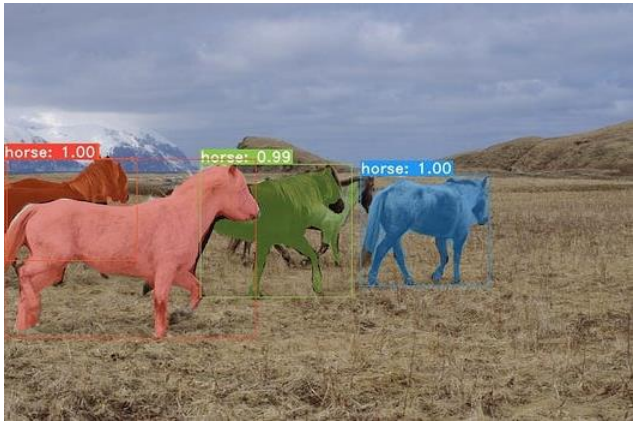
- Additional model output for computing bounding boxes
  - Same as SSD, YOLO, etc…
- Boxes are post-processed to re-colour masks in order to distinguish instances.
- Overlapping instances will be poorly segmented because of box limitations.



Instance Segmentation – Proto Masks

- Additional model output computes per-instance mask predictions.
- Learns to separate objects in each mask which are then fused with semantic mask.
- Handles overlapping instances.

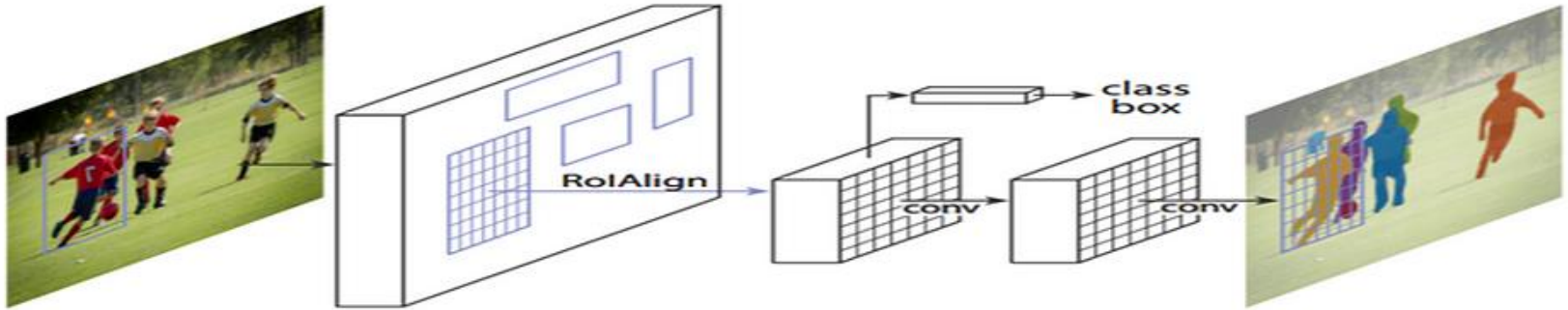




Instance Segmentation – Box Masks

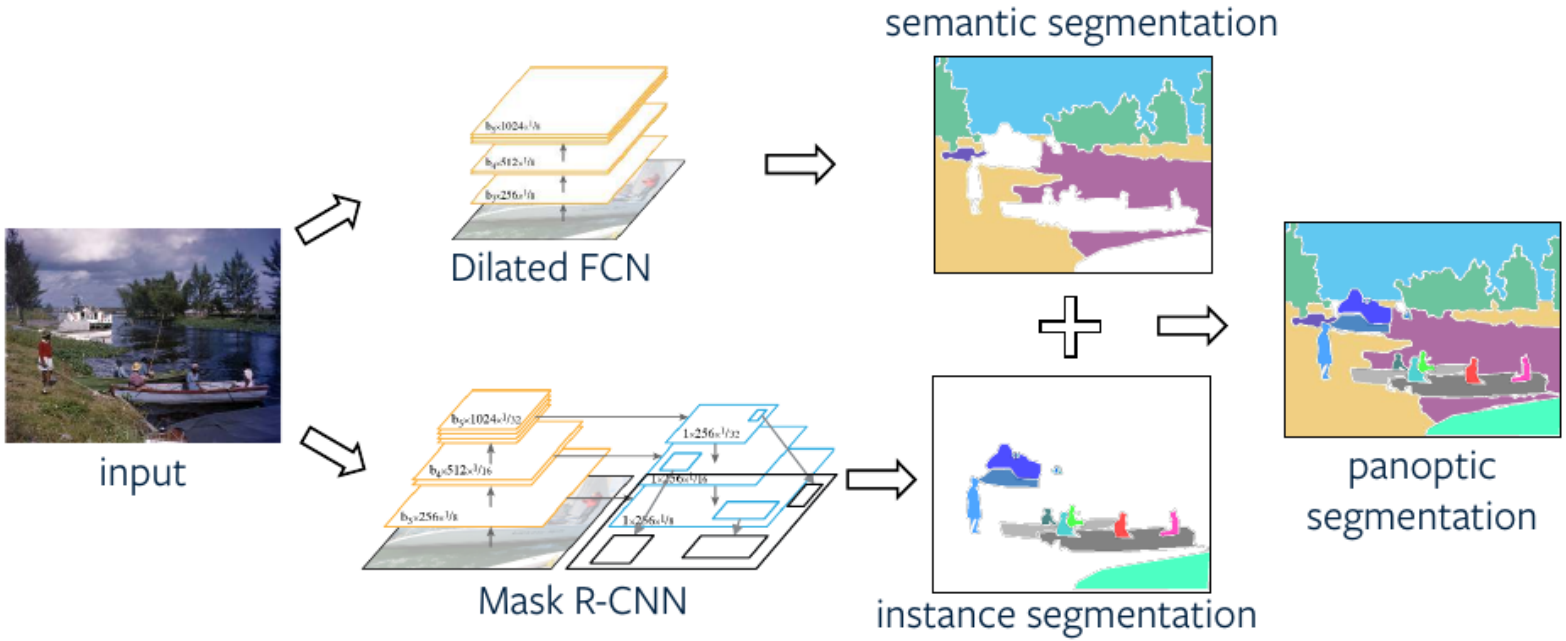
- Extension of detection models. Inherently instance based.

- Instead of predicting boxes for objects, the model predicts masks.



Panoptic Segmentation

Fusing semantic and instance segmentation to detect **“things”** and **“stuff”**

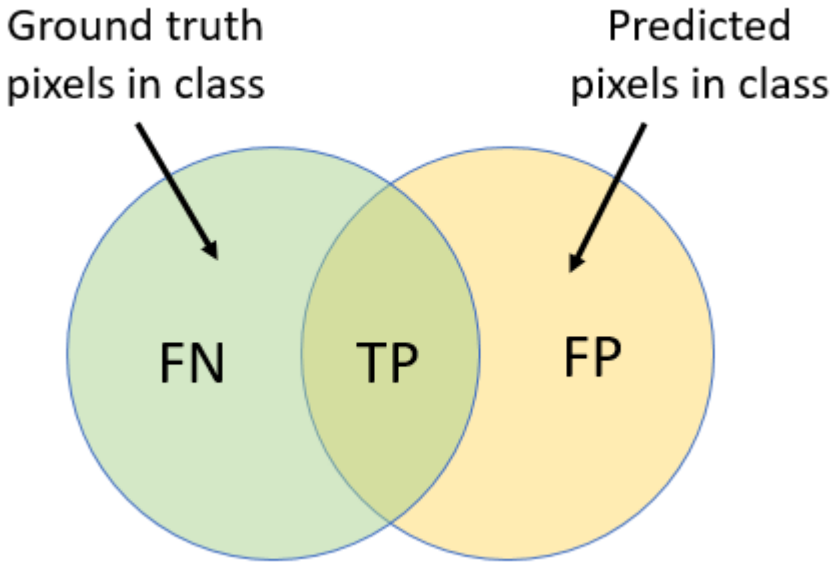


Dataset Types

- Label masks
- Object polygons
- Very high annotation effort
- “Segment Anything Model” has been a game changer for annotation effort

Accuracy Metrics

- Similar IoU concept as detection
- Panoptic Quality “PQ” is a new metric and applied, in part, to all segmentation challenges
- PQ metrics for “things” and “stuffs” categories
- COCO metrics “Panoptic Evaluation”



Computational Requirements

- Same backbone as detection
- Segmentation head incurs ~20% overhead
- Post-processing demands
- Instance and panoptic incur additional overhead

Conclusions

- Semantic segmentation is a technique that enables us to isolate different objects in an image along their contours.
- Improves on detection models for objects with more complex shapes.
- It can be considered an image classification task at a pixel level.

Conclusions

- Semantic segmentation classifies all pixels in an image by their class.
- Instance segmentation refines the semantic masks to separate each object instance.
- Panoptic segmentation fuses semantic and instance segmentation into a single unified model with knowledge of “things” and “stuff”.

Resources

- Datasets
  - https://cocodataset.org/
  - https://www.cityscapes-dataset.com/
  - https://ai.facebook.com/datasets/segment-anything/
- Models
  - https://towardsdatascience.com/u-net-explained-understanding-its-image-segmentation-architecture-56e4842e313a
  - https://learnopencv.com/yolov5-instance-segmentation/
  - https://segment-anything.com/

Thank you! Questions?

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