OverFeat

Classification, Localization and Detection using Deep Learning

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ICCV 2013 • ImageNet Large Scale Visual Recognition Challenge 2013 (ILSVRC2013) Workshop

- **ImageNet Challenge**
  - 2012: classification, localization, fine-grained classification
  - 2013: classification, localization, detection

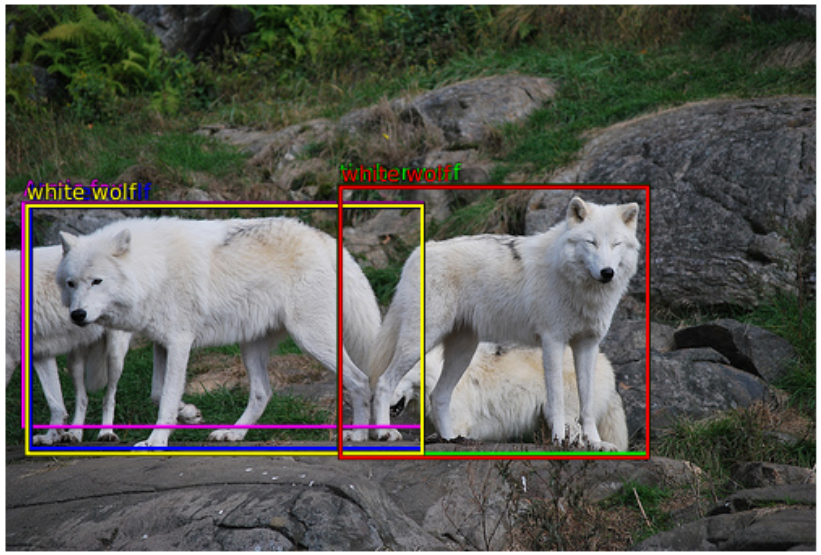
- **Classification:**
  - 1000 classes
  - correct if in the top 5 answers (image may contain multiple classes)

Top 5:
pencil sharpener
pool table
hand blower
oil filter
packet

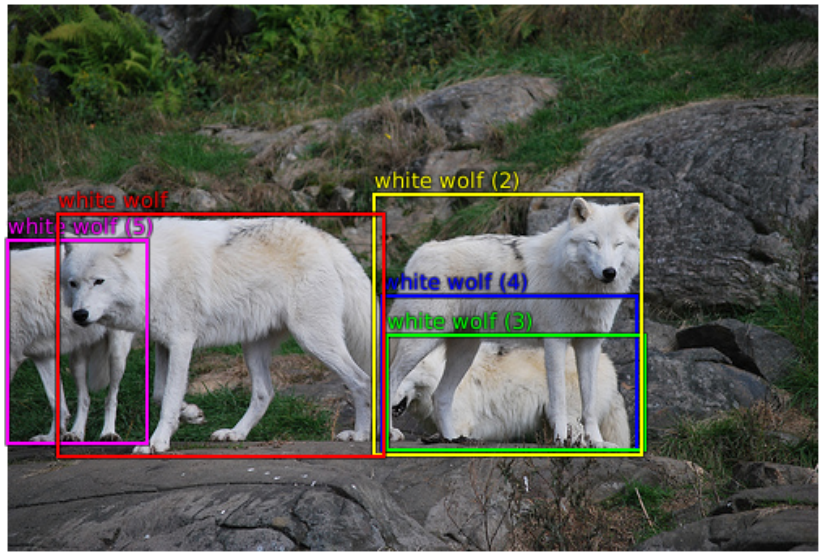
Groundtruth:
pencil sharpener

ILSVRC2012_val_00010000.JPEG

- **Classification + Localization:**
  - 1000 classes
  - predict correct class and return at most 5 bounding boxes that overlap by at least 50%.



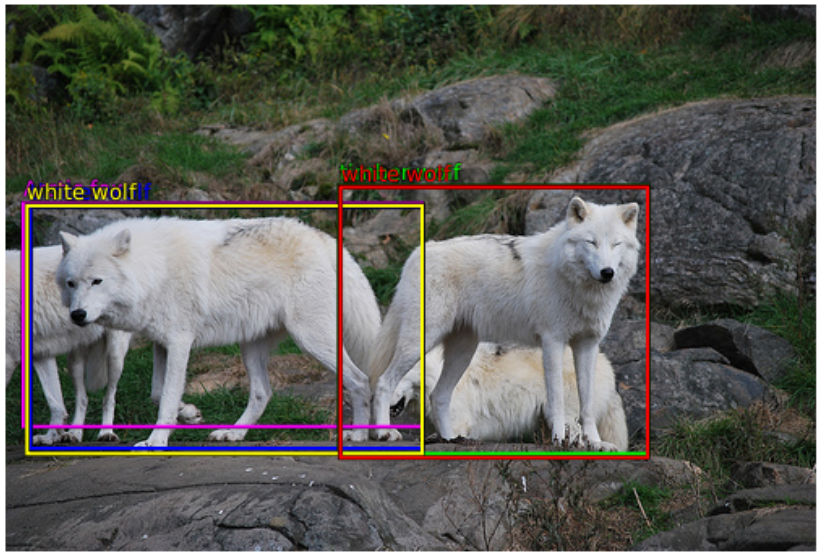
Top 5:
white wolf
white wolf
timber wolf
timber wolf
Arctic fox



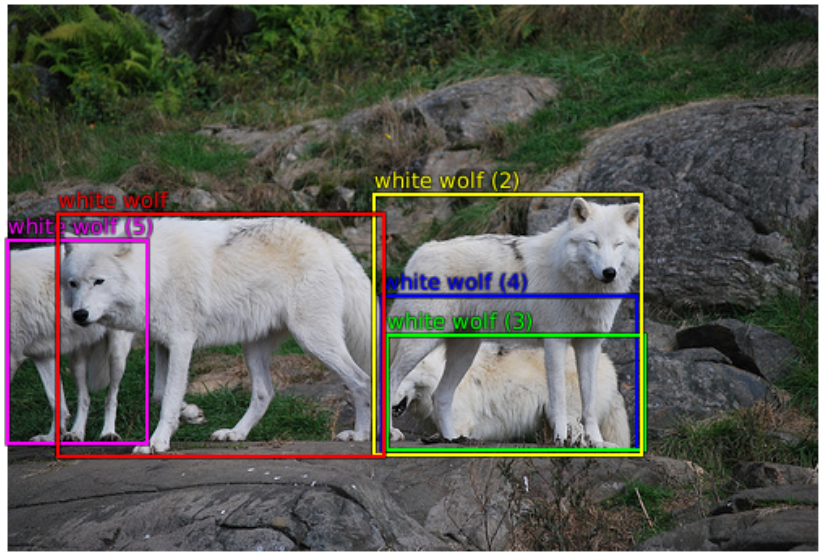
Groundtruth:
white wolf
white wolf (2)
white wolf (3)
white wolf (4)
white wolf (5)

ILSVRC2012_val_00000027.JPEG

- **Localization:**
  - a good measure?
  - classification < localization < detection
  - very good to evaluate localization method independently from other detection challenges (background training)



Top 5:
white wolf
white wolf
timber wolf
timber wolf



Groundtruth:
white wolf
white wolf (2)
white wolf (3)
white wolf (4)

- **Detection:**
  - 200 classes
  - Smaller objects than classification/localization
  - Any number of objects (including zero)
  - Penalty for false positives

Top predictions:
tv or monitor (confidence 11.5)
person (confidence 4.5)
miniskirt (confidence 3.1)

ILSVRC2012_val_00000119.JPEG

Groundtruth:
tv or monitor
tv or monitor (2)
tv or monitor (3)
person
remote control
remote control (2)

Results

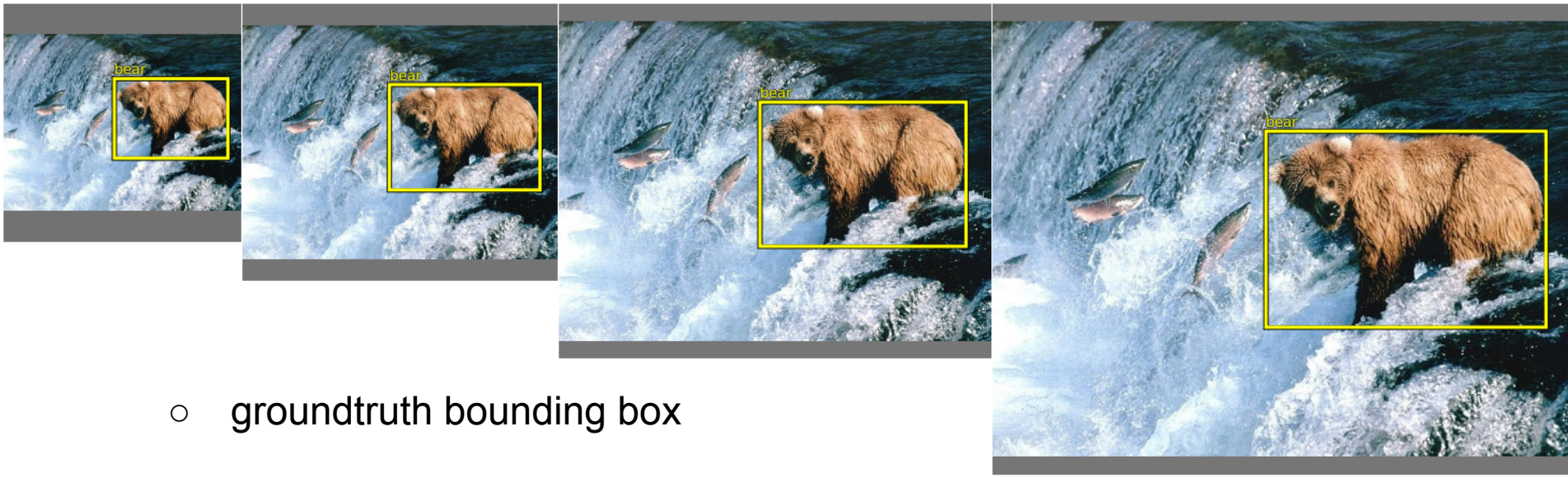
- Official results:
  - **Classification**:
    - 14.2% error
    - **4th position** behind Clarifai-ZF (11.1%), NUS (12.9%), Andrew Howard (13.5%)
  - **Localization**:
    - 29.9% error
    - **1st position**, followed by Alex Krizhevsky (34% in 2012), and Oxford VGG (46%)
  - **Detection**:
    - 19.4% mean AP
    - **3rd position** behind UvA (22.6%) and NEC (20.9%)
- Only team entering all tasks

- **Classification**:
  - standard architecture
  - no normalization
  - voting:
    - multi-view (4 corners + 1 center views + flip = 10 views)
    - 7 models voting
  - GPU implementation
    - fast and low memory footprint important to train bigger models

- **Localization**
  - regression predicting coordinates of bounding boxes
    - top-left (x,y) and bottom-right (x,y)
    - center (x,y), height and width: center does not depend on scale
    - fancier (similar to yann's face pose estimation)
  - replace classifier with regressor, inputs: 256x5x5 (right after last pooling)

- **Detection**:
  - training with background to avoid false positives, trade-off between positive/negative accuracy

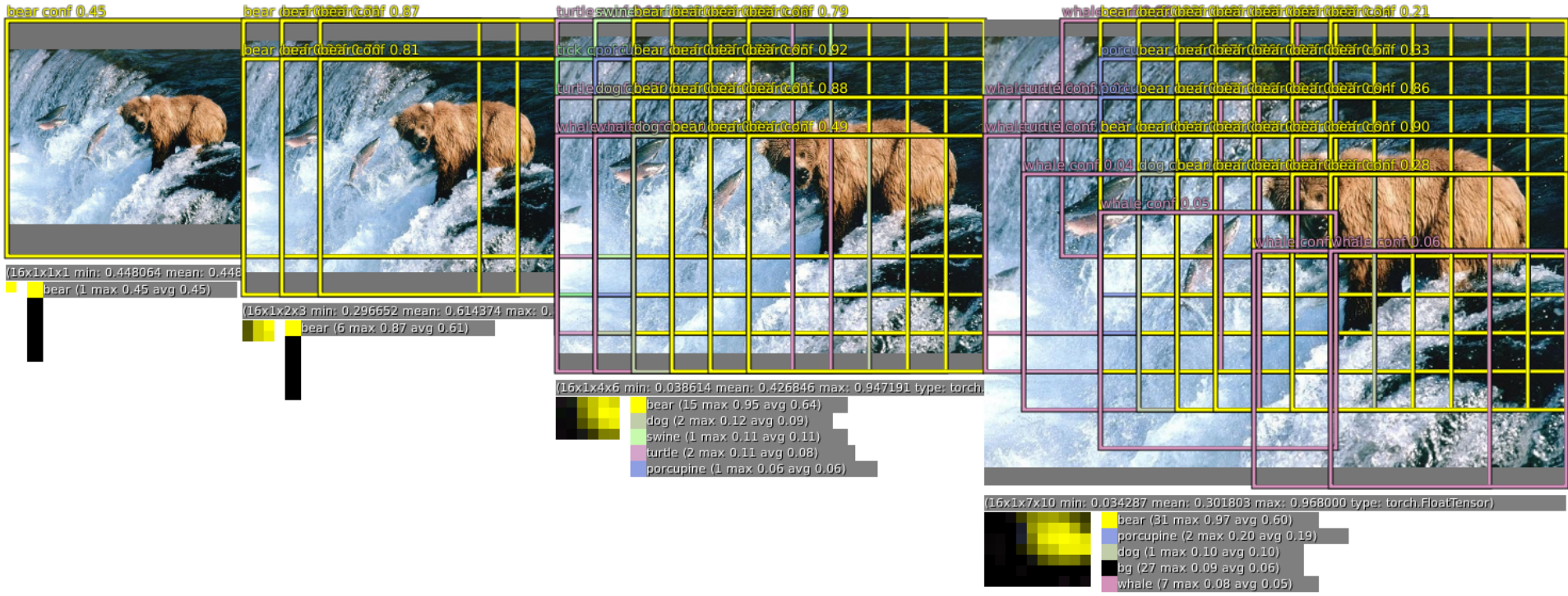
- **Detection / Localization**



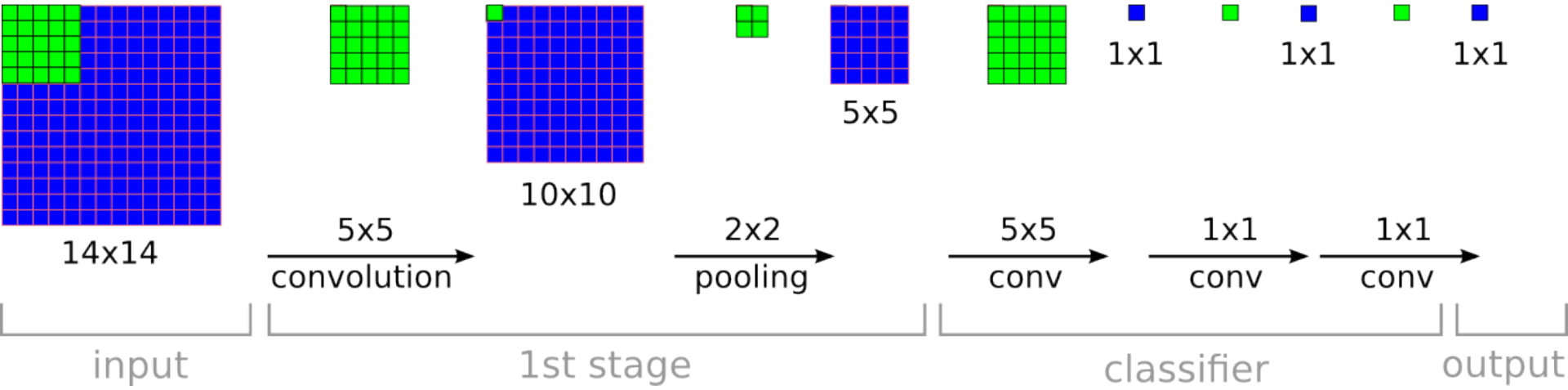
  - groundtruth bounding box

Detection / Localization

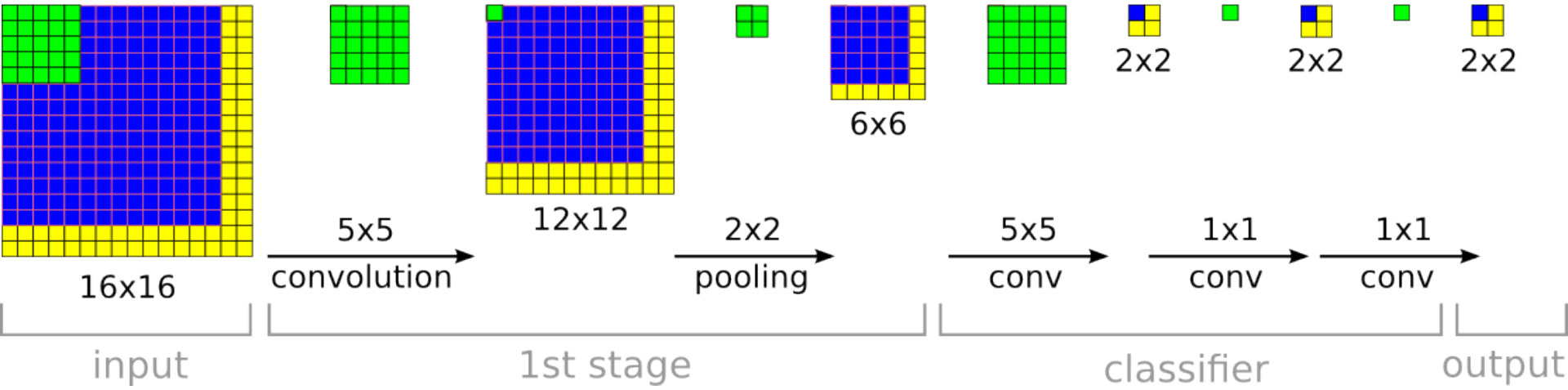
- **ConvNets and detection:**
  - particularly suited for detection
  - reusing neighbor computations
  - no need to recompute entire network at each location



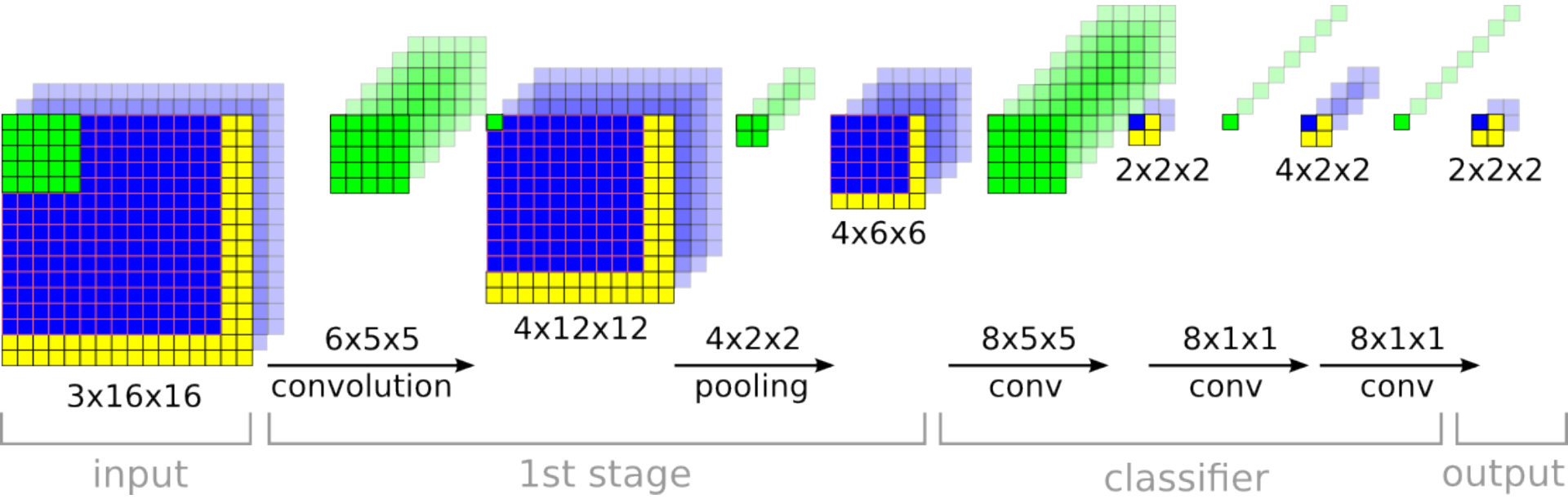
- **Single output:**
  - 1x1 output
  - no feature space
  - blue: feature maps
  - green: operation kernel
  - typical training setup



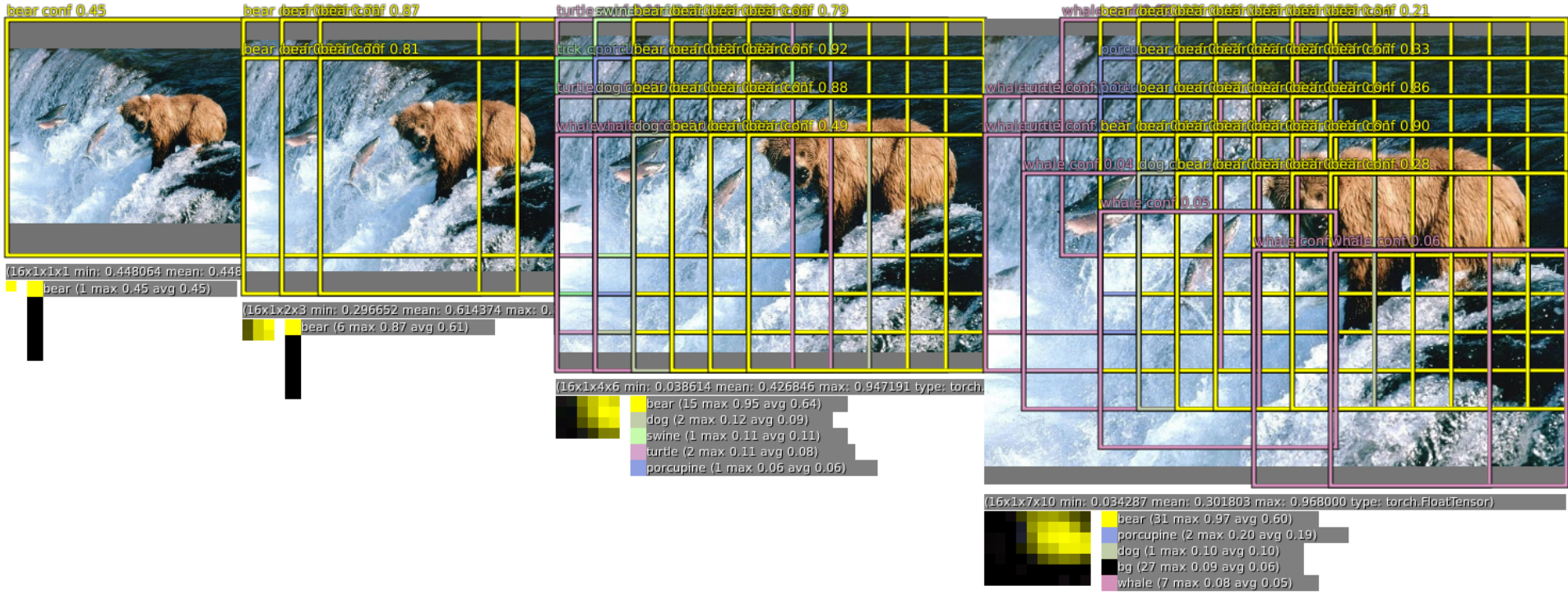
- **Multiple outputs:**
  - 2x2 output
  - input stride 2x2
  - recompute only extra yellow areas



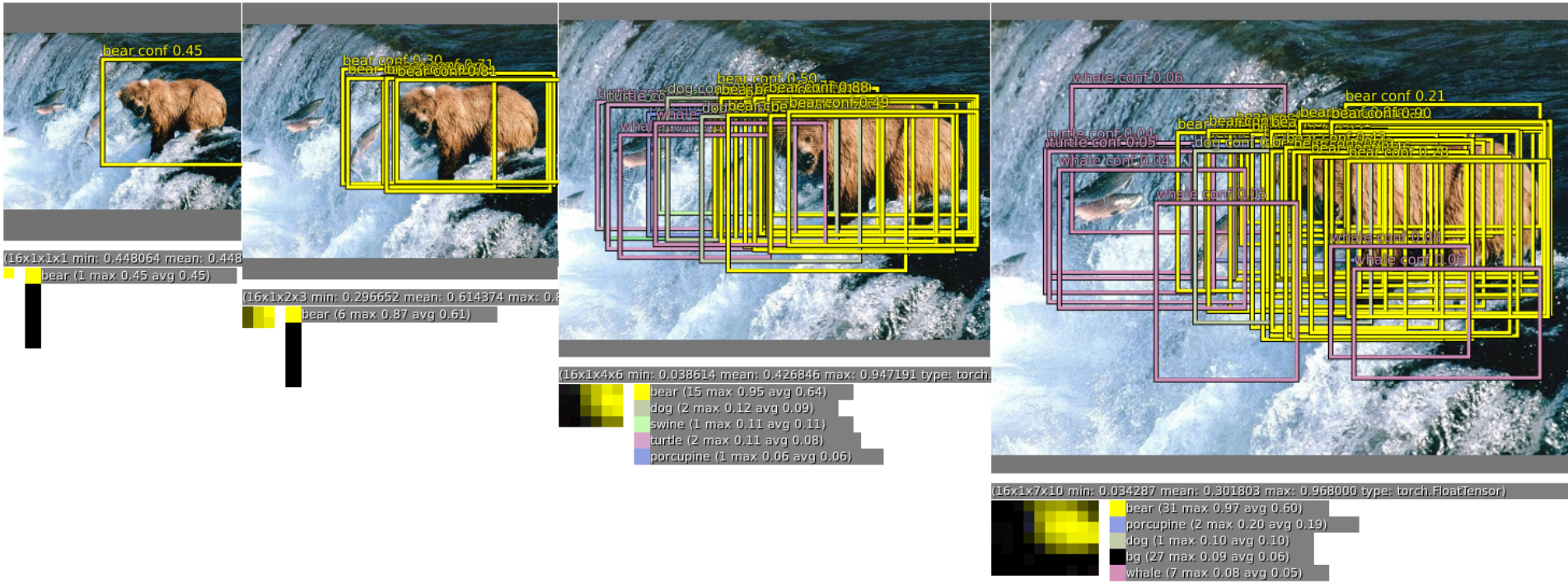
- **With feature space**
  - 3 input channels
  - 4 feature maps
  - 2 feature maps
  - 4 feature maps
  - 2 outputs (e.g. 2-class classifier)



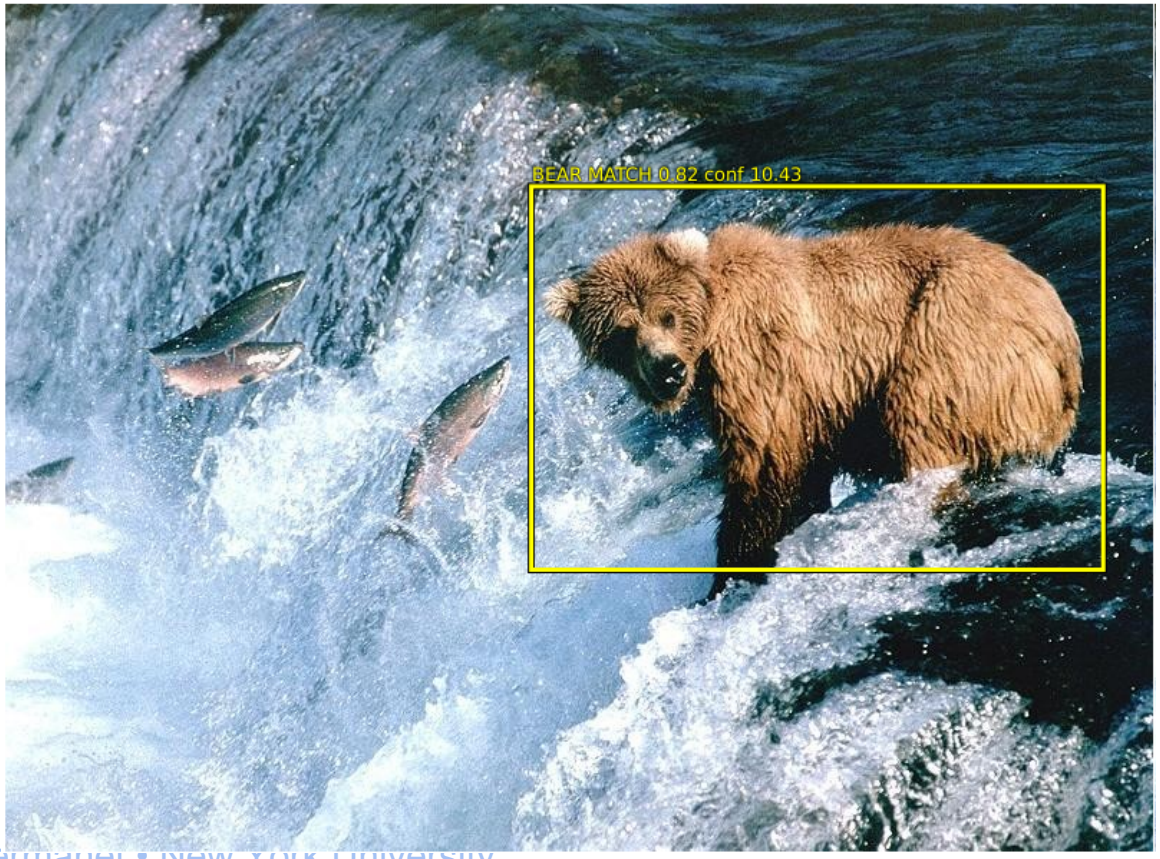
- **Traditional detection approach**:
  - multi-scale
  - sliding window
  - non-maximum suppression (NMS)



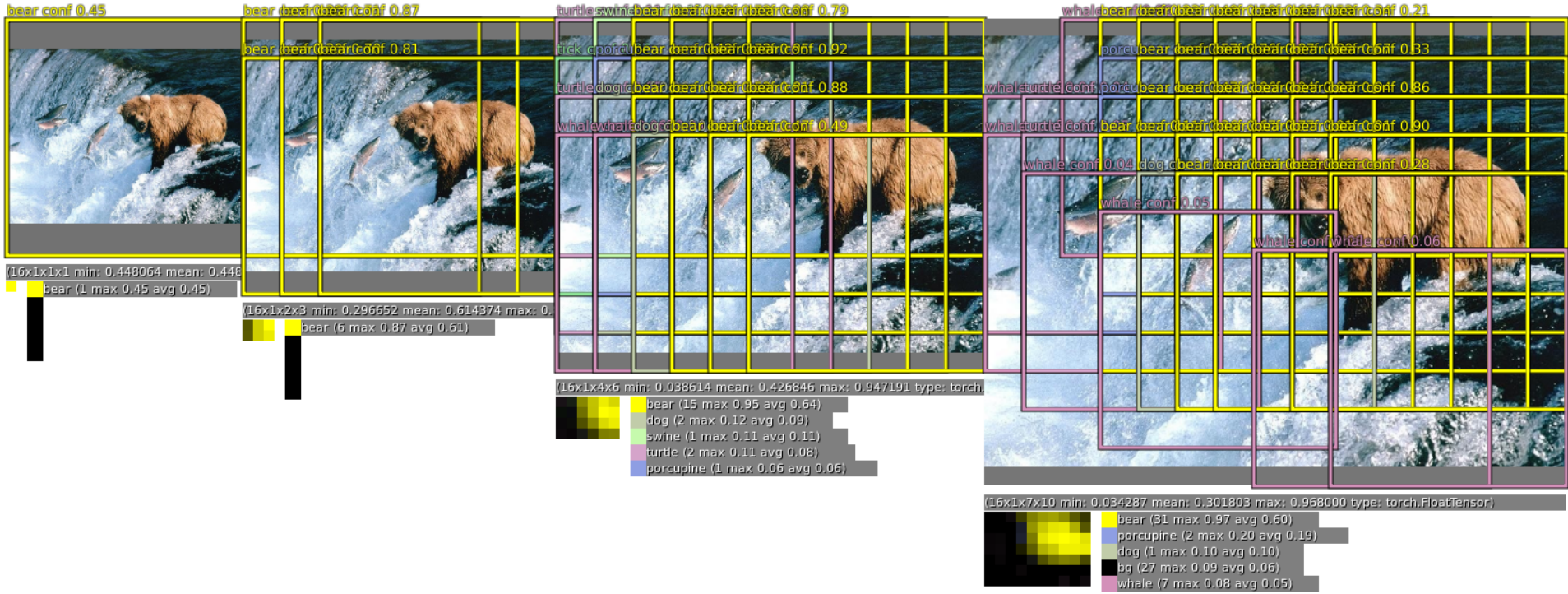
- **Our detection approach**:
  - for each location, predict bounding box
  - accumulate instead of suppress
  - another form of voting



- **Bounding boxes voting**:
  - **voting is good** (classification: views voting + model voting)
  - boosts confidence **high above false positives** ([0,1] up to 10.43 here)
  - more robust to individual localization errors
  - relying less on an accurate background class

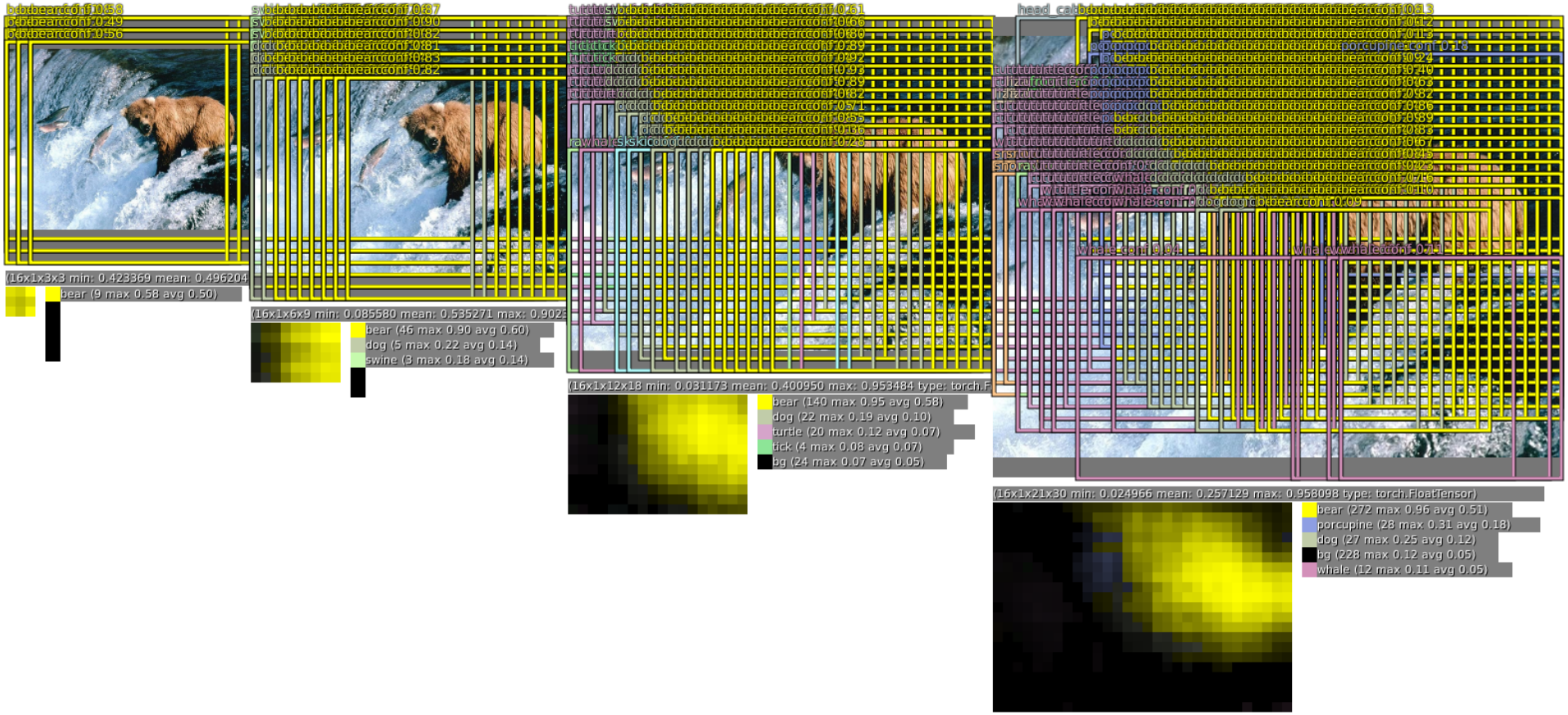


- **Augmenting views of a ConvNet**:
  - the more subsampling, the larger the output stride
  - larger output stride means less views

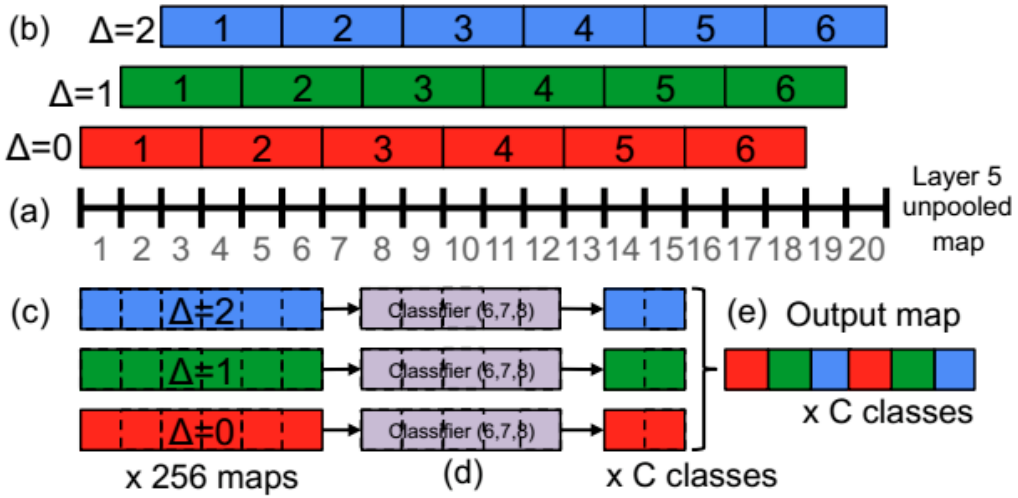


  - e.g.: subsampling x2, x3, x2, x3 => 36 pixels stride
  - 1 pixel shift in output space corresponds to 36 pixels shift in input space

- **Augmenting views of a ConvNet:**
  - 9x more bounding boxes (with last pooling 3x3)



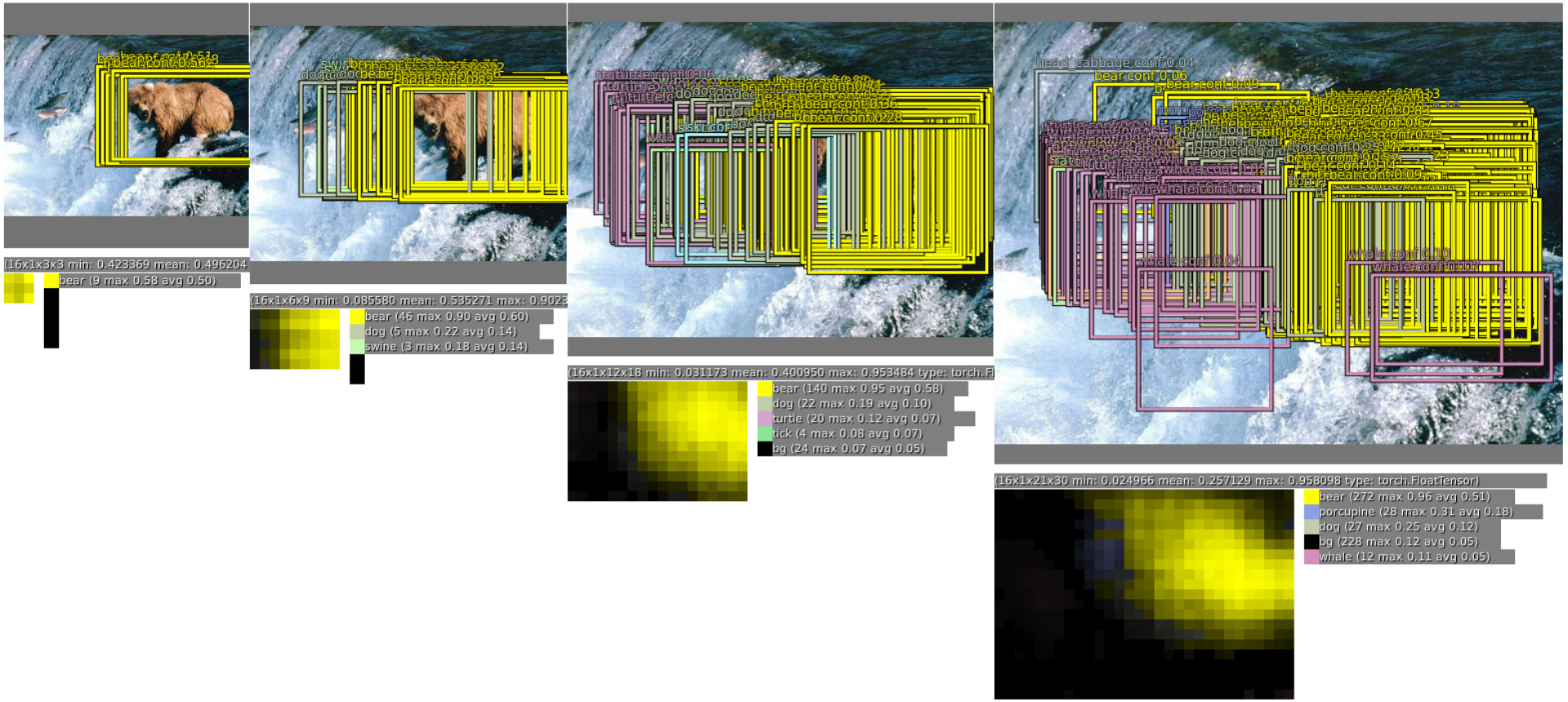
- **Reducing output stride**:
  - example: last pooling 3x3 with stride 3x3
  - change pooling stride to 1x1
  - following layer now must skip every 3 pixels and repeat 9 times



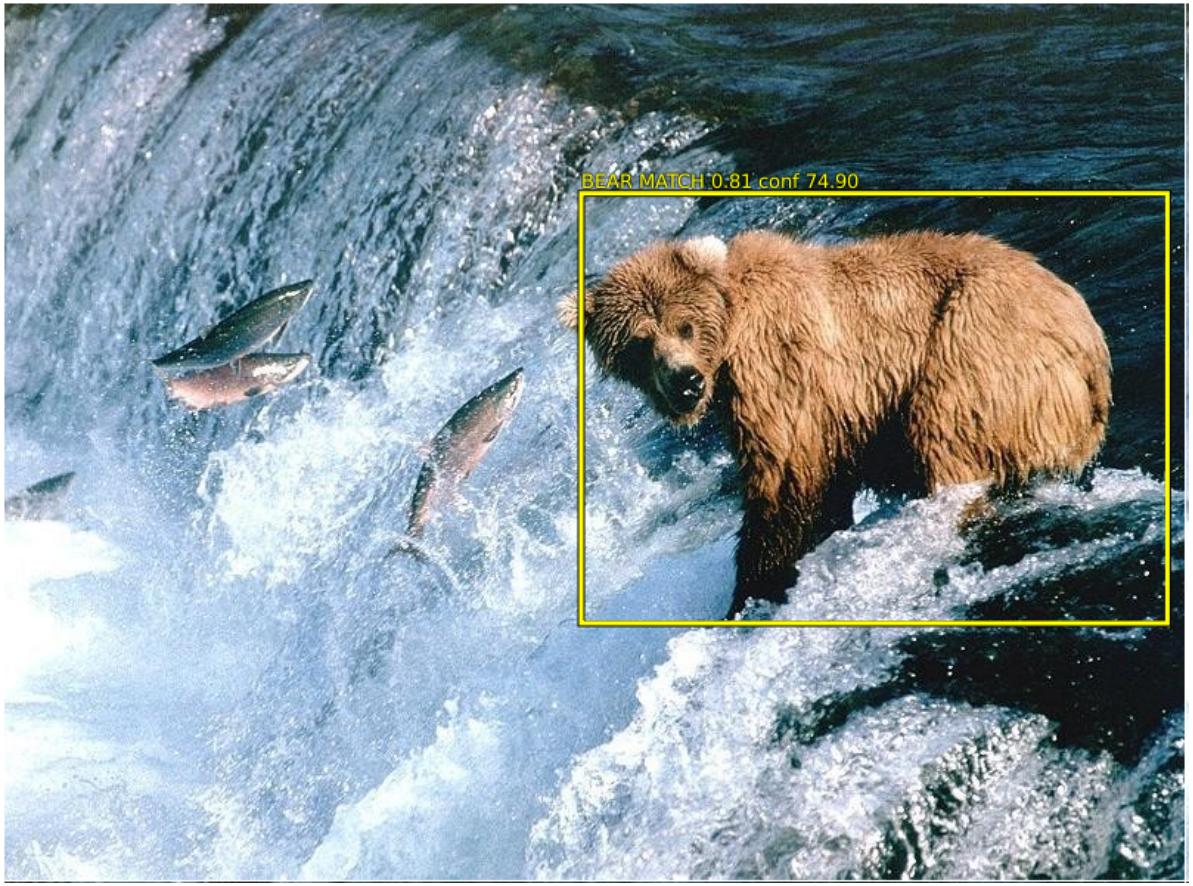
  - technique introduced by Giusti et al.

A. Giusti, D. C. Ciresan, J. Masci, L. M. Gambardella, and J. Schmidhuber. Fast image scanning with deep max-pooling convolutional neural networks. In International Conference on Image Processing (ICIP), 2013.

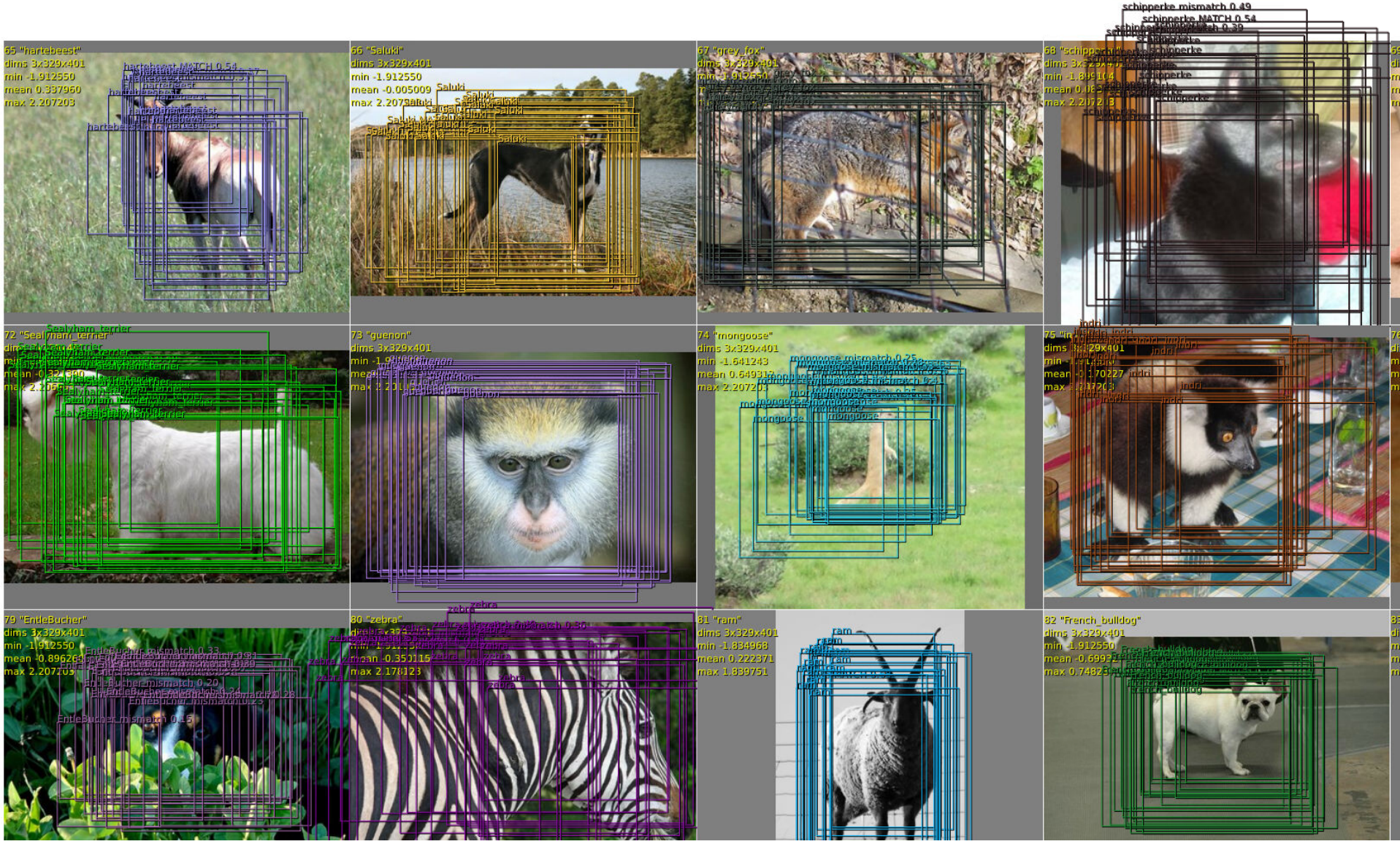
- **Fine stride:**
  - stronger voting
  - e.g. 3x3 bounding boxes instead of 1x1 for first scale



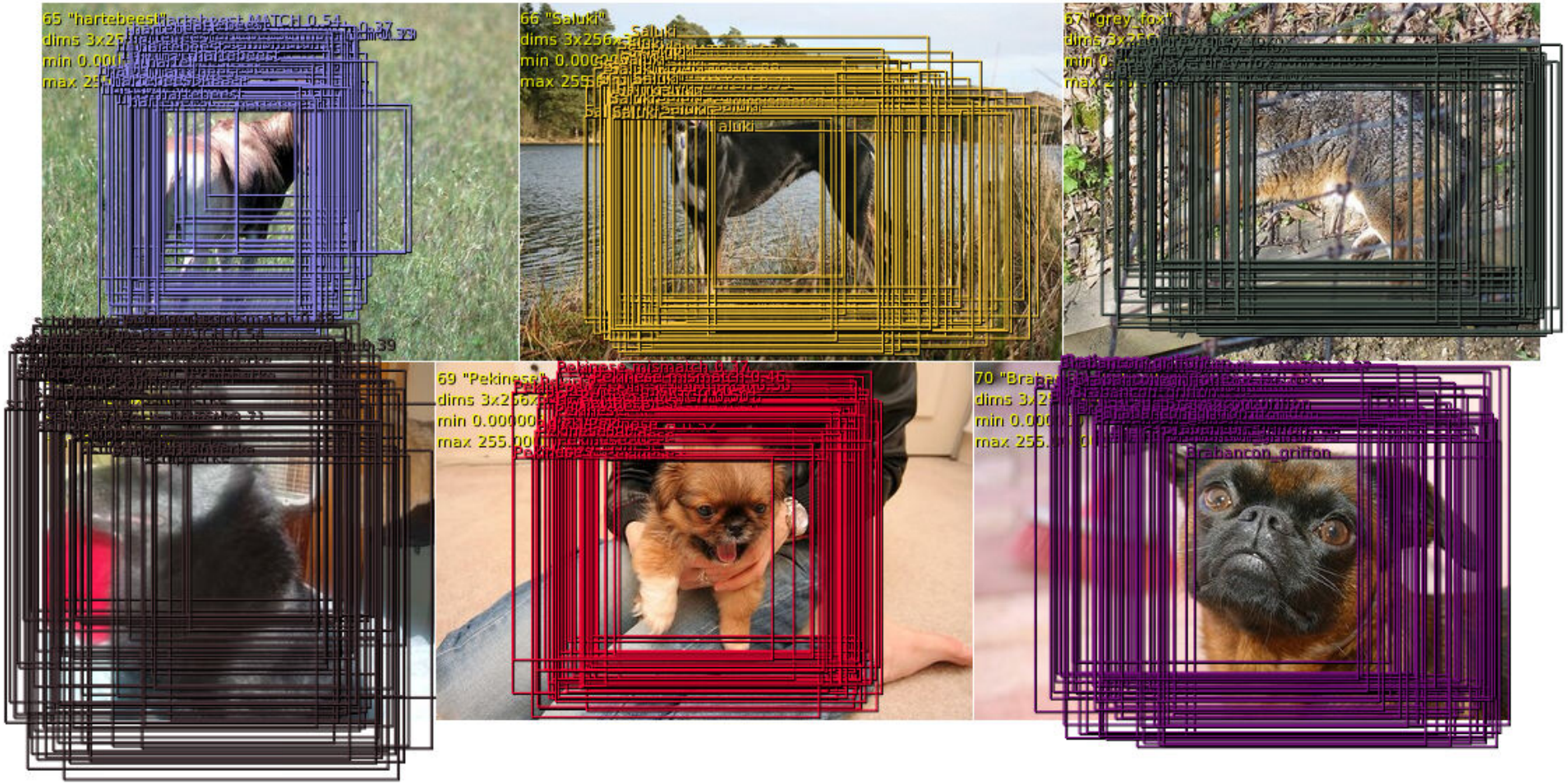
- **Fine stride voting:**
  - confidence boosts from ~10 to ~75
  - more optimal input alignment with network yields stronger activations/confidence



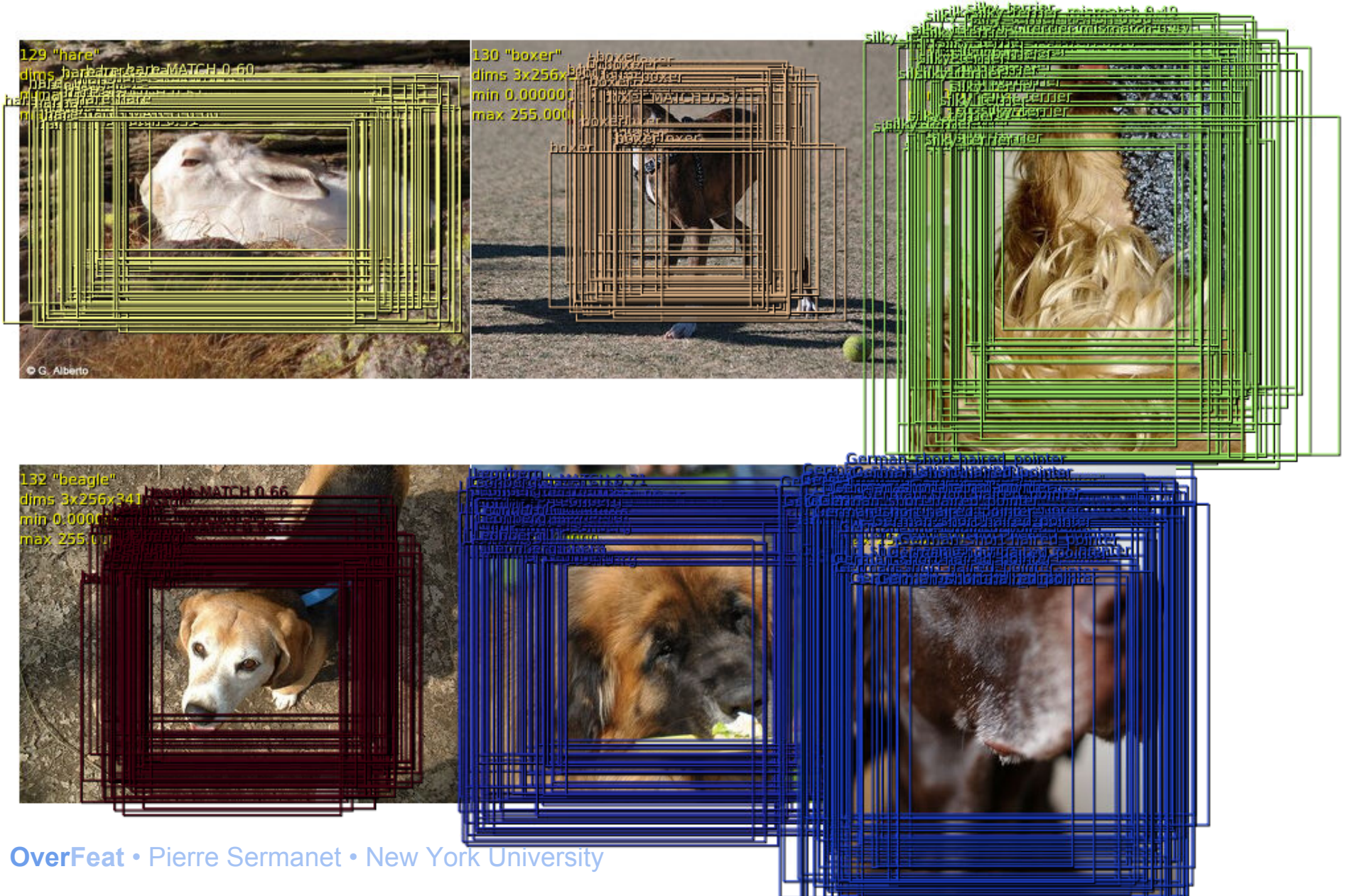
Detection / Localization



Detection / Localization

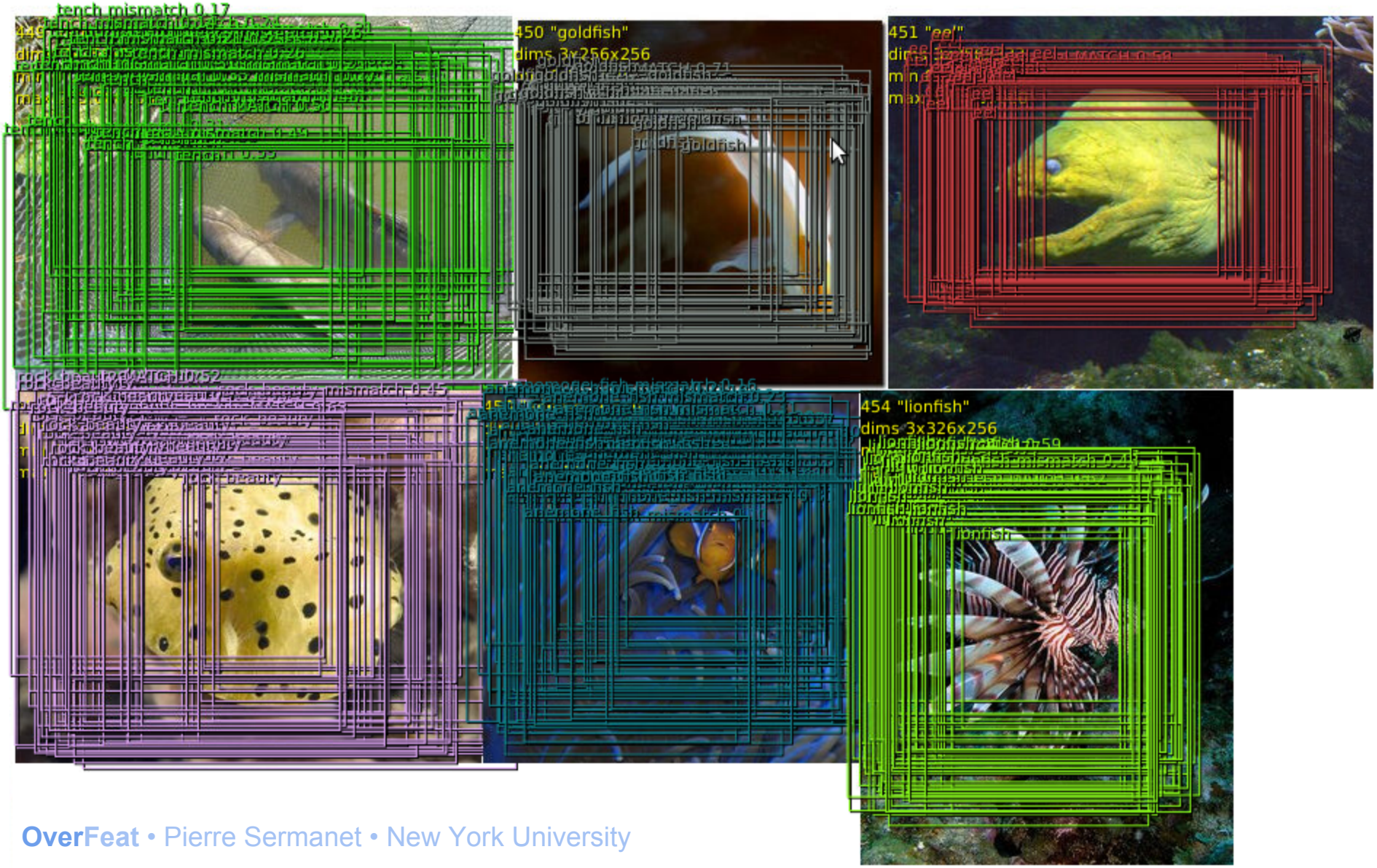


Detection / Localization

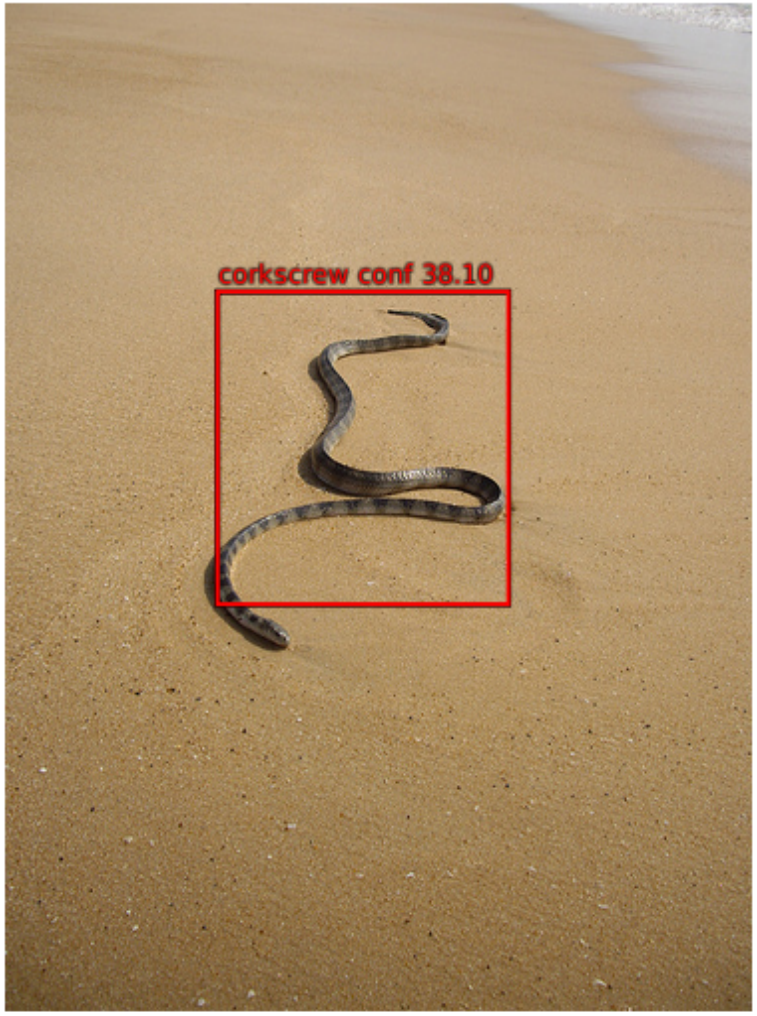


Detection / Localization

Detection / Localization



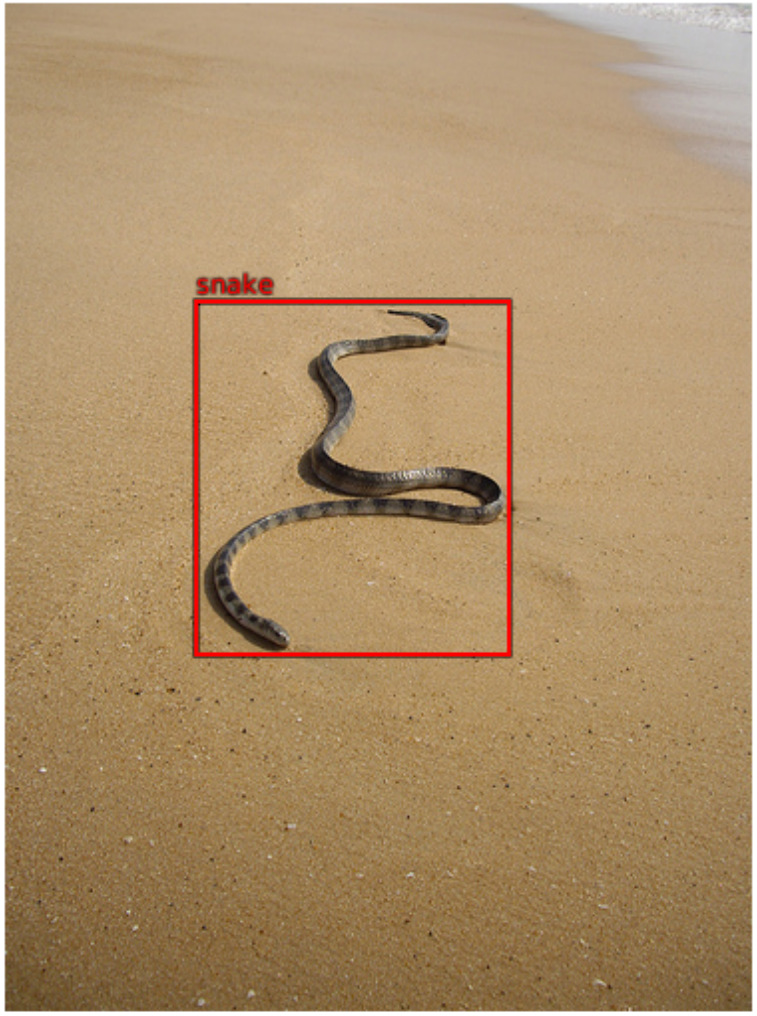
Detection: Failures that make sense



Top predictions:

corkscrew (confidence 38.1)

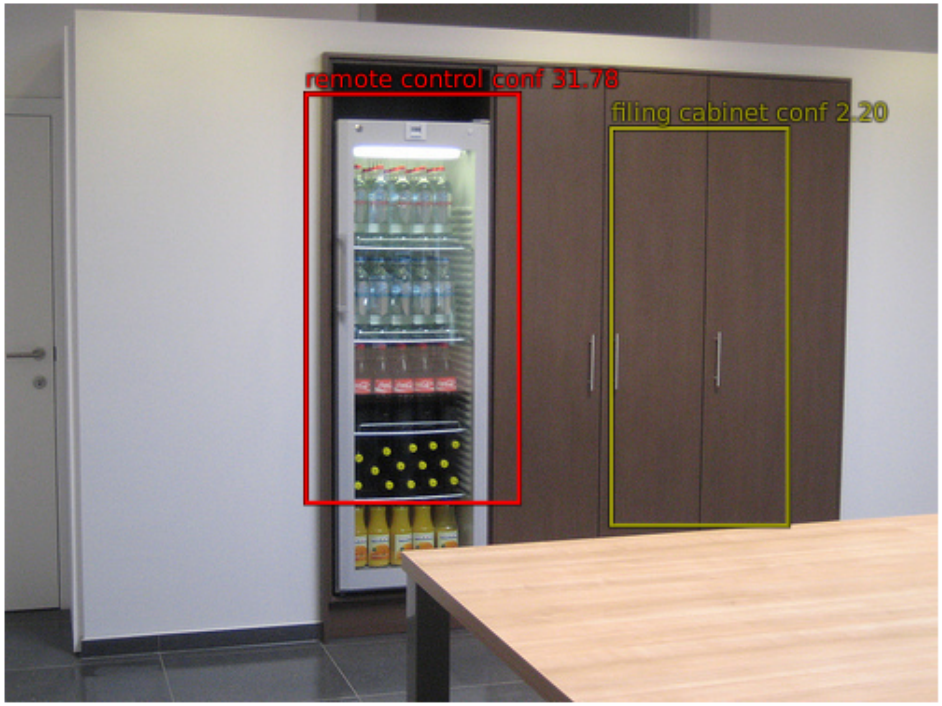
ILSVRC2012_val_00000324.JPEG



Groundtruth:

snake

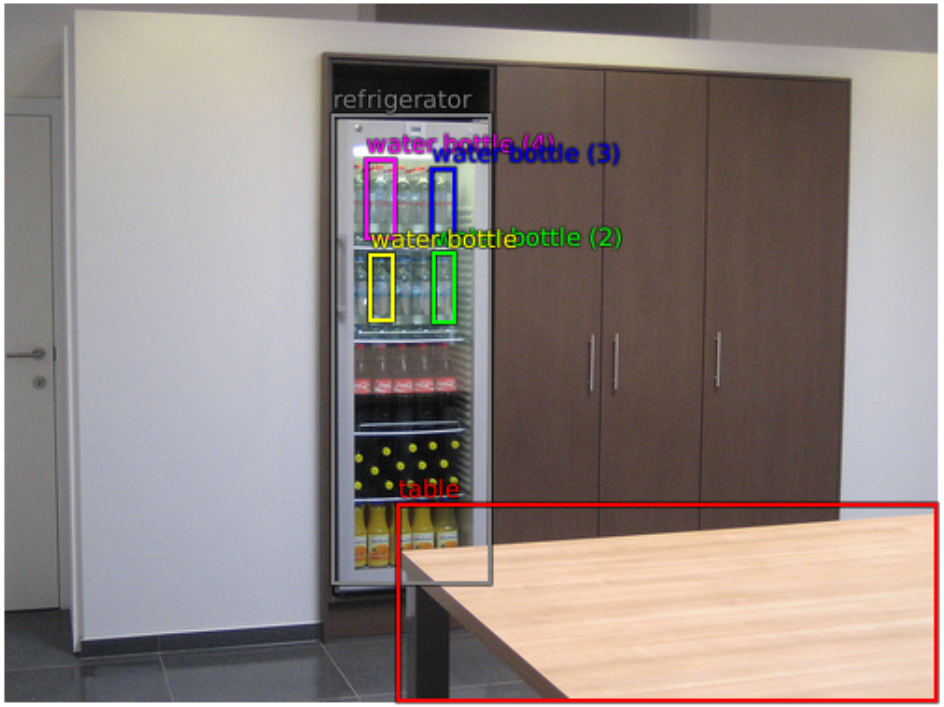
Detection: Failures that make sense



Top predictions:

remote control (confidence 31.8)
filing cabinet (confidence 2.2)

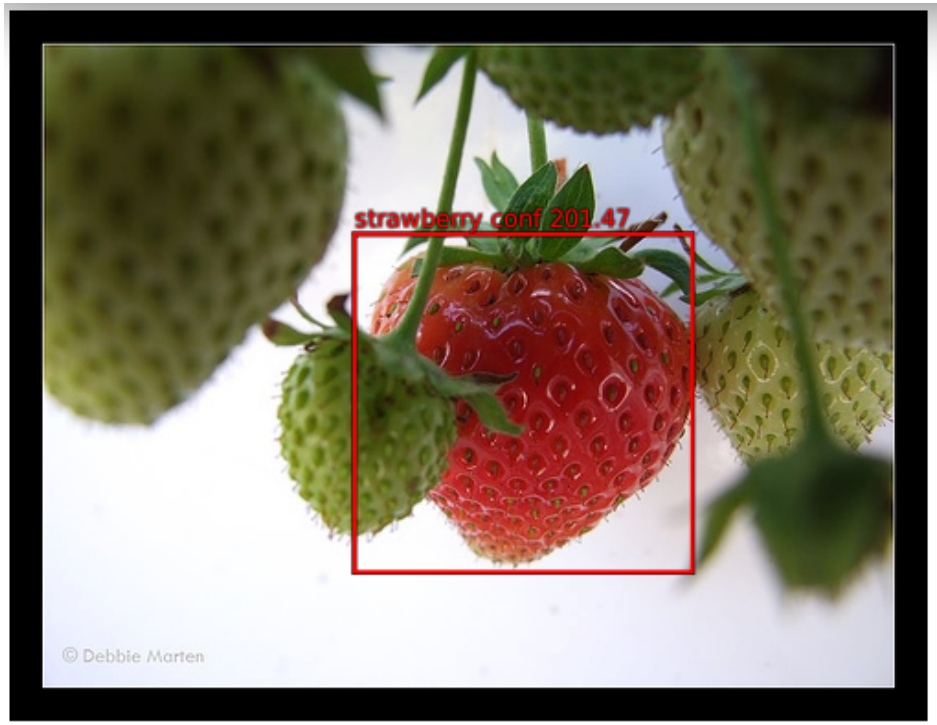
ILSVRC2012_val_00000331.JPEG



Groundtruth:

table
water bottle
water bottle (2)
water bottle (3)
water bottle (4)
refrigerator

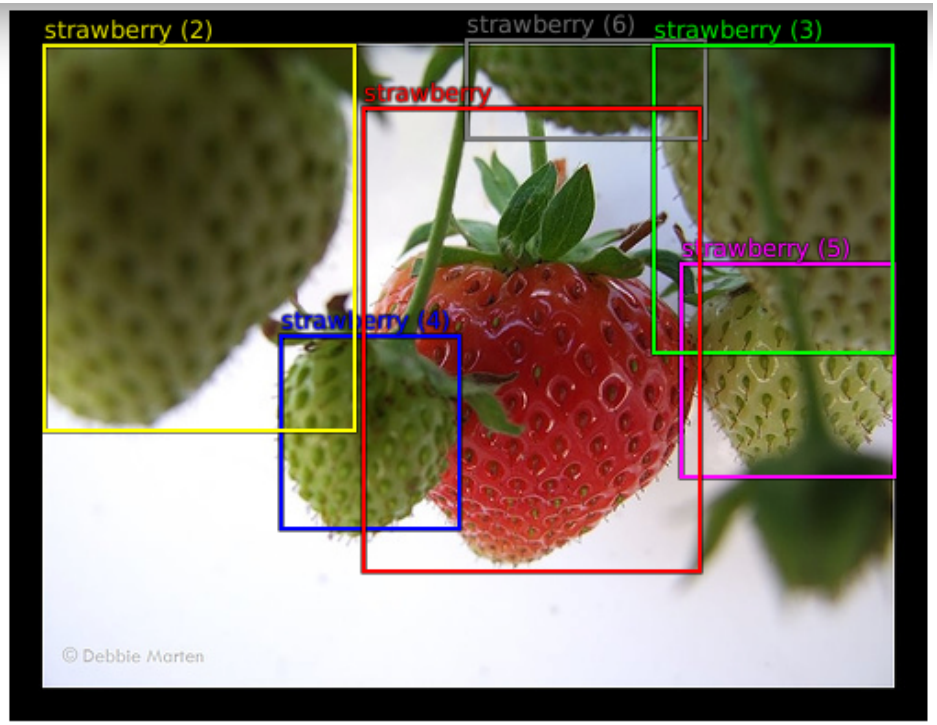
Detection: Interesting Failures



Top predictions:

strawberry (confidence 201.5)

ILSVRC2012_val_00000099.JPEG



Groundtruth:

strawberry
strawberry (2)
strawberry (3)
strawberry (4)
strawberry (5)
strawberry (6)

Interesting detections

Top predictions:

microwave (confidence 5.6)

refrigerator (confidence 2.5)

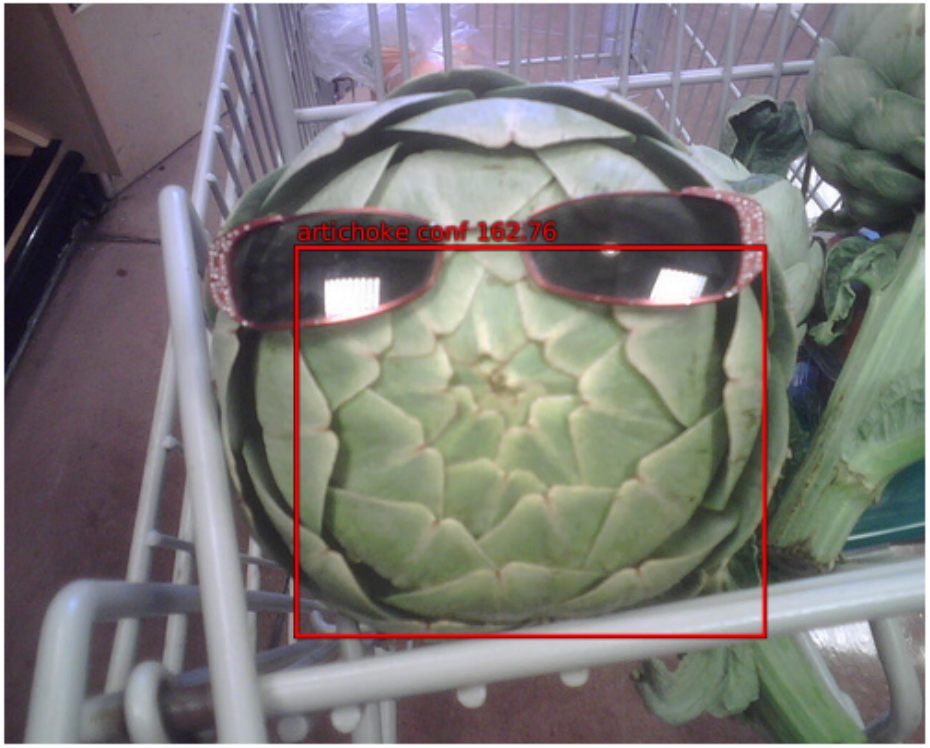
ILSVRC2012_val_00000519.JPEG

Groundtruth:

bowl

microwave

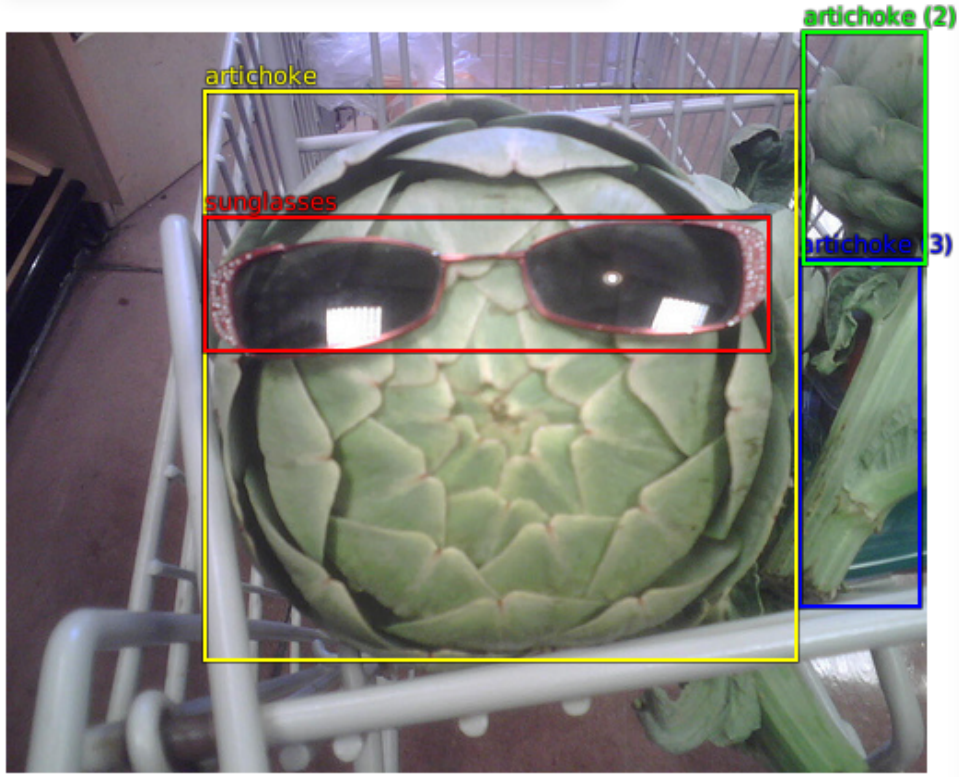
Interesting detections



Top predictions:

artichoke (confidence 162.8)

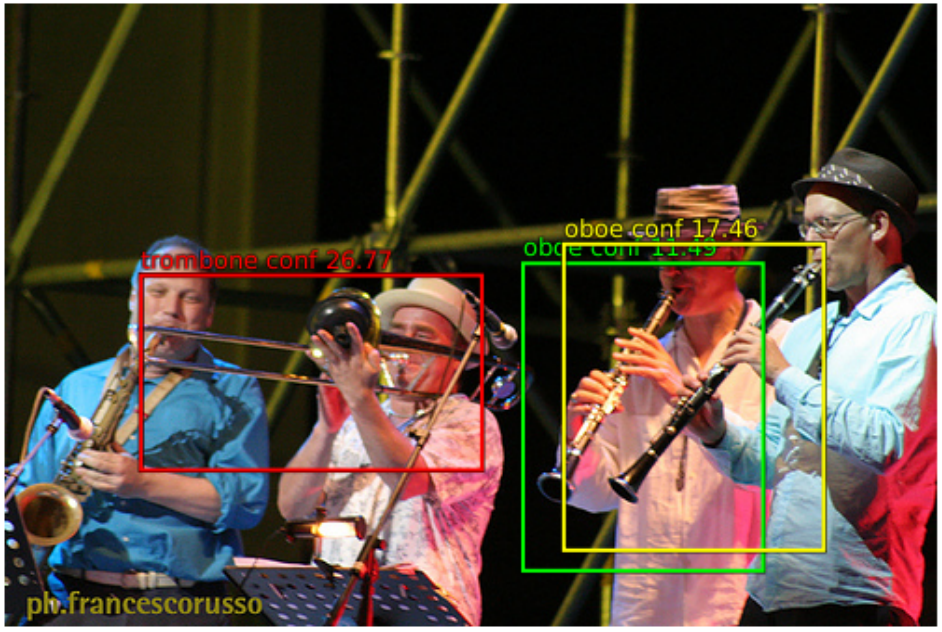
ILSVRC2012_val_00001549.JPEG



Groundtruth:

sunglasses
artichoke
artichoke (2)
artichoke (3)

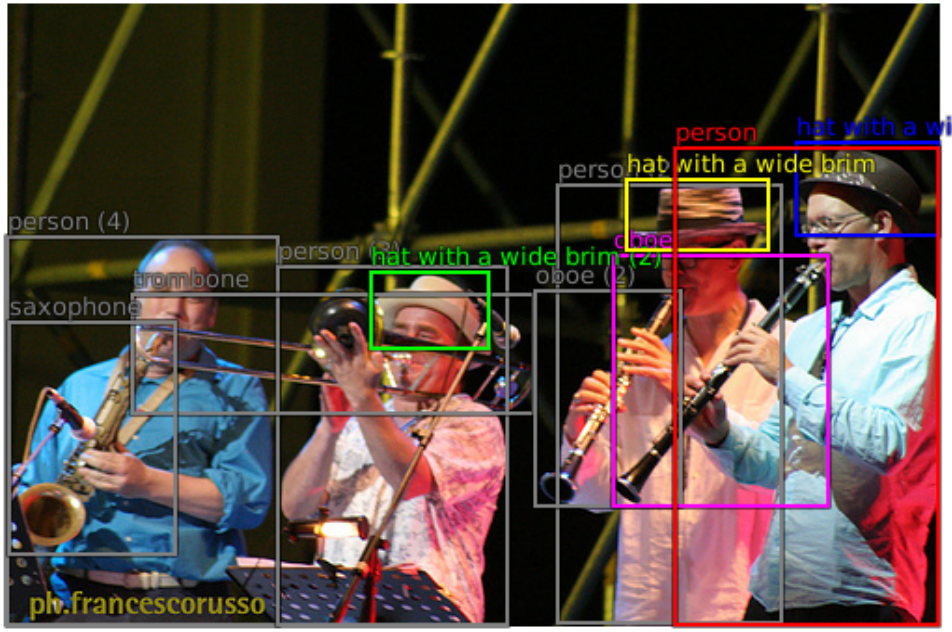
Some hard ones



Top predictions:

trombone (confidence 26.8)
oboe (confidence 17.5)
oboe (confidence 11.5)

ILSVRC2012_val_00000614.JPEG



Groundtruth:

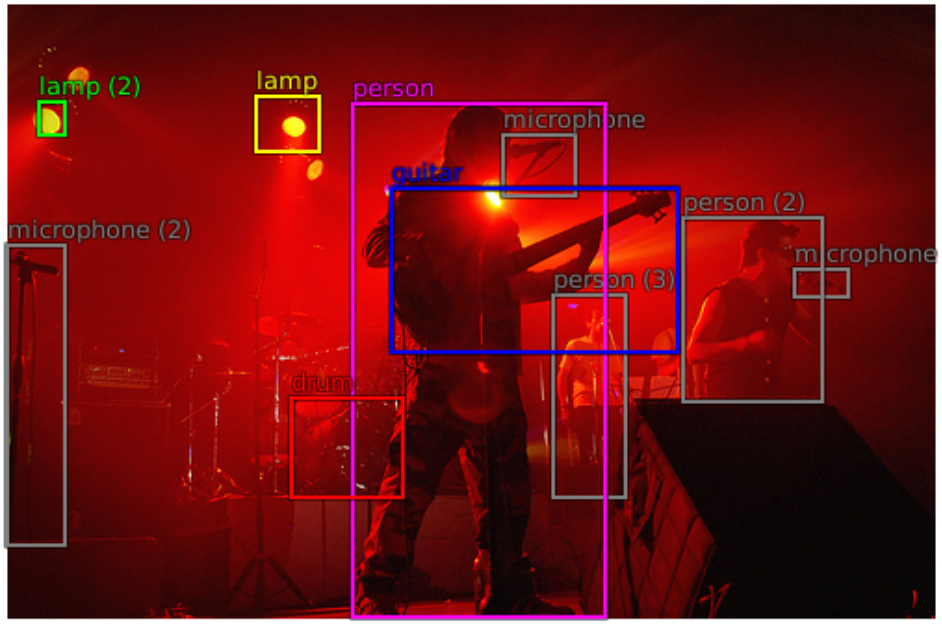
person
hat with a wide brim
hat with a wide brim (2)
hat with a wide brim (3)
oboe
oboe (2)
saxophone
trombone
person (2)
person (3)

Some hard ones

Top predictions:

person (confidence 6.0)

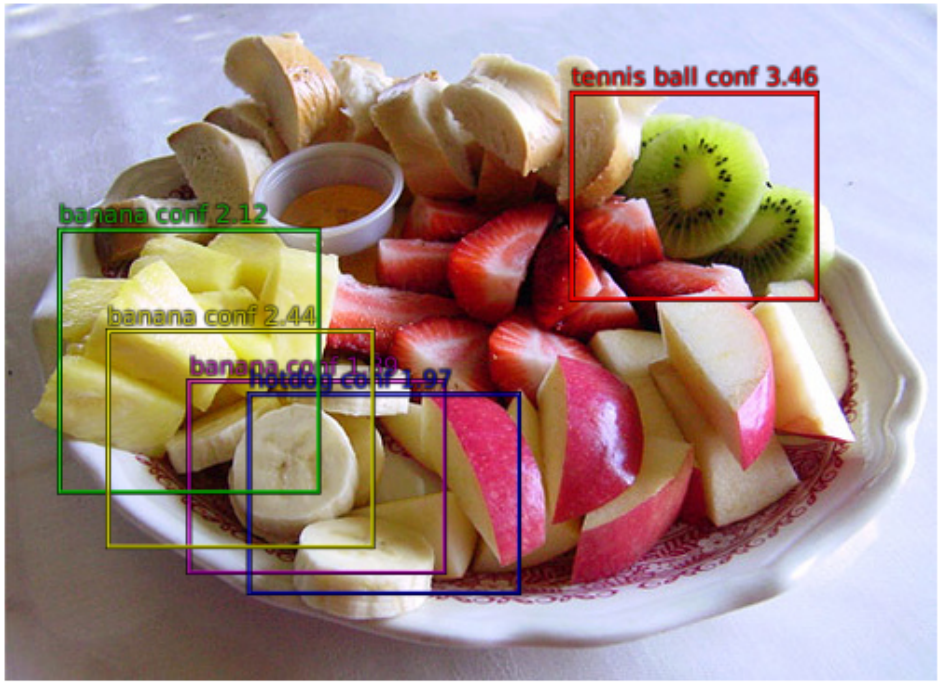
ILSVRC2012_val_00001273.JPEG



Groundtruth:

drum
lamp
lamp (2)
guitar
person
person (2)
person (3)
microphone
microphone (2)
microphone (3)

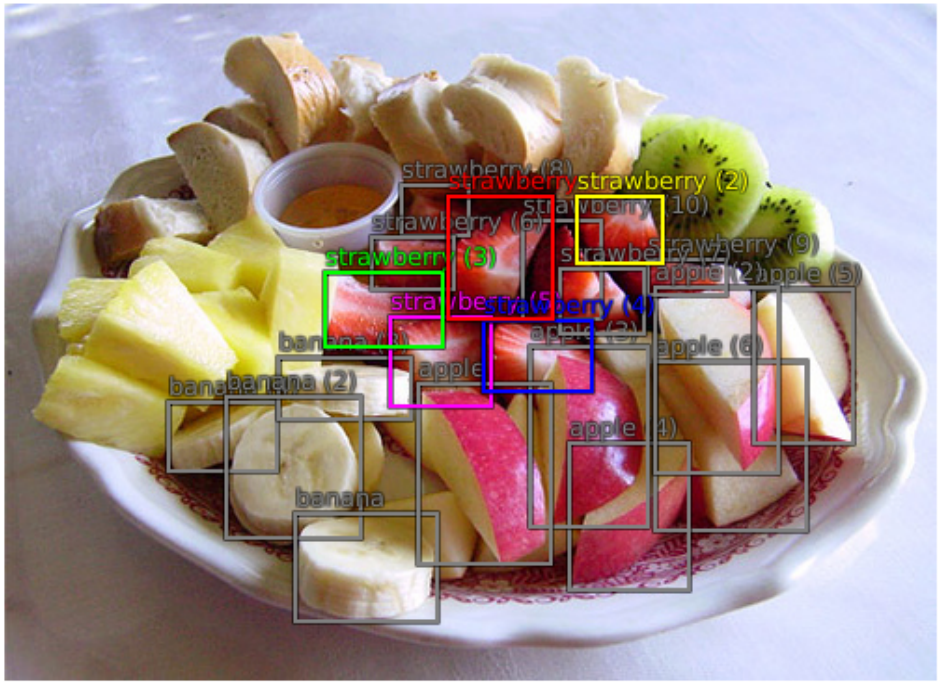
Some hard ones



Top predictions:

tennis ball (confidence 3.5)
banana (confidence 2.4)
banana (confidence 2.1)
hotdog (confidence 2.0)
banana (confidence 1.9)

ILSVRC2012_val_00000320.JPEG

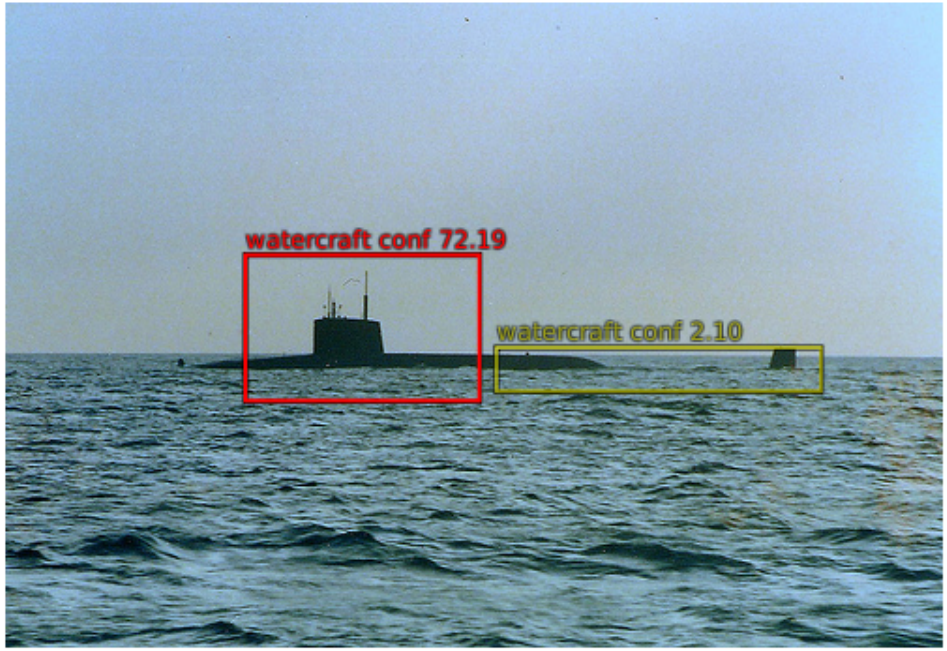


Groundtruth:

strawberry
strawberry (2)
strawberry (3)
strawberry (4)
strawberry (5)
strawberry (6)
strawberry (7)
strawberry (8)
strawberry (9)
strawberry (10)

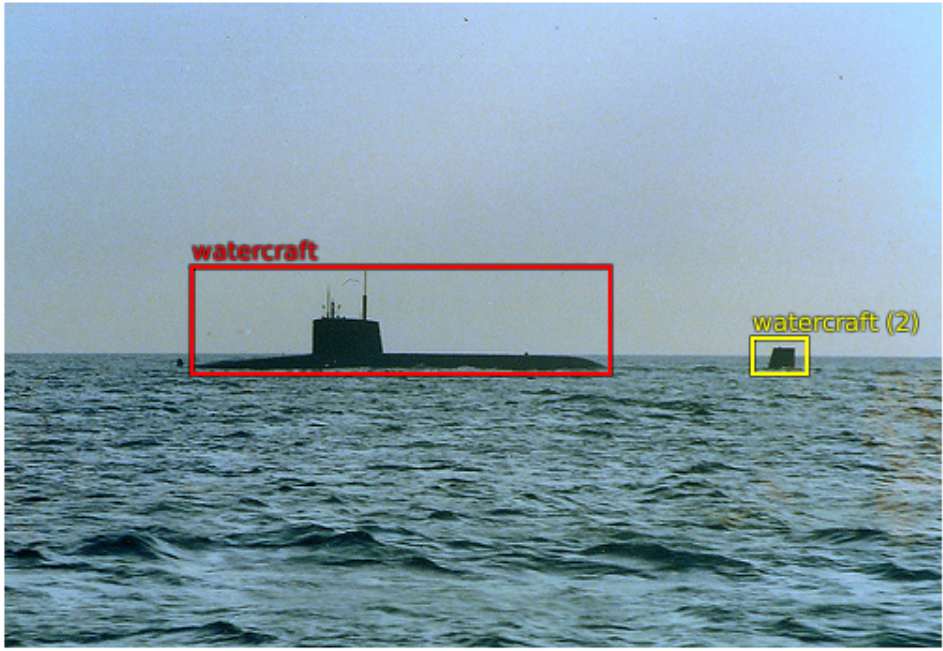
Some hard ones

- **Moving to heat maps measure?**



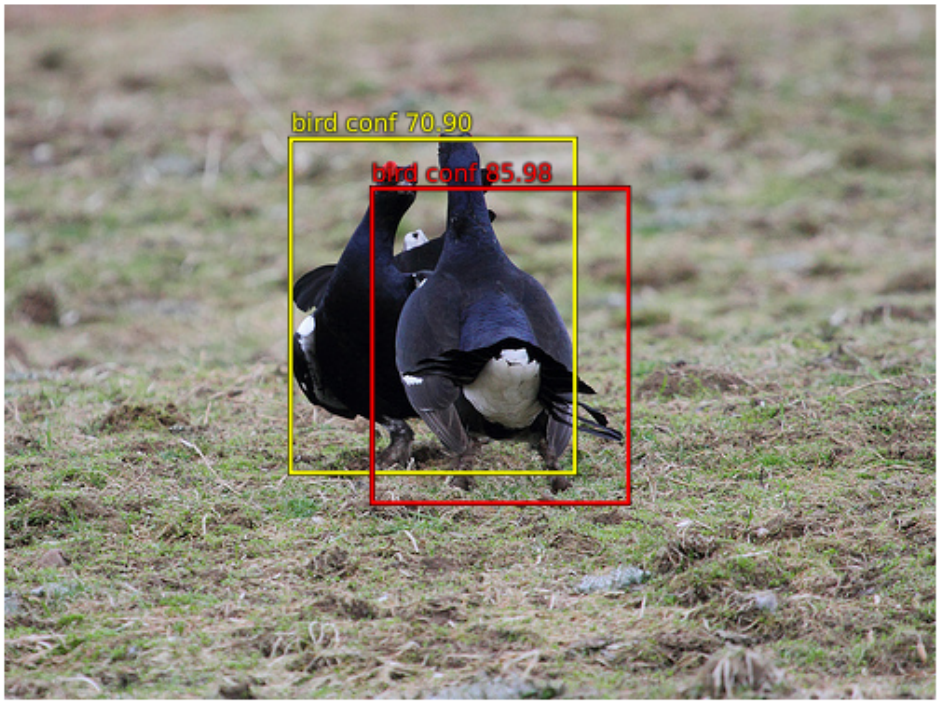
Top predictions:
watercraft (confidence 72.2)
watercraft (confidence 2.1)

ILSVRC2012_val_00000623.JPEG



Groundtruth:
watercraft
watercraft (2)

Some easy ones

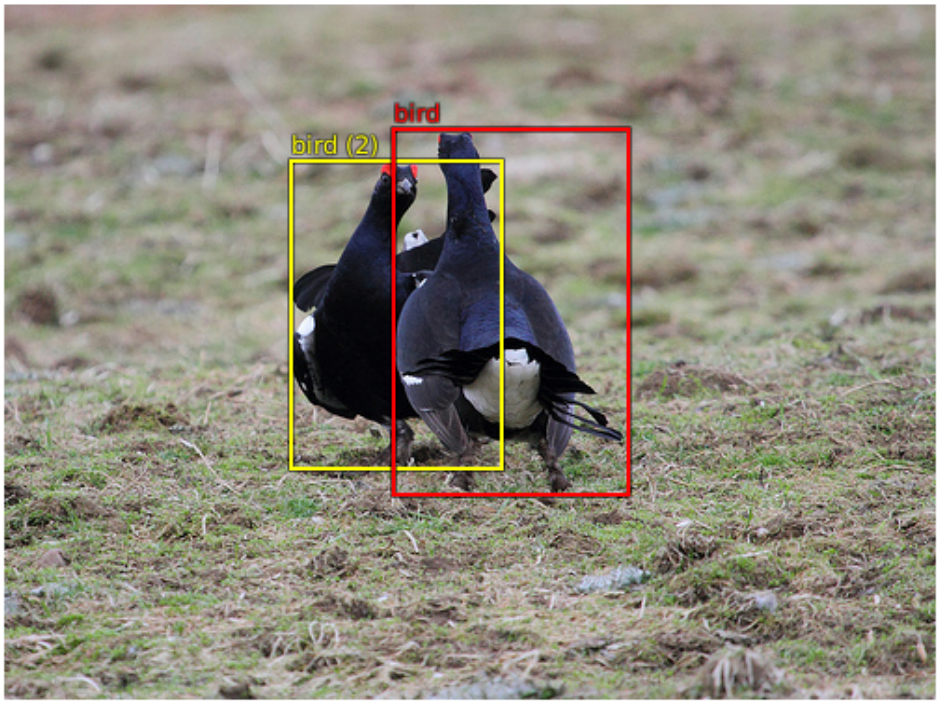


Top predictions:

bird (confidence 86.0)

bird (confidence 70.9)

ILSVRC2012_val_00001136.JPEG

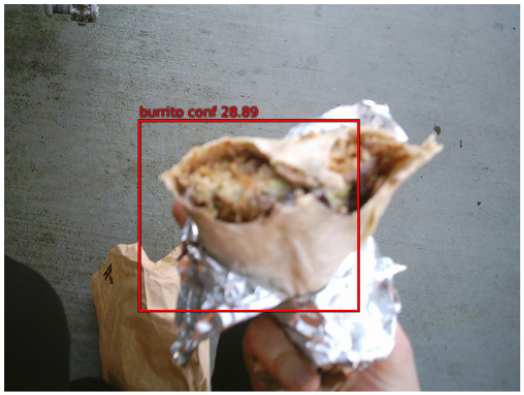


Groundtruth:

bird

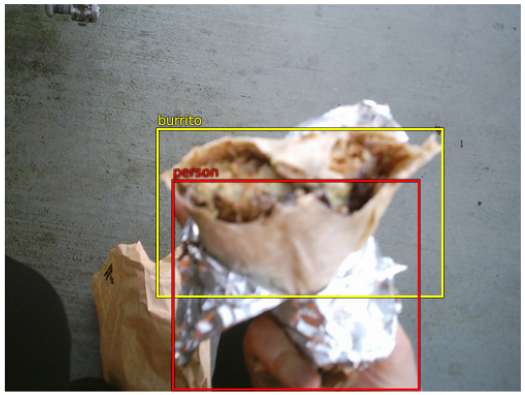
bird (2)

Burrito Detector



Top predictions:
burrito (confidence 28.9)

ILSVRC2012_val_00000572.JPEG



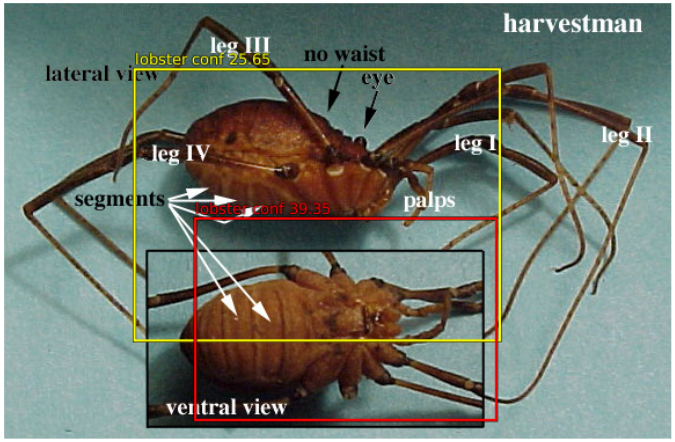
Groundtruth:
person
burrito

Top predictions:
burrito (confidence 17.4)

ILSVRC2012_val_00000606.JPEG

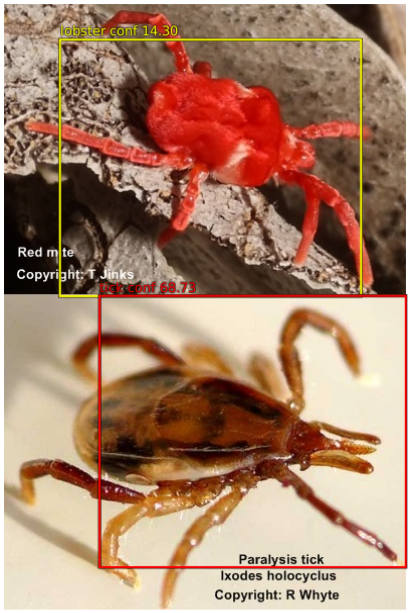
Groundtruth:
burrito
burrito (2)

Tick detector



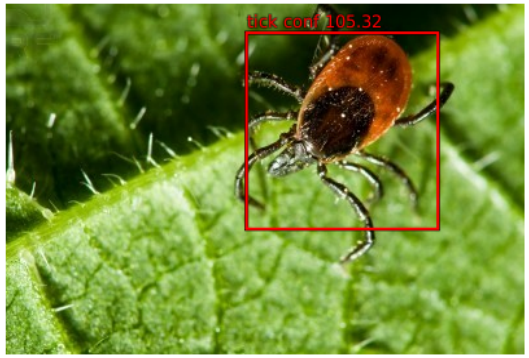
Top predictions:
lobster (confidence 39.3)
lobster (confidence 25.6)

ILSVRC2012_val_00034020.JPEG



Top predictions:
tick (confidence 68.7)
lobster (confidence 14.3)

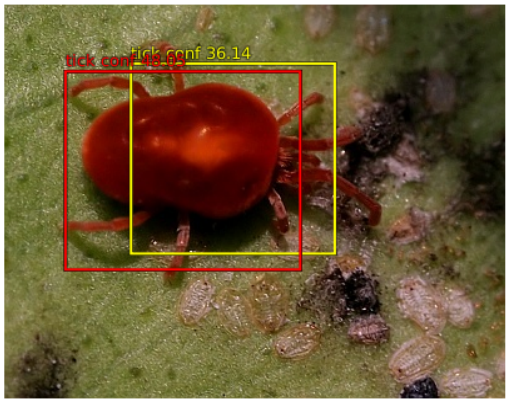
ILSVRC2012_val_00030916.JPEG



Top predictions:
tick (confidence 105.3)

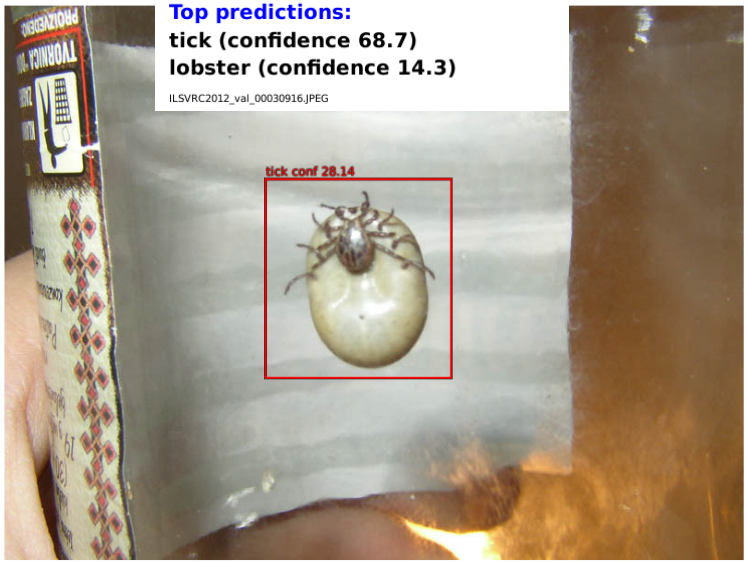
ILSVRC2012_val_00001766.JPEG

Groundtruth:
tick

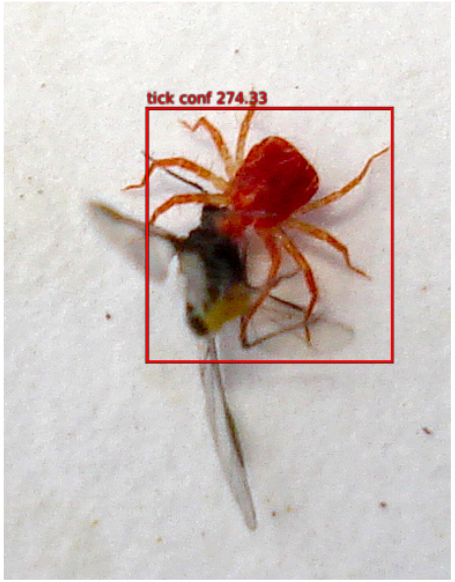


Top predictions:
tick (confidence 48.1)
tick (confidence 36.1)

ILSVRC2012_val_00023564.JPEG



Top predictions:
tick (confidence 28.1)

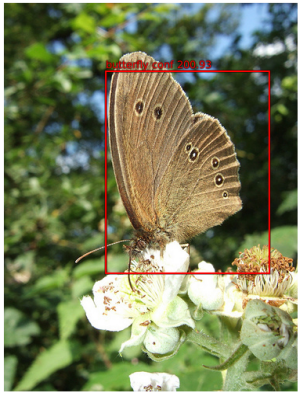


Top predictions:
tick (confidence 274.3)

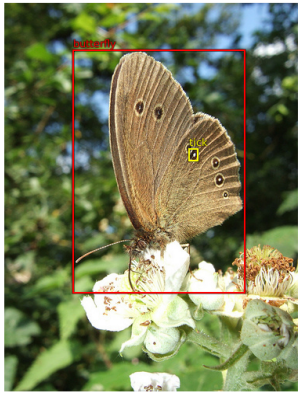
ILSVRC2012_val_00001760.JPEG

Grou
tick
bee

Tick Groundtruth

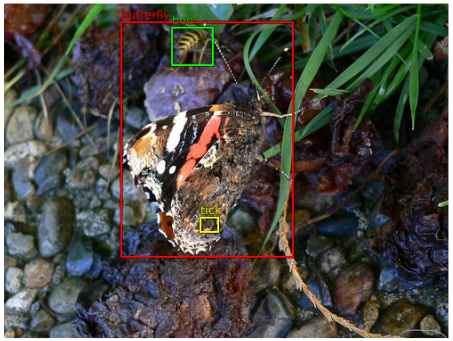


Top predictions:
butterfly (confidence 200.9)
ILSVRC2012_val_00035074.JPEG

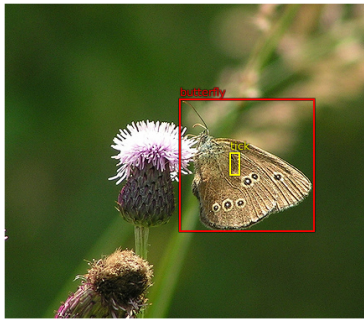


Groundtruth:
butterfly
tick

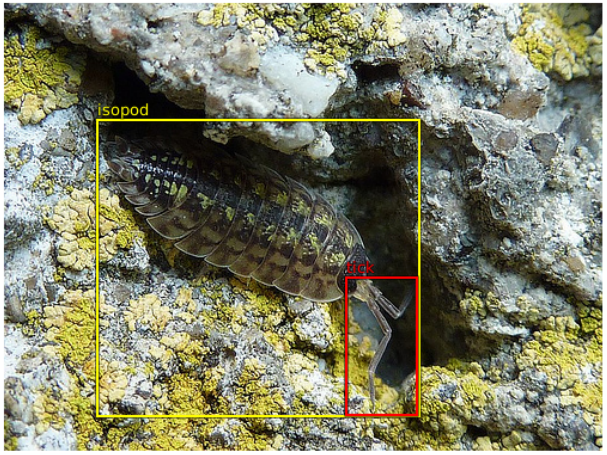
Top predictions:
butterfly (confidence 15.8)
ILSVRC2012_val_00012764.JPEG



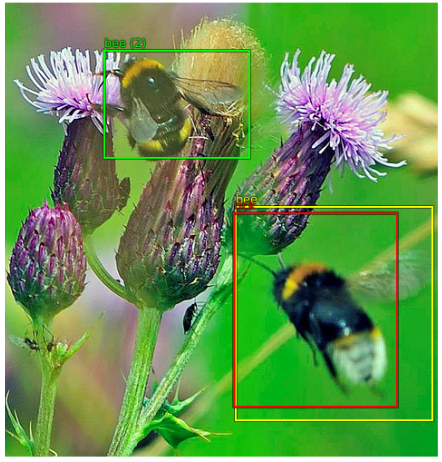
Groundtruth:
butterfly
tick
bee



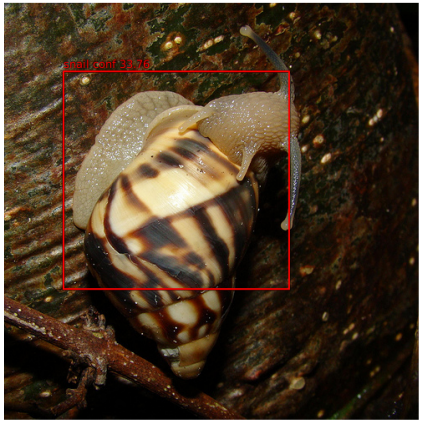
Groundtruth:
butterfly
tick



Groundtruth:
tick
isopod



Groundtruth:
tick
bee
bee (2)



Top predictions:
snail (confidence 33.8)
ILSVRC2012_val_00023206.JPEG

Groundtruth:
snail
tick

- **Coming up next week:**
  - release of our feature extractor (forward only)
    - based on TH tensor library (in C)
    - wrappers: torch, python, matlab
    - extract features at any layer up to 1000-classifier
    - fast in-house cuda code not released
  - other libs:
    - cuda-conv (Alex Krizhevsky)
    - DeCAF (A Deep Convolutional Activation Feature for Generic Visual Recognition, berkeley)

Demos

- **Live demos:**
  - 1000-class classification
  - 1-shot learning

- **Speed:**
  - CPU: ~1 fps
  - GPU: ~10 fps (proprietary cuda code)
  - gpu code is fast in mini-batch mode but also for small batches