Tensor Mask: A Foundation for Dense Object Segmentation

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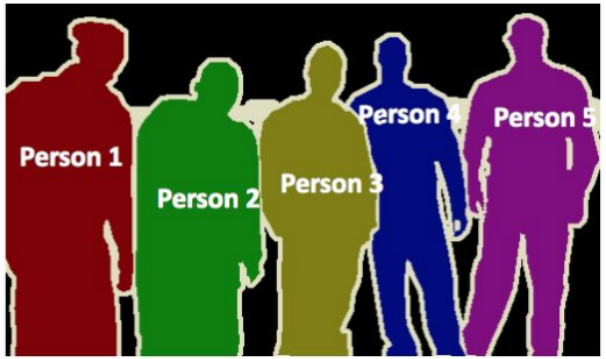
Overview

- Problem Statement
- Related Work
- Tensor Representation for Masks
- Tensor Mask Architecture
- Training
- Losses
- Results
- Implementation

Problem Statement

Instance Segmentation Task

- Label each foreground pixel with object and instance
- Object detection + semantic segmentation



Instance Segmentation

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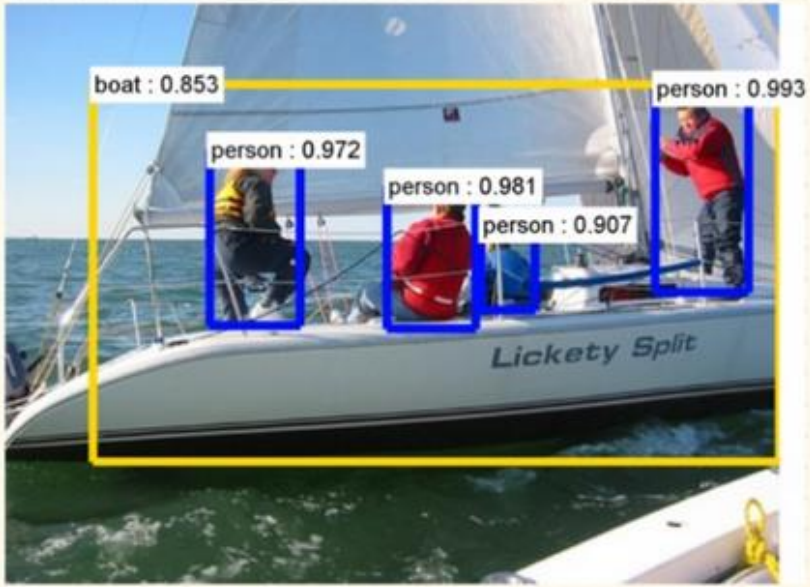
Image classification

✓boat

✓person



Object detection

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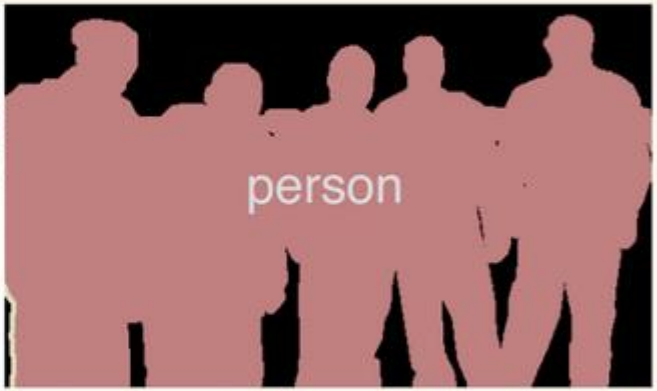
Semantic Segmentation





Semantic segmentation
(pixel-level classification)

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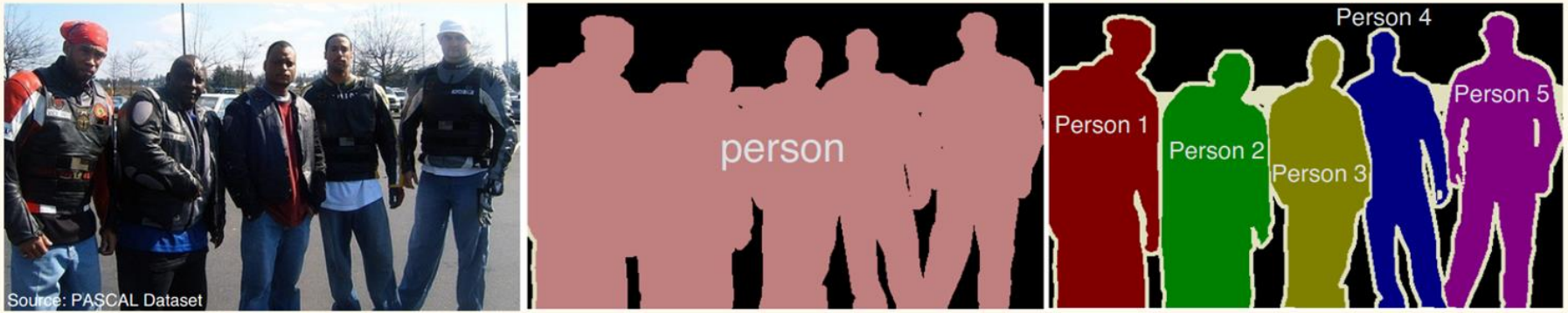
The Instance Segmentation Task

Our task



Semantic segmentation
(pixel-level classification)

Instance segmentation
(pixel-level detection)

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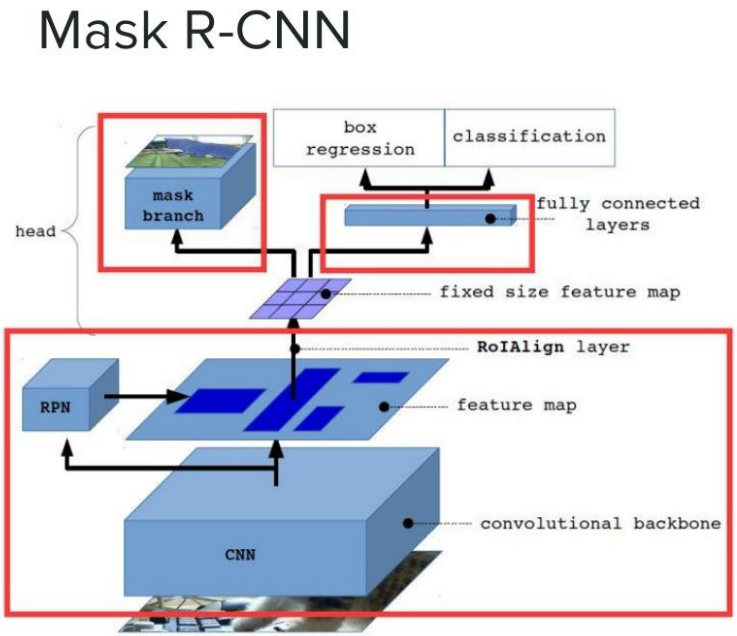
Related Work

Detect then Segment (MaskRCNN)



- BackBone + RPN
- Parallel heads for for box regression and classification
- RoI Align

Mask R-CNN Kaiming He, Georgia Gkioxari, Piotr Dollár, Ross Girshick

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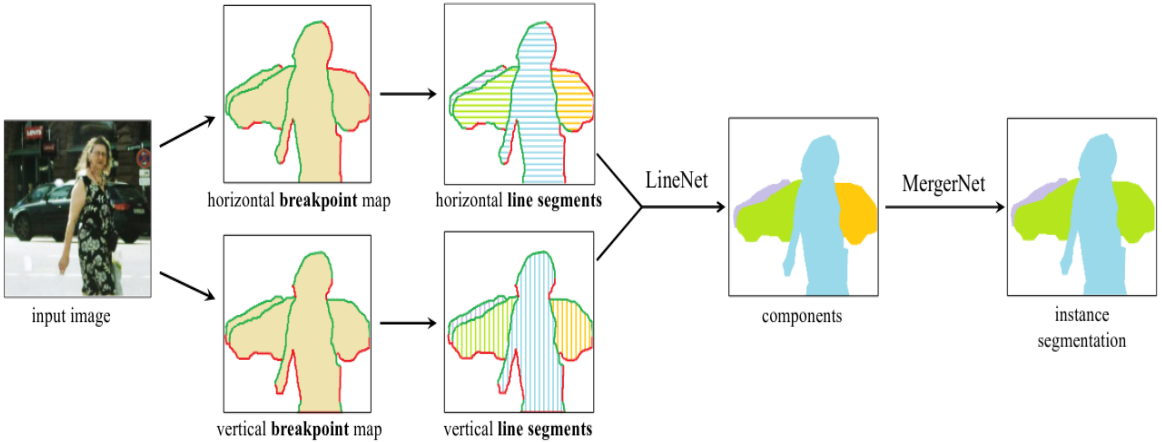
Related Work

Label Pixels then Cluster



SGN: Sequential Grouping Networks for Instance Segmentation

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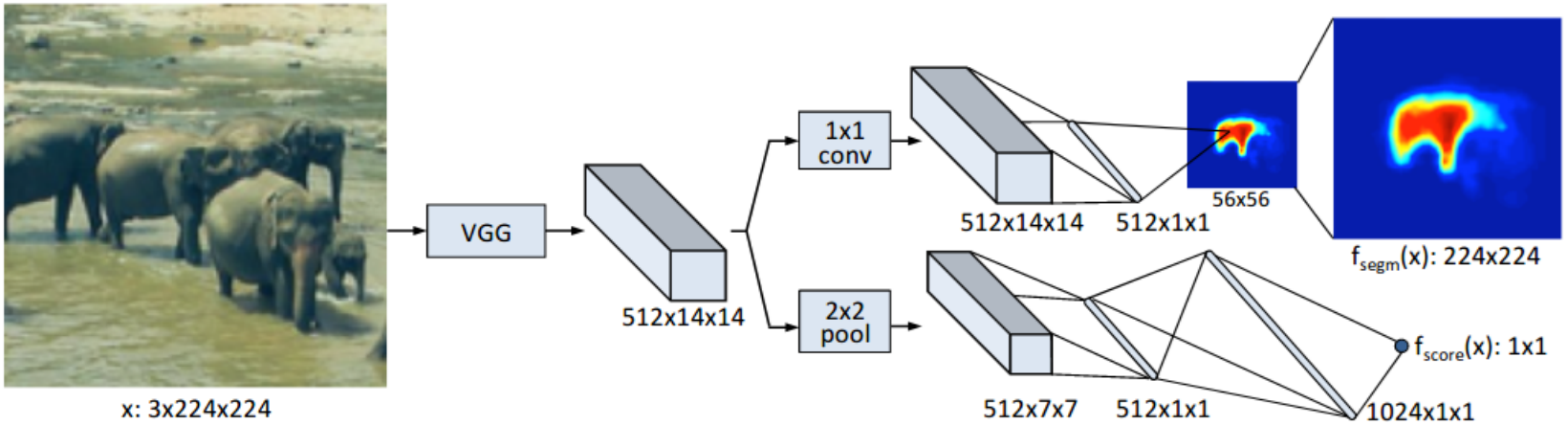
Related Work

Dense Sliding Window methods



Learning to Segment Object Candidates Deep Mask

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Related Work



Results from DeepMAsk

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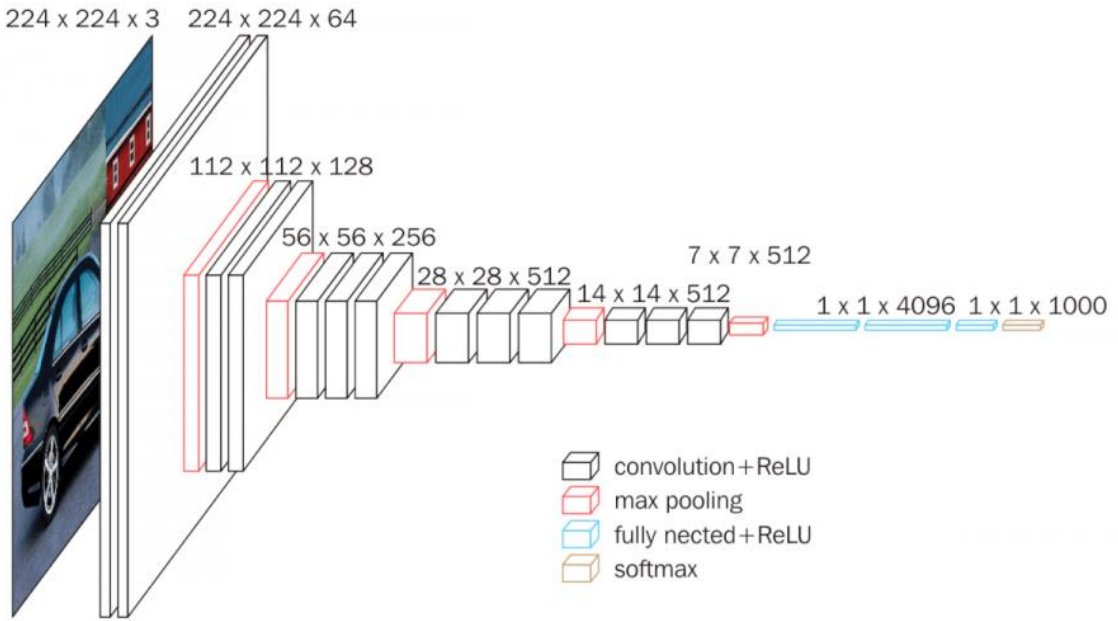
Why Tensor Mask?



- CNN's we have (C, H, W) information (3D Tensors)

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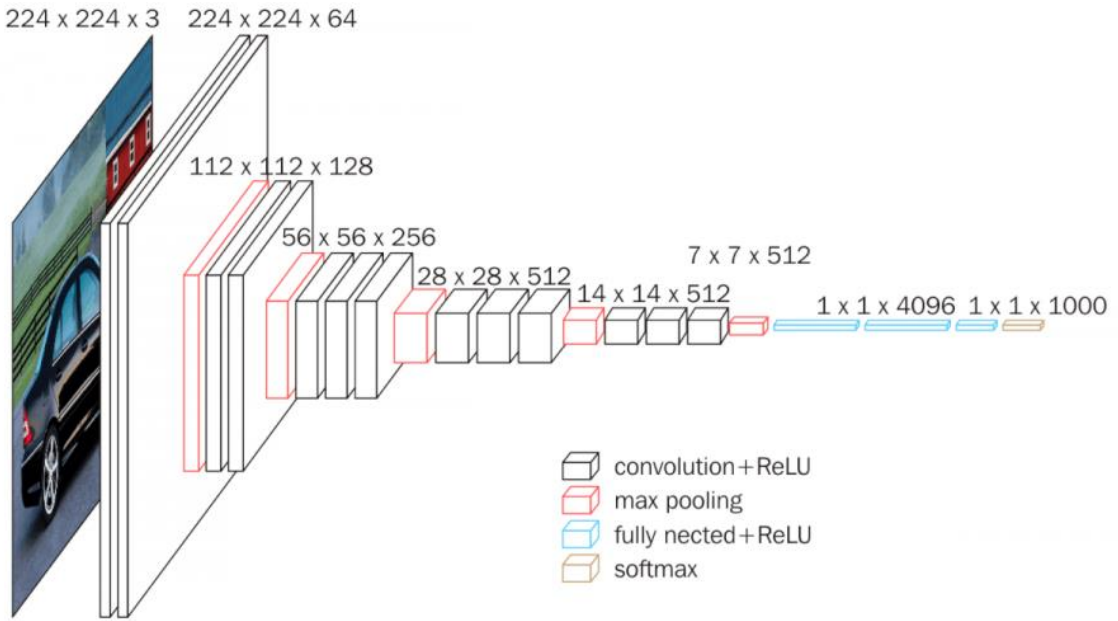
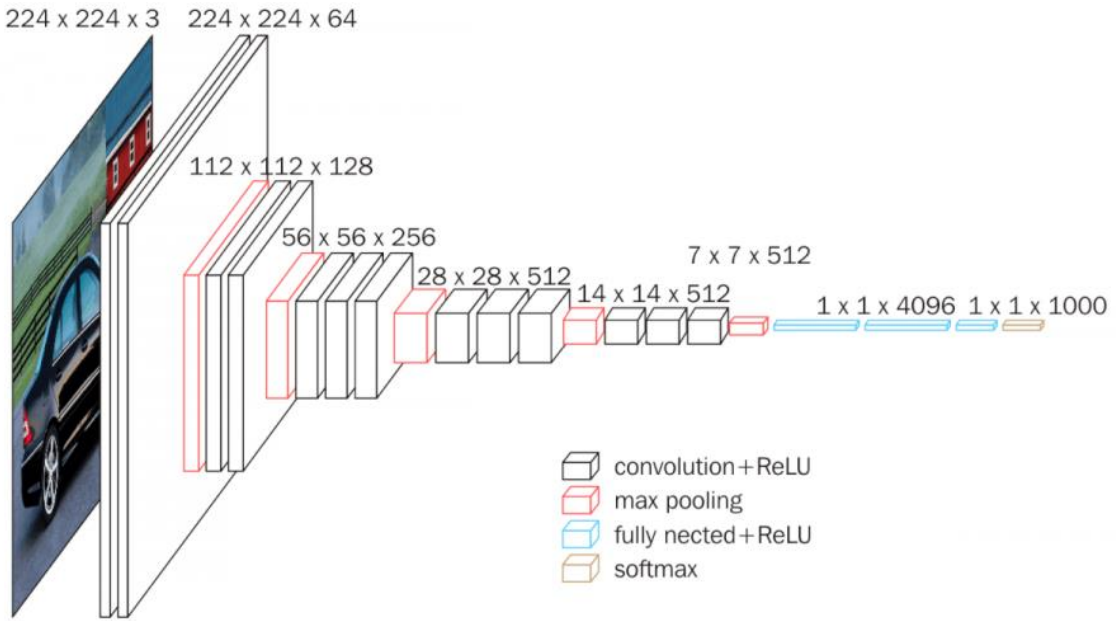
Why Tensor Mask?



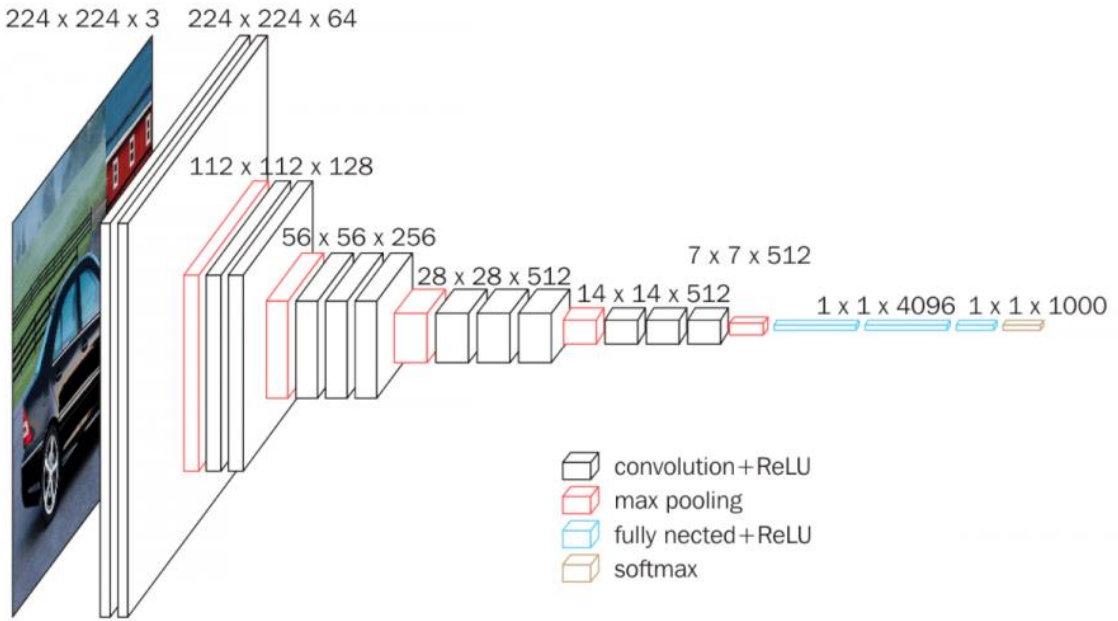
- H, W axis has a geometric meaning as it represents object position

Why Tensor Mask?



- Channel Axis does not have a geometric meaning (has semantic meaning)

Why Tensor Mask?



- Channel Axis, Difficult to manipulate

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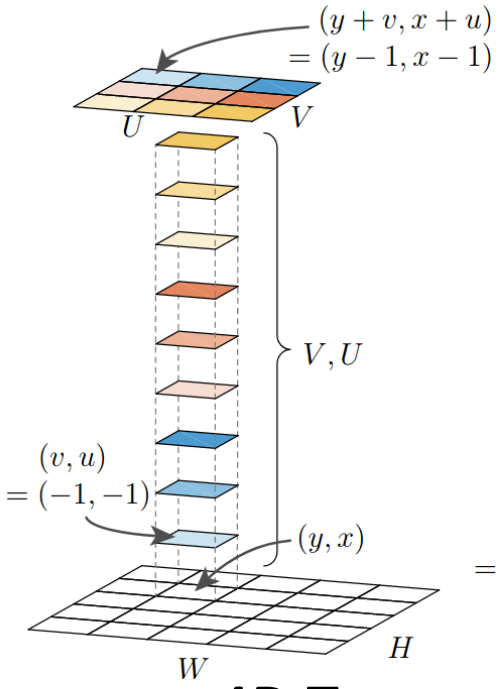
Why Tensor Mask?



- Tensor Mask proposes 4D Tensors (V,U,H,W)
- We convert channel axes to a new dimension (V,U)

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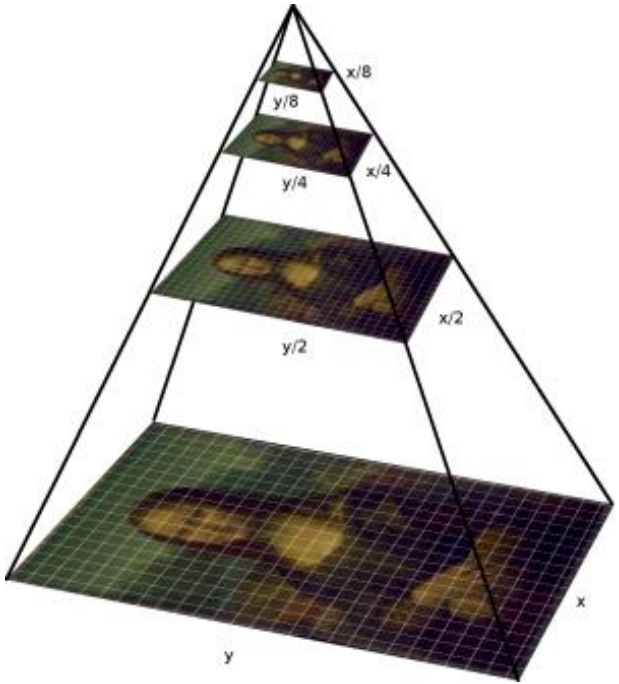
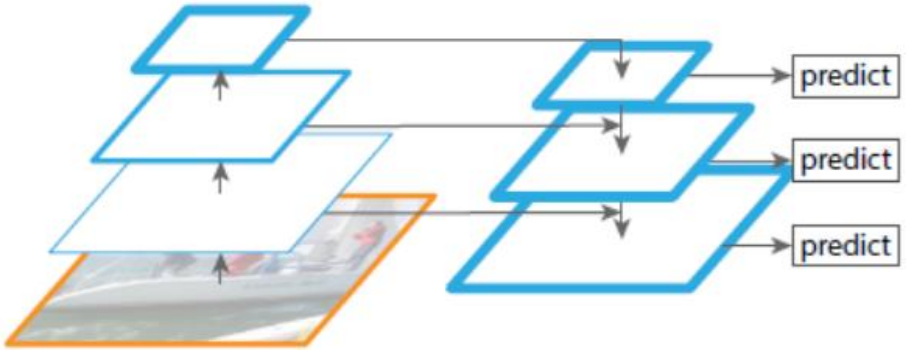
Image Pyramid



Feature Pyramid



Feature Pyramid Network

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Tensor Representation for Masks

(V,U,H,W)

- Higher dimensional (4D) tensor with shape (V,U,H,W).
- Sub-tensor(V,U) represents a mask as a 2D spatial entity.
- Use these high dimensional Tensors to represent image content
- Dense set of sliding windows

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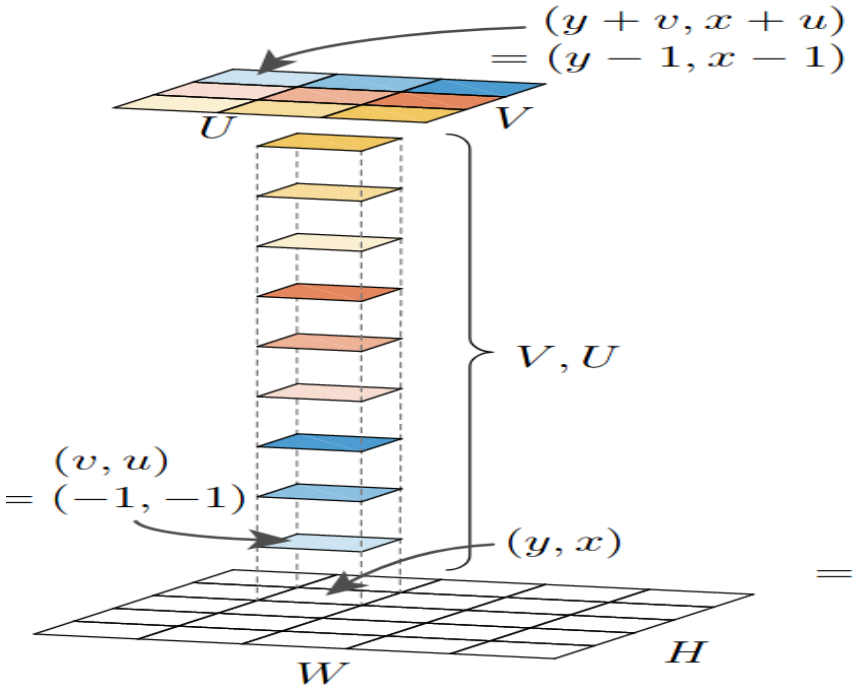
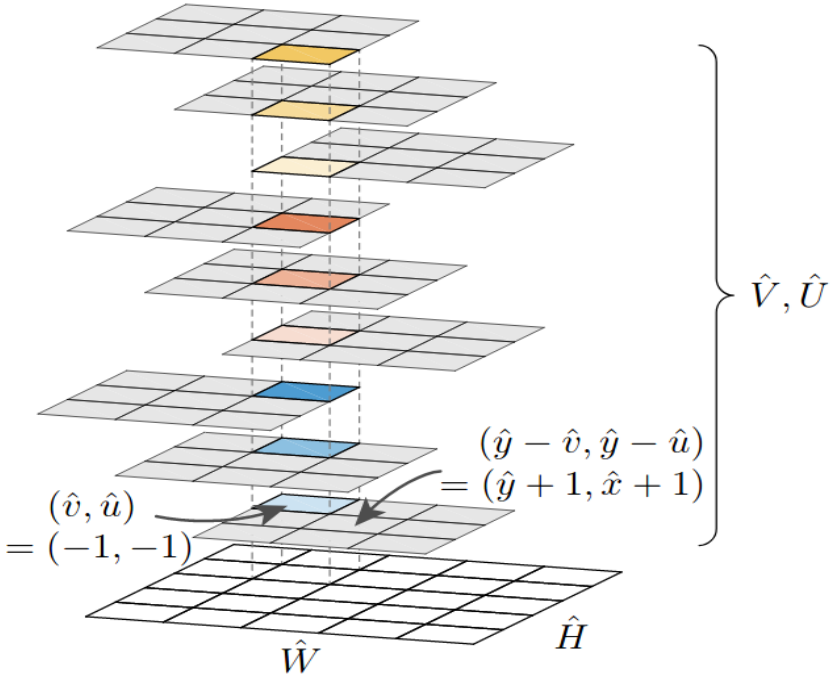
Tensor Representation for Masks



Natural Representation

Tensor Representation for Masks



Aligned Representation

Tensor Representation for Masks

$$\mathcal{F}(v, u, y, x) = \hat{\mathcal{F}}(v, u, y + \alpha v, x + \alpha u).$$

Coordinate Transformation

Tensor Representation for Masks

Upscale Transformation **(λ)**

- Coarse(ˆV ,ˆU) sub-tensors to create Finer(V,U) sub-tensors
- Generates high-resolution masks without inflating channel counts in preceding feature map.

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Tensor Representation for Masks

Tensor BiPyramid

- Number of mask pixels based on scale
- List containing masks
- Shape of Tensors in the list:

$$(2^k V, 2^k U, \frac{1}{2^k} H, \frac{1}{2^k} W)$$

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Tensor Mask Architecture

1. **Mask Prediction Head**
   Generate Masks in Sliding window

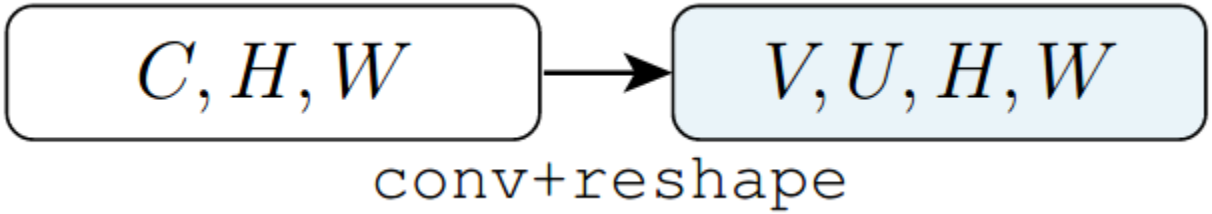
1. **Classification Head**
   Predicts object categories

   Similar to bounding box detection

Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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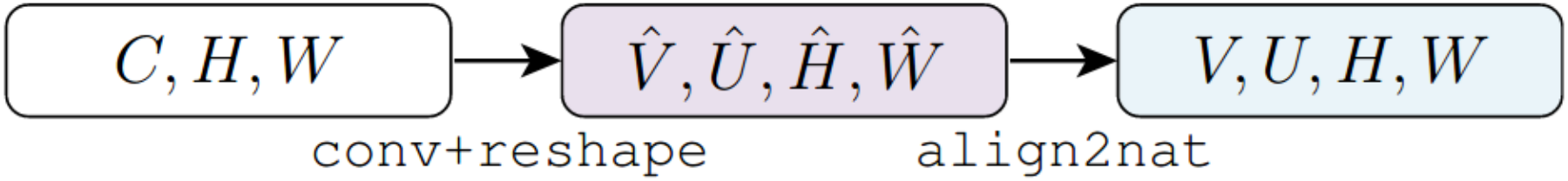
Tensor Mask Architecture

Mask Prediction Head

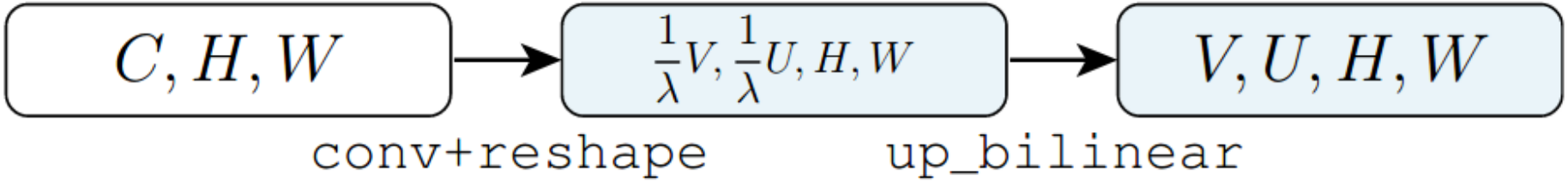
Generate Masks in Sliding window



Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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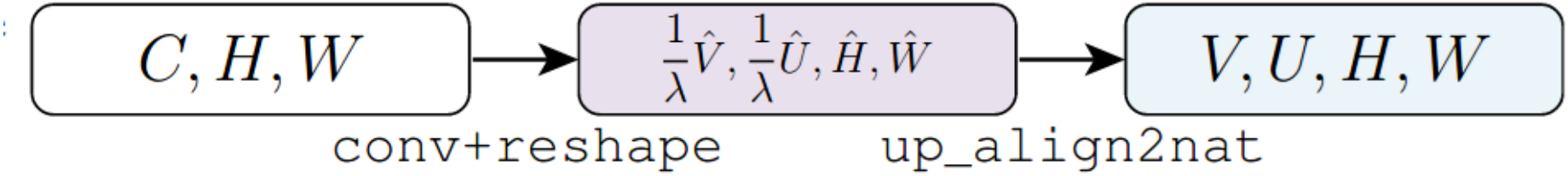
Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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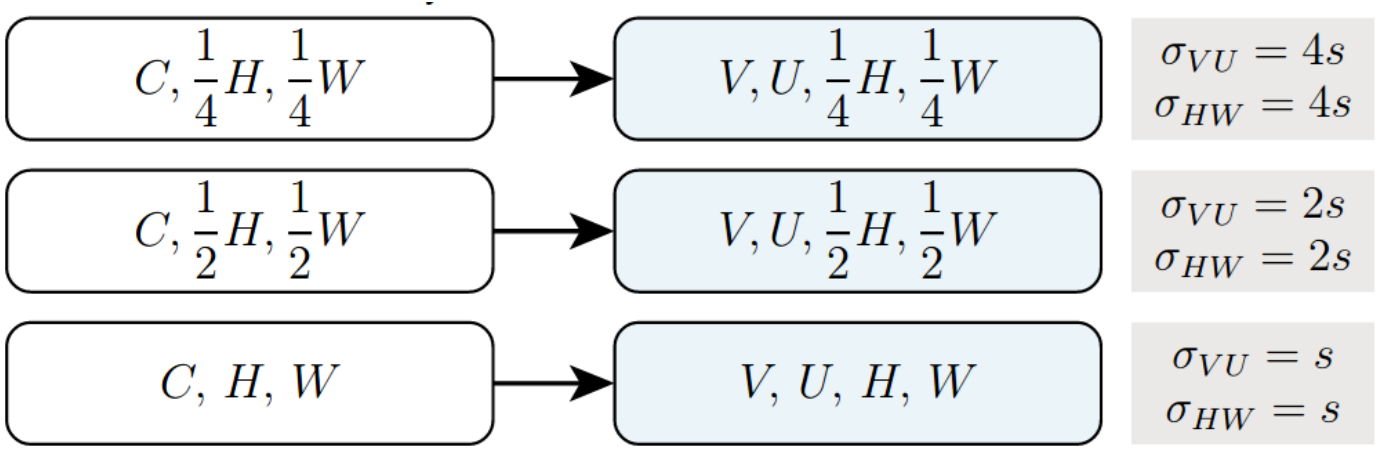
Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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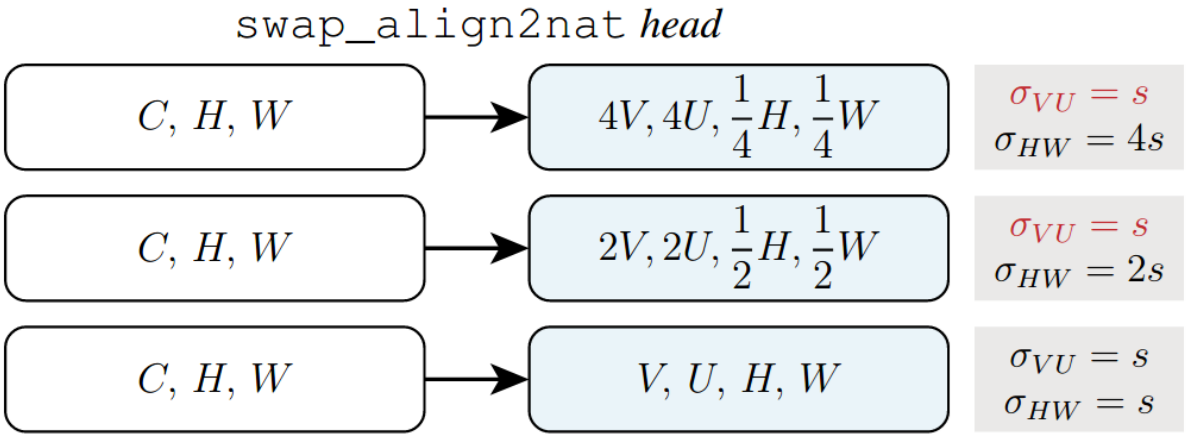
Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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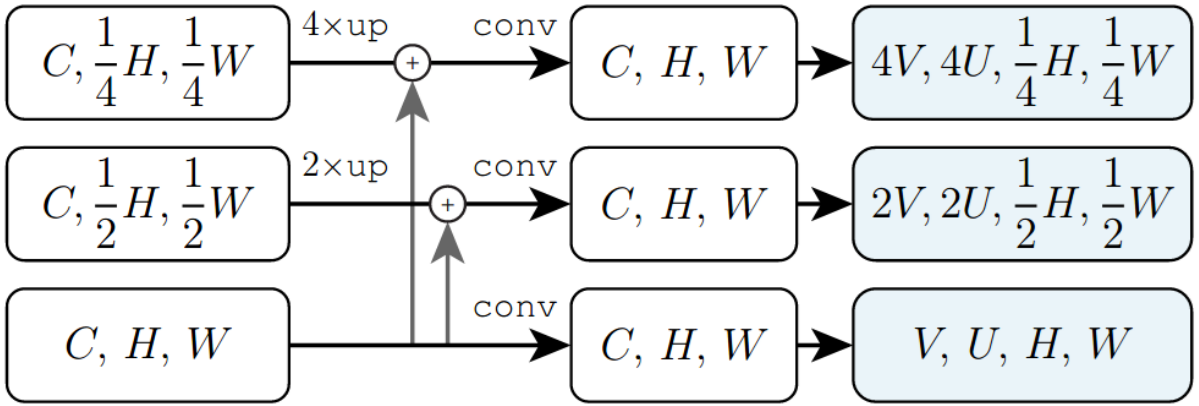
Tensor Mask Architecture

Mask Prediction Head

Generate Masks in Sliding window



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Training

Label Assignment for ground truth mask(“m”):

- Containment

  Window fully contains “m” and the longer side of “m”

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Training

Label Assignment:

- Centrality

Center of “m”’ bounding box is within one unit (σ_{vu}) of the window center in L2 distance

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Training

Label Assignment:

- Uniqueness

There is no other mask m' = m that satisfies the other two conditions

Tensor Mask : Losses

- **For prediction of mask head:**
  Per Pixel Binary classification Loss

- **For box regression:**
  L1 Loss

- **Classification head:**
  Focal Loss

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Dataset: Coco





http://cocodataset.org/#detection-eval

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Results



Natural up-scaling head

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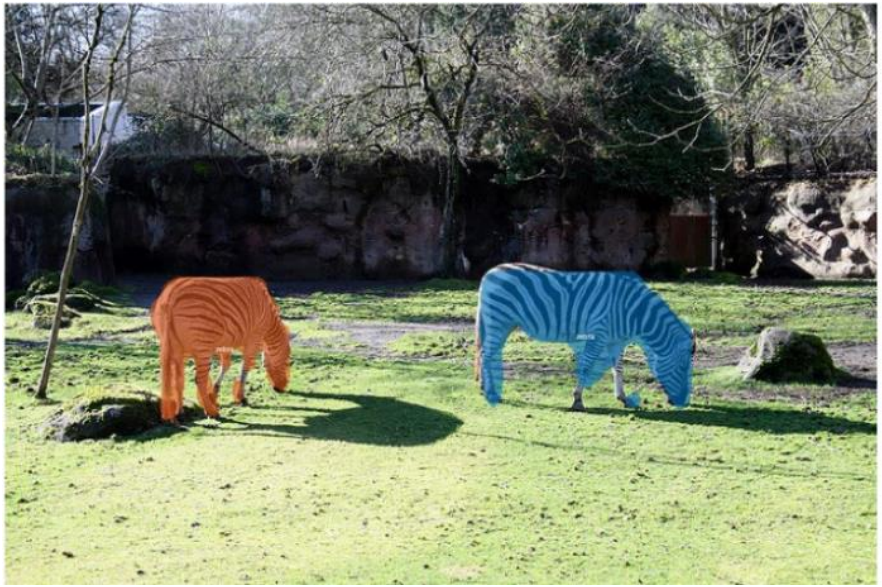
Results





Unaligned head

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Results





Aligned head

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Results

head	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
natural	28.5	52.2	28.6	14.4	30.2	40.1
aligned	28.9	52.5	29.3	14.6	30.8	40.7

Simple heads: natural vs. aligned with V×U=15×15

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Results

head	λ	AP	AP_{50}	AP_{75}	Δ aligned - natural		
natural	1.5	28.0	51.7	27.8	*+0.9*	*+0.7*	*+1.5*
aligned		**28.9**	**52.4**	**29.3**			
natural	3	24.7	48.4	22.7	*+4.1*	*+3.9*	*+6.4*
aligned		**28.8**	**52.3**	**29.1**			
natural	5	19.2	42.1	15.6	*+9.2*	*+9.7*	*+13.0*
aligned		**28.4**	**51.8**	**28.6**			

Upscaling heads: Natural vs. aligned heads (V×U=15×15)

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Results

head	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
feature pyramid, best	28.9	52.5	29.3	14.6	30.8	40.7
tensor bipyramid	**34.0**	**55.2**	**35.8**	**15.3**	**36.3**	**48.4**
Δ	*+5.1*	*+2.7*	*+6.5*	*+0.7*	*+5.5*	*+7.7*

Beast Baseline head on Feature Pyramid vs Tensor bipyramid

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Results

$V \times U$	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
15×15	34.0	55.2	35.8	15.3	36.3	48.4
$15 \times 15, 11 \times 11$	**35.2**	**56.4**	**37.0**	**17.4**	**37.4**	**49.7**
Δ	*+1.2*	*+1.2*	*+1.2*	*+2.1*	*+1.1*	*+1.3*

Window Sizes

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Results

method	backbone	aug	epochs	AP	AP_{50}	AP_{75}	AP_S	AP_M	AP_L
Mask R-CNN [13]	R-50-FPN		24	34.9	57.2	36.9	15.4	36.6	50.8
Mask R-CNN, *ours*	R-50-FPN		24	34.9	56.8	36.8	15.1	36.7	50.6
Mask R-CNN, *ours*	R-50-FPN	✓	72	**36.8**	**59.2**	**39.3**	**17.1**	**38.7**	**52.1**
TensorMask	R-50-FPN	✓	72	35.4	57.2	37.3	16.3	36.8	49.3
Mask R-CNN, *ours*	R-101-FPN	✓	72	**38.3**	**61.2**	**40.8**	**18.2**	**40.6**	**54.1**
TensorMask	R-101-FPN	✓	72	37.1	59.3	39.4	17.4	39.1	51.6

Comparison with Mask R-CNN

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Results

method	aug	epochs	AP^{bb}	AP^{bb}_{50}	AP^{bb}_{75}
RetinaNet, *ours*		24	37.1	55.0	39.9
RetinaNet, *ours*	✓	72	39.3	57.2	42.4
Faster R-CNN, *ours*	✓	72	40.6	61.4	44.2
Mask R-CNN, *ours*	✓	72	41.7	62.5	45.7
TensorMask, *box-only*	✓	72	40.8	60.4	43.9
TensorMask	✓	72	41.6	61.0	45.1

Object detection

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Results

box head	NMS	AP	AP_{50}	AP_{75}	AP^{bb}	AP^{bb}_{50}	AP^{bb}_{75}
✓	bb	35.2	56.4	37.0	41.6	60.8	44.8
✓	mask-bb	34.9	56.0	36.7	39.7	59.1	41.8
	mask-bb	34.8	56.1	36.7	39.4	58.8	41.6

Multi-task benefits

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Results



Mask R-CNN (top row) and TensorMask (bottom row)

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Results



Mask R-CNN (top row) and TensorMask (bottom row)

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Results



Mask R-CNN (top row) and TensorMask (bottom row)

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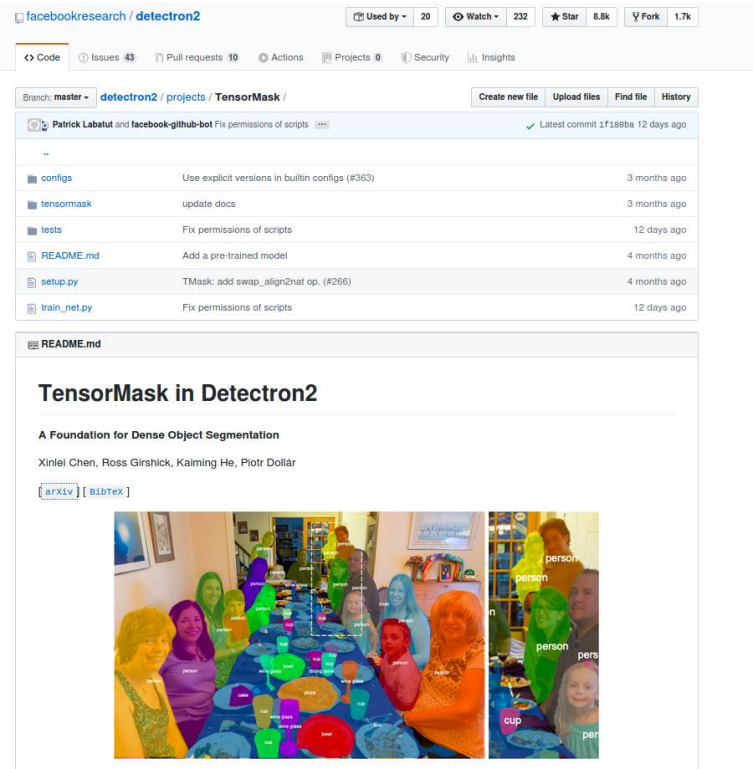
Implementation



https://github.com/facebookresearch/detectron2/tree/master/projects/TensorMask



Detectron2

A research platform and a production library
for **object detection**,
mainly built by Facebook AI Research (FAIR)

https://github.com/facebookresearch/detectron2

What's in Detectron2: model zoo

- Different settings for users to play with
- Standard baselines for researchers
- Efficient models for production (coming soon)

Faster R-CNN:

Name	lr sched	train time (s/iter)	inference time (s/im)	train mem (GB)	box AP	model id	download
R50-C4	1x	0.593	0.110	4.8	35.7	137257644	model | metrics
R50-DC5	1x	0.380	0.068	5.0	37.3	137847829	model | metrics
R50-FPN	1x	0.210	0.055	3.0	37.9	137257794	model | metrics
R50-C4	3x	0.589	0.110	4.8	38.4	137849393	model | metrics
R50-DC5	3x	0.378	0.073	5.0	39.0	137849425	model | metrics
R50-FPN	3x	0.209	0.047	3.0	40.2	137849458	model | metrics
R101-C4	3x	0.656	0.149	5.9	41.1	138204752	model | metrics
R101-DC5	3x	0.452	0.082	6.1	40.6	138204841	model | metrics
R101-FPN	3x	0.286	0.063	4.1	42.0	137851257	model | metrics
X101-FPN	3x	0.638	0.120	6.7	43.0	139173657	model | metrics

RetinaNet:

Name	lr sched	train time (s/iter)	inference time (s/im)	train mem (GB)	box AP	model id	download
R50	1x	0.200	0.062	3.9	36.5	137593951	model | metrics
R50	3x	0.201	0.063	3.9	37.9	137849486	model | metrics
R101	3x	0.280	0.080	5.1	39.9	138363263	model | metrics

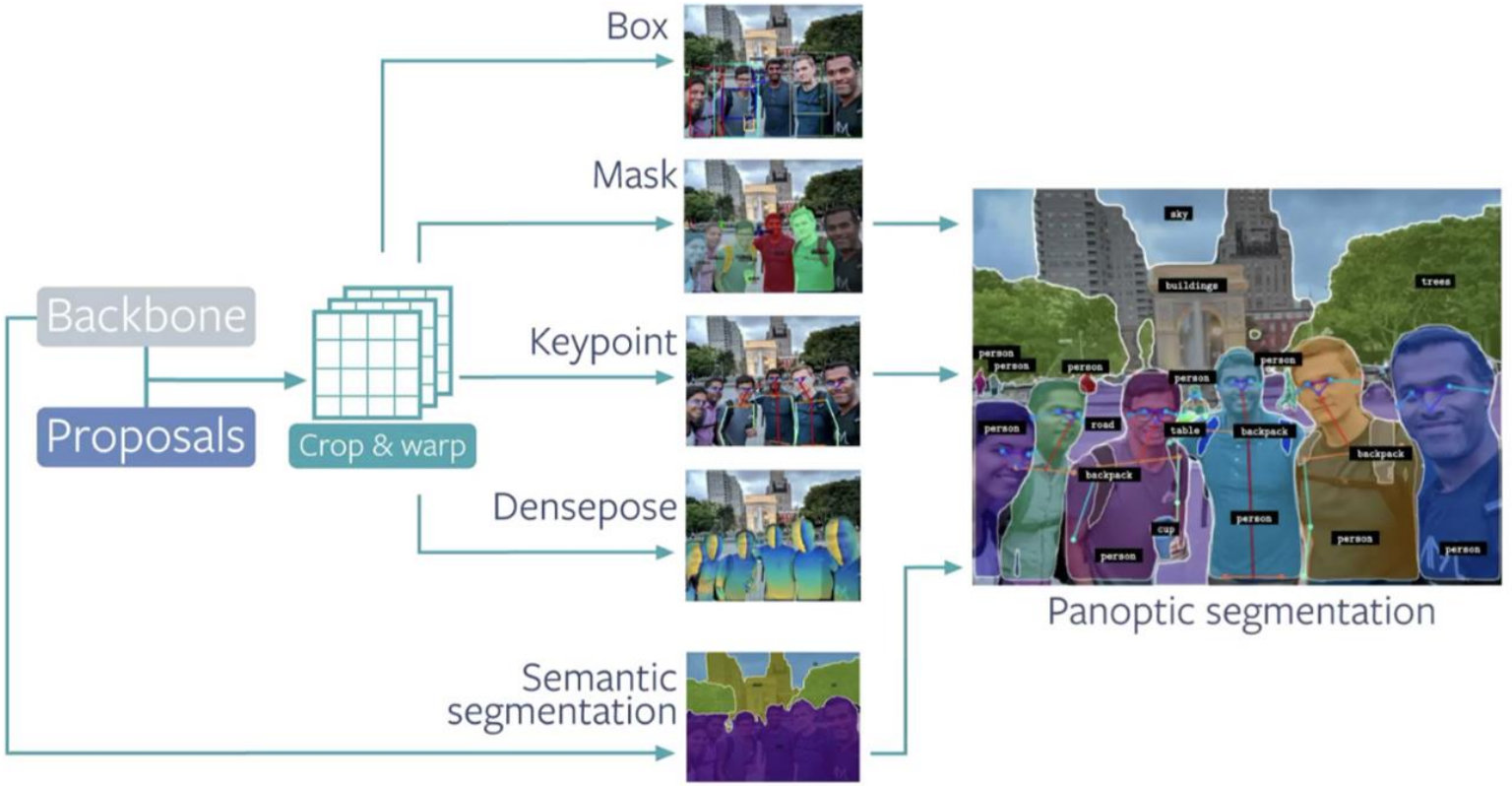
RPN & Fast R-CNN:

Name	lr sched	train time (s/iter)	inference time (s/im)	train mem (GB)	box AP	prop. AR	model id	download
RPN R50-C4	1x	0.130	0.051	1.5		51.6	137258005	model | metrics
RPN R50-FPN	1x	0.186	0.045	2.7		58.0	137258492	model | metrics

https://github.com/facebookresearch/detectron2/blob/master/MODEL_ZOO.md

What's in Detectron2: Generalized R-CNN Models

(+ a few other types of models: RetinaNet, TensorMask, etc.)




Thank You
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