TENSORBOARD & OBJECT DETECTION

12 OCTOBER 2022
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OVERVIEW

- The Individual Pieces
  - Object detection
  - TensorFlow
  - TensorBoard
- TensorBoard + Object Detection
- TensorBoard on HPC
- Understanding the TensorBoard interface

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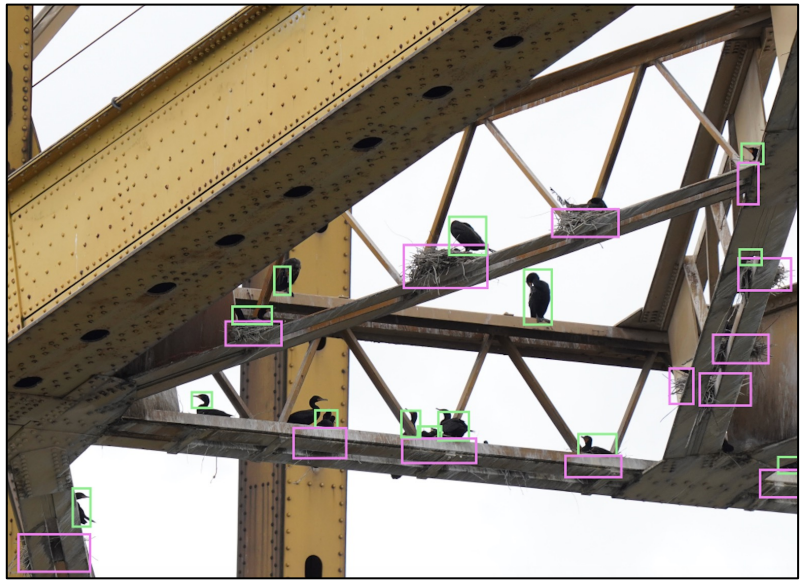
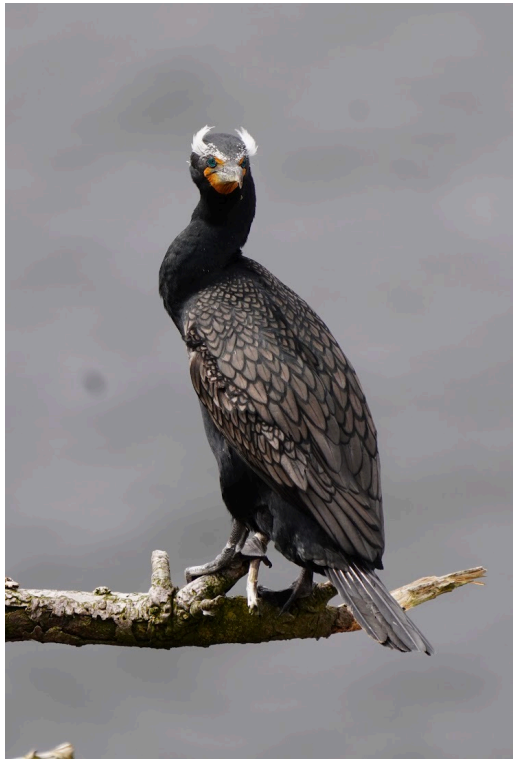
OBJECT DETECTION

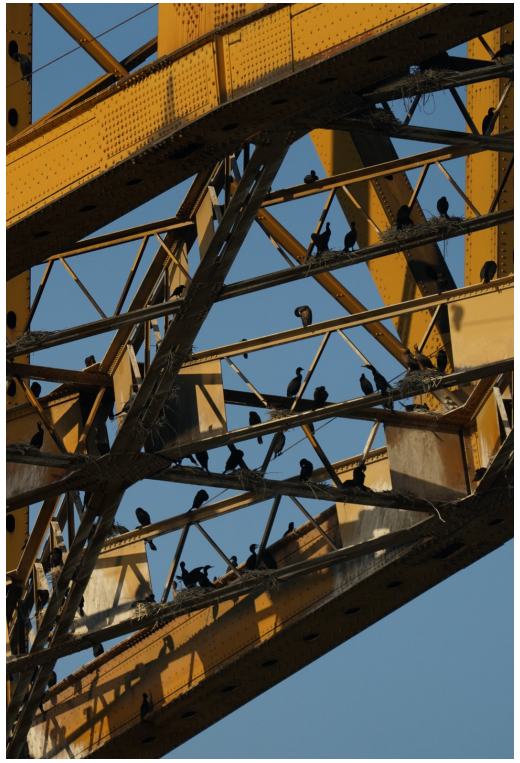
OBJECT DETECTION

- Computer vision task where a trained model identify objects within an image or video
- Applications include self-driving vehicles, remote sensing, wildlife monitoring



WILDLIFE MONITORING EXAMPLE





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TENSORFLOW

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TENSORFLOW

- A free & open source library for machine learning, focused on deep neural networks

- The Alliance TensorFlow documentation

* TF is available in other languages (e.g. JavaScript, C++, Java) but is most commonly used with Python

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OBJECT DETECTION & TENSORFLOW

- The TensorFlow Object Detection API is one of the research models/implementations provided in the TF Model Garden

- Learn more in TF's object detection tutorial & the Object Detection API's Training & Evaluation with TensorFlow 2 guide

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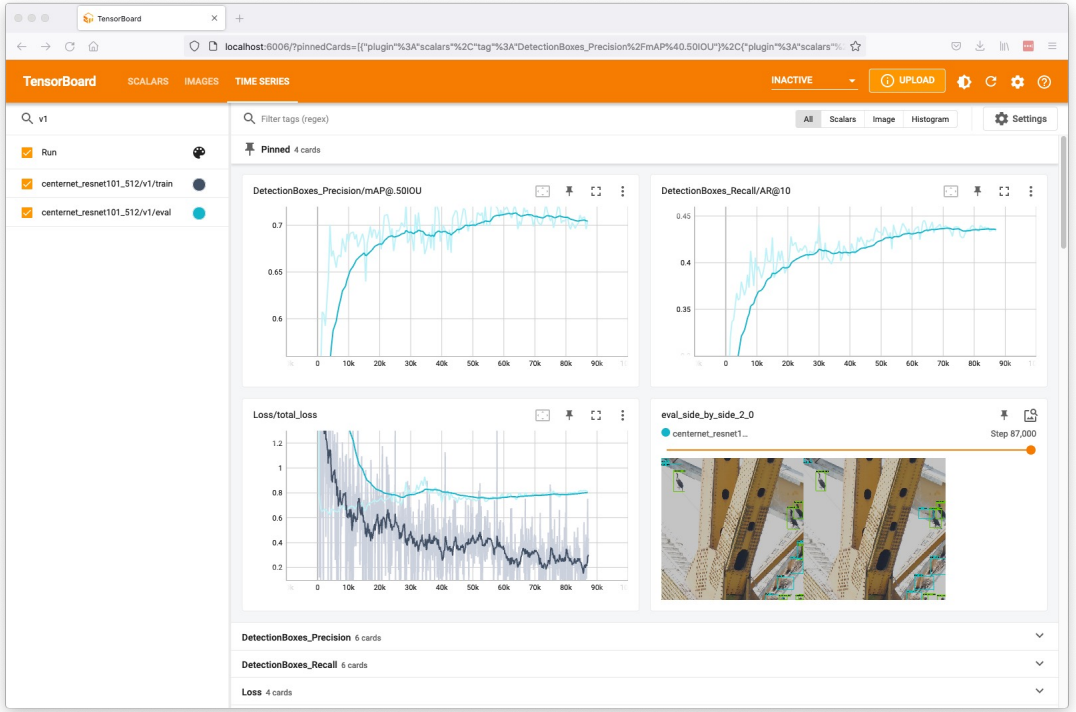
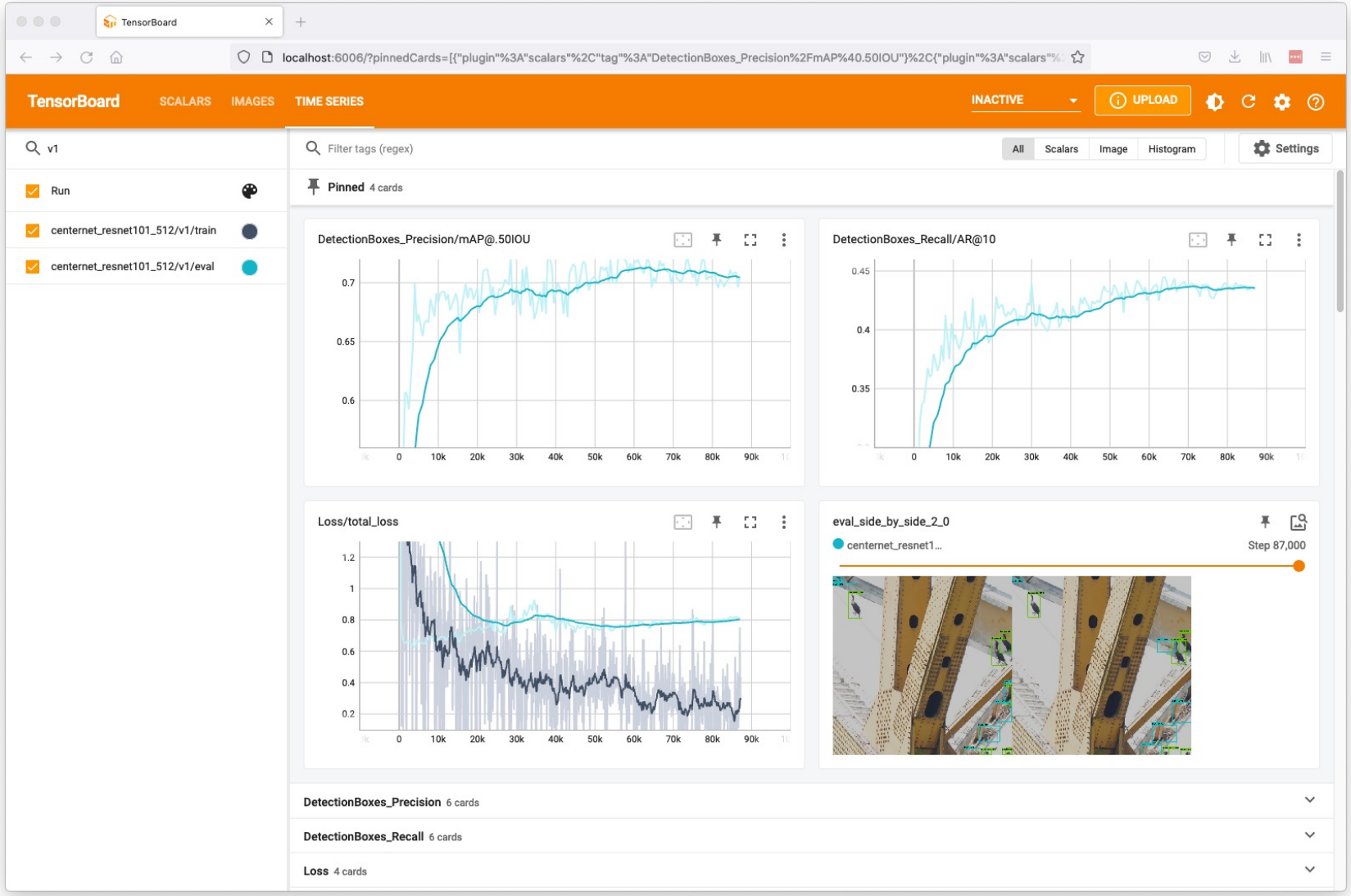
TENSORBOARD

WHAT IS TENSORBOARD?

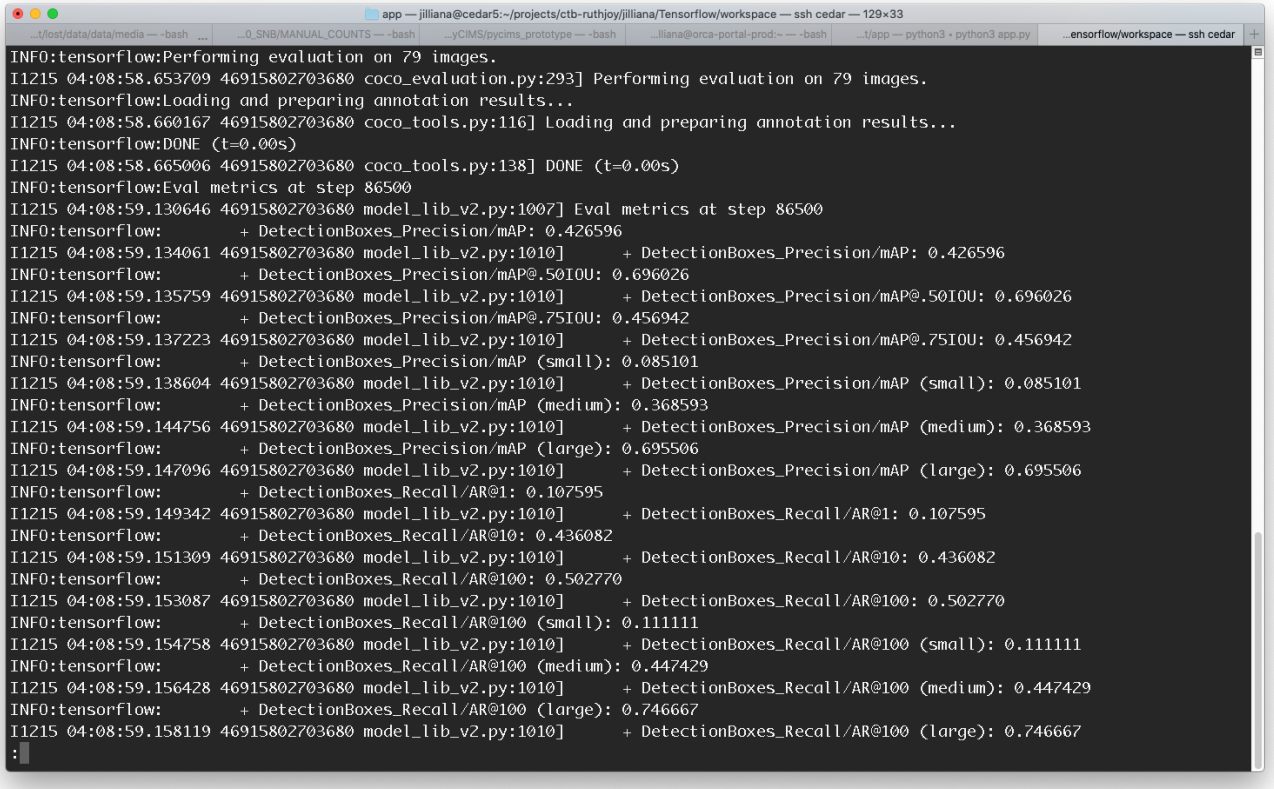
- TF's visual toolkit for machine learning experimentation
- Visually track model information (e.g. model structure, mAP, etc)




TensorBoard
localhost:6006/?pinnedCards=[{"plugin"%3A"scalars"%2C"tag"%3A"DetectionBoxes_Precision%2FmAP%40.50IOU"}%2C{"plugin"%3A"scalars"%
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
v1
Filter tags (regex)
All
Scalars
Image
Histogram
Settings
Run
centernet_resnet101_512/v1/train
centernet_resnet101_512/v1/eval
Pinned 4 cards
DetectionBoxes_Precision/mAP@.50IOU
0.7
0.65
0.6
0 10k 20k 30k 40k 50k 60k 70k 80k 90k
DetectionBoxes_Recall/AR@10
0.45
0.4
0.35
0 10k 20k 30k 40k 50k 60k 70k 80k 90k
Loss/total_loss
1.2
1
0.8
0.6
0.4
0.2
0 10k 20k 30k 40k 50k 60k 70k 80k 90k
eval_side_by_side_2_0
centernet_resnet1...
Step 87,000
DetectionBoxes_Precision 6 cards
DetectionBoxes_Recall 6 cards
Loss 4 cards

WHY USE TENSORBOARD?

- Machine Learning usually requires experimentation
- We need a way to compare models (aka runs)
- Ideally we want to avoid manually inspecting logs



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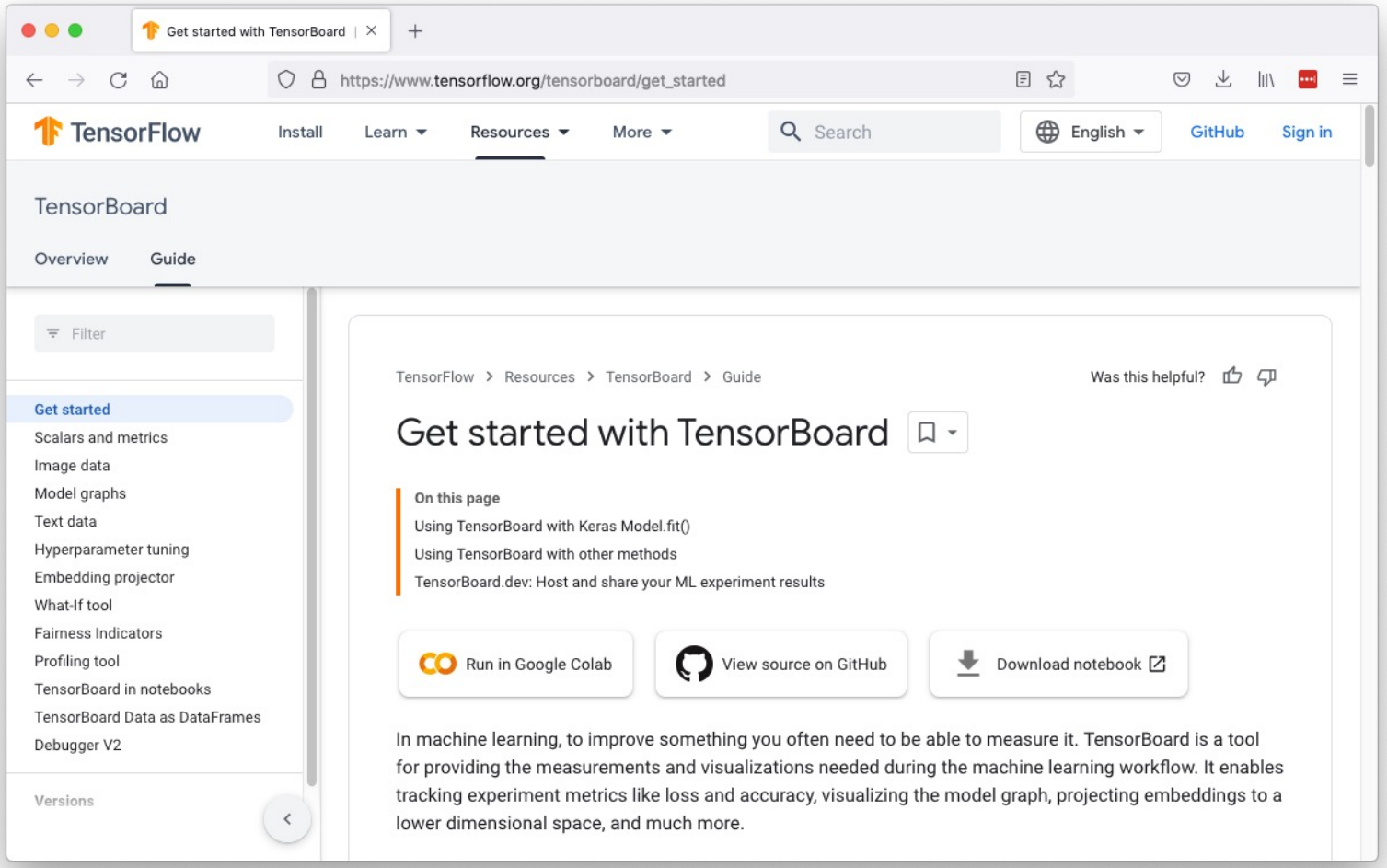
HOW DOES TENSORBOARD WORK?

- TensorFlow writes event files during model training
- TensorBoard parses these files & generates visualizations
- You can control what events are logged using `FileWriter` instance(s)

MORE ON TENSORBOARD

→ [TensorBoard guide]



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TENSORBOARD + OBJECT DETECTION

SETTING UP EVENT FILES

- Setup `pipeline.config` to generate event files for scalars* and images*
- `eval_config` – how should evaluation be done?
- `eval_input_reader` – what data should be used for evaluation?

```
eval_config: {
  metrics_set: "coco_detection_metrics"
  use_moving_averages: false
  batch_size: 1
  num_visualizations: 50
  min_score_threshold: 0.1
}

eval_input_reader: {
  label_map_path: "models/snb3/label_map.pbtxt"
  shuffle: false
  num_epochs: 1
  tf_record_input_reader {
    input_path: "models/snb3/validation.tfrecord-*"
  }
}
```

* Other info (e.g. graph structure, Tensor histograms) can be tracked too, but we won't cover this today.

SCALARS

- By default evaluation uses [COCO detection metrics]

2. Metrics

The following 12 metrics are used for characterizing the performance of an object detector on COCO:

```
Average Precision (AP):
  AP                  % AP at IoU=.50:.05:.95 (primary challenge metric)
  AP^IoU=.50          % AP at IoU=.50 (PASCAL VOC metric)
  AP^IoU=.75          % AP at IoU=.75 (strict metric)
AP Across Scales:
  AP^small            % AP for small objects: area < 32^2
  AP^medium           % AP for medium objects: 32^2 < area < 96^2
  AP^large            % AP for large objects: area > 96^2
Average Recall (AR):
  AR^max=1            % AR given 1 detection per image
  AR^max=10           % AR given 100 detections per image
  AR^max=100          % AR given 100 detections per image
AR Across Scales:
  AR^small            % AR for small objects: area < 32^2
  AR^medium           % AR for medium objects: 32^2 < area < 96^2
  AR^large            % AR for large objects: area > 96^2
```

1. Unless otherwise specified, *AP and AR are averaged over multiple Intersection over Union (IoU) values*. Specifically we use 10 IoU thresholds of .50:.05:.95. This is a break from tradition, where AP is computed at a single IoU of .50 (which corresponds to our metric $AP^{IoU=.50}$). Averaging over IoUs rewards detectors with better localization.
2. AP is averaged over all categories. Traditionally, this is called "mean average precision" (mAP). We make no distinction between AP and mAP (and likewise AR and mAR) and assume the difference is clear from context.
3. AP (averaged across all 10 IoU thresholds and all 80 categories) will determine the challenge winner. This should be considered the single most important metric when considering performance on COCO.
4. In COCO, there are more small objects than large objects. Specifically: approximately 41% of objects are small (area < 32^2), 34% are medium (32^2 < area < 96^2), and 24% are large (area > 96^2). Area is measured as the number of pixels in the segmentation mask.
5. AR is the maximum recall given a fixed number of detections per image, averaged over categories and IoUs. AR is related to the metric of the same name used in proposal evaluation but is computed on a per-category basis.
6. All metrics are computed allowing for at most 100 top-scoring detections per image (across all categories).
7. The evaluation metrics for detection with bounding boxes and segmentation masks are identical in all respects except for the IoU computation (which is performed over boxes or masks, respectively).

SCALARS

- Specified using `metrics_set`
- See the docs for the other available metrics

```
eval_config: {
  metrics_set: "coco_detection_metrics"
  use_moving_averages: false
  batch_size: 1
  num_visualizations: 50
  min_score_threshold: 0.1
}

eval_input_reader: {
  label_map_path: "models/snb3/label_map.pbtxt"
  shuffle: false
  num_epochs: 1
  tf_record_input_reader {
    input_path: "models/snb3/validation.tfrecord-*"
  }
}
```

IMAGES

- Visualize model predictions on evaluation data
- Compare ground truth with predictions

```
eval_config: {
  metrics_set: "coco_detection_metrics"
  use_moving_averages: false
  batch_size: 1
  num_visualizations: 50
  min_score_threshold: 0.1
}

eval_input_reader: {
  label_map_path: "models/snb3/label_map.pbtxt"
  shuffle: false
  num_epochs: 1
  tf_record_input_reader {
    input_path: "models/snb3/validation.tfrecord-*"
  }
}
```

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IMAGES

- Specified with `num_visualizations`
- `min_score_threshold` controls which detections are visualized
- To explore other options, checkout the `eval.proto` file

```
eval_config: {
  metrics_set: "coco_detection_metrics"
  use_moving_averages: false
  batch_size: 1
  num_visualizations: 50
  min_score_threshold: 0.1
}

eval_input_reader: {
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  shuffle: false
  num_epochs: 1
  tf_record_input_reader {
    input_path: "models/snb3/validation.tfrecord-*"
  }
}
```

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TENSORBOARD ON HPC

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TENSORBOARD ON HPC

- During model training
- After model training is complete

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DURING MODEL TRAINING

- Adjust your job script
- Submit your job as normal
- Connect to the node running the job
- Visit TensorBoard in your browser

DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

Activate evaluation in your job script

```
python model_main_tf2.py \
  --pipeline_config_path=$MODELDIR/pipeline.config \
  --model_dir=$MODELDIR \
  --checkpoint_dir=$MODELDIR \
  --num_workers=1 \
  --sample_1_of_n_eval_examples=1 &
```

Activate TensorBoard in your job script

```
tensorboard --logdir=$MODELDIR --host 0.0.0.0 --load_fast false &
```

DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

- Submit your job to the cluster as normal

```
sbatch train_model.sh
```

- Wait for your job to begin

DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

- Find what node your model is running on

`squeue -u user`

```
   JOBID     USER      ACCOUNT           NAME  ST  TIME_LEFT NODES CPUS TRES_PER_N MIN_MEM NODELIST (REASON)
47623590 jilliana def-jilliana       train.sh   R       9:43     1    1 gres:gpu:1     32G cdr250 (None)
```

Job ID

HPC node

DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

→ Find the node your model is running on

→ Find the port TensorBoard is running on

```
grep "TensorBoard" slurm-JOBID.out
```

```
TensorBoard 2.6.0 at http://0.0.0.0:6006/ (Press CTRL+C to quit)
```

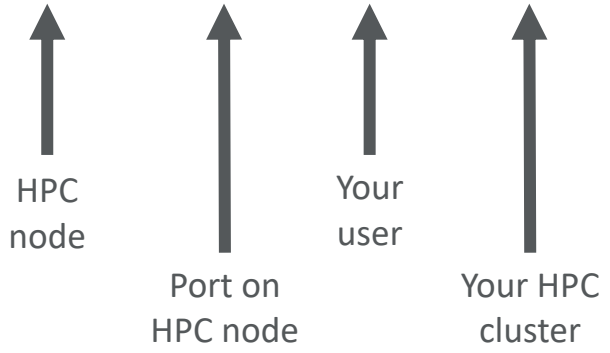
Port on HPC node

DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

- Find what node your model is running on
- Find what port TensorBoard is running on
- Connect to the node where training is happening

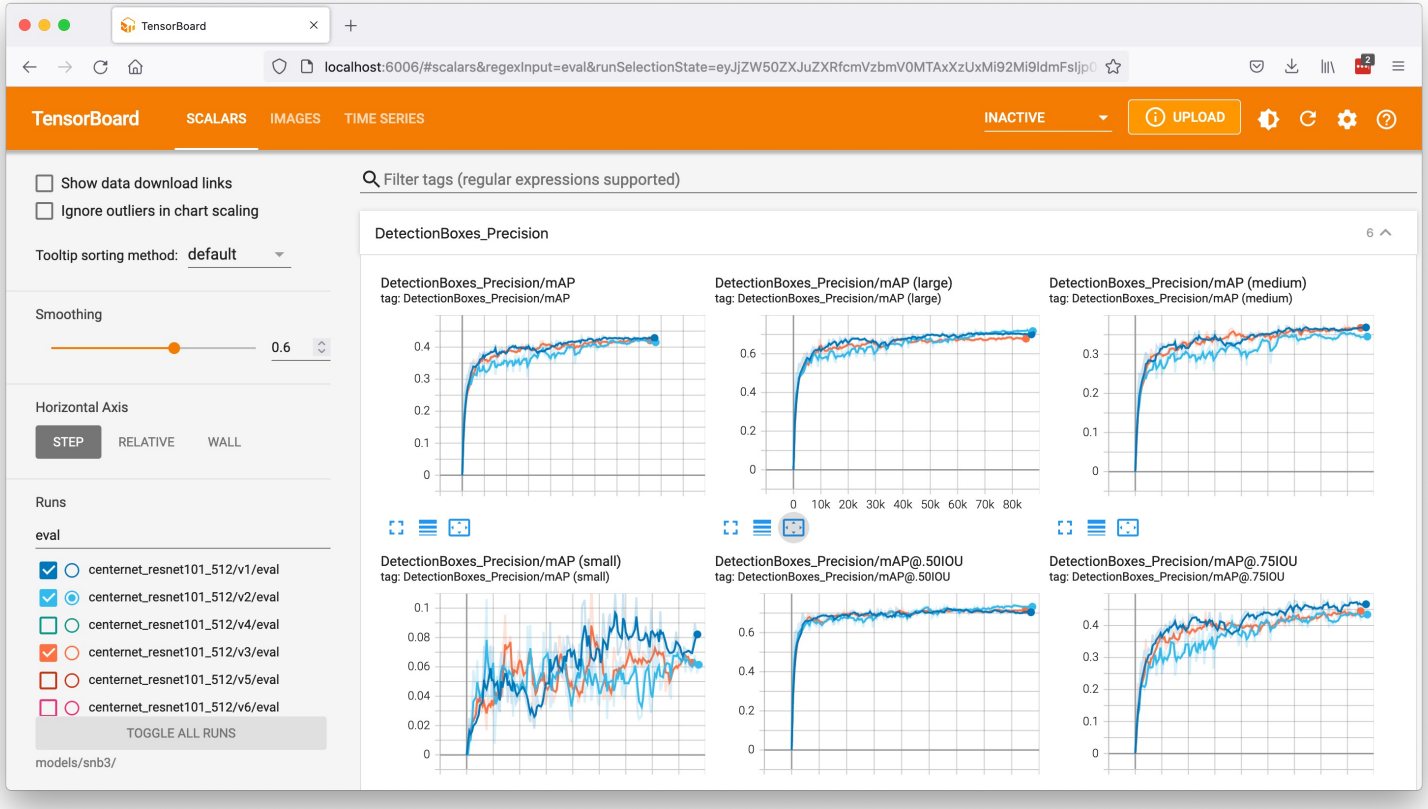
```
ssh -N -f -L localhost:6006:cdr917:6006 user@cedar.computecanada.ca
```



DURING MODEL TRAINING

ADJUST → SUBMIT → CONNECT → VISIT

- Visit localhost:6006 on your favourite browser



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AFTER MODEL TRAINING*

- Request an interactive job
- Start TensorBoard
- Connect to the node running the job
- Visit TensorBoard in your browser

* Requires event files to have been generated during training

AFTER MODEL TRAINING

REQUEST → START TENSORBOARD → CONNECT → VISIT

- Request an interactive job

```
salloc --mem=16GB --time=1:00:00
```

- Wait for the interactive session to begin

```
[jilliana@cedar1 Tensorflow]$ salloc --account=def-jilliana --time=1:00:00
salloc: Pending job allocation 47519849
salloc: job 47519849 queued and waiting for resources
salloc: job 47519849 has been allocated resources
salloc: Granted job allocation 47519849
[jilliana@cdr544 Tensorflow]$
```

HPC node

AFTER MODEL TRAINING

REQUEST → START TENSORBOARD → CONNECT → VISIT

Run TensorBoard

```
tensorboard --logdir=models/dir/ --host 0.0.0.0 --load_fast false
```

Wait for confirmation that TensorBoard is running

```
[jilliana@cdr783 workspace]$ tensorboard --logdir=models/snb3/ --host 0.0.0.0 --load_fast false
2022-10-10 15:49:15.936765: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dynamic library 'libcud
a.so.1'; dlerror: libcuda.so.1: cannot open shared object file: No such file or directory
2022-10-10 15:49:15.937499: W tensorflow/stream_executor/cuda/cuda_driver.cc:269] failed call to cuInit: UNKNOWN ERROR (303)
2022-10-10 15:49:15.937903: I tensorflow/stream_executor/cuda/cuda_diagnostics.cc:156] kernel driver does not appear to be running
 on this host (cdr783.int.cedar.computecanada.ca): /proc/driver/nvidia/version does not exist
TensorBoard 2.9.1 at http://0.0.0.0:6006/ (Press CTRL+C to quit)
```

Port on HPC node

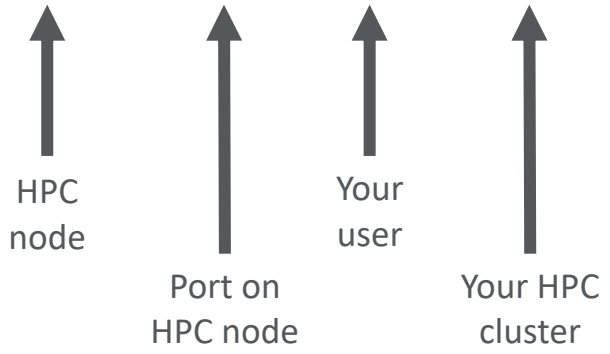
AFTER MODEL TRAINING

REQUEST → START TENSORBOARD → CONNECT → VISIT

→ Find what node & port your job is running on

→ Connect to the node where training is happening

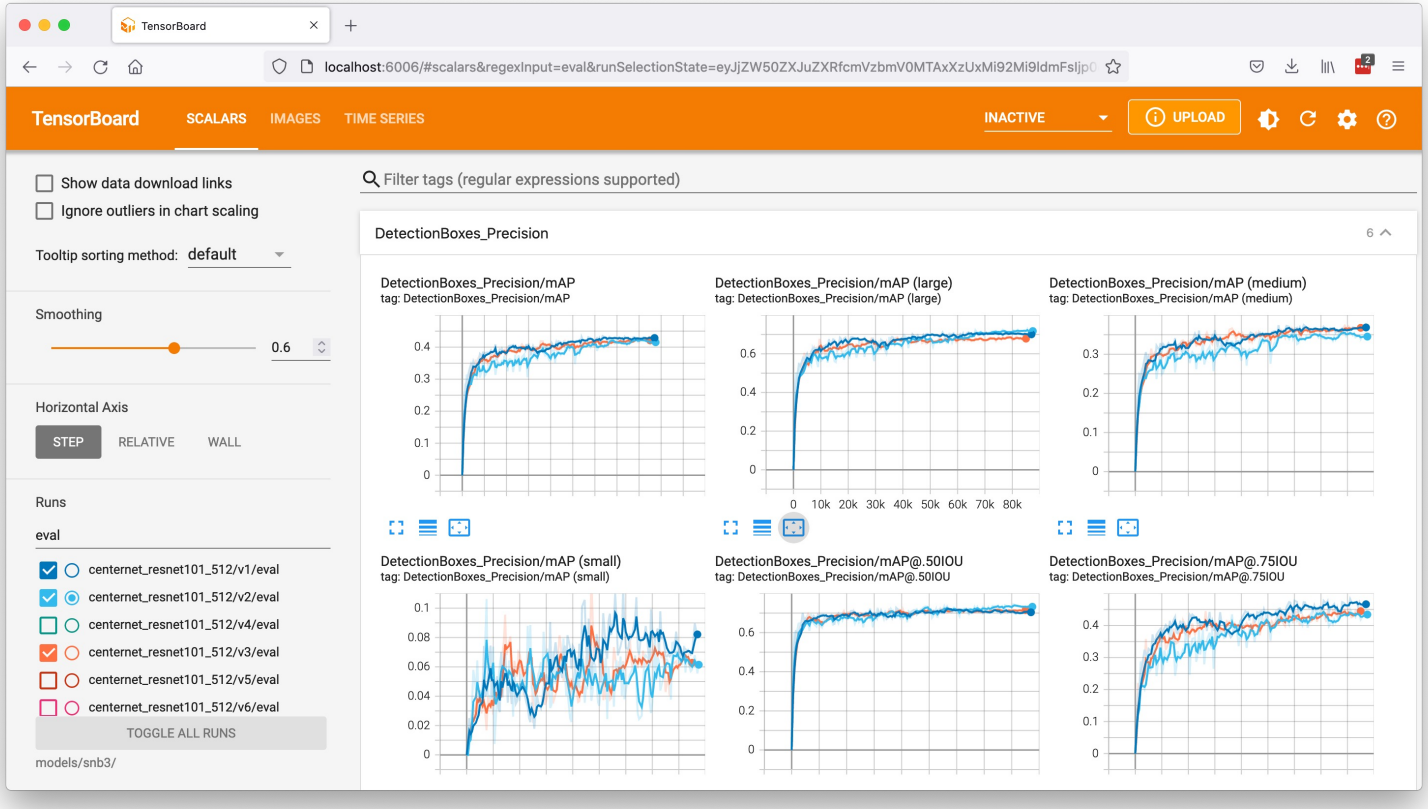
```
ssh -N -f -L localhost:6006:cdr917:6006 user@cedar.computecanada.ca
```



AFTER MODEL TRAINING

REQUEST → START TENSORBOARD → CONNECT → VISIT

- Visit localhost:6006 on your favourite browser



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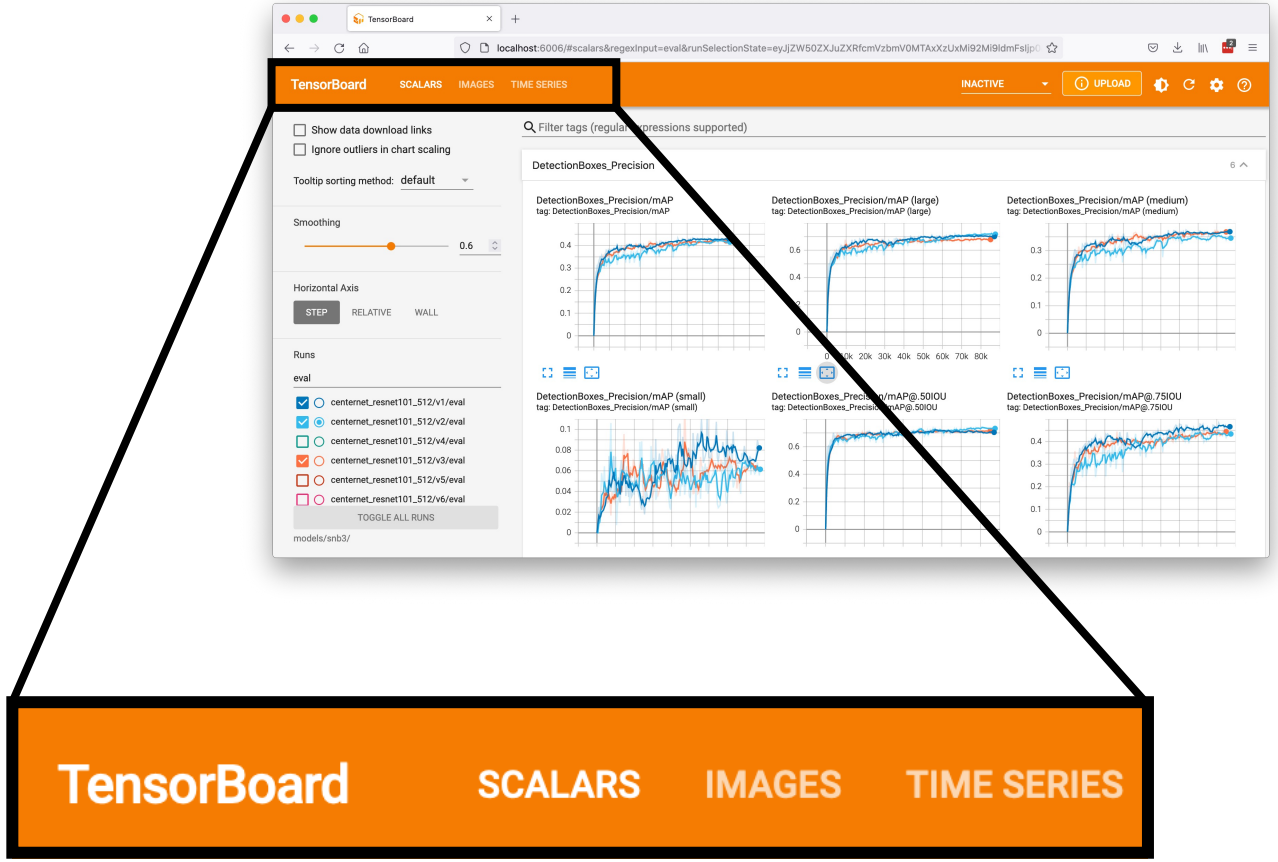
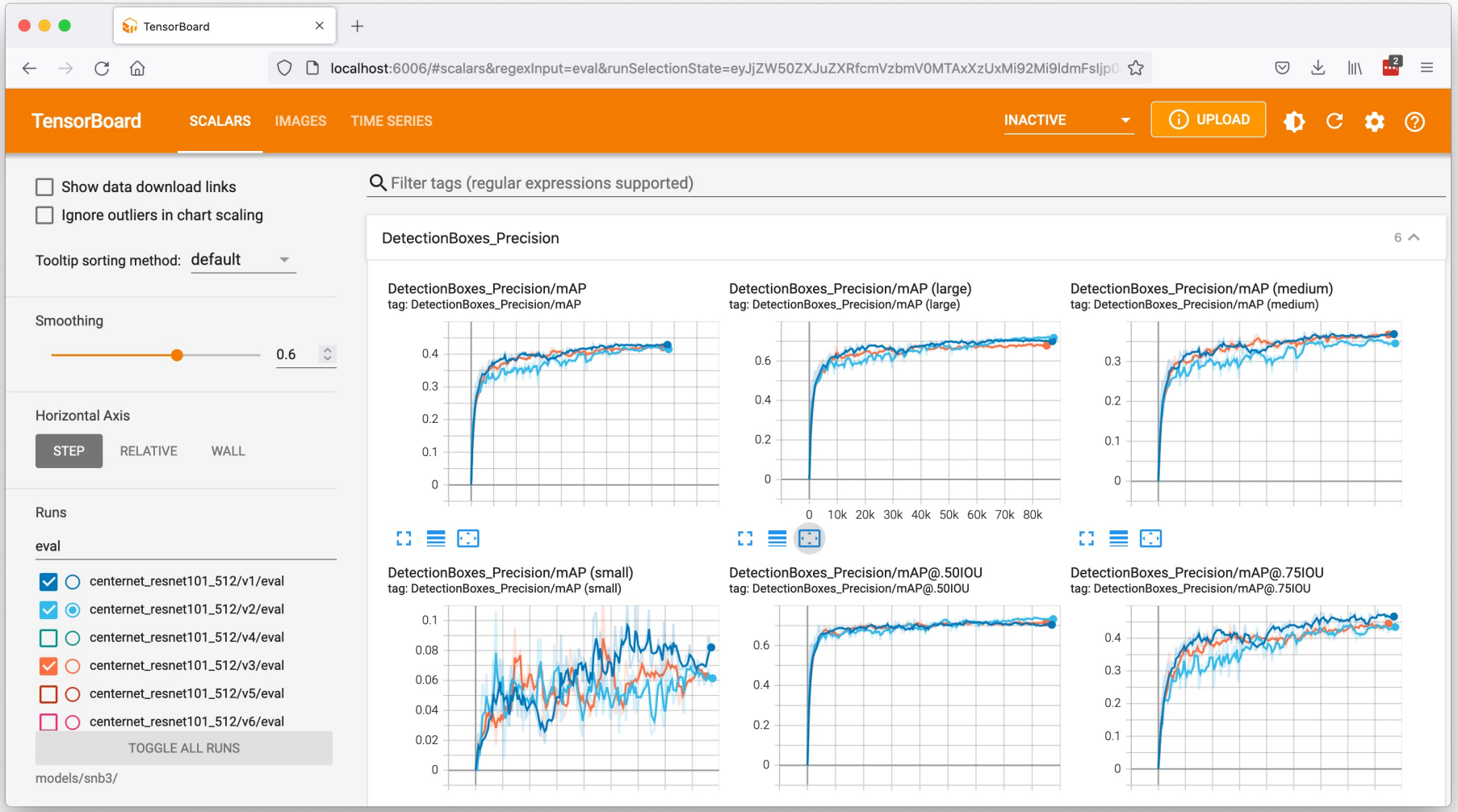
EXPLORING TENSORBOARD

EXPLORING TENSORBOARD

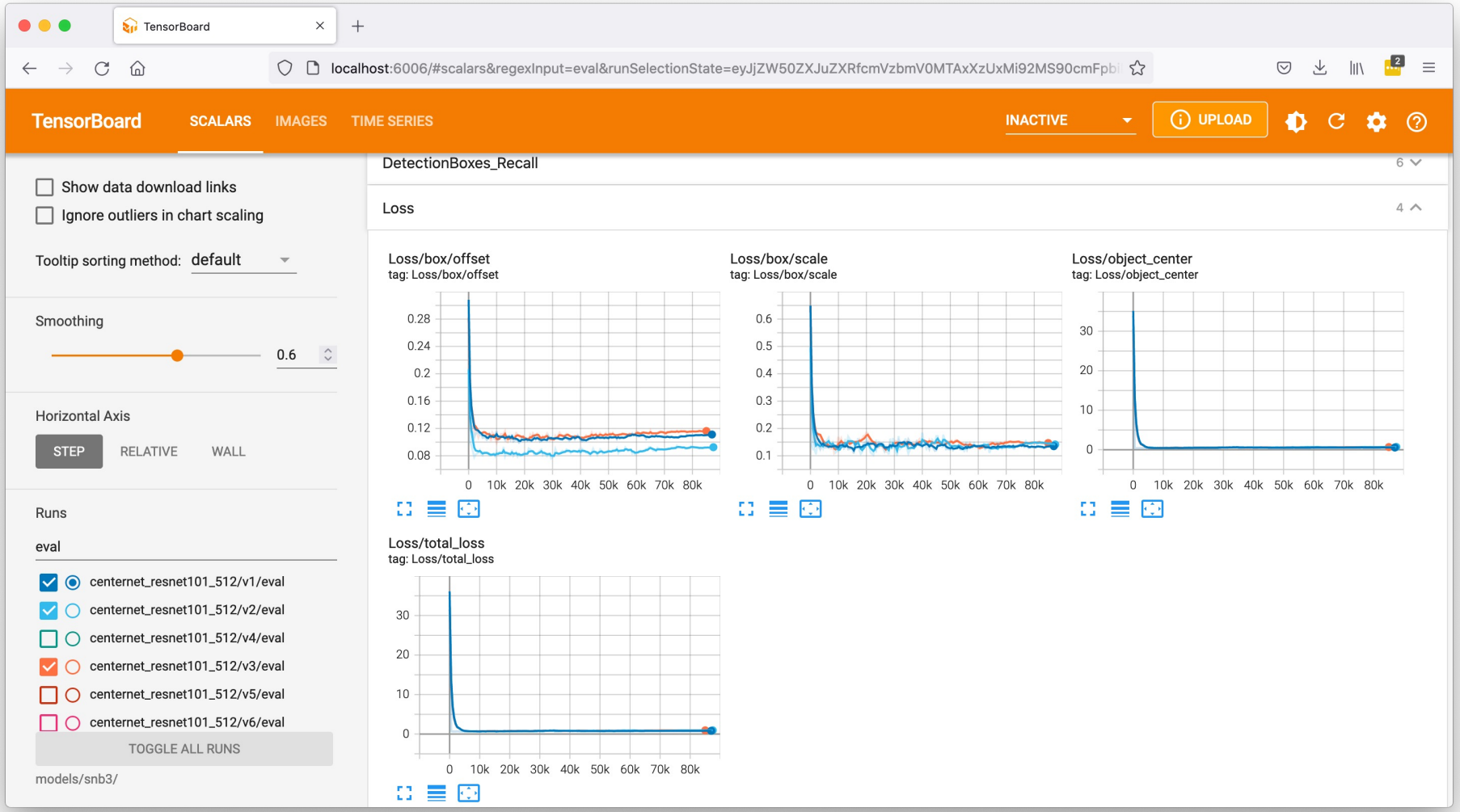
- Scalars
- Images
- Time Series



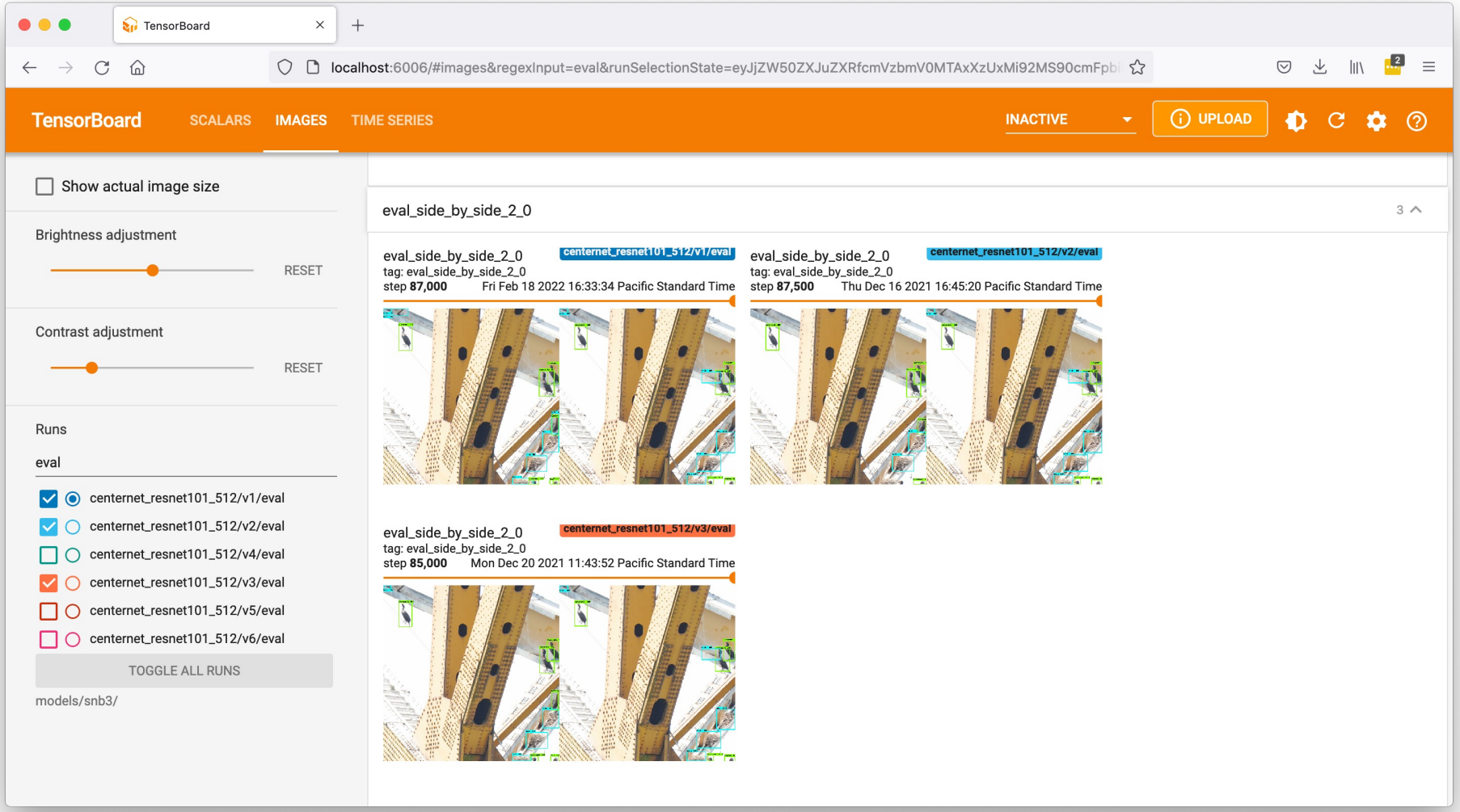
SCALARS


TensorBoard
localhost:6006/#scalars&regexInput=eval&runSelectionState=eyJjZW50ZXJuZXRfcmVzbmV0MTAxXzUxMi92Mi9ldmFsIjp0
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
Show data download links
Ignore outliers in chart scaling
Tooltip sorting method: default
Smoothing
0.6
Horizontal Axis
STEP
RELATIVE
WALL
Runs
eval
centernet_resnet101_512/v1/eval
centernet_resnet101_512/v2/eval
centernet_resnet101_512/v4/eval
centernet_resnet101_512/v3/eval
centernet_resnet101_512/v5/eval
centernet_resnet101_512/v6/eval
TOGGLE ALL RUNS
models/snb3/
Filter tags (regular expressions supported)
DetectionBoxes_Precision
6
DetectionBoxes_Precision/mAP
tag: DetectionBoxes_Precision/mAP
DetectionBoxes_Precision/mAP (large)
tag: DetectionBoxes_Precision/mAP (large)
DetectionBoxes_Precision/mAP (medium)
tag: DetectionBoxes_Precision/mAP (medium)
DetectionBoxes_Precision/mAP (small)
tag: DetectionBoxes_Precision/mAP (small)
DetectionBoxes_Precision/mAP@.50IOU
tag: DetectionBoxes_Precision/mAP@.50IOU
DetectionBoxes_Precision/mAP@.75IOU
tag: DetectionBoxes_Precision/mAP@.75IOU

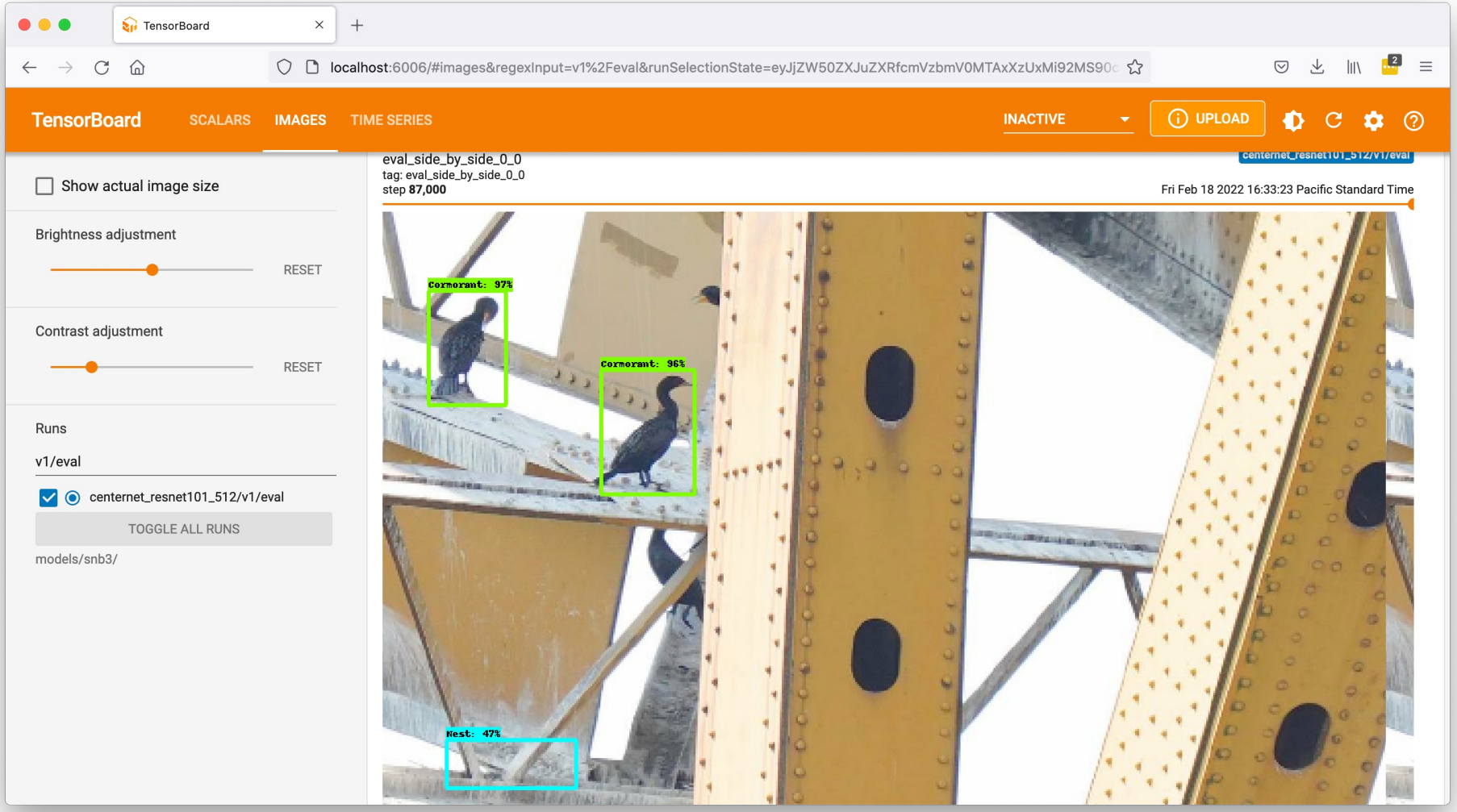
SCALARS


TensorBoard
localhost:6006/#scalars&regexInput=eval&runSelectionState=eyJjZW50ZXJuZXRfcmVzbmV0MTAxXzUxMi92MS90cmFpbi
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
Show data download links
Ignore outliers in chart scaling
Tooltip sorting method: default
Smoothing
0.6
Horizontal Axis
STEP
RELATIVE
WALL
Runs
eval
centernet_resnet101_512/v1/eval
centernet_resnet101_512/v2/eval
centernet_resnet101_512/v4/eval
centernet_resnet101_512/v3/eval
centernet_resnet101_512/v5/eval
centernet_resnet101_512/v6/eval
TOGGLE ALL RUNS
models/snb3/
DetectionBoxes_Recall
6
Loss
4
Loss/box/offset
tag: Loss/box/offset
Loss/box/scale
tag: Loss/box/scale
Loss/object_center
tag: Loss/object_center
Loss/total_loss
tag: Loss/total_loss
0 10k 20k 30k 40k 50k 60k 70k 80k

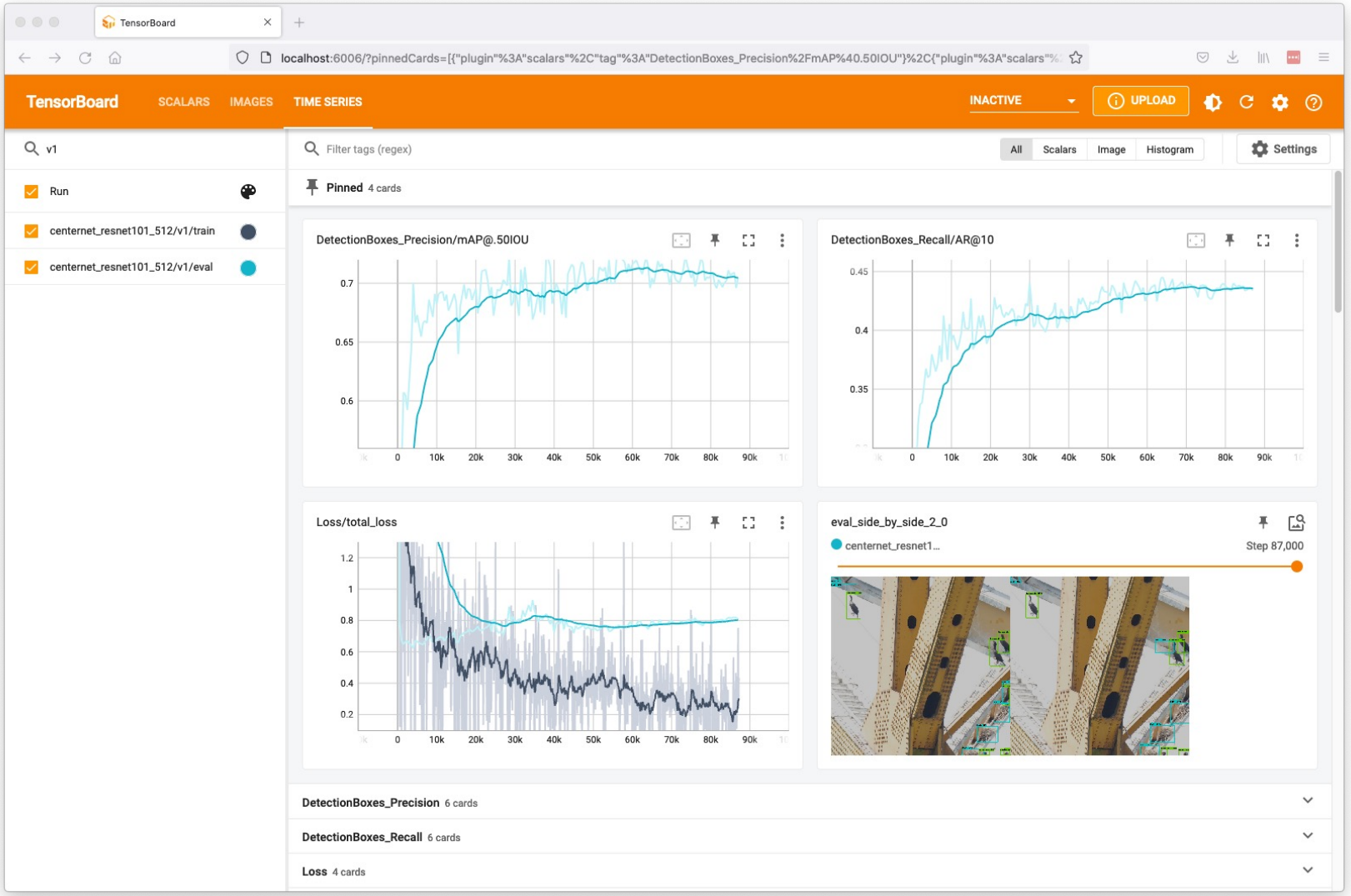
IMAGES


TensorBoard
localhost:6006/#images&regexInput=eval&runSelectionState=eyJjZW50ZXJuZXRfcmVzbnV0MTAxXzUxMi92MS90cmFpb
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
Show actual image size
Brightness adjustment
RESET
Contrast adjustment
RESET
Runs
eval
centernet_resnet101_512/v1/eval
centernet_resnet101_512/v2/eval
centernet_resnet101_512/v4/eval
centernet_resnet101_512/v3/eval
centernet_resnet101_512/v5/eval
centernet_resnet101_512/v6/eval
TOGGLE ALL RUNS
models/snb3/
eval_side_by_side_2_0
3
eval_side_by_side_2_0
centernet_resnet101_512/v1/eval
tag: eval_side_by_side_2_0
step 87,000
Fri Feb 18 2022 16:33:34 Pacific Standard Time
eval_side_by_side_2_0
centernet_resnet101_512/v2/eval
tag: eval_side_by_side_2_0
step 87,500
Thu Dec 16 2021 16:45:20 Pacific Standard Time
eval_side_by_side_2_0
centernet_resnet101_512/v3/eval
tag: eval_side_by_side_2_0
step 85,000
Mon Dec 20 2021 11:43:52 Pacific Standard Time

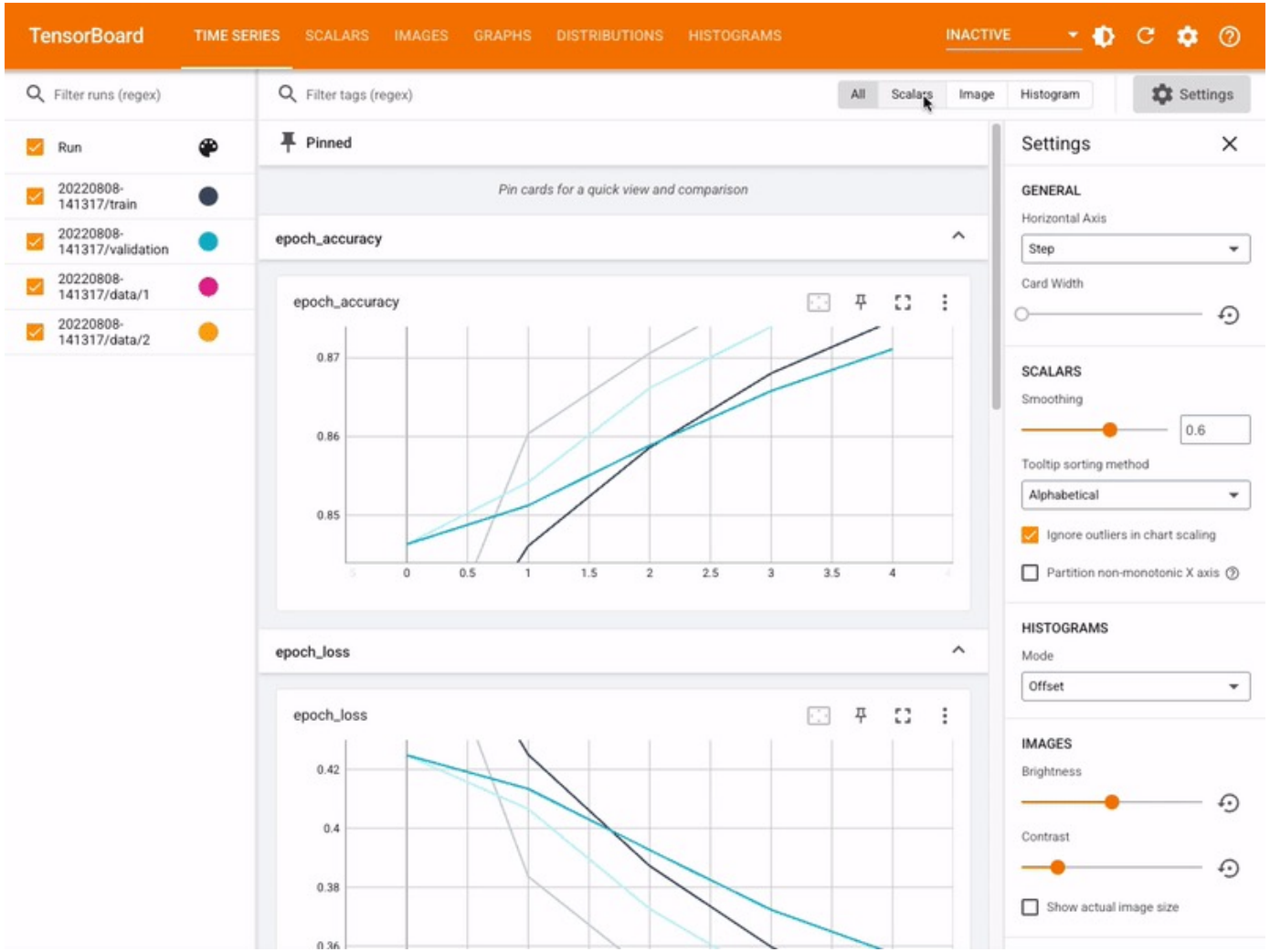
IMAGES


TensorBoard
localhost:6006/#images&regexInput=v1%2Feval&runSelectionState=eyJjZW50ZXJuZXRfcmVzbmV0MTAxXzUxMi92MS90
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
Show actual image size
Brightness adjustment
RESET
Contrast adjustment
RESET
Runs
v1/eval
centernet_resnet101_512/v1/eval
TOGGLE ALL RUNS
models/snb3/
eval_side_by_side_0_0
tag: eval_side_by_side_0_0
step 87,000
Fri Feb 18 2022 16:33:23 Pacific Standard Time
Cormorant: 97%
Cormorant: 96%
Nest: 47%

TIME SERIES


TensorBoard
localhost:6006/?pinnedCards=[{"plugin"%3A"scalars"%2C"tag"%3A"DetectionBoxes_Precision%2FmAP%40.50IOU"}%2C{"plugin"%3A"scalars"%
TensorBoard
SCALARS
IMAGES
TIME SERIES
INACTIVE
UPLOAD
v1
Filter tags (regex)
All
Scalars
Image
Histogram
Settings
Run
centernet_resnet101_512/v1/train
centernet_resnet101_512/v1/eval
Pinned 4 cards
DetectionBoxes_Precision/mAP@.50IOU
DetectionBoxes_Recall/AR@10
Loss/total_loss
eval_side_by_side_2_0
centernet_resnet1...
Step 87,000
DetectionBoxes_Precision 6 cards
DetectionBoxes_Recall 6 cards
Loss 4 cards

OTHER TENSORBOARD DASHBOARDS



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THANK YOU

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QUESTIONS?