Semantic Segmentation

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- **What is the difference?**

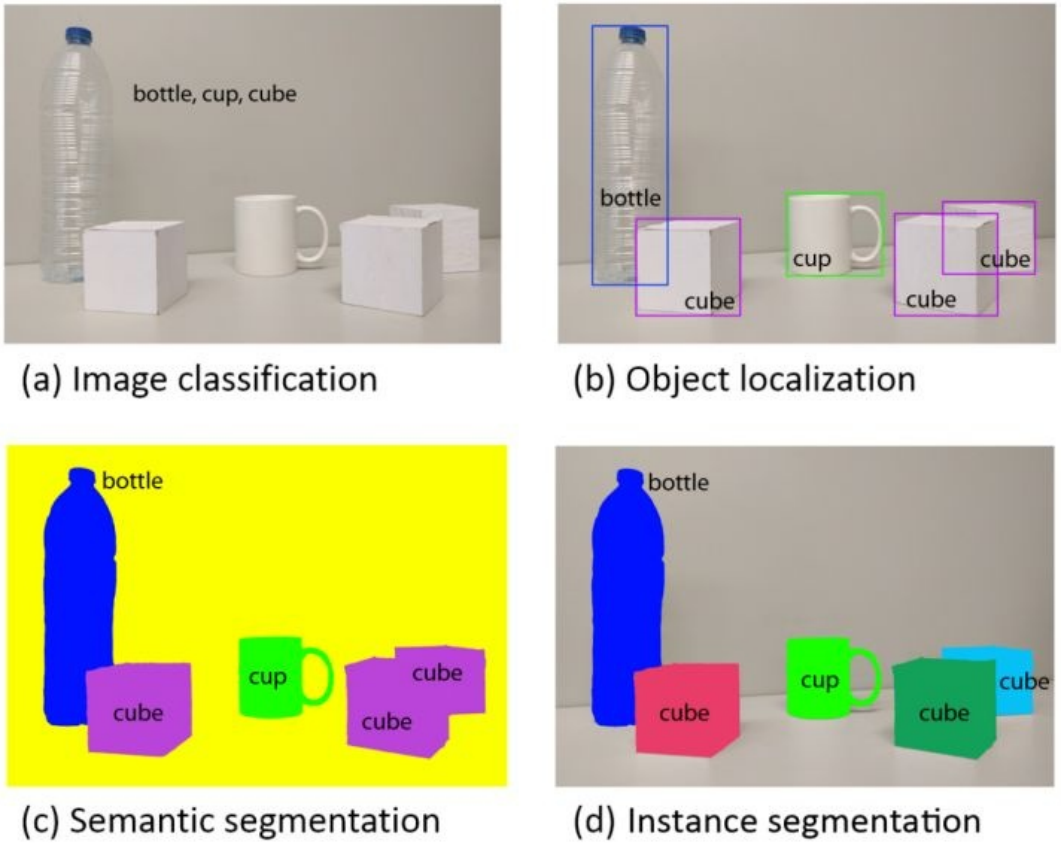


Figure 1: Top 4 tasks in computer vision.

Image Segmentation

- **What is Image Segmentation?**
  A fundamental topic in computer vision. The task of semantic image segmentation is to classify each pixel in the image.
- **Why Image Segmentation?**
  - Robot vision and understanding
  - Autonomous driving
  - Medical purposes (ISBI Challenge)
  - Object Detection in Satellite Imagery

Datasets we have

- **PASCAL context dataset**
  - Include more labels with similar context, such as chair, sofa, horse, and cow.
- **ADE20K dataset**
  - The most challenging one with a large number of scene-centric images exhaustively annotated with objects and object parts.
- **Cityscapes dataset**
  - For semantic urban scene understanding. Contains 5000 high quality pixel-level finely annotated images collected from 50 cities in different seasons.
- **ISBI Dataset**
  - For segmentation of neuronal structures in electron microscopy images.
- **Satellite Dataset**

Dataset: Cityscapes

(a) Input 1

(b) Input 2

(c) Input 3

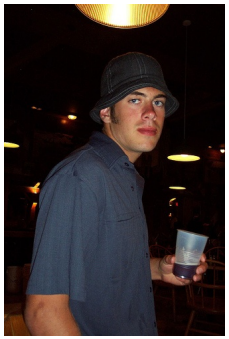
(d) Pred 1

(e) Pred 2

(f) Pred 3

Figure 2: PspNet Cityscapes Example

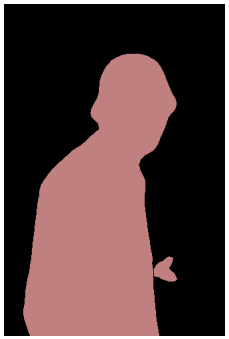
Dataset: VOC2012



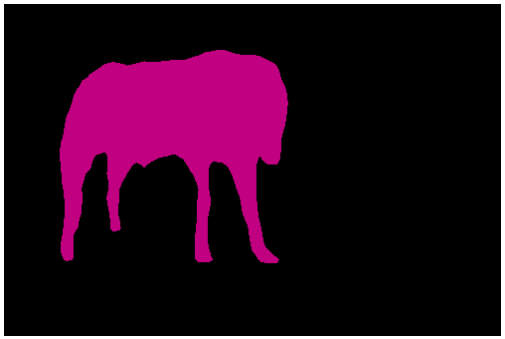
(a) Input 1

(b) Input 2

(c) Input 3



(d) Pred 1

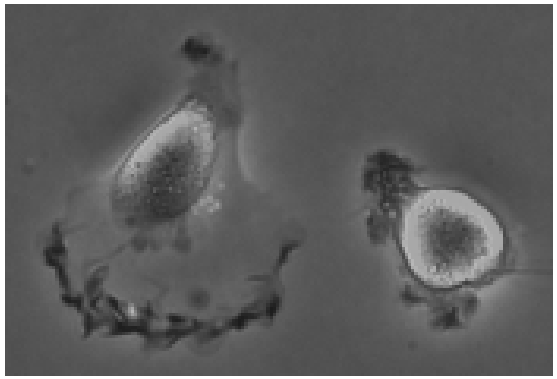


(e) Pred 2

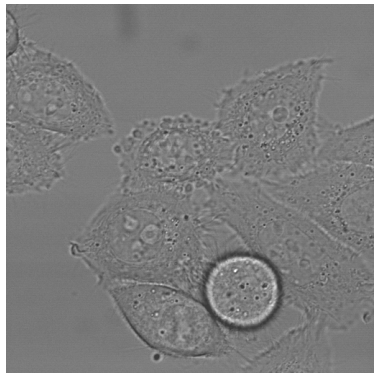
(f) Pred 3

Figure 3: PspNet VOC2012 Example

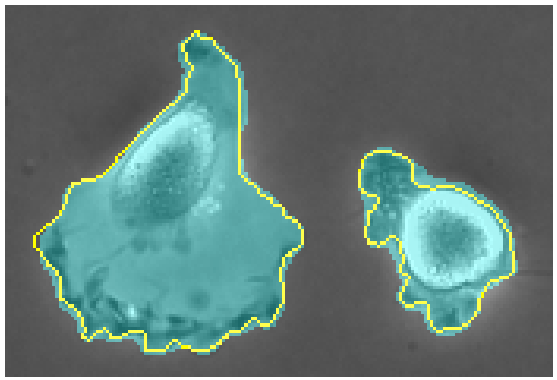
Biomedical Dataset



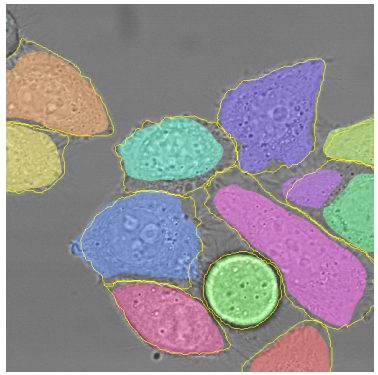
(a) Input 1



(b) Input 2



(c) Pred 1



(d) Pred 2

Figure 4: U-Net Example [3]

Satellite Dataset

Dataset: Eye in the Sky

(a) Input (b) Ground Truth (c) Pred

Figure 5: U-Net Training Example

Dataset: Eye in the Sky

(a) Input

(b) Pred

Figure 6: U-Net Testing Example

Satellite Dataset

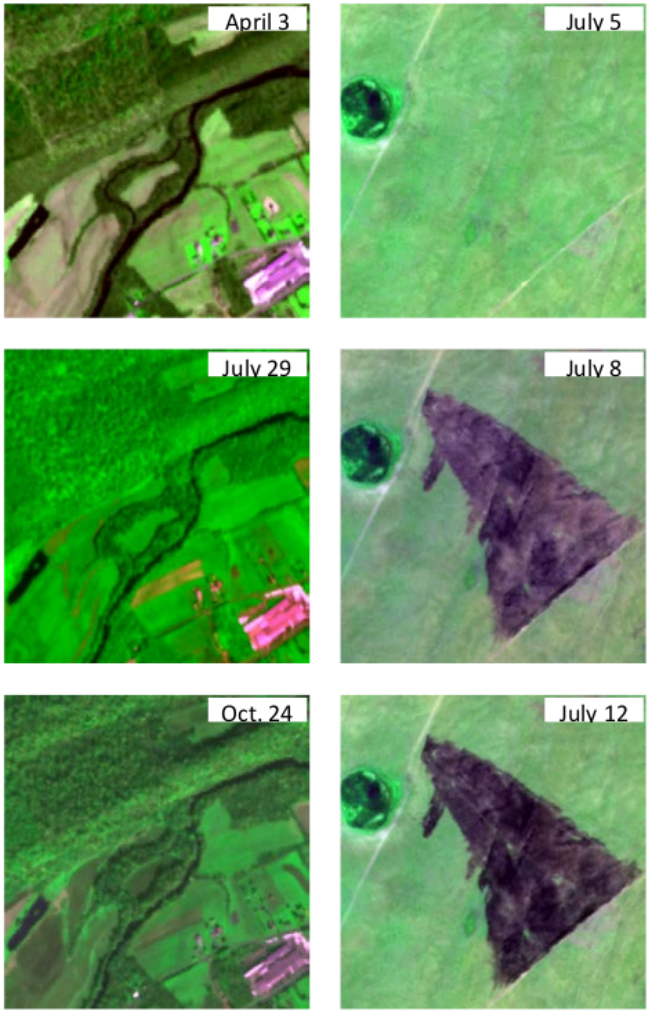


Figure 7: Dove Image Dateset. Left: Tree cover in non-winter seasons (forest and fields in Pennsylvania, USA.) Right: Burned area evolution over a week (grassland in Madagascar.)

- **FCNs (Fully Convolutional Networks)**
- **PSPNet (Pyramid Scene Parsing Network)**
- **U-Net**
- **SegNet**
- RCNNs (Region-based CNNs)
- Adversarial Models (GAN)

Basic ideas for segmentation

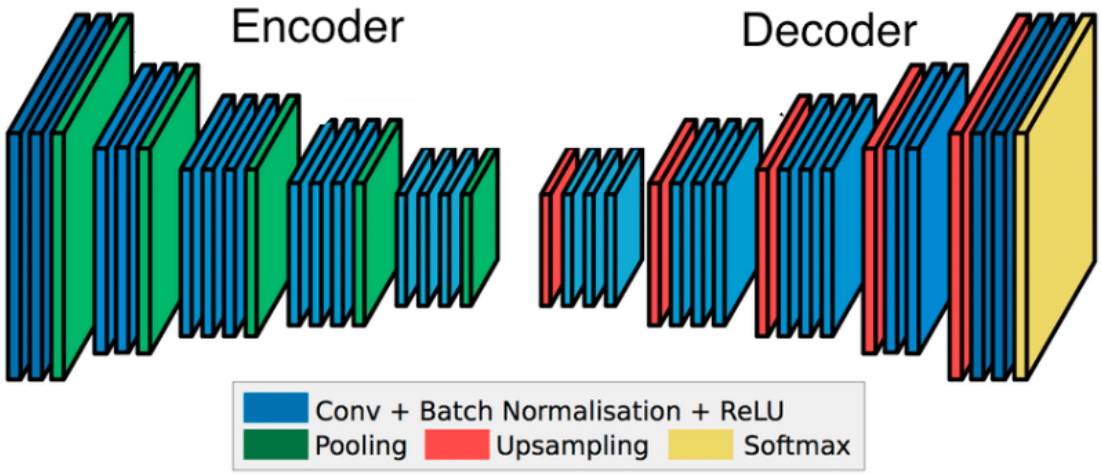


Figure 8: Encoder and Decoder [4]

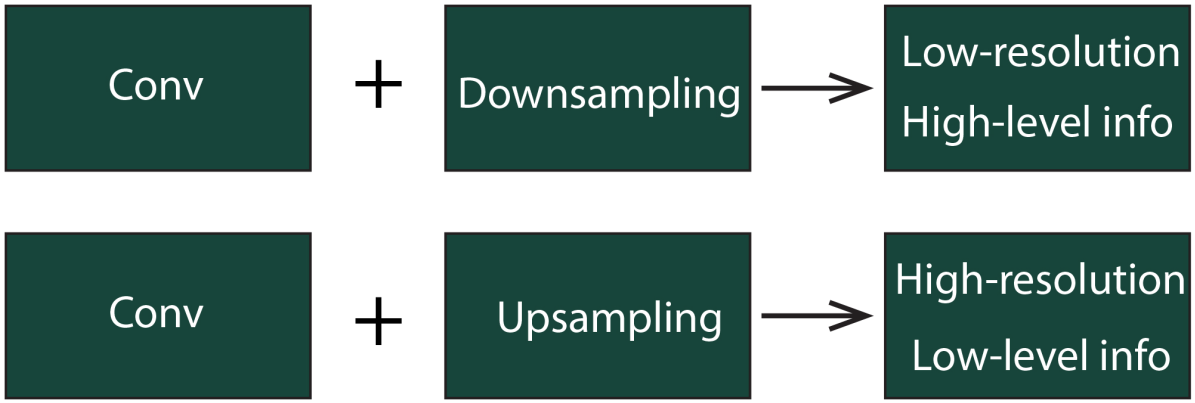


Figure 9: Layers in the encoder and decoder [4]

Basic ideas for segmentation

- Convolutional layers are involved in the image segmentation.
  - The initial layers learn to detect features like color and edges.
  - Deeper layers learn to detect features such as different objects.
- Downsampling is down by pooling layers.
- No Fully connected layer needed.
  - Image classification maps the spatial tensor to a vector.

$$(N, C, H, W) \to (N, C \times H \times W) \to (N, H) \to (N, \#\text{of classes})$$

  - Image segmentation needs to keep the spatial information.

Basic ideas for segmentation

- Produce high-resolution segmentation outputs by using the low-resolution spatial tensor.
  - Add more convolutional layers
  - Add upsampling layers which increase the sizer of the spatial tensor.
- Loss function
  - Cross-Entropy on each pixel.
- Data augmentation
  - If we have limited training sets, the result is not good since the model might overfitting.
  - Increase the size of the dataset by random transformation such as rotation, scale, and flipping on the images to enlarge our dataset.

Encoder: Base model

- Some initial layers of the base CNN network are used in the encoder.
- Choices:
  - ResNet: By Microsoft, large number of layers
  - VGG16: By Oxford, lesser layers than ResNet, faster to train.
  - MoboileNet: By Google, for a small model size and faster inference time
- Depends on the use case:
  - The number of training images.
  - Size of images.
  - The domain of the images.

Decoder: Upsampling

- Learnable parameters are used
  - Transposed convolution
- No learnable parameters are used
  - Nearest Neighbor interpolation
  - Bed of Nails interpolation
  - Bilinear interpolation
  - Max-Pooling indices

Detailed information is listed in the Semantic_Segmentation.pdf

- Decoder: Bilinear

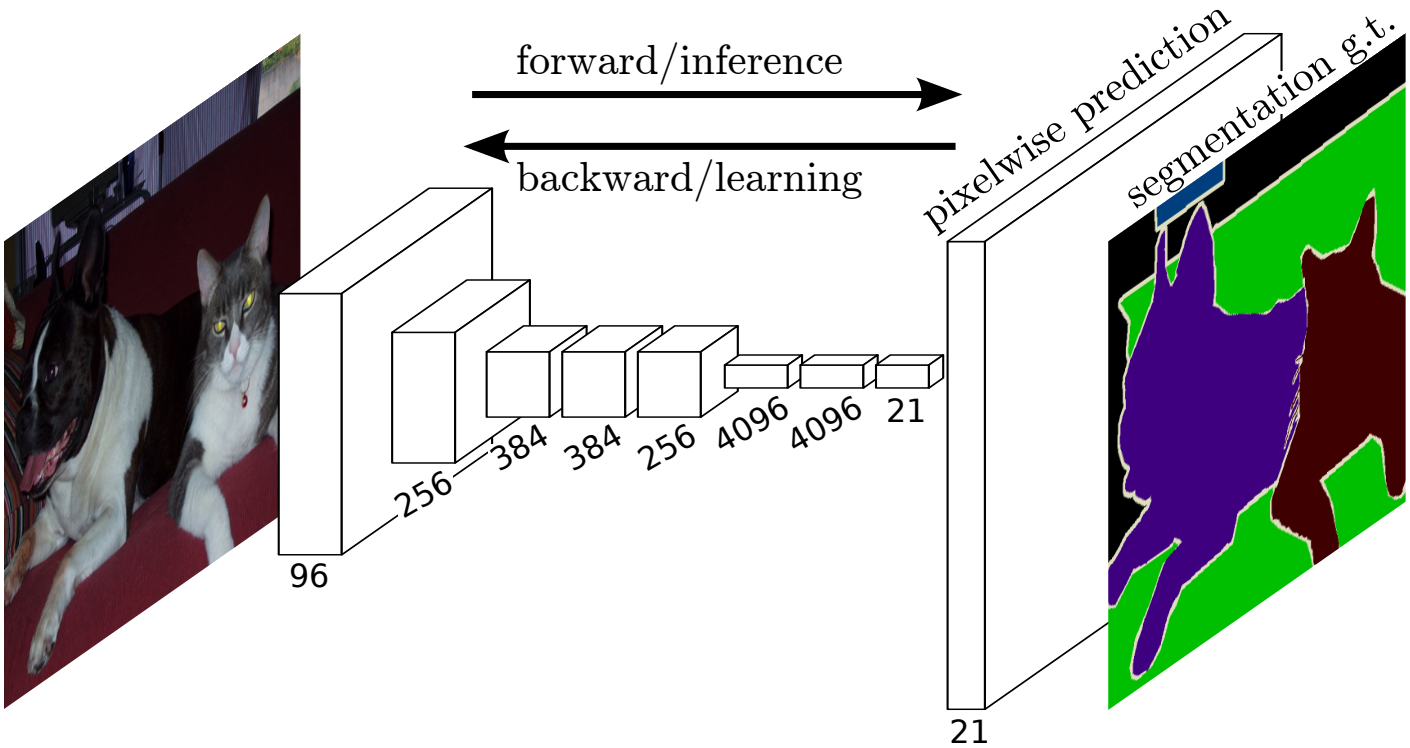


Figure 10: Overview of FCN[1].

- Decoder: Max-Pooling indices

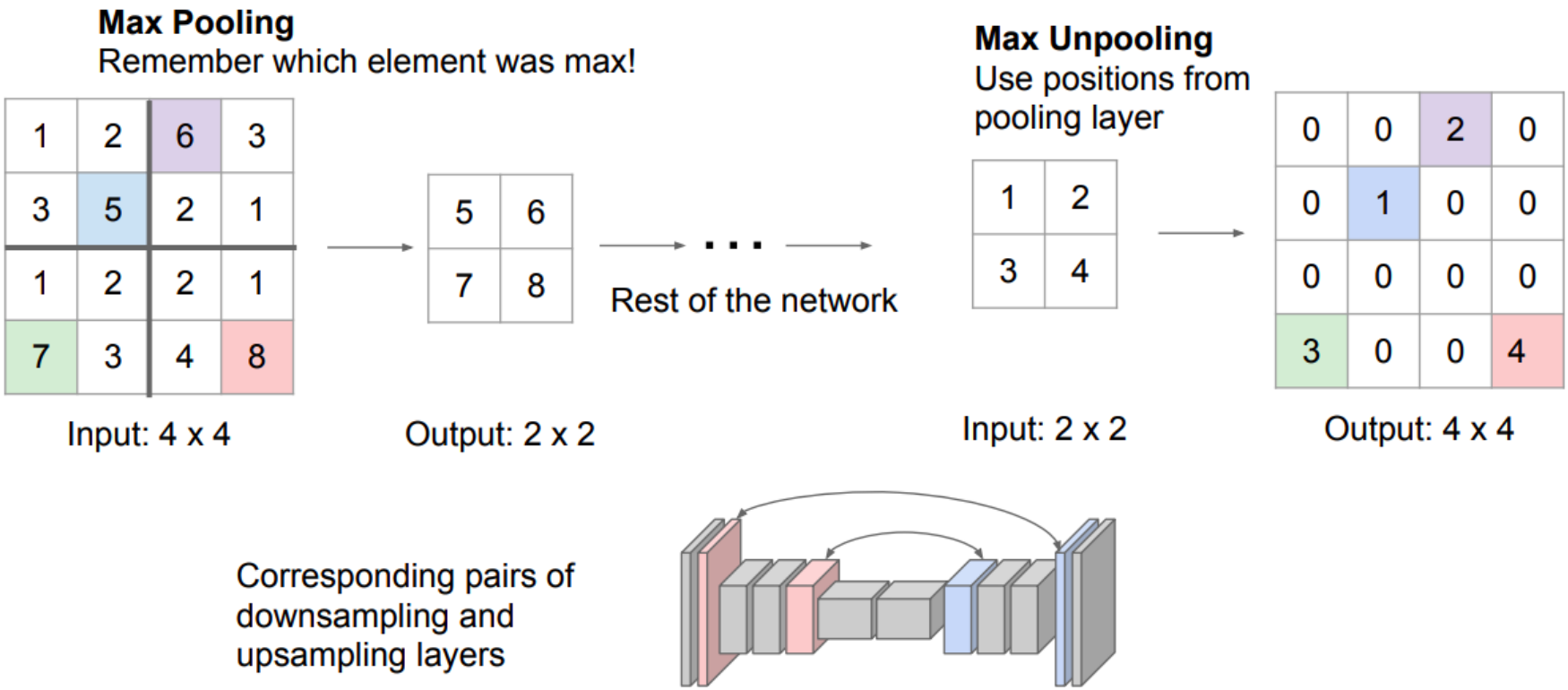


Figure 11: Downsampling and Upsampling.

Segmentation architecture: SegNet

Advantages of using Max-Pooling indices:

- It improves boundary delineation
- Reduces the number of parameters enabling end-to-end training
- This upsampling method an be incorporated into any encoder-decoder architecture.

- Decoder: Bilinear

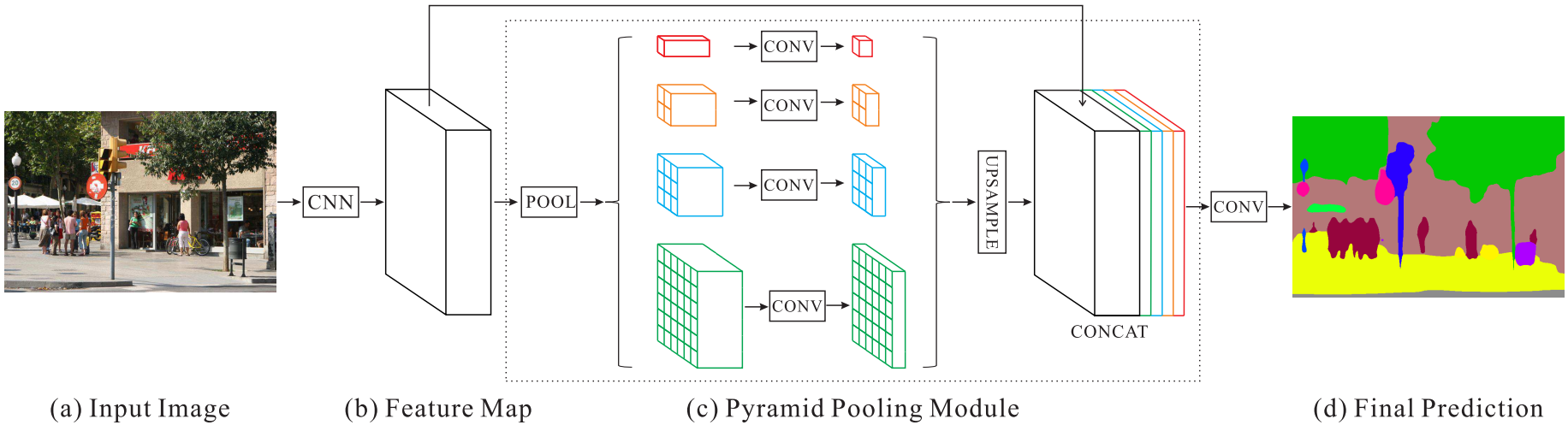


Figure 12: Architecture of PSPNet[2].

- Decoder: Transposed convolution

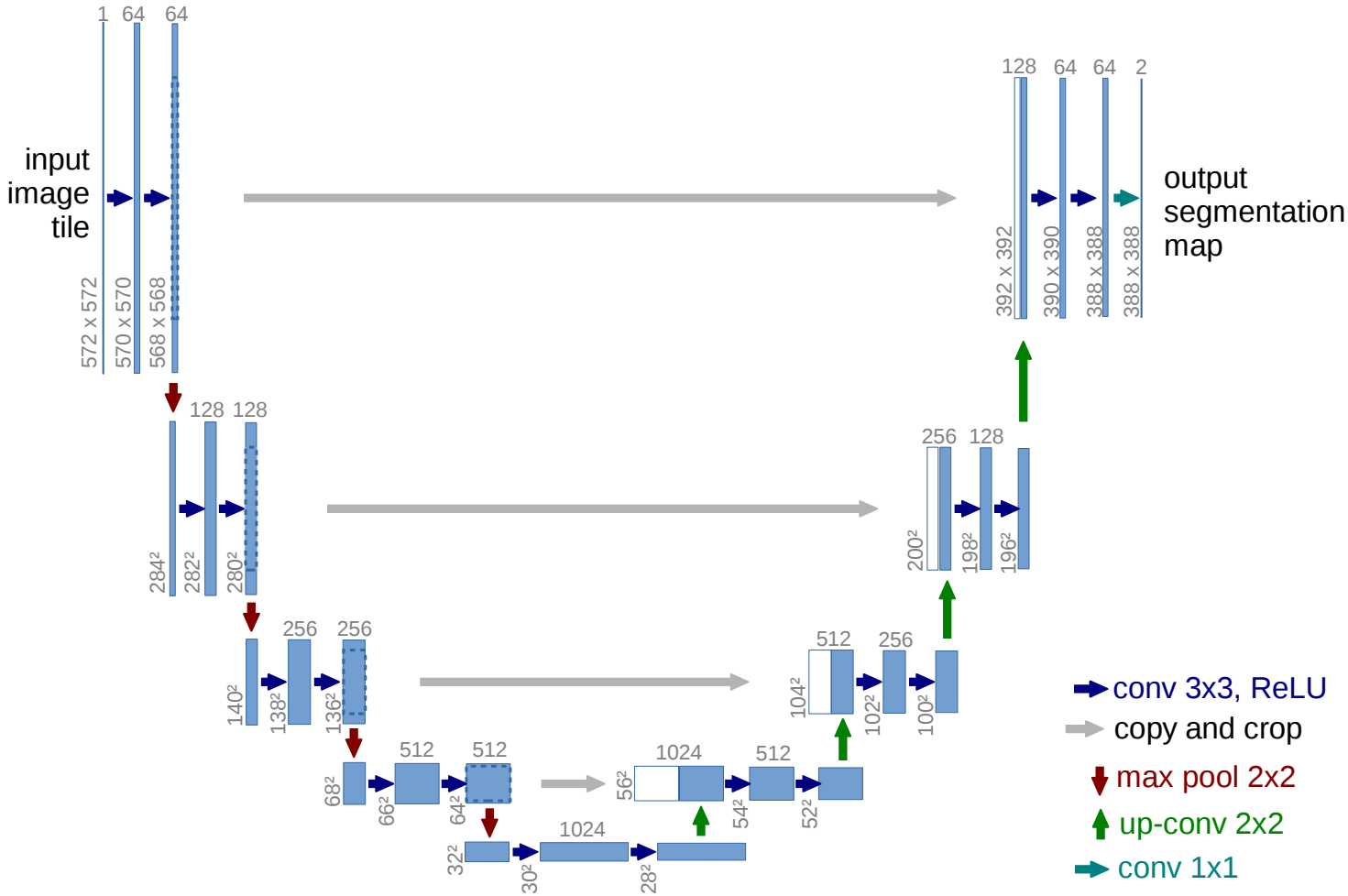
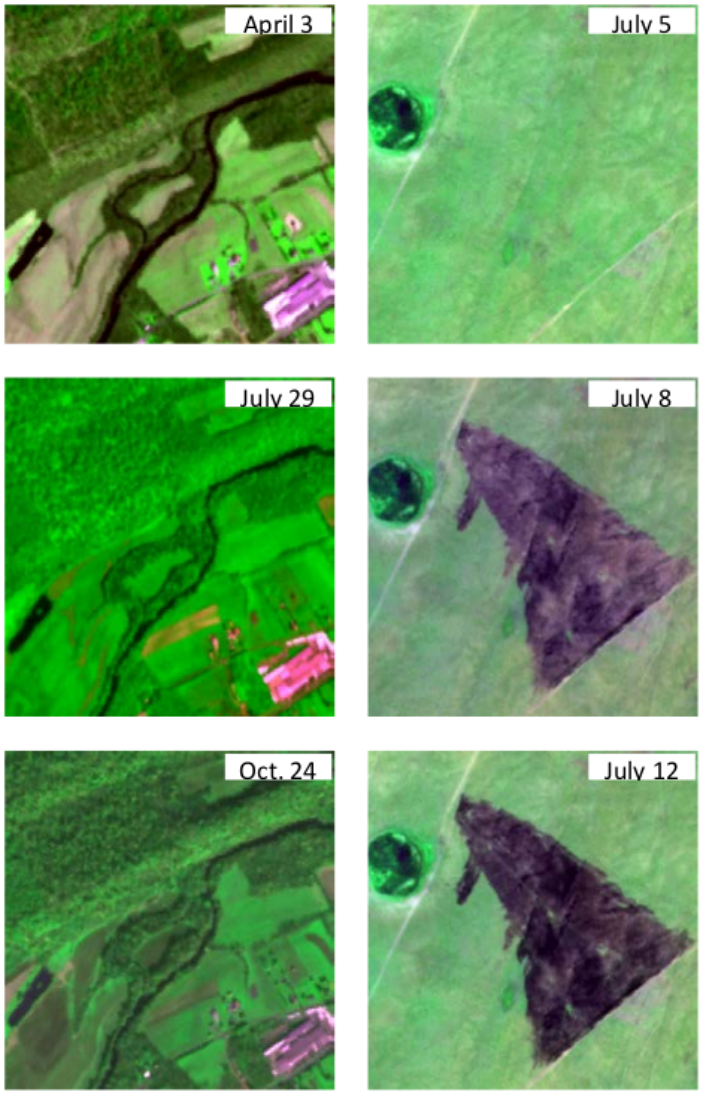


Figure 13: Architecture of U-Net[3].

Segmentation architecture: U-Net

- Used for biomedical image segmentation.
- Instead of using pooling indices, the entire feature maps are transfer from encoder to decoder, then with concatenation to perform convolution.
- Require more memory for this large model.

Recurrent U-Net



- We propose to develop and apply a multi-temporal deep learning approach to PLANET time series.

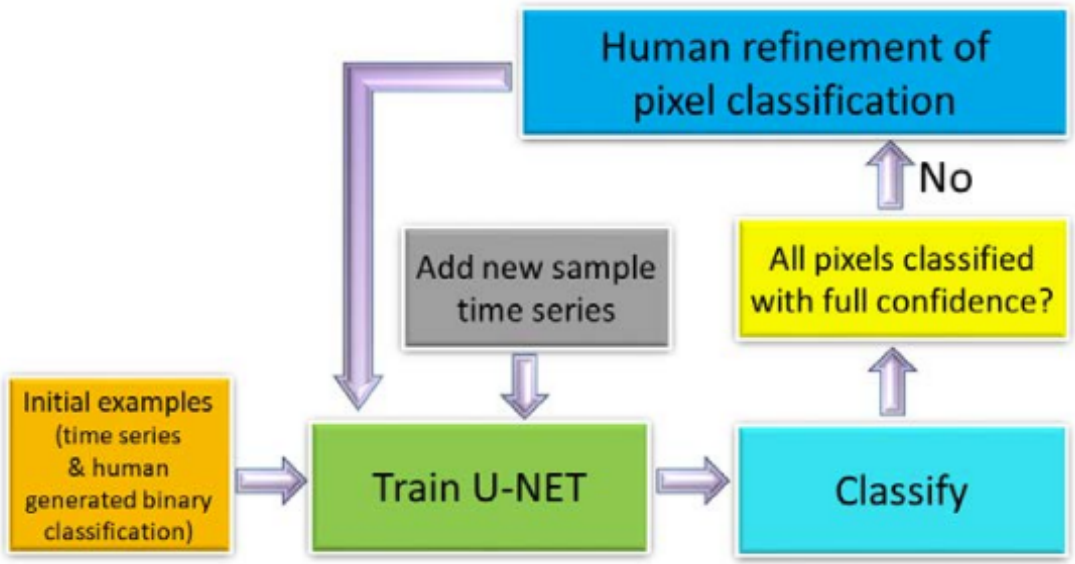


Figure 14: Workflow of the iterative semi-automatic active learning training data set generation process.

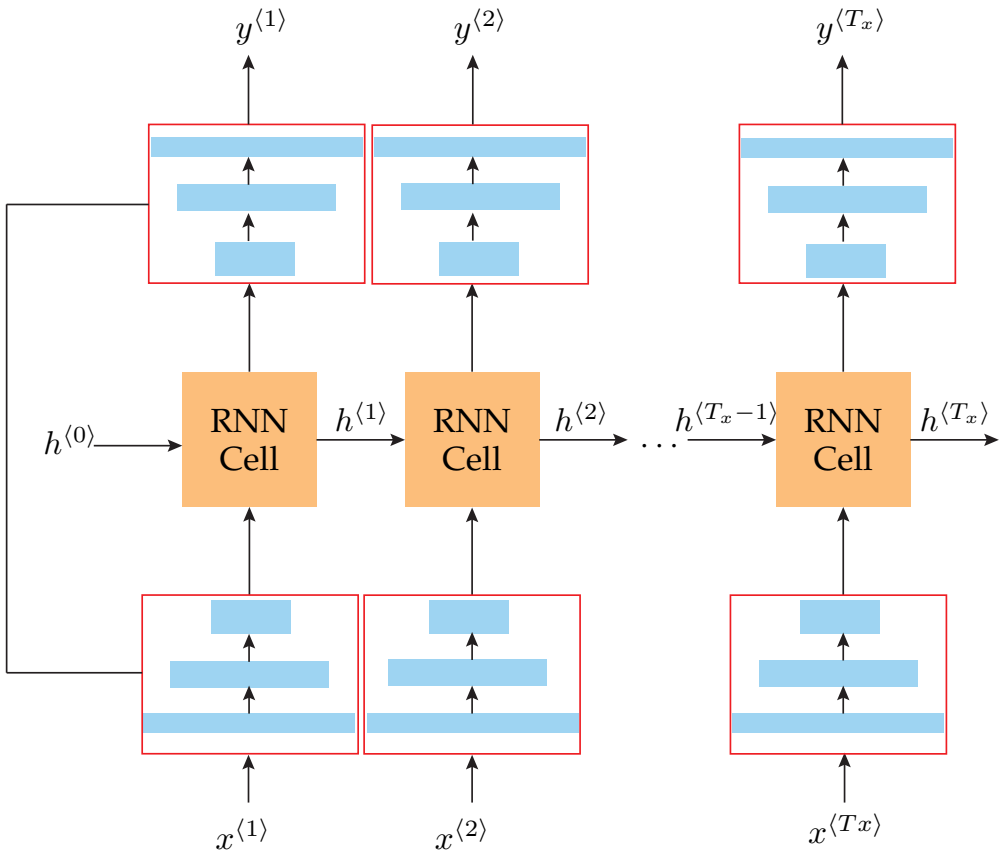


Figure 15: The structure of Recurrent U-Net.

- Pixel Accuracy: the percent of pixels in our image that are classified correctly.
- Intersection-Over-Union(IoU,Jaccard index): One of the most commonly used metrics in semantic segmentation.

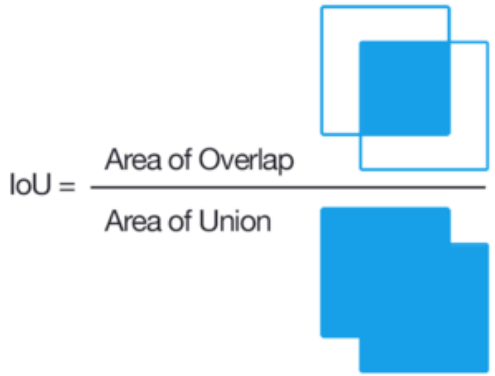


Figure 16: IoU. Source: Wikipedia

Github projects

- Fully convolutional networks (FCNs): https://github.com/shelhamer/fcn.berkeleyvision.org
- Region-based Convolutional Neural Networks (RCNNs): https://github.com/rbgirshick/py-faster-rcnn
- PspNet:https://github.com/hszhao/semseg
- U-Net: https://github.com/zhixuhao/unet
- SegNet: https://github.com/toimcio/SegNet-tensorflow
- Adversarial Models (GAN): https://github.com/albertbou92/Semantic-Segmentation-with-Adversarial-Networks

References

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2. Zhao, Hengshuang, et al. "Pyramid scene parsing network." Proceedings of the IEEE conference on computer vision and pattern recognition. 2017. PSPNet
3. 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. U-Net
4. Syed, Arsal, and Brendan Tran Morris. "SSeg-LSTM: Semantic Scene Segmentation for Trajectory Prediction." 2019 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2019. SSeg-LSTM