Convolutional Neural Network (2)

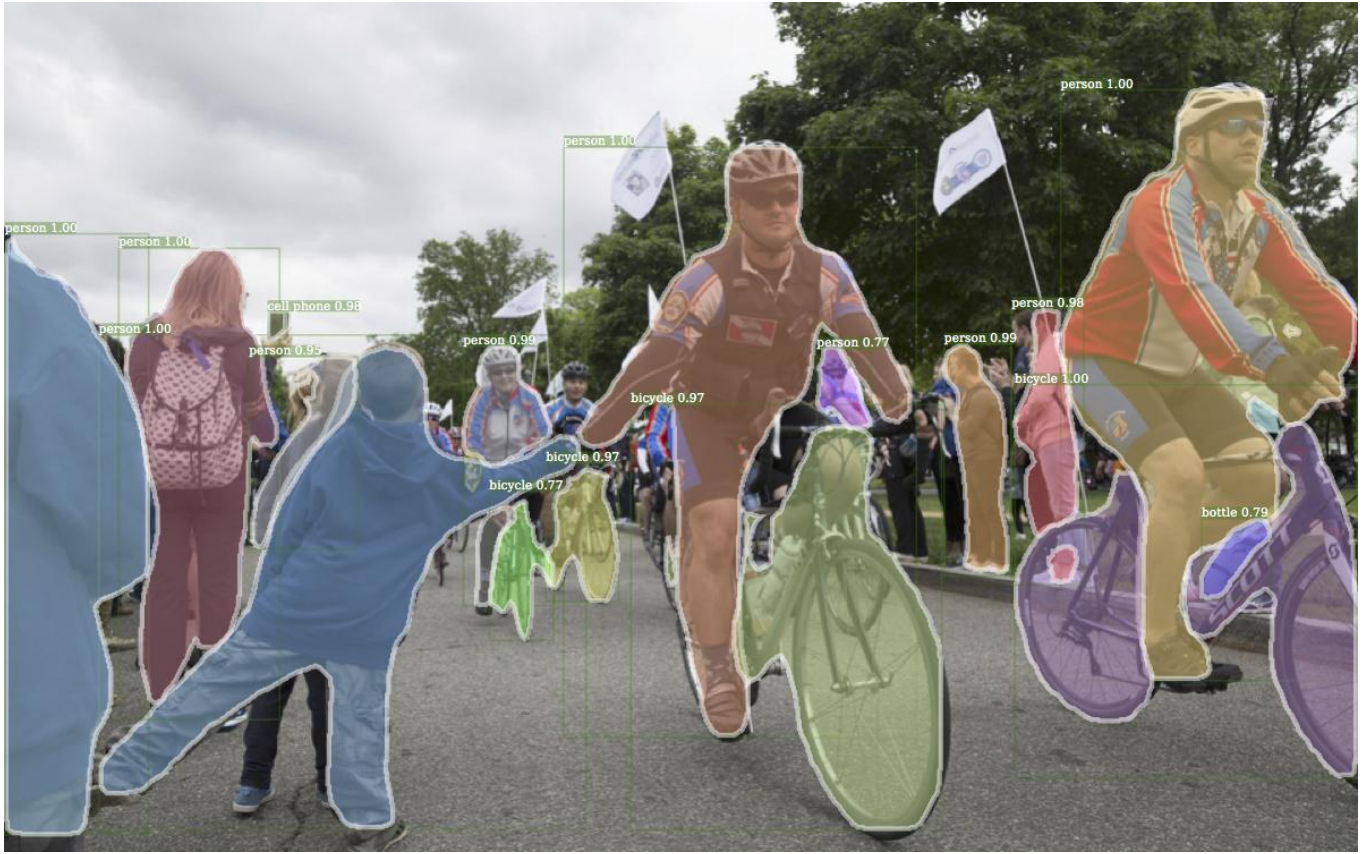
Sofa?

Teera Laiteerapong
31 March 2019

Image source: http://www.keet.us/portfolio_page/mini-sofa.
More information: http://rocknrollnerd.github.io/ml/2015/05/27/leopard-sofa.html

COCO Dataset

COCO (COmmon objects in COntext)



Source: https://github.com/facebookresearch/Detectron

Annotation Pipeline

(a) Category labeling (b) Instance spotting (c) Instance segmentation

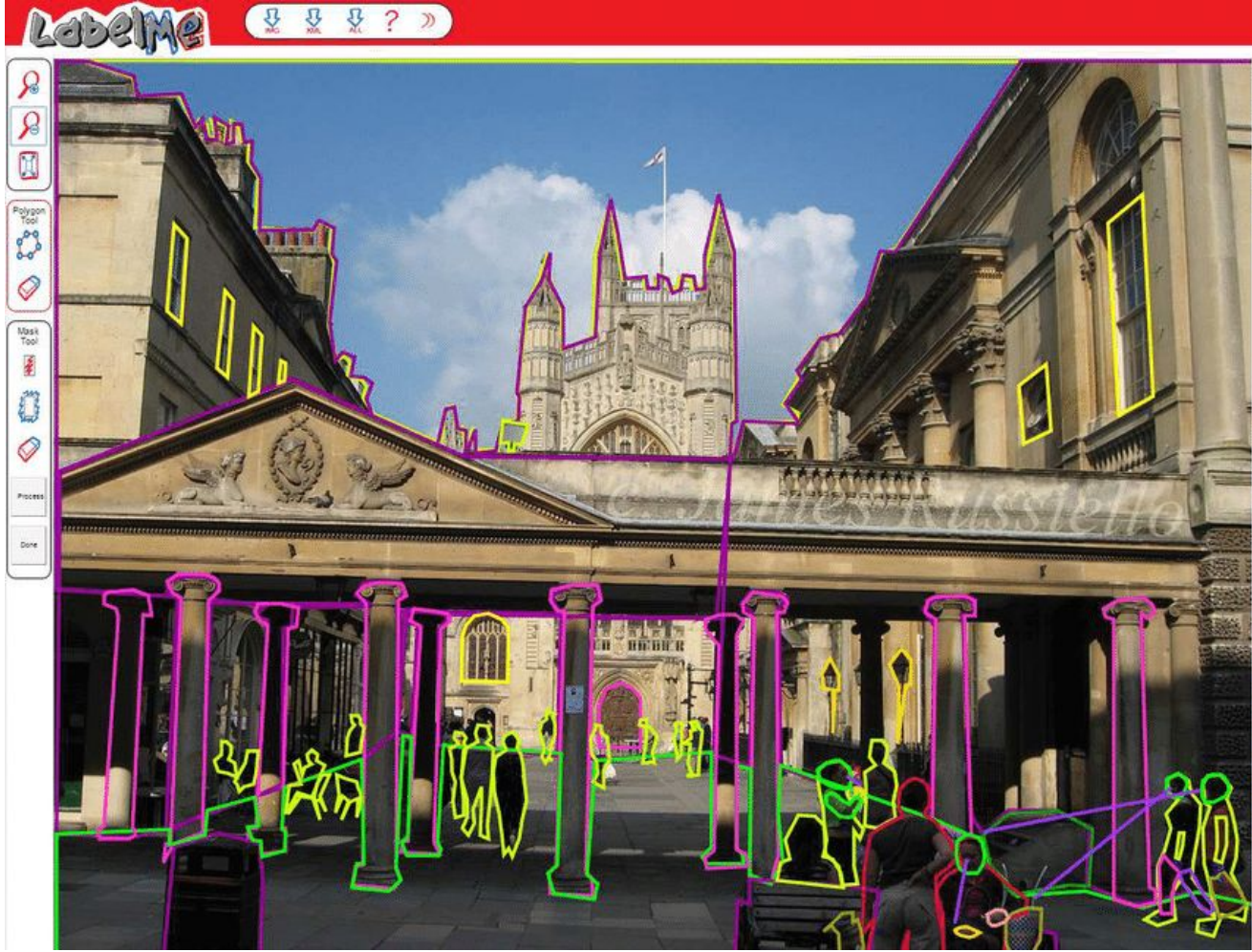
Fig. 3: Our annotation pipeline is split into 3 primary tasks: (a) labeling the categories present in the image (§4.1), (b) locating and marking all instances of the labeled categories (§4.2), and (c) segmenting each object instance (§4.3).

- **Category labeling**, 91 objects types that would be easily recognizable by **4-8 years old kids**. With a total of **2.5 million labeled instances** in **328k images**.
- **For instance spotting**, it took **8 workers** for a total of **~10k worker hours**.
- **For instance segmentation**, segmenting 2,500,000 object instances is an extremely time consuming task requiring over **22 worker hours per 1,000 segmentations (55,000 hours)**.
- **In total**: 70,000 worker hours. If minimum wage is 300 THB then the total cost would be 2,625,000 THB or 8 THB/image.

Source: https://arxiv.org/pdf/1405.0312.pdf

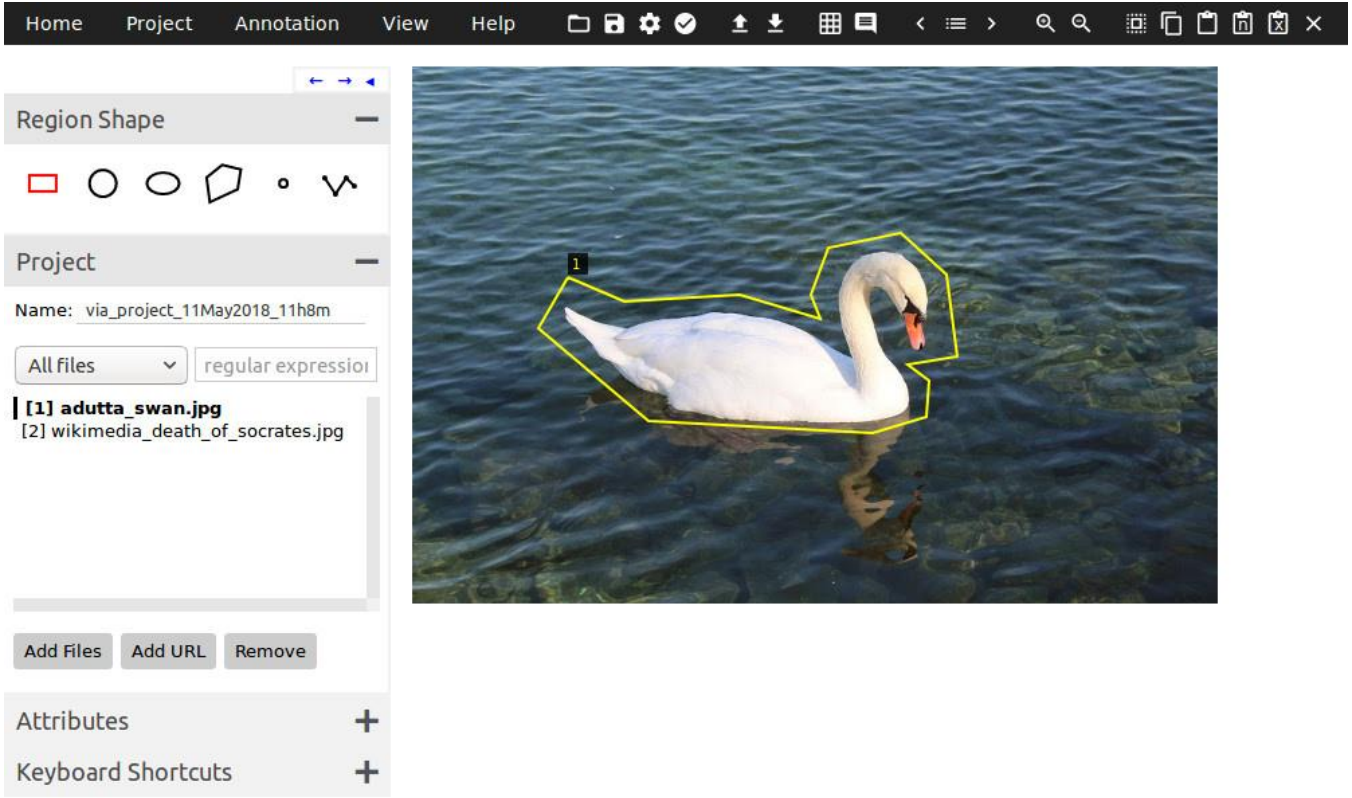
Labeling Tools

LabelMe



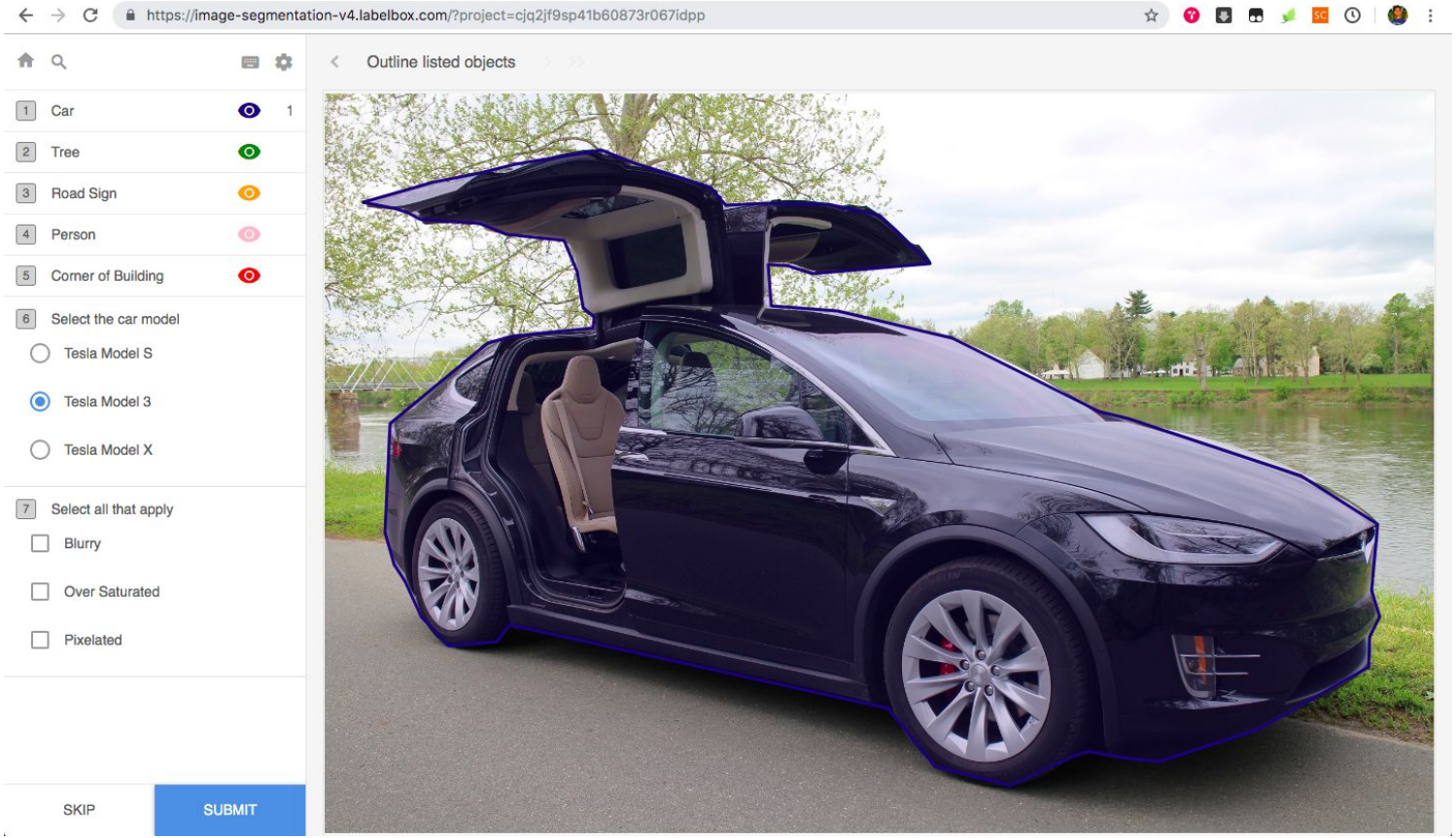
Source: https://github.com/CSAILVision/LabelMeAnnotationTool

VGG Image Annotator (VIA)



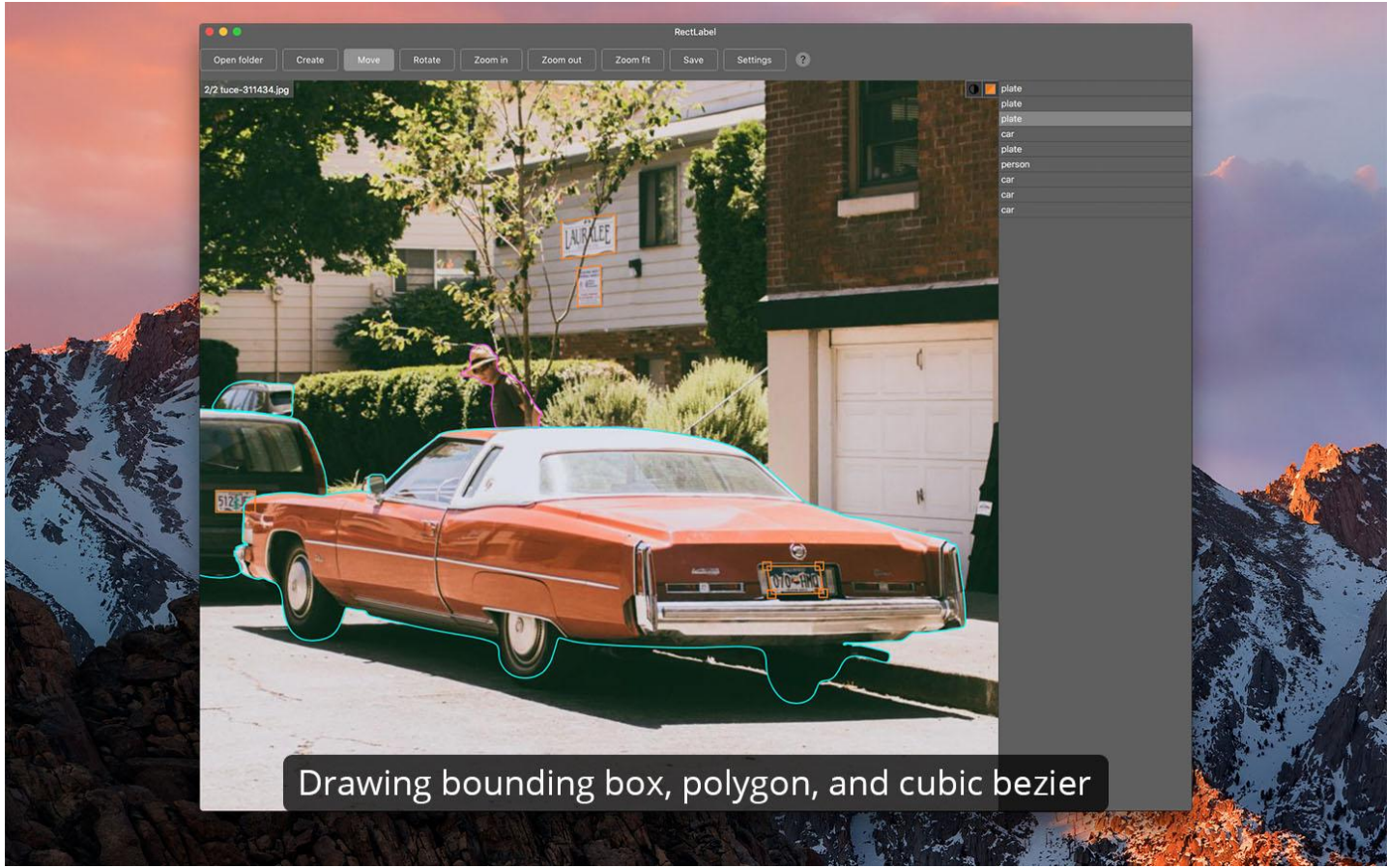
Source: http://www.robots.ox.ac.uk/~vgg/software/via/via_demo.html

LabelBox



Source: https://labelbox.com/

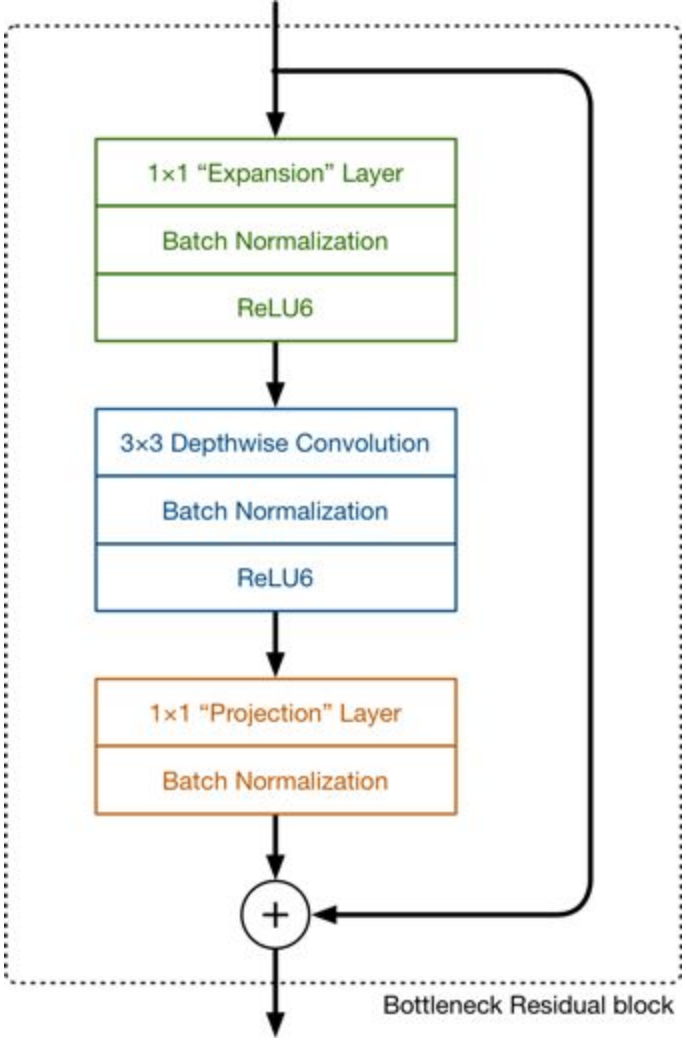
RectLabel



Source: https://rectlabel.com/

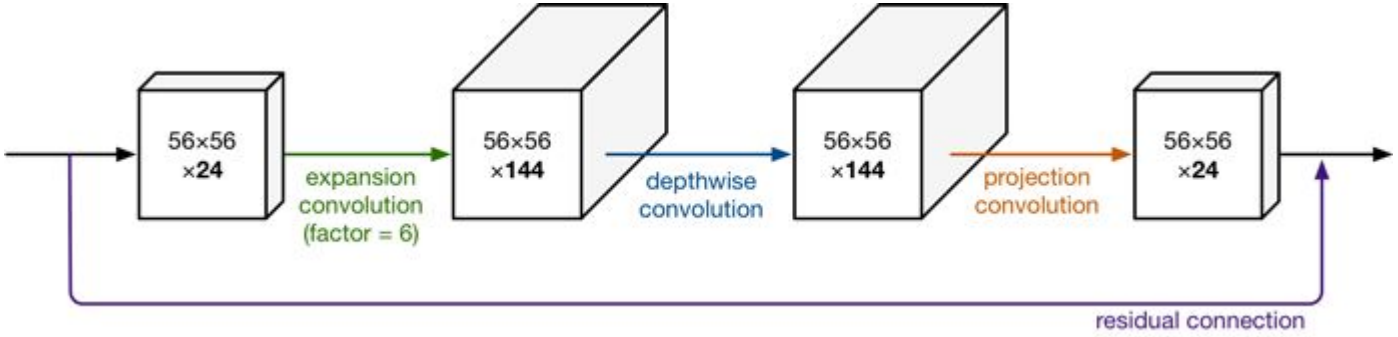
MobileNetV2

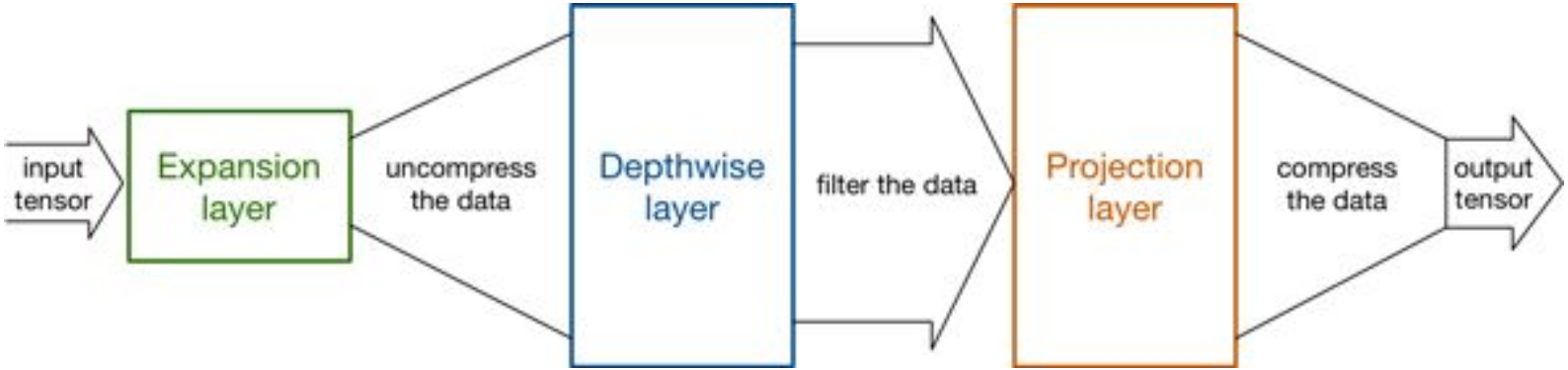
MobileNetV2



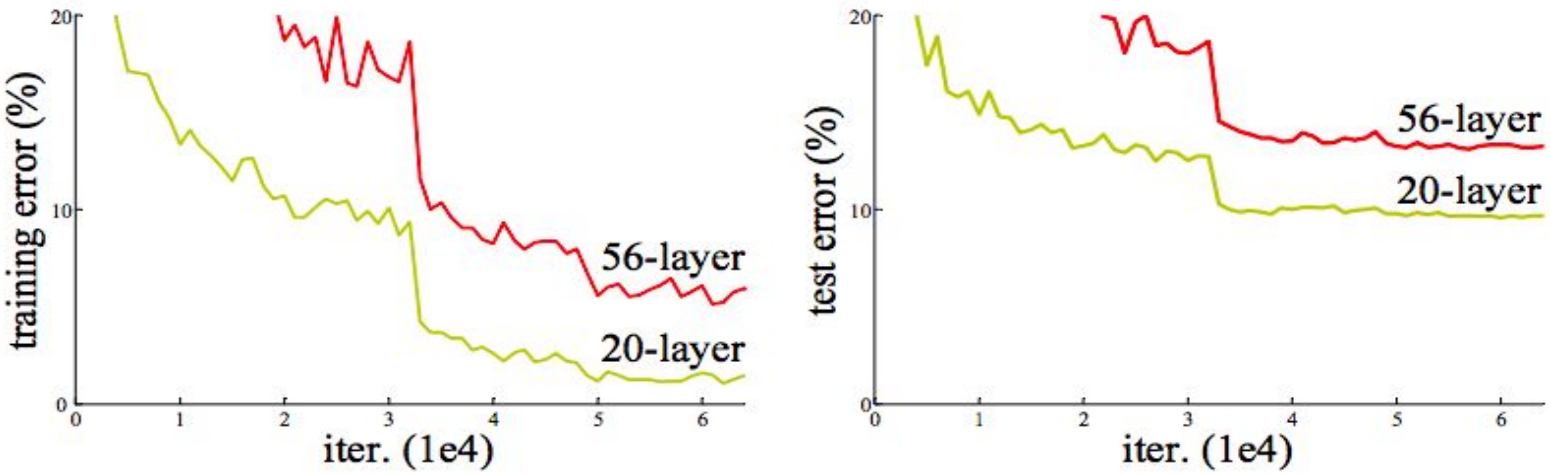
Source: https://machinethink.net/blog/mobilenet-v2/

MobileNetV2 (2)





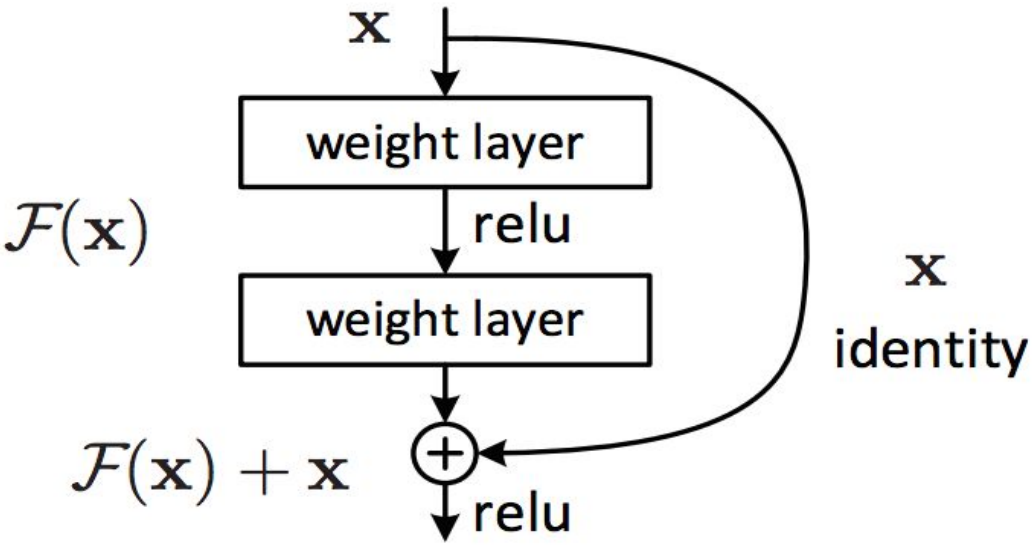
ResNet



Training error (left) and test error (right) on CIFAR-10 with 20-layer and 56-layer plain networks. The deeper network has higher training error, and thus test error.

Source: https://arxiv.org/pdf/1512.03385.pdf

ResNet (2)



Residual block.
Source: https://arxiv.org/pdf/1512.03385.pdf

DAWNBench

An End-to-End Deep Learning Benchmark and Competition

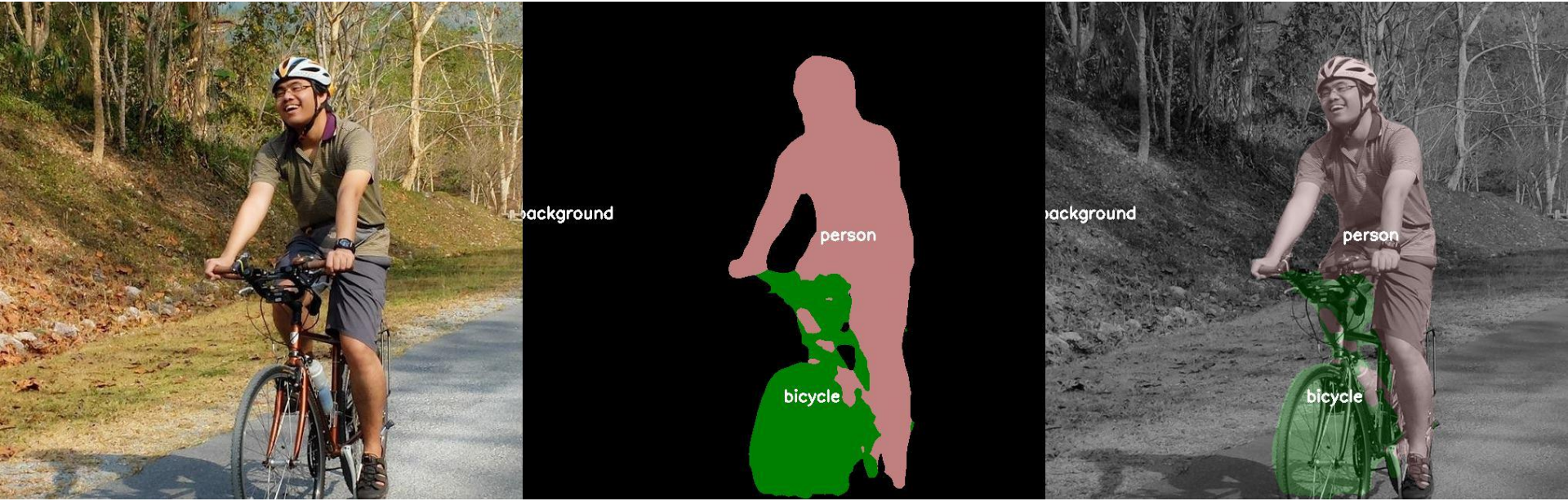
ImageNet Training

Submission Date	Model	Time to 93% Accuracy	Cost (USD)	Max Accuracy	Hardware	Framework
Sep 2018	ResNet50 *Google Cloud TPU* source	2:44:31	$12.60	93.34%	GCP n1-standard-2, Cloud TPU	TensorFlow v1.11.0
Sep 2018	ResNet50 *Google Cloud TPU* source	5:52:31	$27.00	93.36%	GCP n1-standard-2, Cloud TPU	TensorFlow v1.11.0
Feb 2019	Resnet 50 v1 *GE Healthcare (Min Zhang)* source	1:44:34	$42.66	93.24%	8*V100 (single p3.16xlarge)	tensorflow 1.11 + horovod
Sep 2018	Resnet 50 *Andrew Shaw, Yaroslav Bulatov, Jeremy Howard* source	0:29:43	$48.48	93.02%	32 * V100 (4 machines - AWS p3.16xlarge)	ncluster / Pytorch 0.5.0a0+0e8088d
Apr 2018	AmoebaNet-D N6F256 *Google Cloud TPU*	7:28:30	$49.30	93.11%	GCP n1-standard-2, Cloud TPU	TensorFlow 1.8.0-

Source: https://dawn.cs.stanford.edu/benchmark/ImageNet/train.html

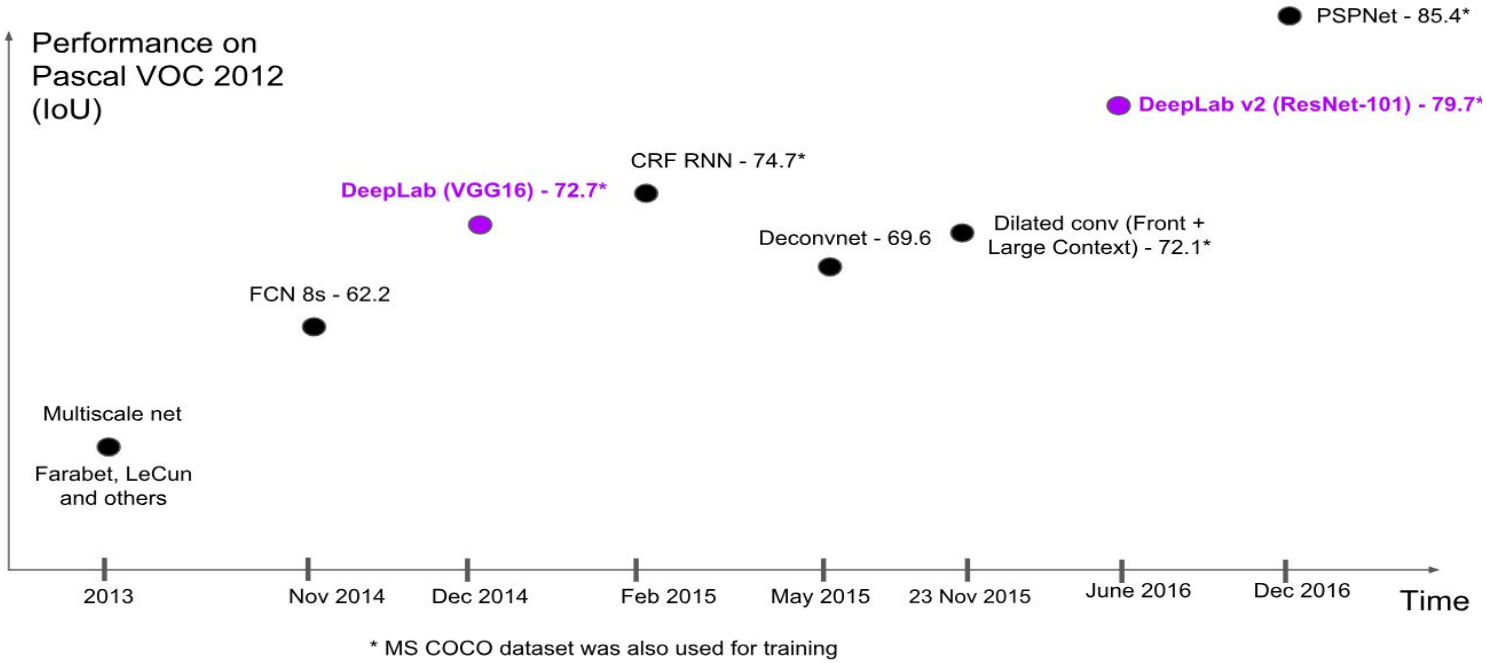
Semantic Segmentation

Semantic Segmentation



A result of image segmentation using fully convolutional neural network.

Semantic Segmentation Progress



Semantic segmentation progress.

Source: https://docs.google.com/presentation/d/1b4rM1VlUi_g3fJJKxfsNa8frmE42yk6q8U5ZUwdLX2g/pub?

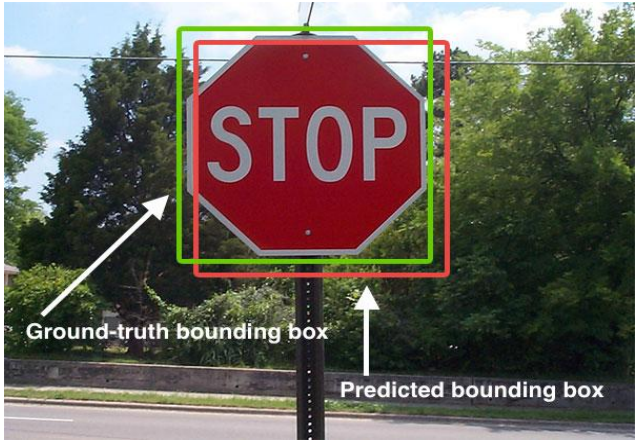
Semantic Segmentation Progress in 2018

	mean	aero plane	bicycle	bird	boat	bottle	bus	car	cat	chair	cow	dining table	dog	horse	motor bike	person	potted plant	sheep	sofa	train	tv/ monitor	submission date
DeepLabv3+_JFT [?]	**89.0**	**97.5**	77.9	96.2	80.4	**90.8**	**98.3**	**95.5**	**97.6**	58.8	**96.1**	79.2	**95.0**	97.3	94.1	**93.8**	78.5	**95.5**	74.4	93.8	81.6	09-Feb-201
DeepLabv3+_AASPP [?]	88.5	97.4	**80.3**	**97.1**	80.1	89.3	97.4	94.1	96.9	**61.9**	95.1	77.2	94.2	**97.5**	**94.4**	93.0	72.4	93.8	72.6	93.3	83.3	22-May-201
SRC-B-MachineLearningLab [?]	88.5	97.2	78.6	**97.1**	80.6	89.7	97.4	93.7	96.7	59.1	95.4	81.1	93.2	**97.5**	94.2	92.9	73.5	93.3	74.2	91.0	85.0	19-Apr-201
** MSCI ** [?]	88.0	96.8	76.8	97.0	80.6	89.3	97.4	93.8	97.1	56.7	94.3	78.3	93.5	97.1	94.0	92.8	72.3	92.6	73.6	90.8	**85.4**	08-Jul-201
ExFuse [?]	87.9	96.8	**80.3**	97.0	**82.5**	87.8	96.3	92.6	96.4	53.3	94.3	78.4	94.1	94.9	91.6	92.3	**81.7**	94.8	70.3	90.1	83.8	22-May-201
DeepLabv3+ [?]	87.8	97.0	77.1	**97.1**	79.3	89.3	97.4	93.2	96.6	56.9	95.0	79.2	93.1	97.0	94.0	92.8	71.3	92.9	72.4	91.0	84.9	09-Feb-201
DeepLabv3-JFT [?]	86.9	96.9	73.2	95.5	78.4	86.5	96.8	90.3	97.1	51.4	95.0	73.4	94.0	96.8	94.0	92.3	81.5	95.4	67.2	90.8	81.8	05-Aug-201
DIS [?]	86.8	94.0	73.3	93.5	79.1	84.8	95.4	89.5	93.4	53.6	94.8	79.0	93.6	95.2	91.5	89.6	78.1	93.0	**79.4**	**94.3**	81.3	13-Sep-201
CASIA_IVA_SDN [?]	86.6	96.9	78.6	96.0	79.6	84.1	97.1	91.9	96.6	48.5	94.3	78.9	93.6	95.5	92.1	91.1	75.0	93.8	64.8	89.0	84.6	29-Jul-201
IDW-CNN [?]	86.3	94.8	67.3	93.4	74.8	84.6	95.3	89.6	93.6	54.1	94.9	79.0	93.3	95.5	91.7	89.2	77.5	93.7	79.2	94.0	80.8	30-Jun-201
DFN [?]	86.2	96.4	78.6	95.5	79.1	86.4	97.1	91.4	95.0	47.7	92.9	77.2	91.0	96.7	92.2	91.7	76.5	93.1	64.4	88.3	81.2	15-Jan-201
EncNet [?]	85.9	95.3	76.9	94.2	80.2	85.3	96.5	90.8	96.3	47.9	93.9	80.0	92.4	96.6	90.5	91.5	70.9	93.6	66.5	87.7	80.8	15-Mar-201
HPN [?]	85.8	94.1	67.0	95.2	81.9	88.3	95.5	90.4	95.9	40.0	92.7	**82.5**	91.7	95.3	92.6	91.6	73.6	94.1	69.4	91.1	81.9	13-Dec-201
DeepLabv3 [?]	85.7	96.4	76.6	92.7	77.8	87.6	96.7	90.2	95.4	47.5	93.4	76.3	91.4	97.2	91.0	92.1	71.3	90.9	68.9	90.8	79.3	20-Jun-201
PSPNet [?]	85.4	95.8	72.7	95.0	78.9	84.4	94.7	92.0	95.7	43.1	91.0	80.3	91.3	96.3	92.3	90.1	71.5	94.4	66.9	88.8	82.0	06-Dec-201

Semantic segmentation progress in 2018.

Source: http://host.robots.ox.ac.uk:8080/leaderboard/displaylb.php?challengeid=11&compid=6

Evaluation Method



$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

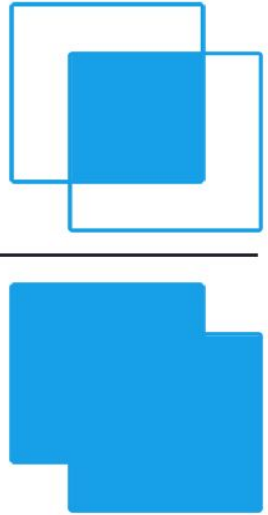
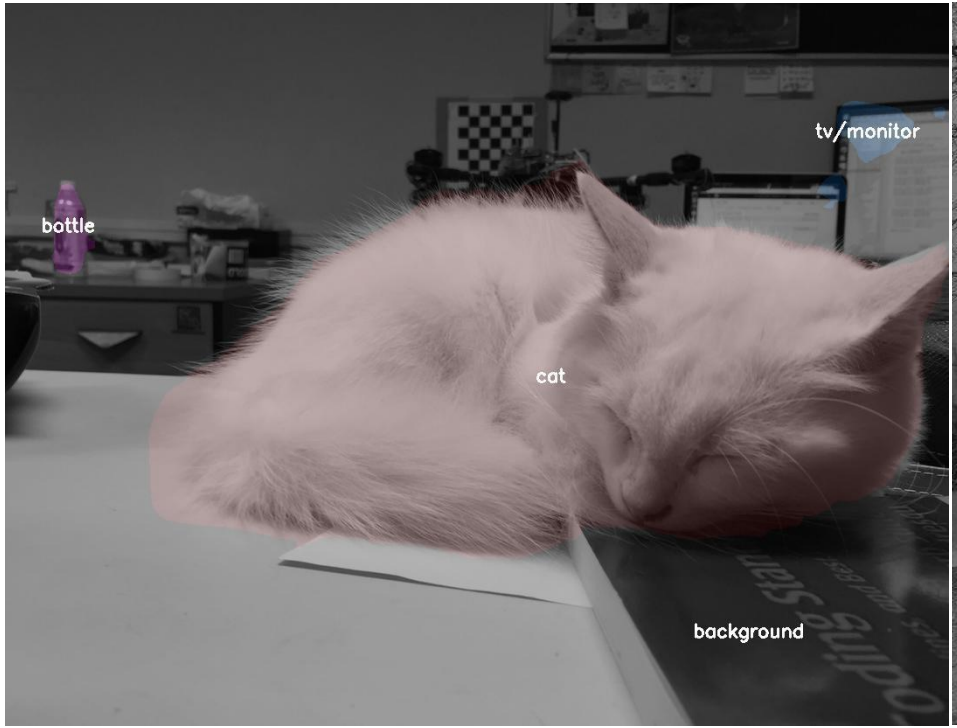


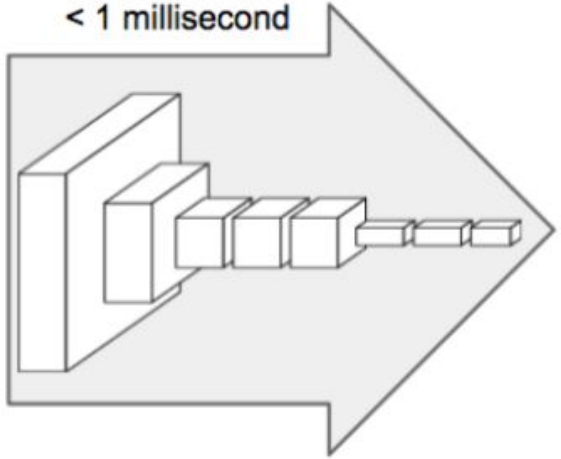
Figure 8: Intersection over Union (Jaccard Index).
Source: https://en.wikipedia.org/wiki/Jaccard_index

FCN Example Results



Fully Convolutional Neural Network

CNNs Perform Classification

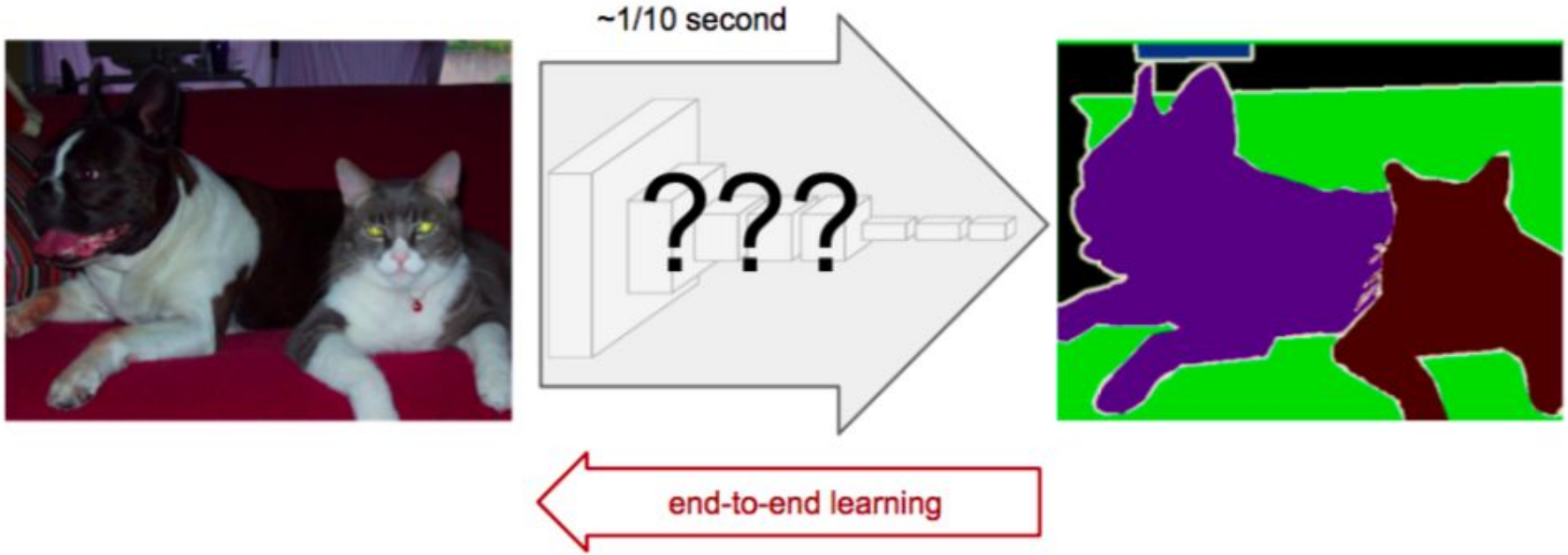


"tabby cat"

1000-dim vector

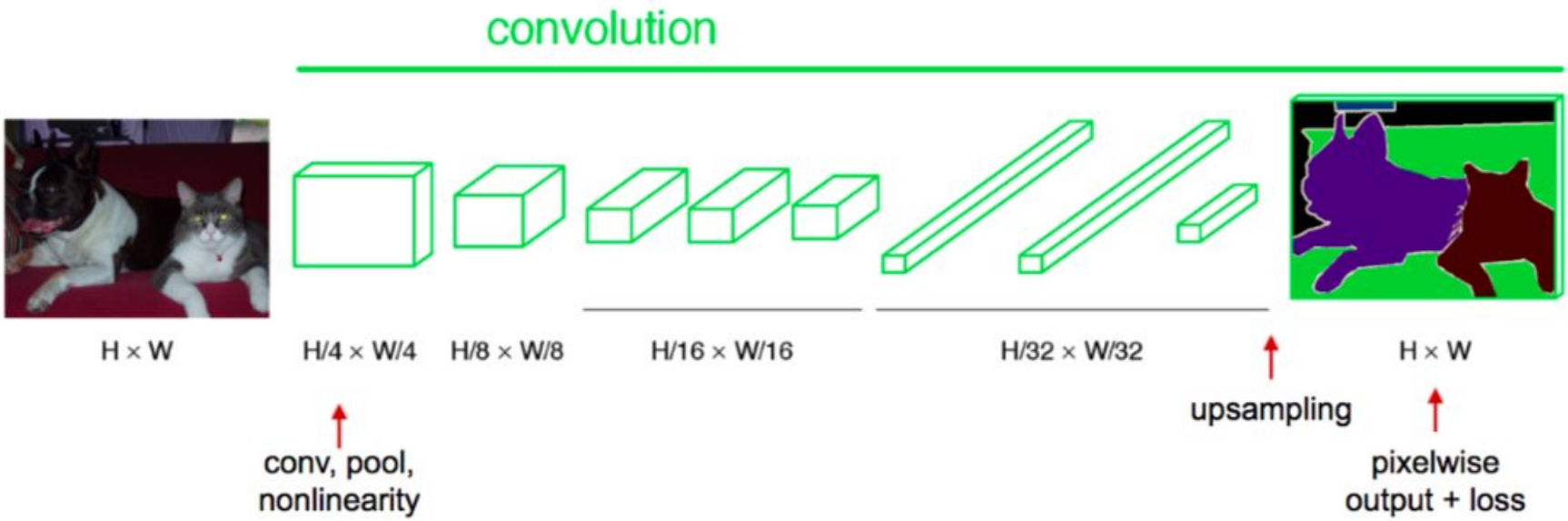
Source: https://docs.google.com/presentation/d/1VeWFMpZ8XN7OC3URZP4WdXvOGYckoFWGVN7hApoXVnc/edit#slide=id.g19540bd54f_0_32

End to End Learning for Image Segmentation



Source: https://docs.google.com/presentation/d/1VeWFMpZ8XN7OC3URZP4WdXvOGYckoFWGVN7hApoXVnc/edit#slide=id.g19540bd54f_0_32

FCN Architecture



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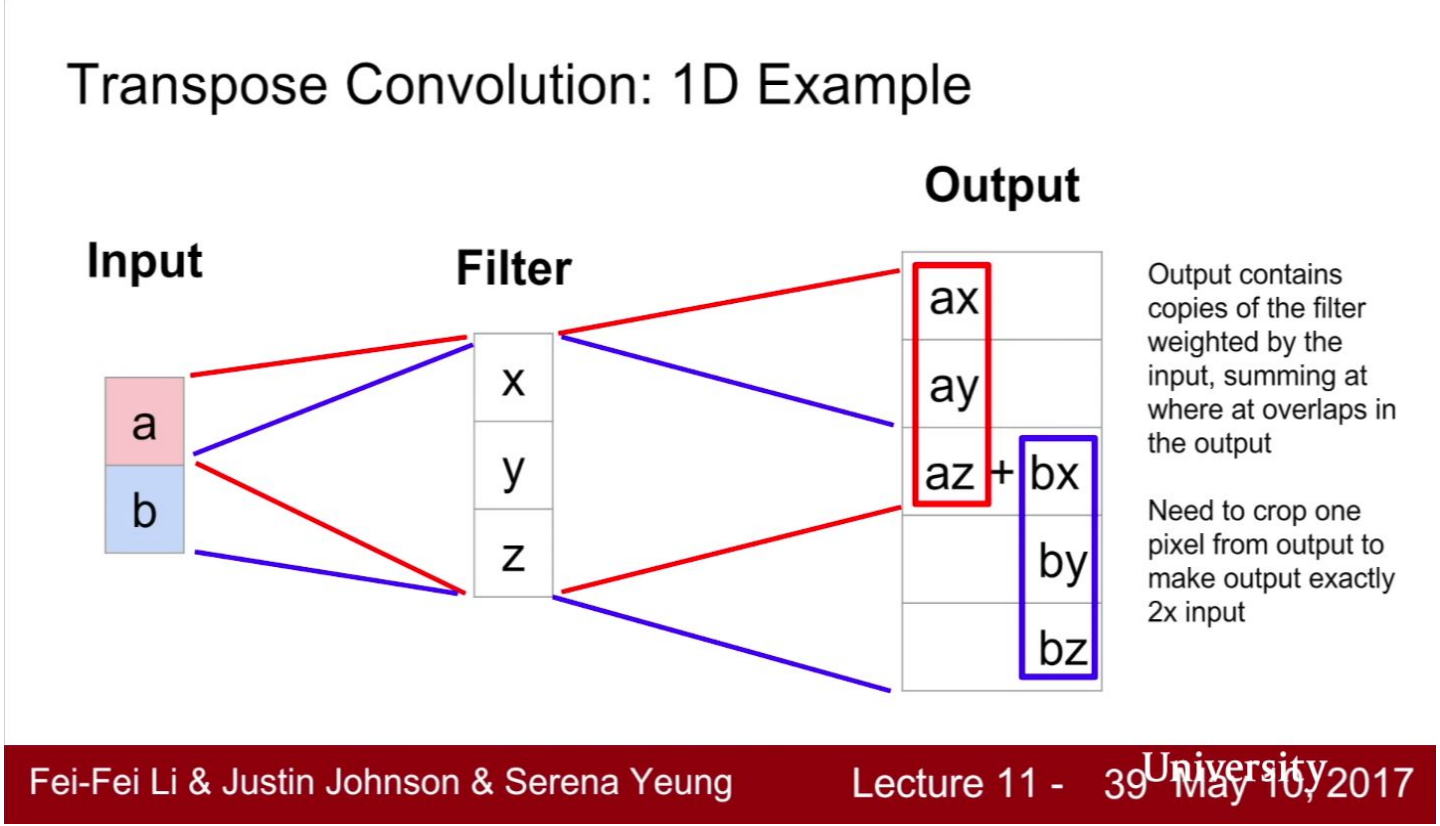
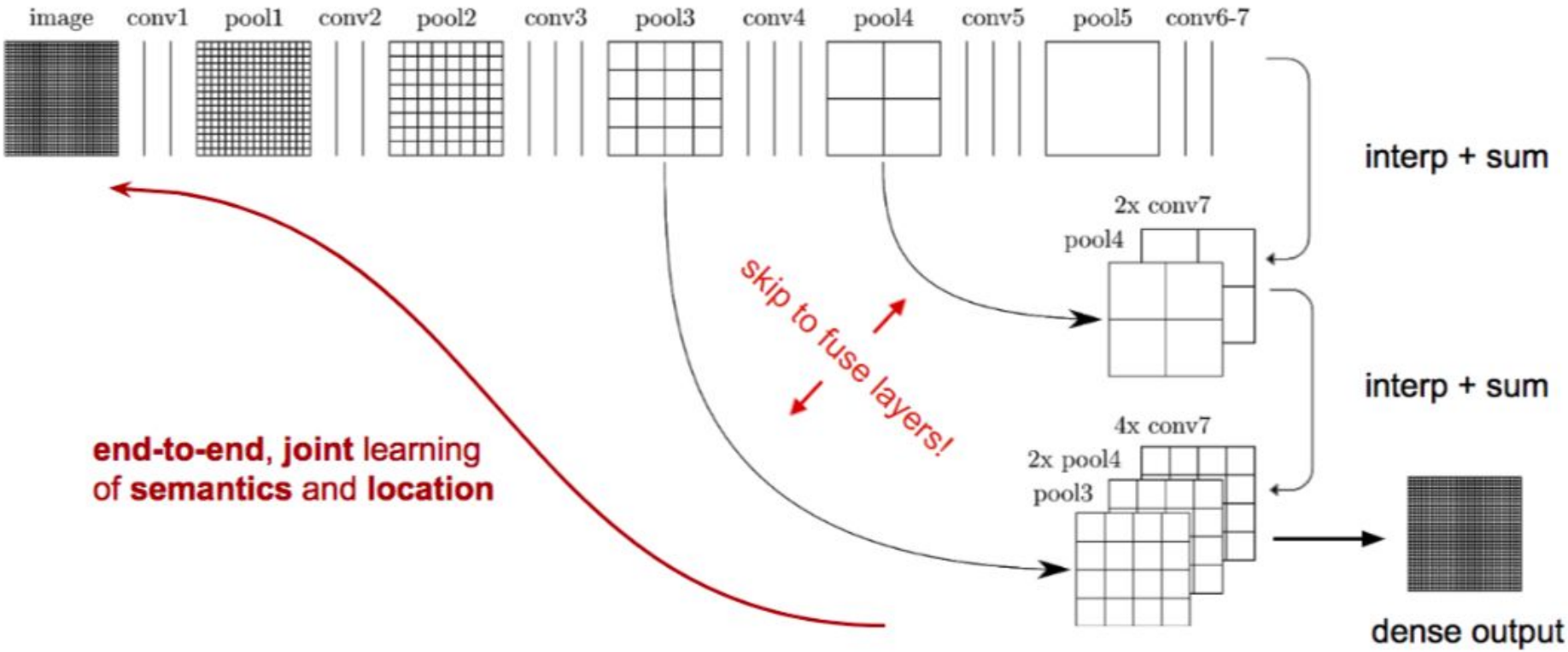


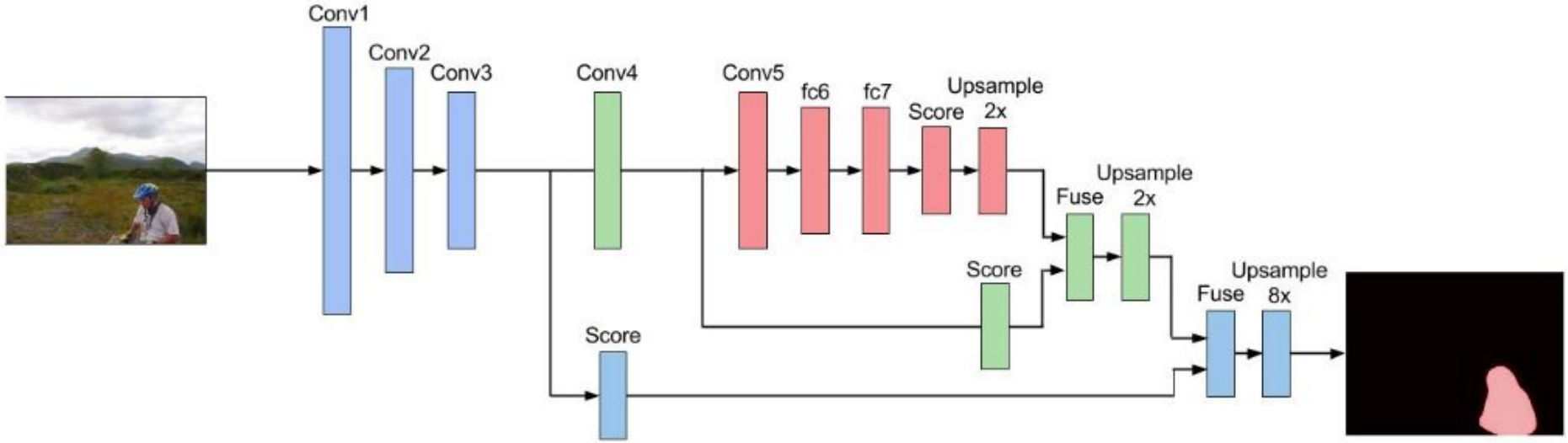
Transpose Convolution Example. Reprint from Fei-fei & Justin Johnson & Serena Yeung Lecture.

Skip Connections



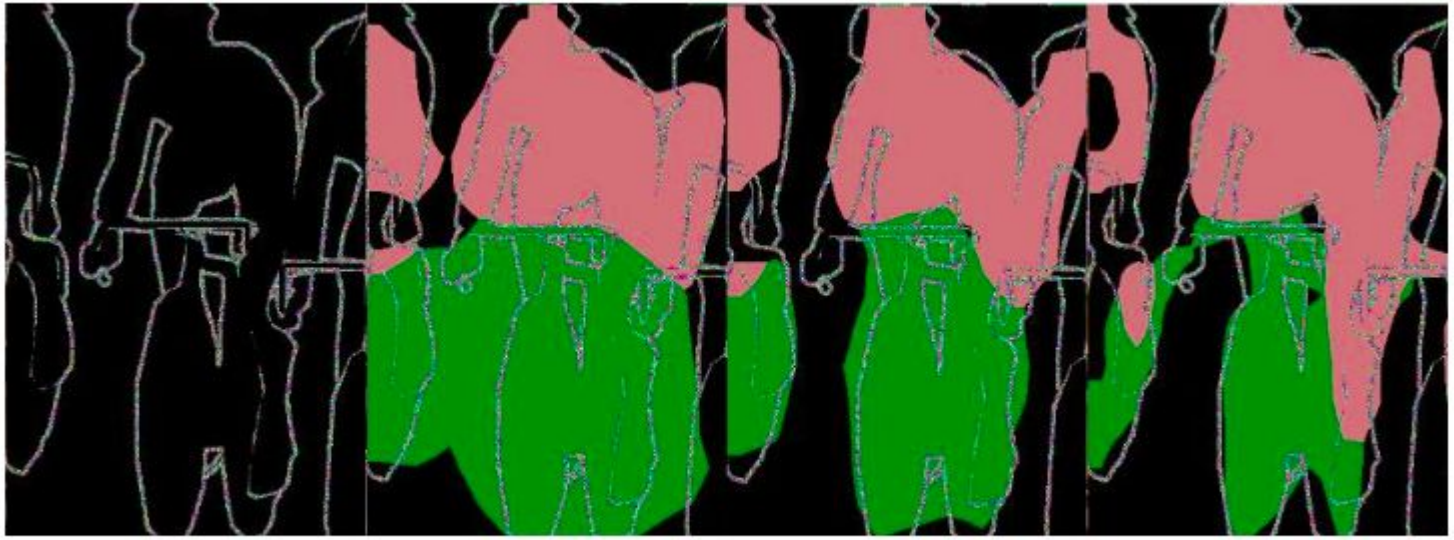
Source: https://docs.google.com/presentation/d/1VeWFMpZ8XN7OC3URZP4WdXvOGYckoFWGVN7hApoXVnc/edit#slide=id.g19540bd54f_0_32

skip FCN computation



Source: https://docs.google.com/presentation/d/1VeWFMpZ8XN7OC3URZP4WdXvOGYckoFWGVN7hApoXVnc/edit#slide=id.g19540bd54f_0_32

Begin with FCN32s



(a) (b) (c) (d)

FCN32s segmentation results. (a) Result of the first iteration. (b) Result of 4,000th iteration. (c) Result of 16,000th iteration (d) Result of 100,000th iteration.

Continue with FCN16s

(a) (b) (c) (d)

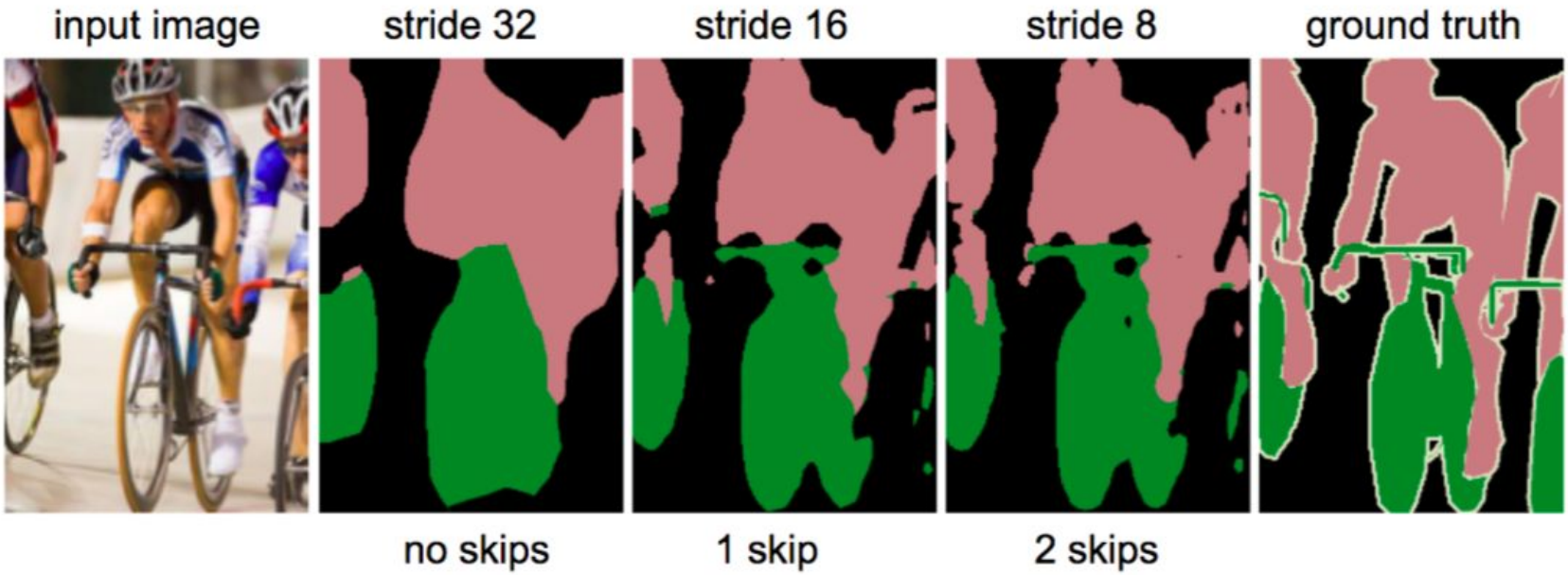
FCN16s segmentation results. (a) Result of the first iteration. (b) Result of 4,000th iteration. (c) Result of 16,000th iteration (d) Result of 100,000th iteration.

Finally, Refine with FCN8s

(a) (b) (c) (d)

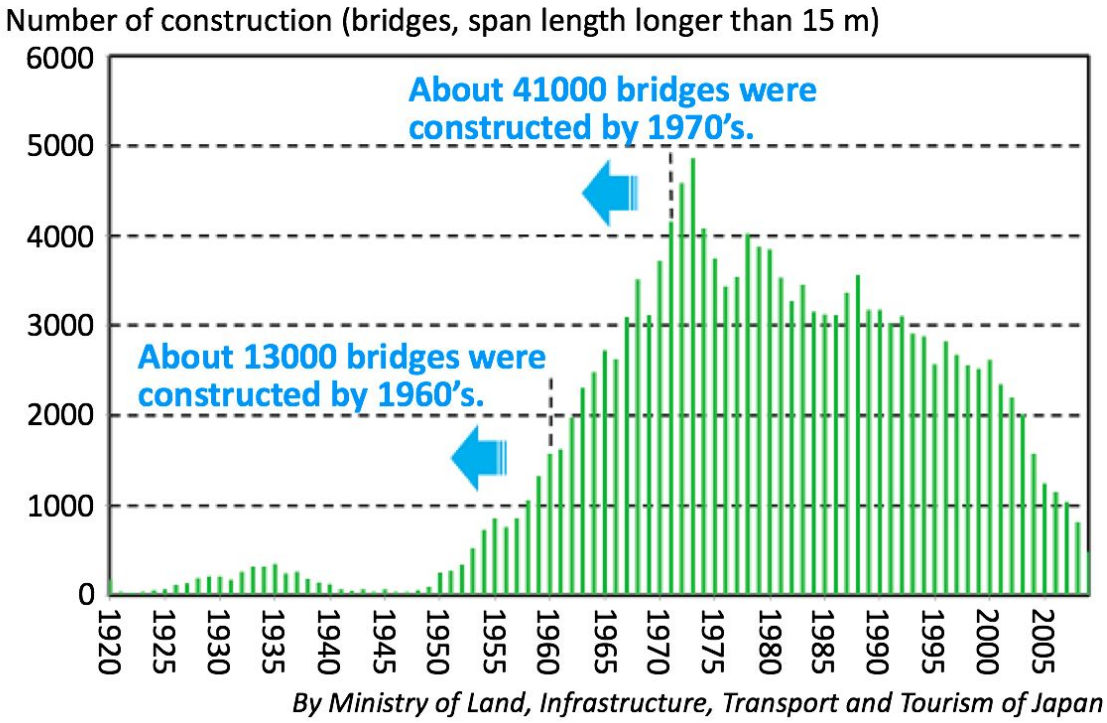
FCN8s segmentation results. (a) Result of the first iteration. (b) Result of 4,000th iteration. (c) Result of 16,000th iteration (d) Result of 100,000th iteration.

Skip Layer Refinement



Source: https://docs.google.com/presentation/d/1VeWFMpZ8XN7OC3URZP4WdXvOGYckoFWGVN7hApoXVnc/edit#slide=id.g19540bd54f_0_32

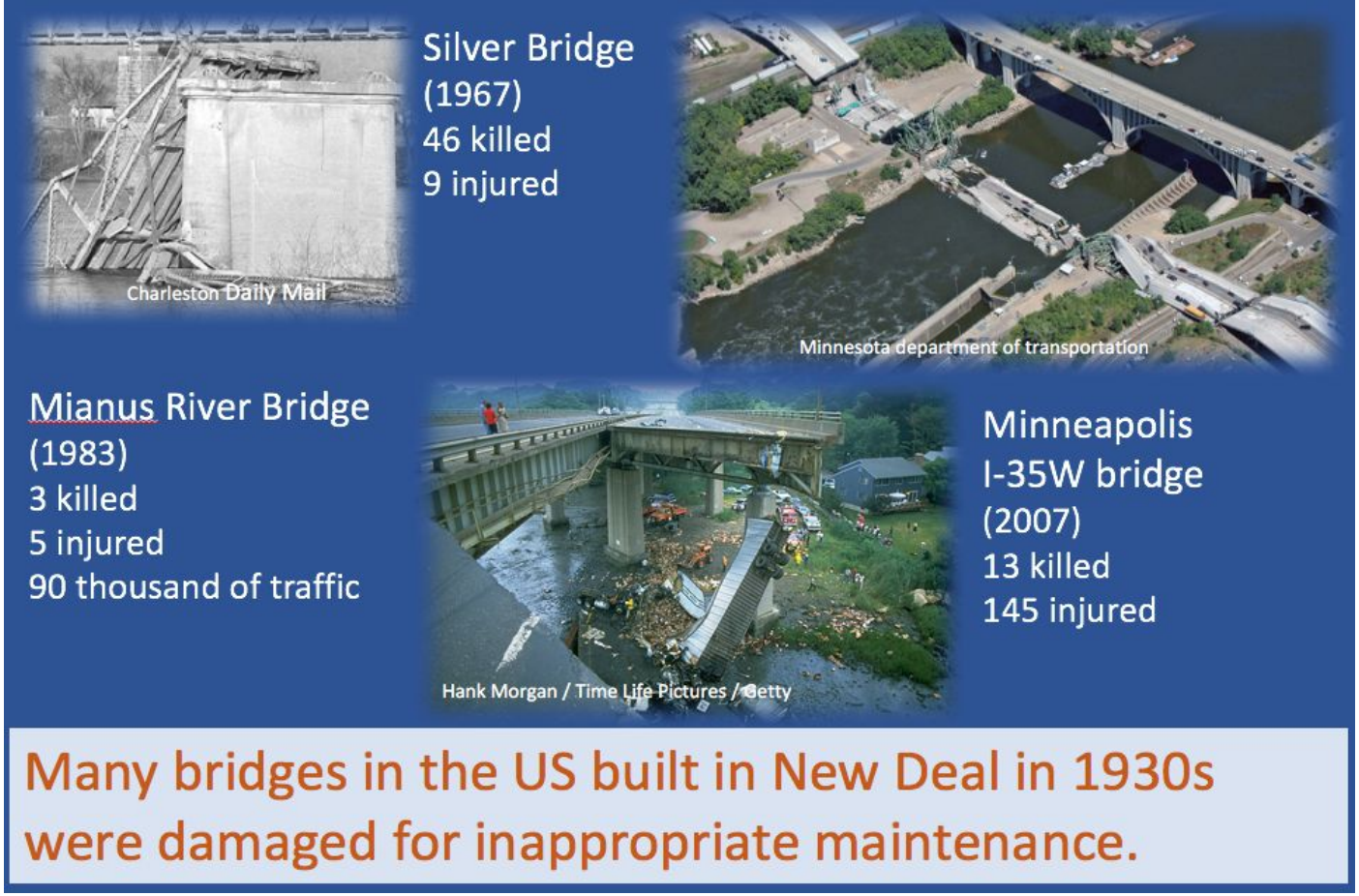
A Story of Dataset



Aging of Infrastructure in Japan.

Source: Koji MATSUMOTO, Deteriorations of Road Infrastructures in Japan

The 1st SIP International Seminar on Infrastructure Asset Management Present and Future Road Infrastructure Management in Thailand and Japan



The collapse of bridges.

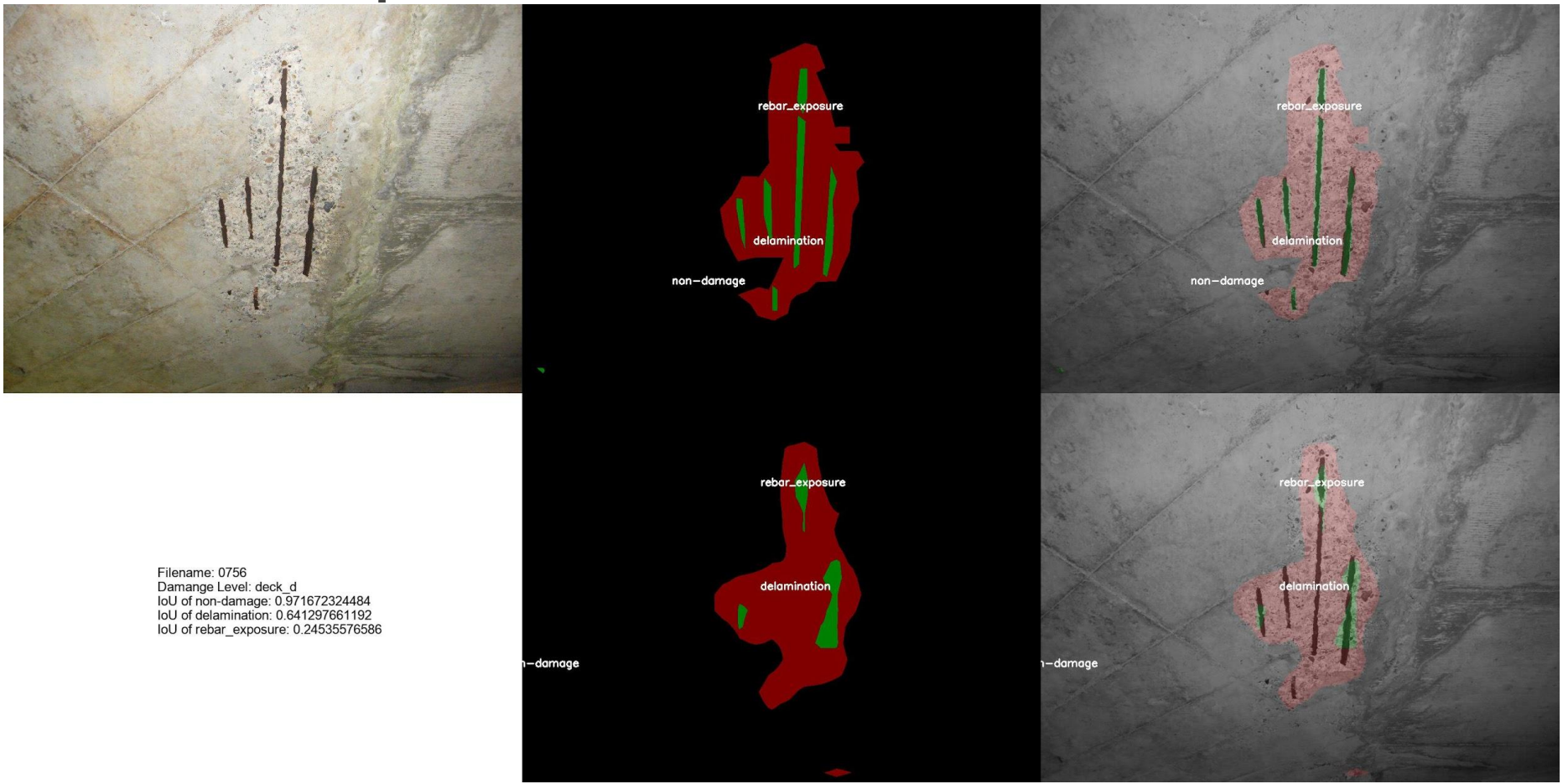
Source: Kohei NAGAI, Current state and issues of bridge management in Japan, Difficulty of maintenance in rural area

Bridge Maintenance in Japan

Bridge Maintenance in Japan.

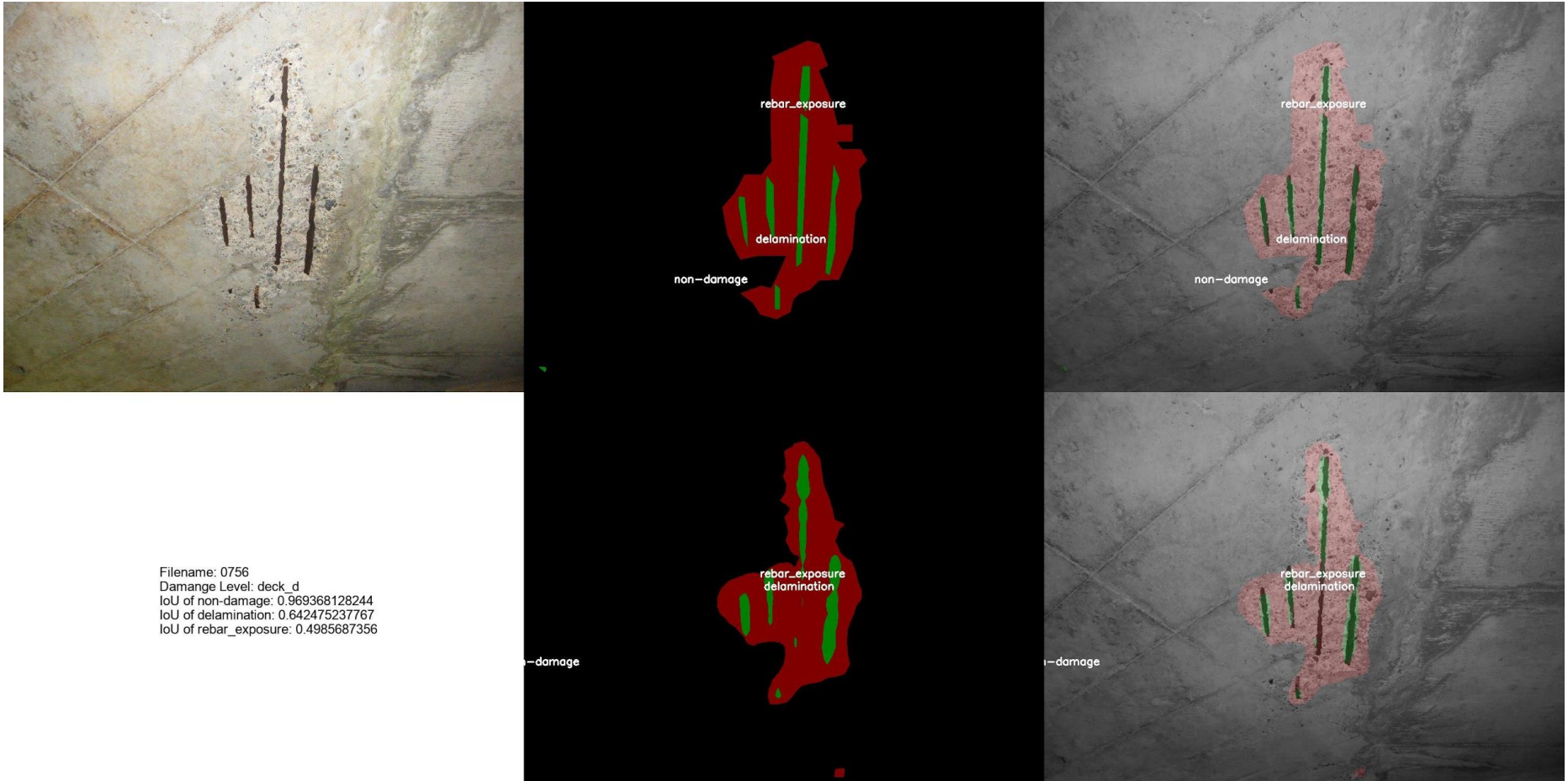
Source: Kohei NAGAI, Current state and issues of bridge management in Japan, Difficulty of maintenance in rural area

FCN32s Example Results



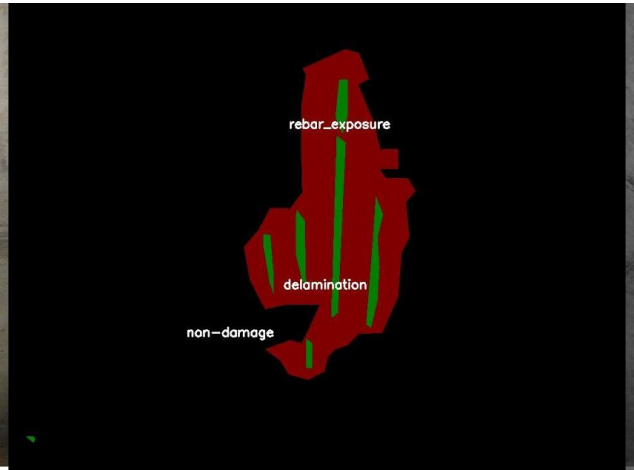
Filename: 0756
Damange Level: deck_d
IoU of non-damage: 0.971672324484
IoU of delamination: 0.641297661192
IoU of rebar_exposure: 0.24535576586

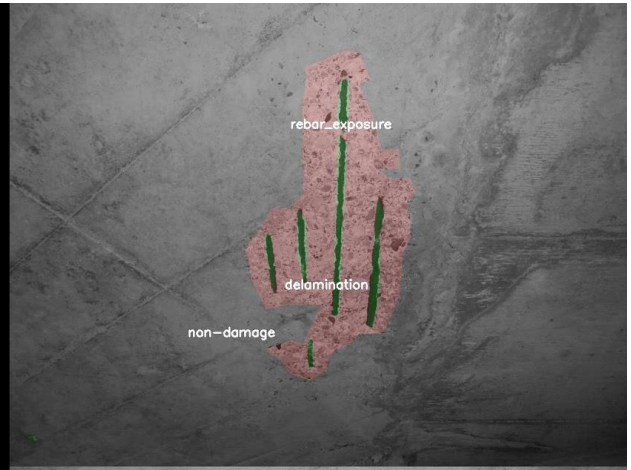
FCN16s Example Results



Filename: 0756
Damange Level: deck_d
IoU of non-damage: 0.969368128244
IoU of delamination: 0.642475237767
IoU of rebar_exposure: 0.4985687356

FCN8s Example Results





Filename: 0756
Damange Level: deck_d
IoU of non-damage: 0.973142311846
IoU of delamination: 0.704042450075
IoU of rebar_exposure: 0.638358049228

Hyperparameters

Bridge Dataset:

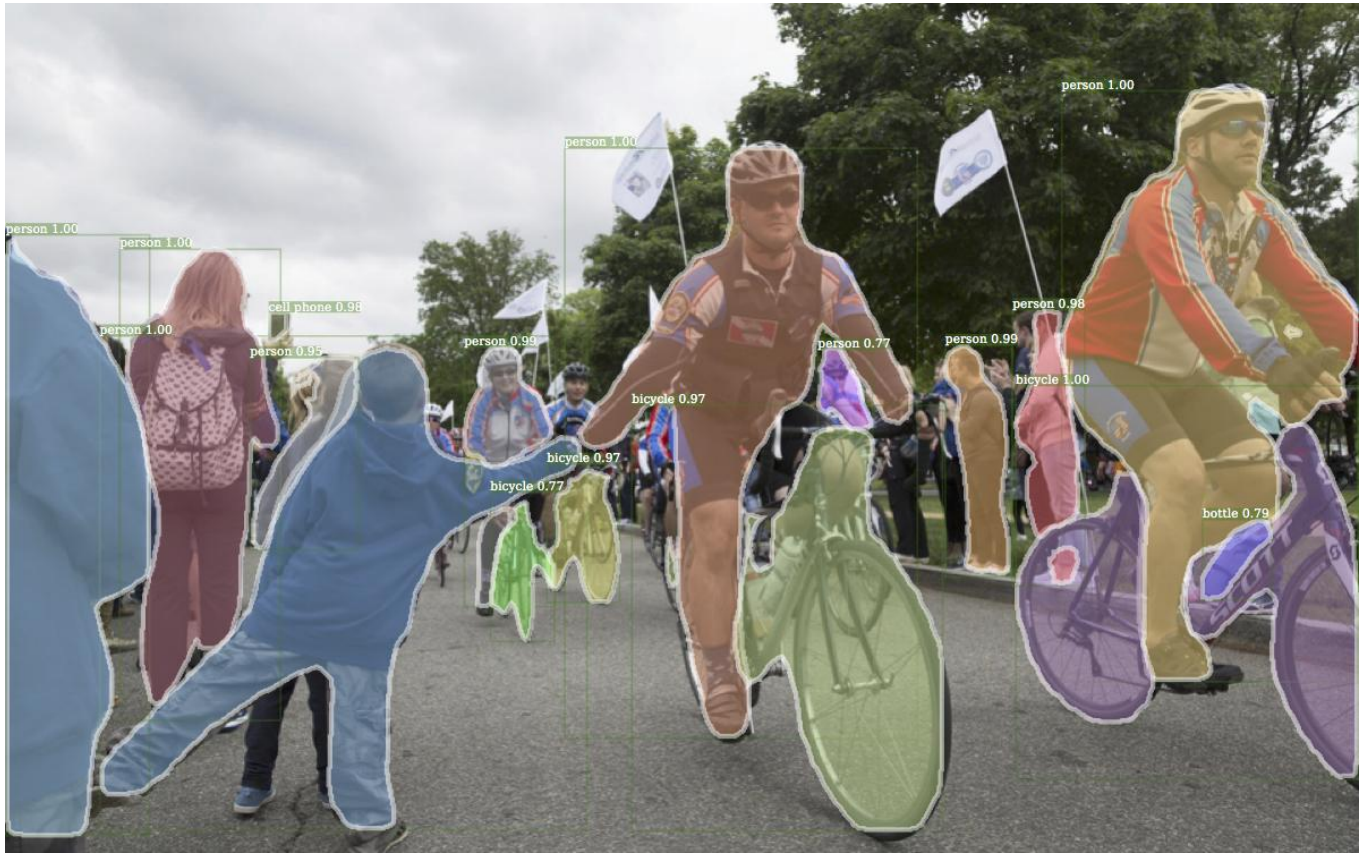
- 422 of labelled deck images
- Lower resolution threshold 1 Megapixel
- 70:30 Split into 296 images for training data and 126 images for validation data
- 256x256 random crop

Hyperparameters:

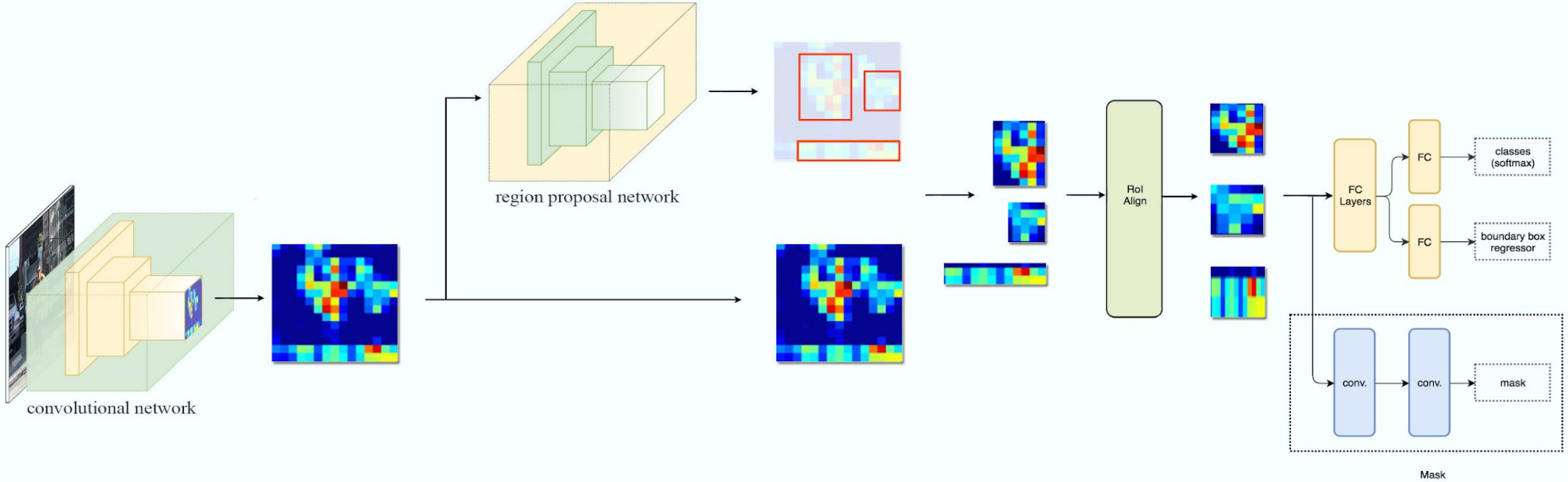
- Batch size: 1
- Learning rate: 1e-10
- Weight decay: 0.0005
- Momentum: 0.99
- Optimizer: Stochastic Gradient Descent with Momentum

Mask R-CNN

Instance Segmentation



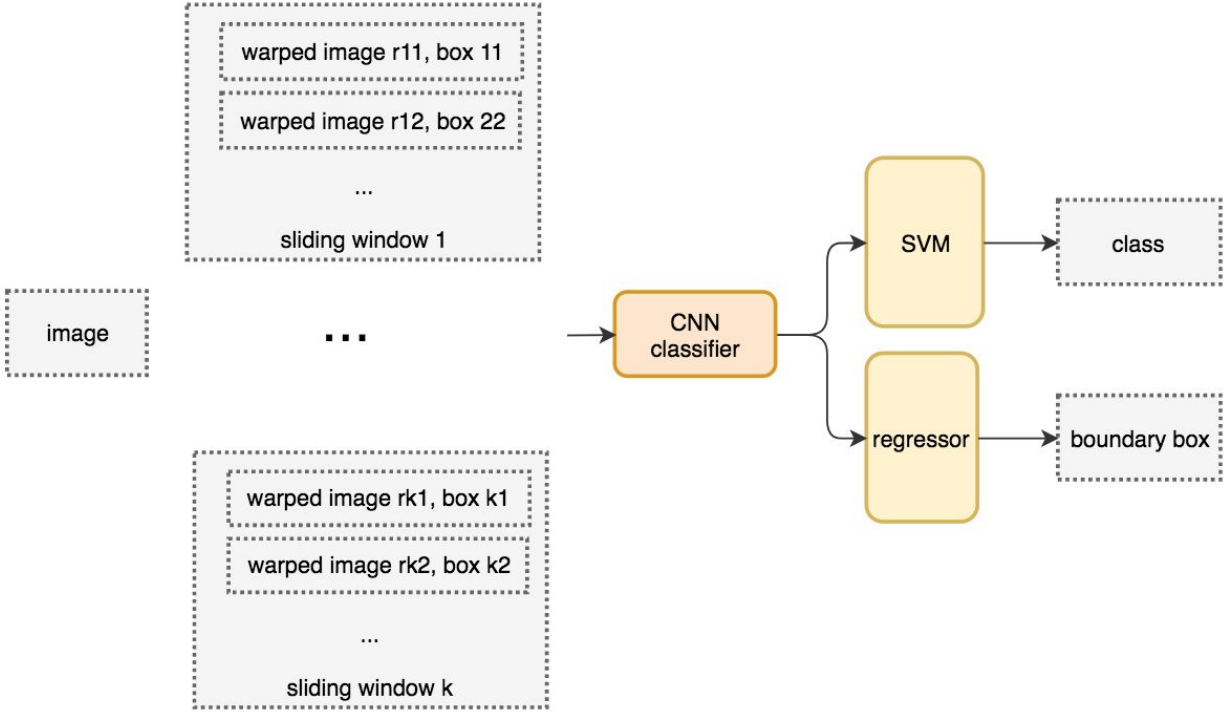
Mask R-CNN (He et al., 2017)



Mask R-CNN Architecture.

Source: https://medium.com/@jonathan_hui/image-segmentation-with-mask-r-cnn-ebe6d793272

Sliding Window Detector



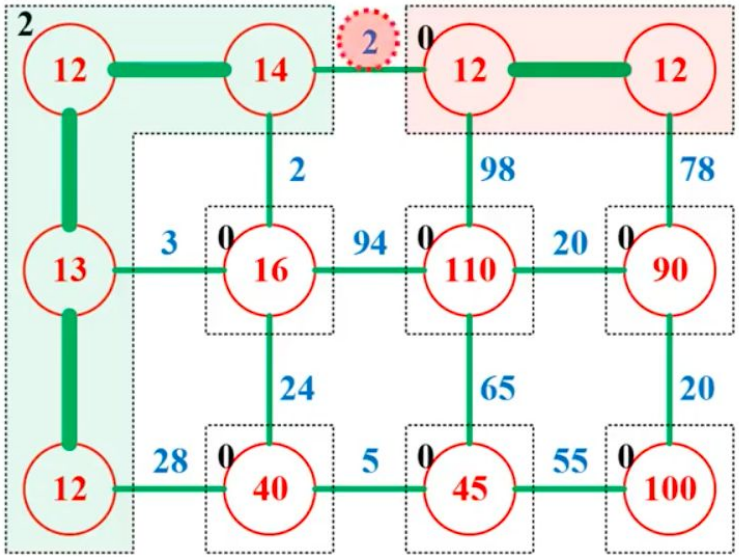
Sliding Window Detector Architecture.

Source: https://medium.com/@jonathan_hui/what-do-we-learn-from-region-based-object-detectors-faster-r-cnn-r-fcn-fpn-7e354377a7c9

Graph-based Segmentation (Felzenszwalb & Huttenlocher, 2004)

- Tiny Example ($k = 100$)

$$\begin{cases} w(e_q) \le Int(C_i) + \dfrac{k}{\tau(C_i)} \\ w(e_q) \le Int(C_j) + \dfrac{k}{\tau(C_j)} \end{cases}$$

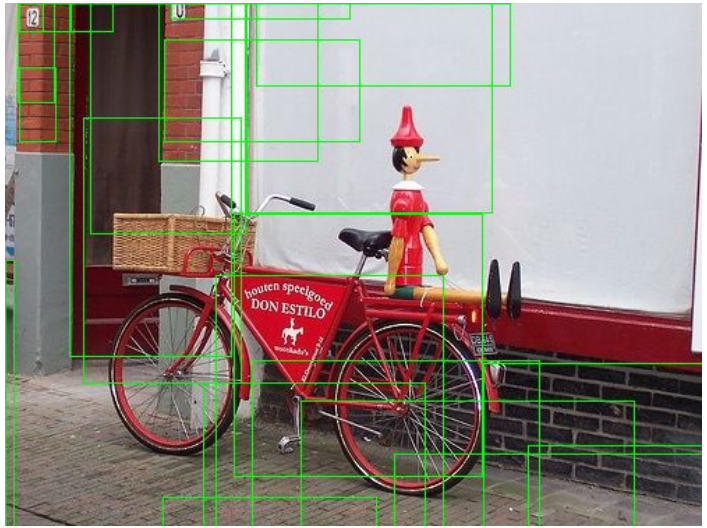


$$2 \le 2 + \frac{100}{4} = 27$$

$$2 \le 0 + \frac{100}{2} = 50$$

Graph-based Segmentation Example.
Source: https://www.youtube.com/watch?v=iDKeR_swA8g

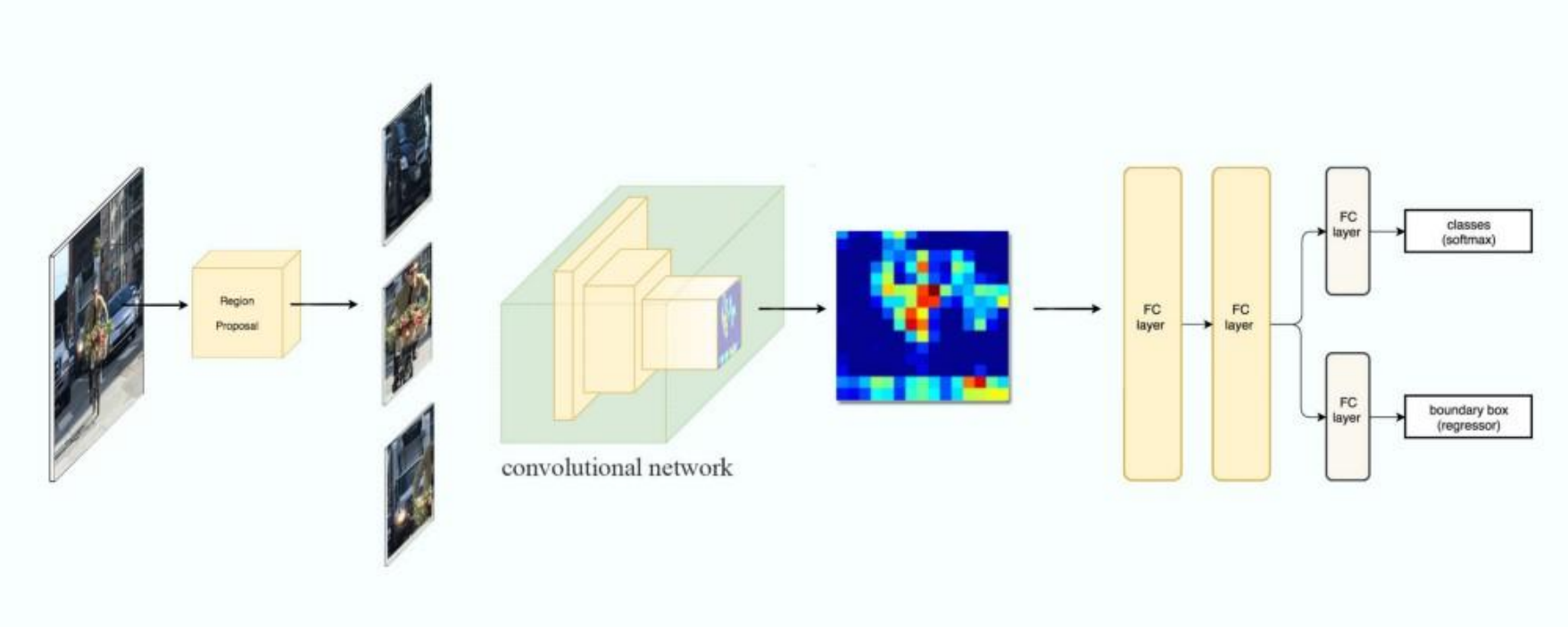
Selective Search (Uijlings, Van De Sande, Gevers, & Smeulders, 2013)



A Selective Search Example. Selective Search gets the segmentation output from graph-based segmentation and group adjacent region based on color, texture, size, and shape similarity.

Source: https://github.com/belltailjp/selective_search_py

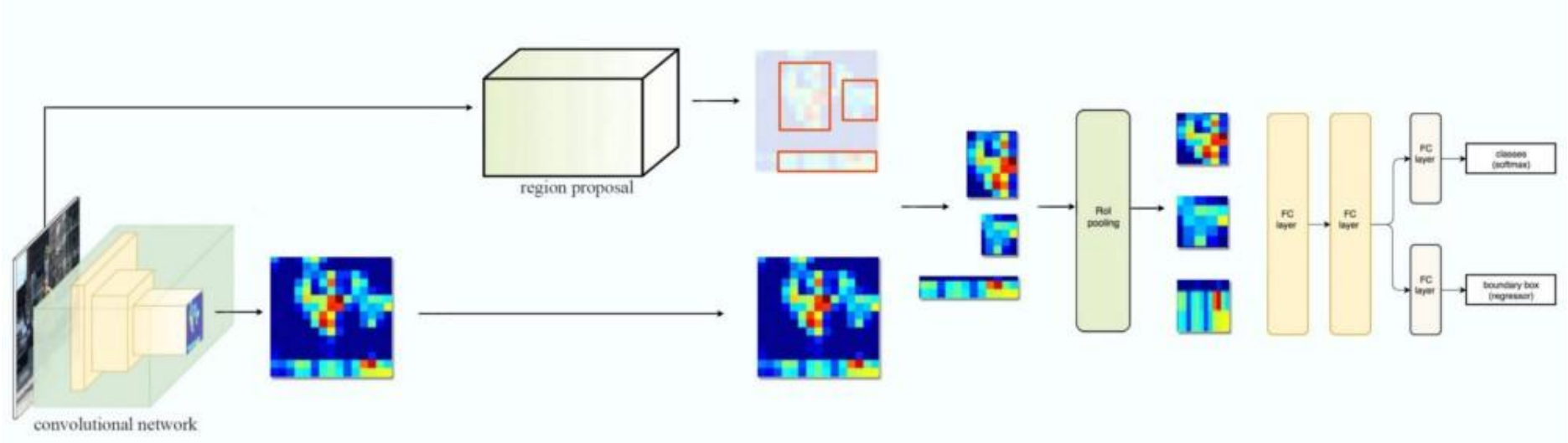
Region-based CNN (Girshick et al., 2014)



Region-based CNN Architecture.

Source: https://medium.com/@jonathan_hui/what-do-we-learn-from-region-based-object-detectors-faster-r-cnn-r-fcn-fpn-7e354377a7c9

Fast R-CNN (Girshick, 2015)



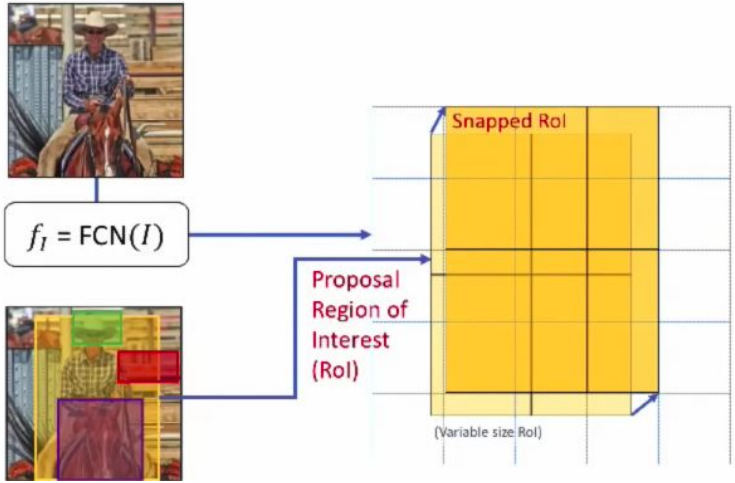
Fast R-CNN

Source: https://medium.com/@jonathan_hui/what-do-we-learn-from-region-based-object-detectors-faster-r-cnn-r-fcn-fpn-7e354377a7c9

Region of Interest Pooling (RoIPool)

He, Zhang, Ren, Sun. Spatial Pyramid Pooling in Deep Convolutional Networks for Visual Recognition. ECCV 2014.

RoIPool (on each Proposal)

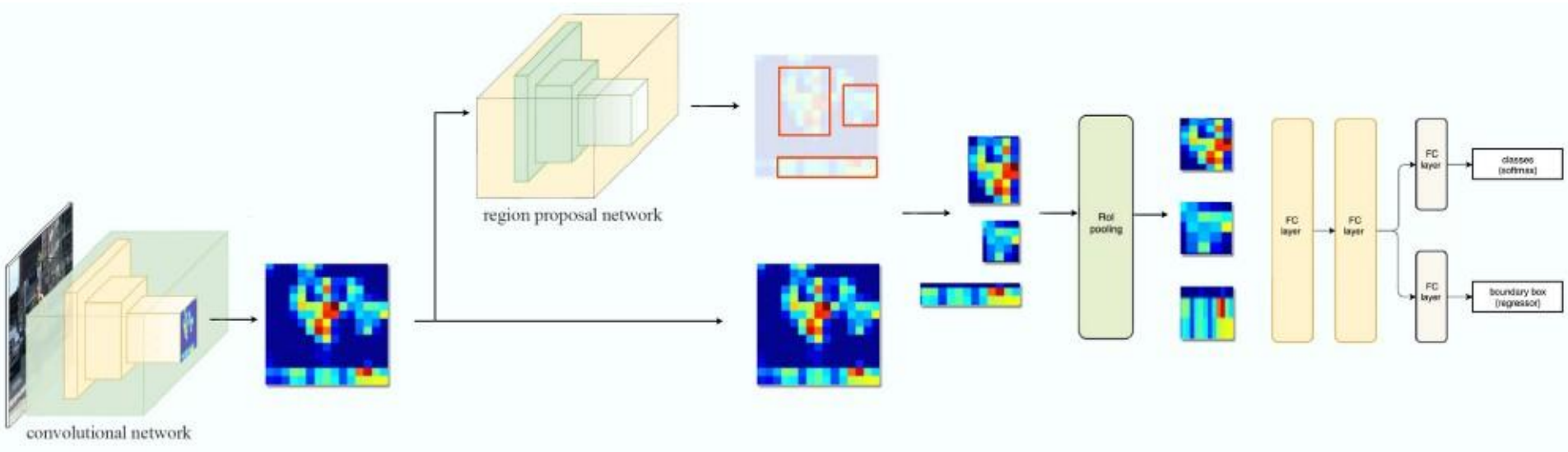


Key innovation in SPP-net
[He et al. 2014]

RoIPool is applied to each proposal generated by selective search and then warp the variable size region proposals into in a predefined size shape.

Source: https://www.youtube.com/watch?v=m60uJVIE4Ys

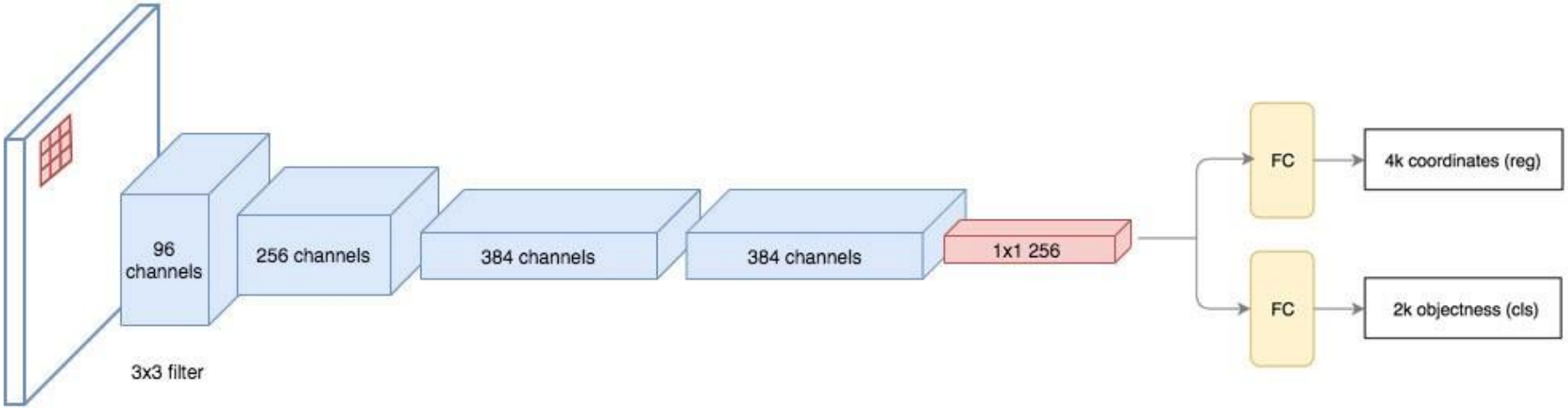
Faster R-CNN (Ren et al., 2017)



Faster R-CNN

Source: https://medium.com/@jonathan_hui/what-do-we-learn-from-region-based-object-detectors-faster-r-cnn-r-fcn-fpn-7e354377a7c9

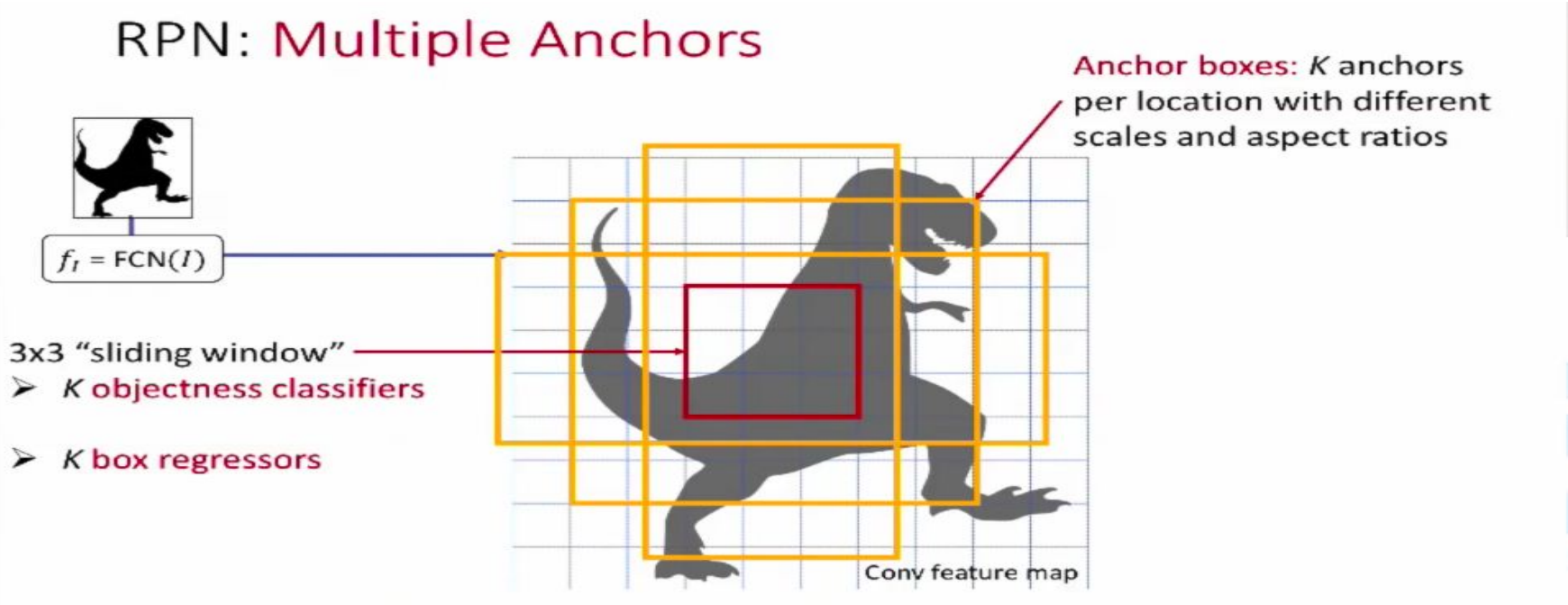
Region Proposal Network (1)



Region Proposal network

Source: https://medium.com/@jonathan_hui/what-do-we-learn-from-region-based-object-detectors-faster-r-cnn-r-fcn-fpn-7e354377a7c9

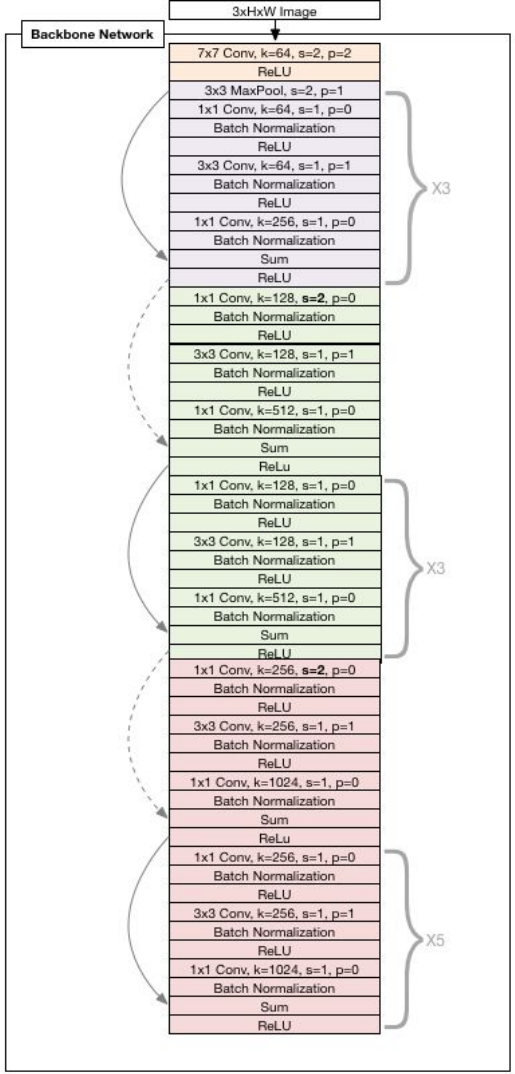
Region Proposal Network (2)



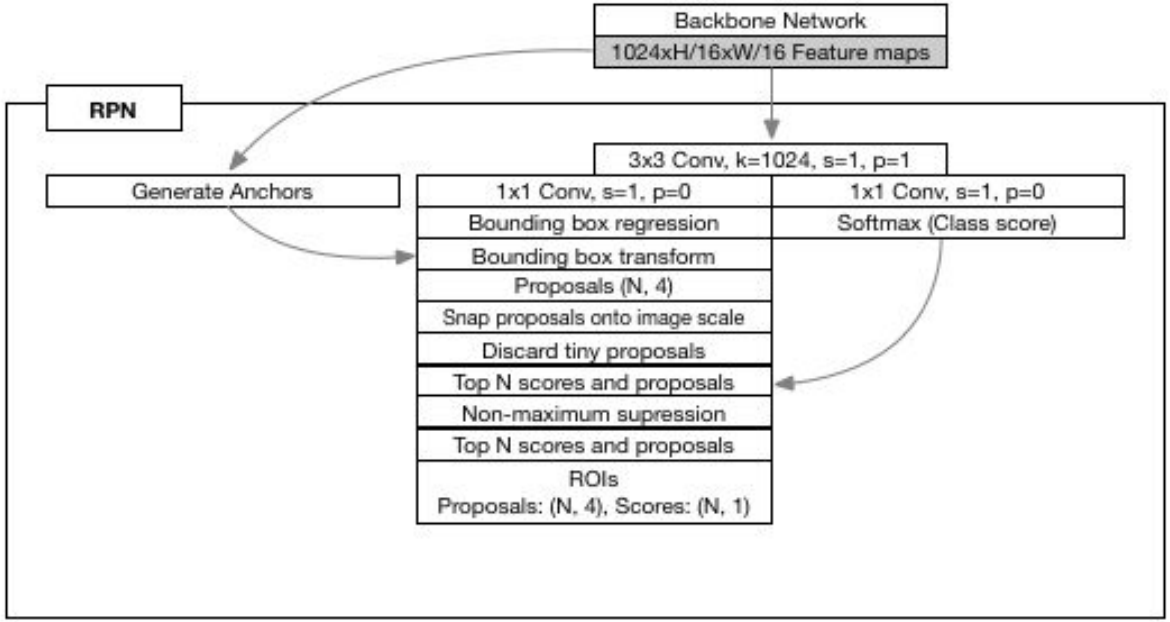
Sliding window on feature maps with multiple anchors.
Source: https://www.youtube.com/watch?v=m60uJVIE4Ys

Backbone Network: ResNet-50

Mask R-CNN backbone network. The first residual block begins after MaxPool. Curly braces indicate stacked residual units. Feature maps shrink two times for each residual block due to the convolutional layer with stride 2. Dotted arrows indicate that the residual unit increases resolution using zero padding.

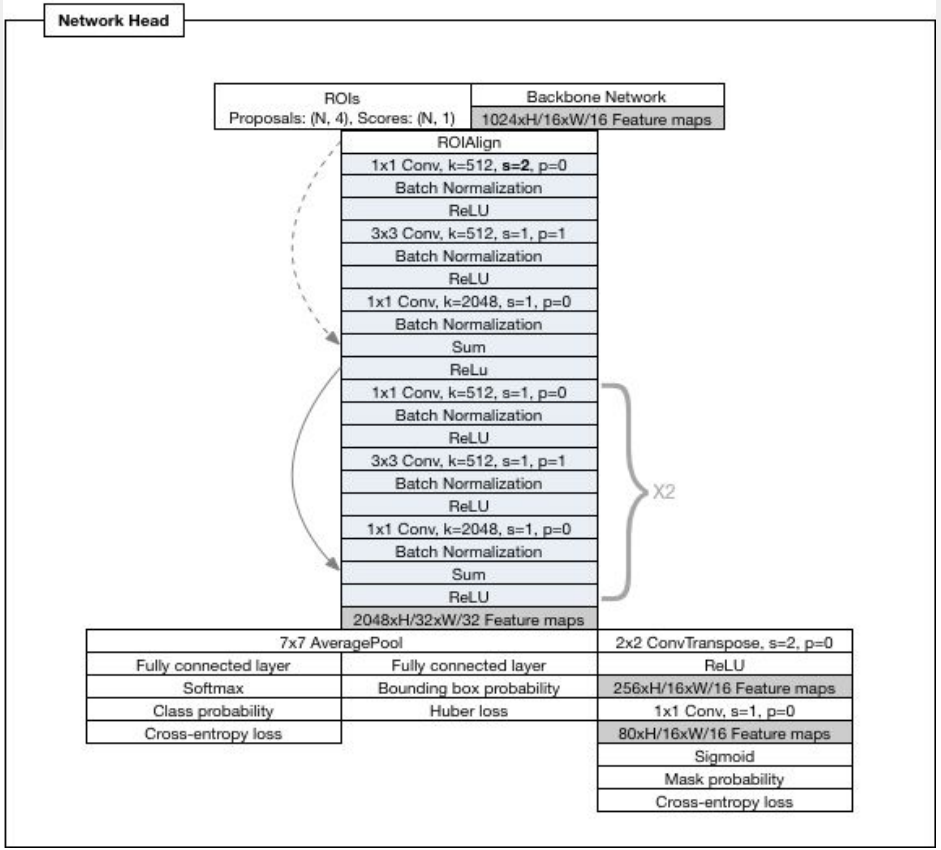


ResNet-50 with RPN



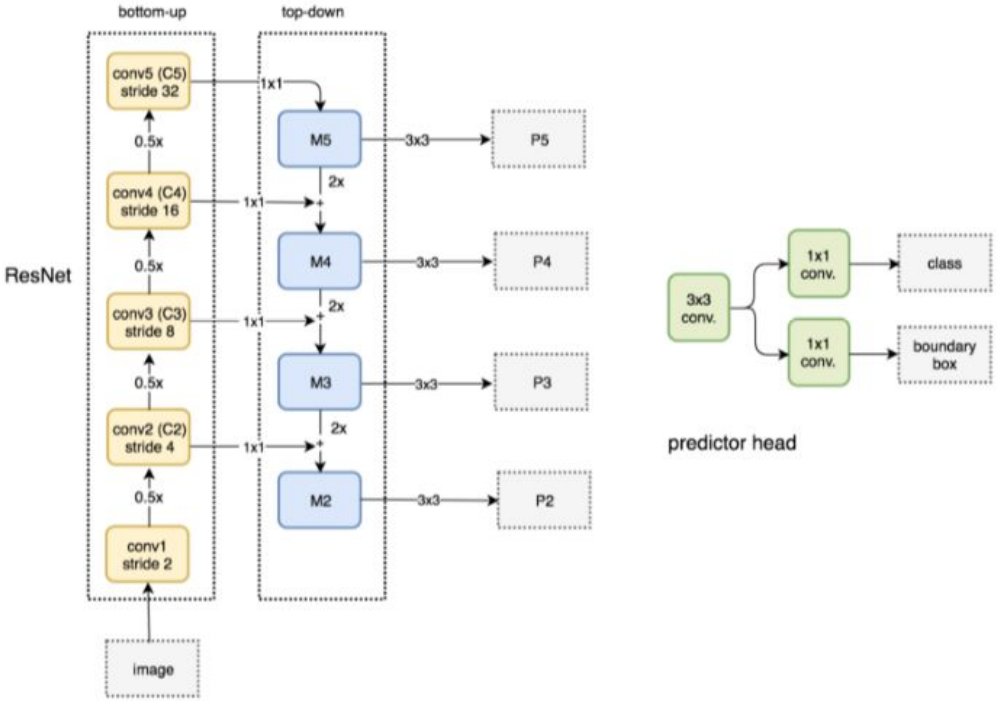
Region proposal network. The output of the network is a set of proposals based on the input feature maps and pre-defined anchors. The proposal properties are the top x-axis, top y-axis, width, and height.

ResNet-50 Network Head



Network head. The network head takes ROIs from the region proposal network and backbone network feature maps and feed them to a ROIAlign layer and the last residual block. The network head terminate at a softmax cross-entropy loss layer for class probability, Huber loss is used for bounding box probabilities, and Sigmoid cross-entropy loss is used for mask probabilities.

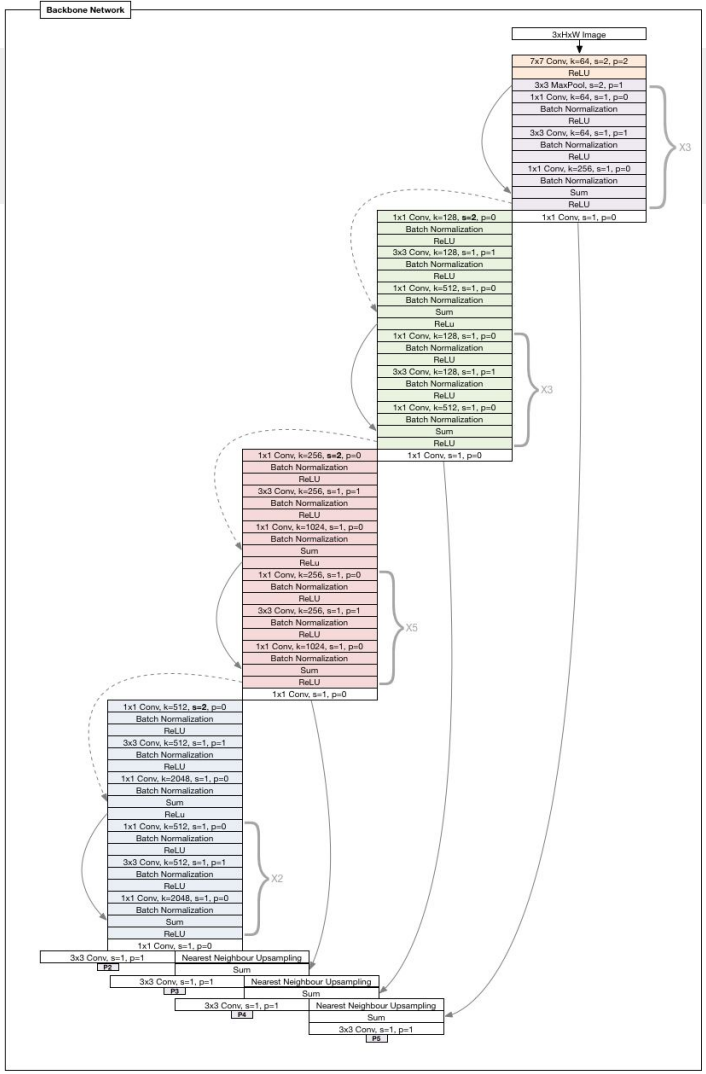
Feature Pyramid Network



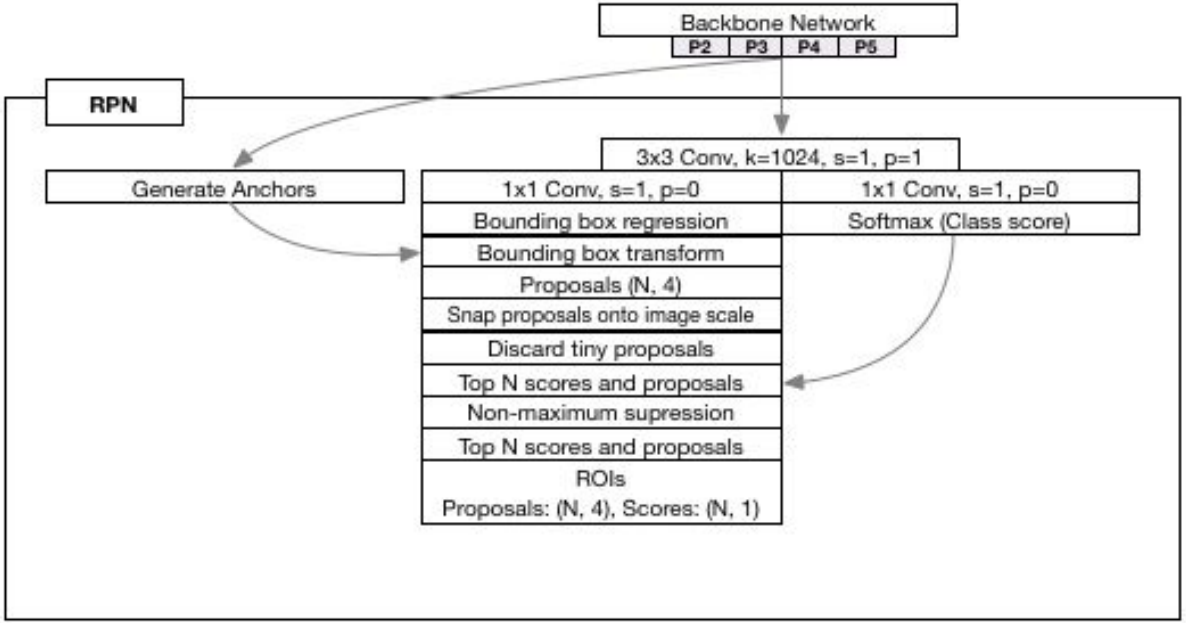
The structure of a feature pyramid network (FPN) using residual neural network (ResNet).
Source: https://medium.com/@jonathan_hui/understanding-feature-pyramid-networks-for-object-detection-fpn-45b227b9106c

Backbone Network: ResNet-50 with FPN

Mask R-CNN ResNet-50 backbone network with feature pyramid network. The idea of the feature pyramid network is the same as shown previously. P2, P3, P4, and P5 are feature maps with multiple scales.

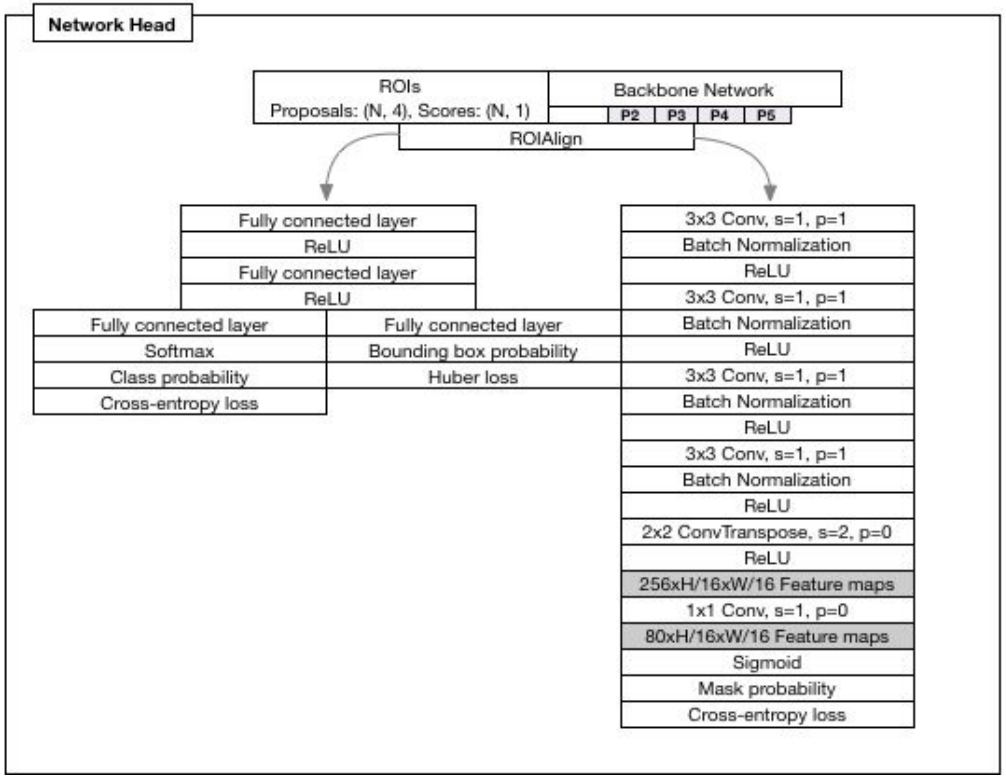


ResNet-50 with FPN and RPN



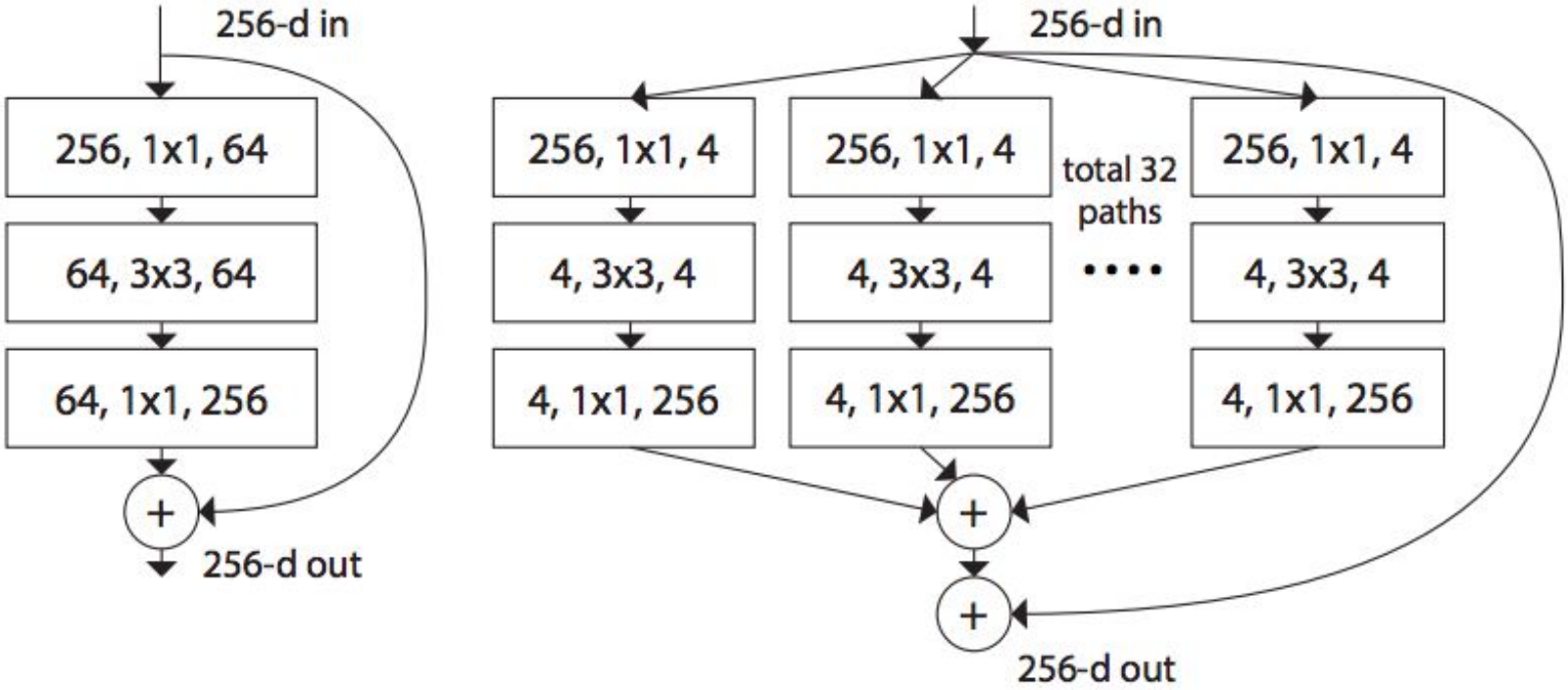
Mask R-CNN ResNet-50 region proposal network with feature pyramid network.

ResNet-50 Network Head



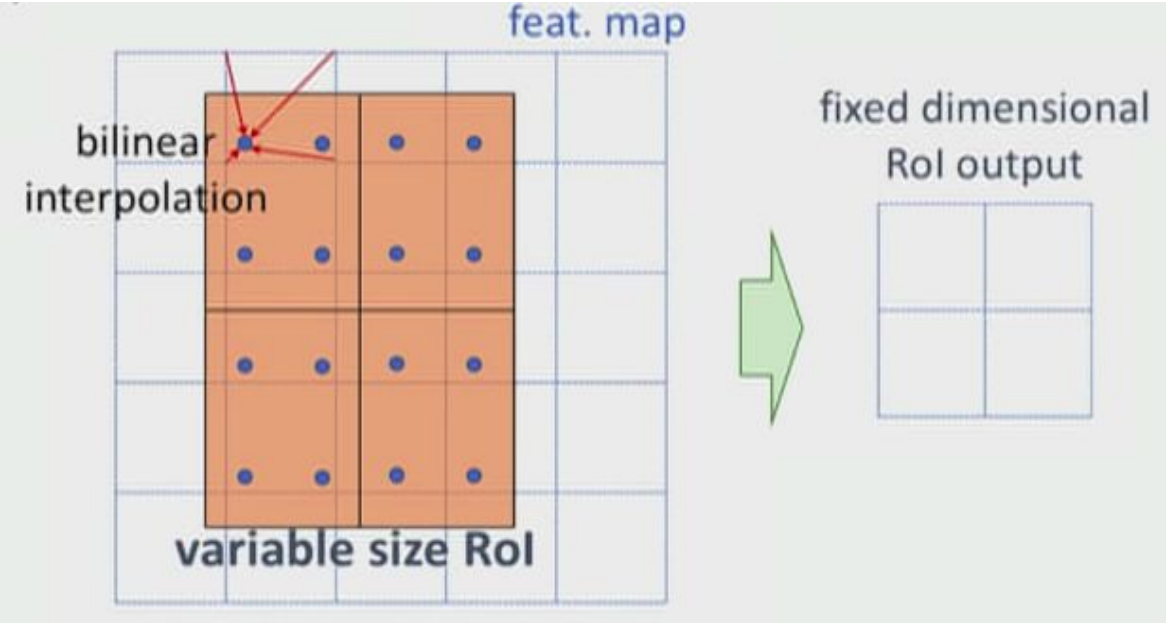
Mask R-CNN ResNet-50 with FPN network head.

ResNeXt (Xie et al., 2017)



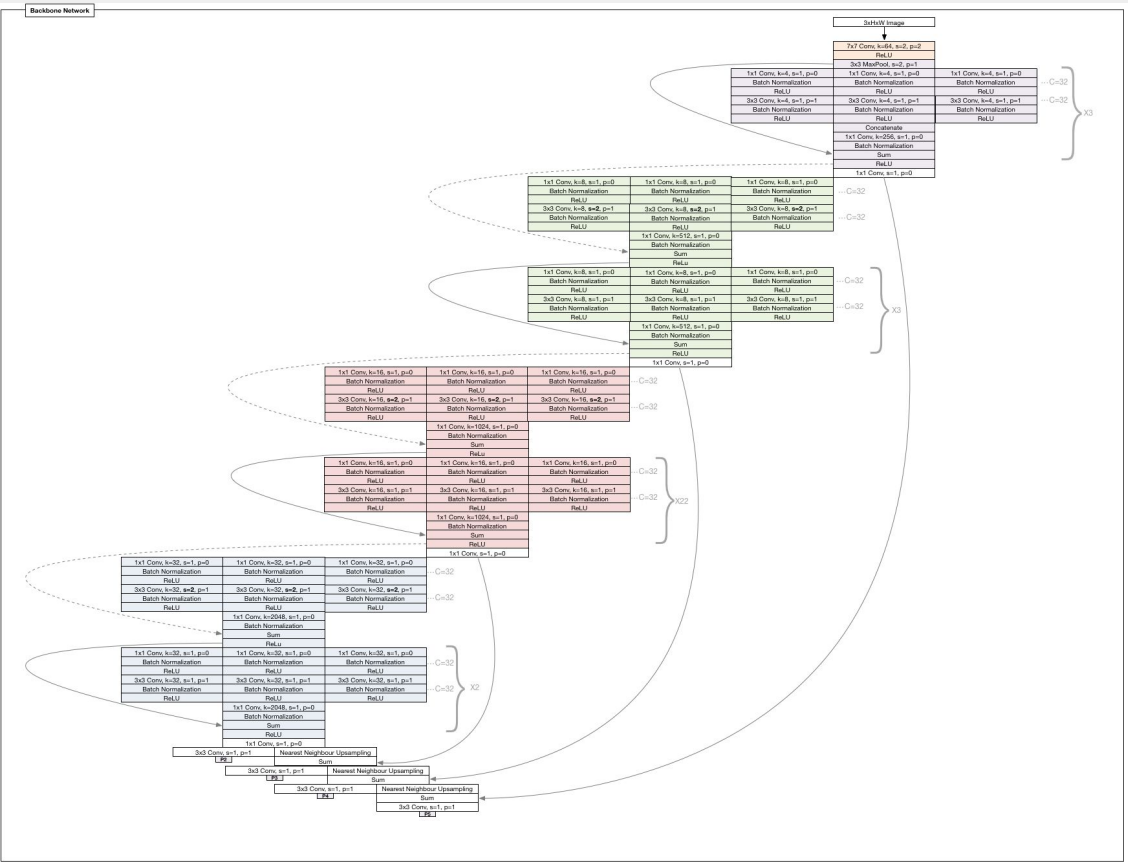
Left: A block of ResNet. Right: A block of ResNeXt.

Region of Interest Feature Alignment (He et al., 2017)



Region of interest feature alignment is another major contribution of Mask R-CNN. It reduce misalignment from quantization with bilinear interpolation which improve segmentation performance.
Source: https://www.youtube.com/watch?v=g7z4mkfRjI4

ResNeXt-101 with FPN



Mask R-CNN ResNeXt-101 backbone network with feature pyramid network.

COCO Dataset Format Conversion from Pascal VOC Format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9</y></pt><pt><x>74</x><y>19</y></pt><pt><x>74</x></pt><pt><x>322</x><y>80</y></pt><pt><x>320</x><y>88</y></pt><pt><x>318</x><y>94</y></pt><pt><x>323</x><y>96</y></pt><pt><x>329</x><y>99</y></pt><pt><x>329</x><y>103</y></pt><pt><x>328</x><y>109</y></pt><pt><x>320</x><y>116</y></pt><pt><x>3
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erified>0</verified><occluded>yes</occluded><attributes>1</attributes><parts><hasparts/></parts><date>26-Mar-2018
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Pascal VOC XML Annotation


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{
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      "id": 1,
      "file_name": "400192.jpg",
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      "license": 1,
      "coco_url": "",
      "flickr_url": ""
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  ],
  "annotations": [
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      "image_id": 1,
      "category_id": 2,
      "iscrowd": 0,
      "area": 1199,
      "bbox": [
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        595.0,
        20.0,
        92.0
      ],
      "segmentation": [
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          3.5,
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          12.0,
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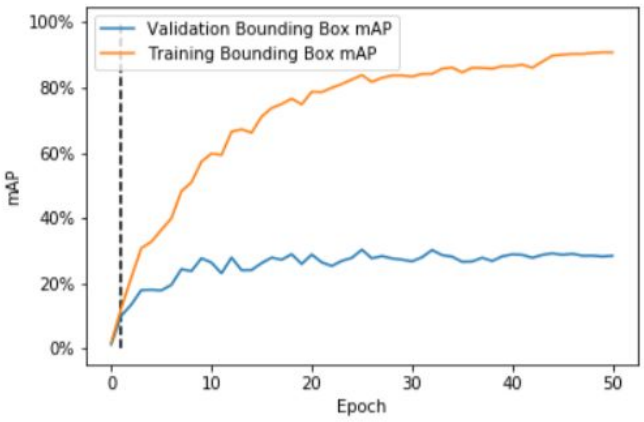
          15.5,
          595.0,
          16.5,
          600.0,
          16.5,
          616.0,
          23.5,
          654.0,
          23.5,
          673.0,
```

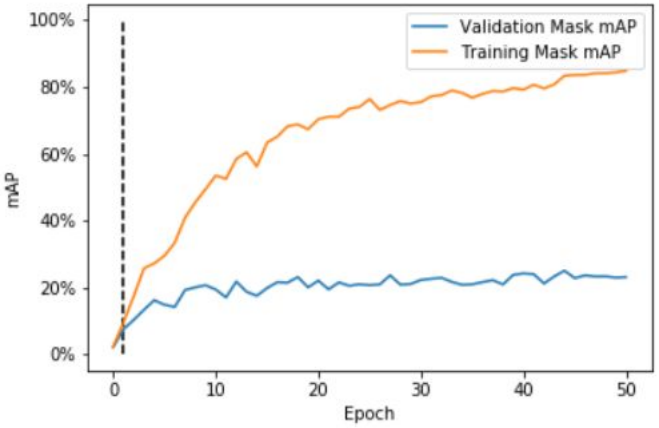

COCO JSON Annotation with Instance Segmentation

Hyperparameters

- Image per batch: 2 (2 GPUs)
- Learning rate:
  - Base learning rate: 0.005
  - After iteration 26,000: 0.0025
  - After iteration 29,000: 0.00125
- Weight decay: 0.0001
- Momentum: 0.9

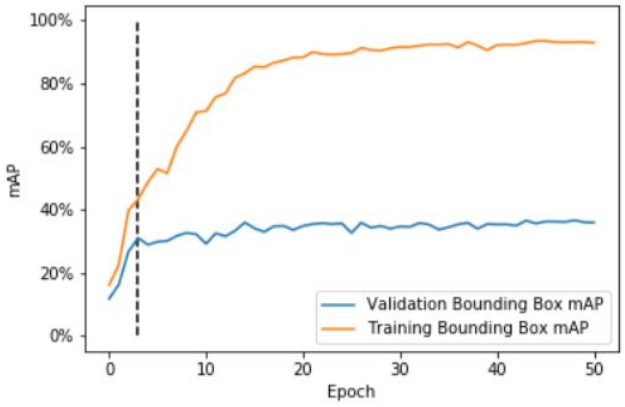
Experimental Results (1)

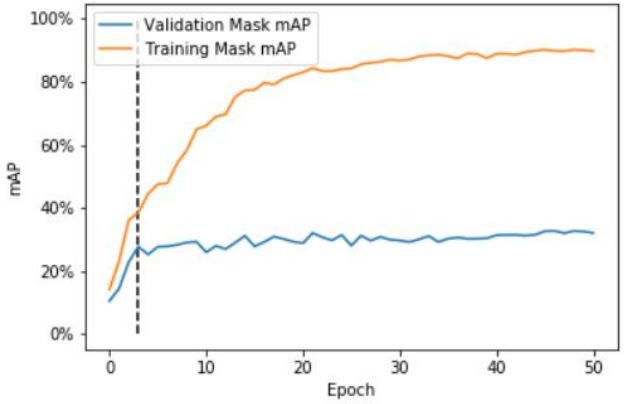




Left: Evaluation results for bounding boxes with Mask R-CNN using ResNet-50. Right: Evaluation results for masks with Mask R-CNN using ResNet-50.

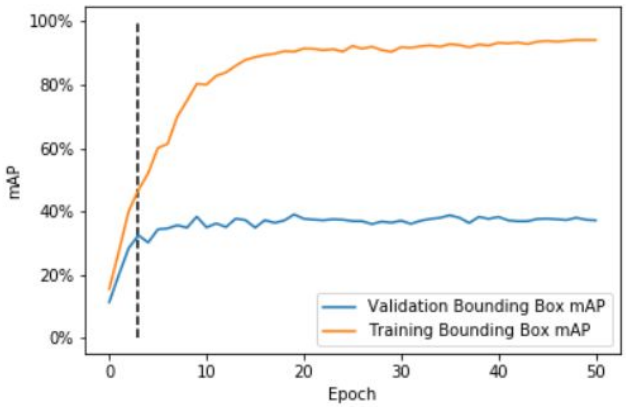
Experimental Results (2)

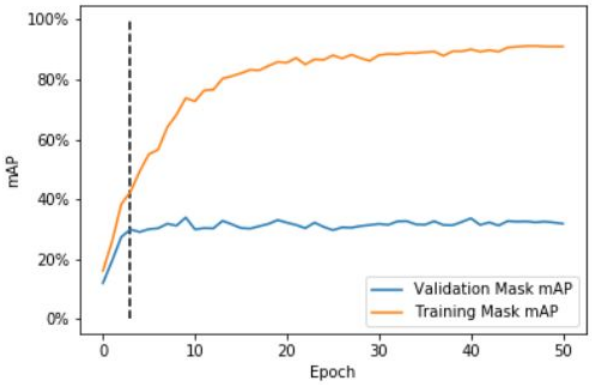




Left: Evaluation results for bounding boxes with Mask R-CNN using ResNet-50 and FPN. Right: Evaluation results for masks with Mask R-CNN using ResNet-50 and FPN.

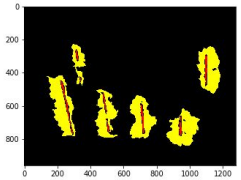
Experimental Results (3)





Left: Evaluation results for bounding boxes with Mask R-CNN using ResNeXt-101 and FPN. Right: Evaluation results for masks with Mask R-CNN using ResNeXt-101 and FPN.

Annotations of a test image (1)

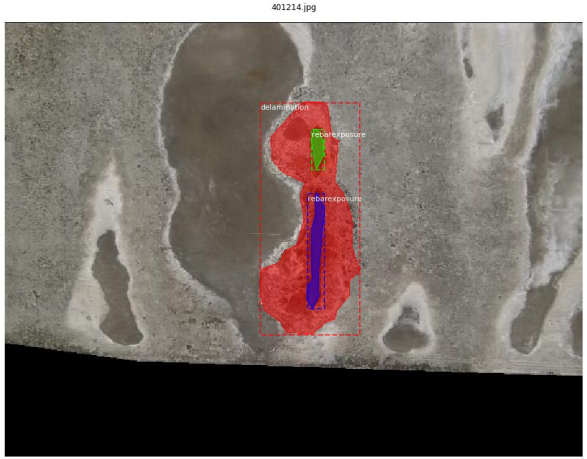


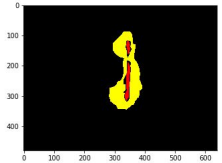
401298.png annotation file. Left: Annotations in COCO format, Right: Annotations from Pascal VOC format.

An example of a test image (1)

Figure 28: A sample prediction from the test set (401298.png) with Mask R-CNN, ResNeXt-101, and FPN.

Annotations of a test image (2)





401214.png annotation files. Left: Annotations in COCO format, Right: Annotations from Pascal VOC format.

An example of a test image (2)

A sample prediction from the test set (401214.png) with Mask R-CNN, ResNeXt-101, and FPN.