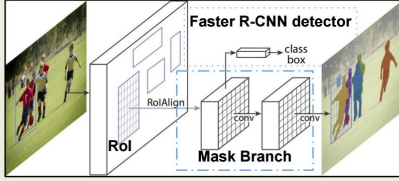# Separating Overlapping Galaxies with Mask R-CNN

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Objective

Most observed astronomical objects have some overlap with neighboring objects. However, scientific measurements require isolated galaxy images. We try to perform detection and segmentation of overlapping galaxies using Mask Region-based CNN (Mask R-CNN).[1]

Mask R-CNN

- Framework performs object detection in parallel with generating high-quality segmentation mask on each Region of Interest (RoI).
- Backbone: ResNet-101 with Feature Pyramid Network (FPN) → extracts RoI.
- Head: applied separately to each RoI
  - Faster R-CNN[2] → bounding box recognition.
  - Mask → segmentation.
- This analysis used Tensorflow, Keras implementation of the architecture.[3]

Head architecture
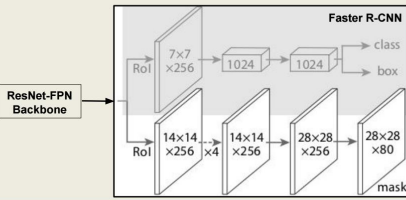
Loss function

- Multi-task loss on each sampled RoI:

$$L = L_{\text{cls}} + L_{\text{mask}} + L_{\text{box}}$$

$$-(y\log(p) + (1-y)\log(1-p))$$

$$-\sum y\log(p)$$

$$\sum_{i \in x,y,w,h} \text{smooth}_{L_1}(p_i - y_i)$$

$$\text{smooth}_{L_1}(x) = \begin{cases} 0.5x^2, & \text{if } |x| < 1. \\ |x| - 0.5, & \text{otherwise.} \end{cases}$$

Data

- Simulated images of two-galaxy pairs with varied overlap.

Example training data

H x W=128x128   galaxy

Overlapping galaxy image   Segmentation Mask
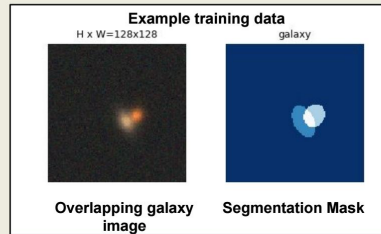
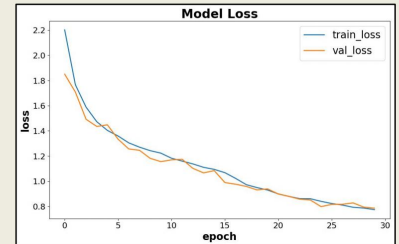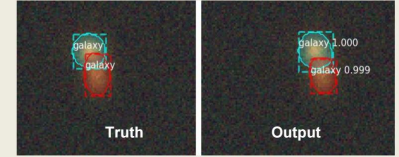| Dataset	Training	Validation	Test
20,000 images	18,000 (72,000 with augmentation)	1,000	1,000
	90%	5%	5%

Training

- Initialize with pre-trained weights on MS COCO[4].
- Mini-batch size: 64

Two-stage training

1. Head only: 15 epochs, 0.001 learning rate
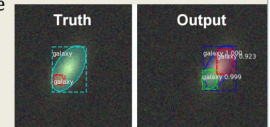2. All layers: 20 epochs, 0.0005 learning rate

Results

- Test set mean Average Precision (mAP): 0.87

Truth   Output

Future Work

- Network performance limited by dataset: galaxies do not have sharp edges.
- Modify end layers of network to output individual galaxies instead of segmentation maps.
- Include different kinds of sources and perform classification as well.

Truth   Output

References

[1] https://github.com/facebookresearch/detectron
[2] https://github.com/rbgirshick/fast-rcnn
[3] https://github.com/matterport/Mask_RCNN
[4] http://cocodataset.org/#home