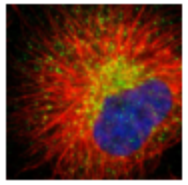
Review my approach for
Human Protein Atlas - Single Cell Classification
Kaggle Competition



Human Protein Atlas - Single Cell Classification

Find individual human cell differences in microscope images

Featured · Code Competition · 3 days ago

15/757
Top 2%

Summary

1. I used 2 stages approach

   1st : image classification for getting CAM

   2nd : Semantic segmentation with pseudo label from 1st stage CAM

2. My initial plan SC-CAM x Puzzle CAM did not work.

3. Successfully train 2nd stage semantic segmentation

4. Compared to the TOP 1 solution

   - use the same 2 stages pseudo label approach

   - but each stage for TOP 1 solution got much better score.

     TOP 1 solution was evolving a research result for this cell problem.

Outline

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1. Introduction to “Human Protein Atlas - Single Cell Classification”
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    - CAM/Puzzle CAM approach
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6. Check top 1 solution

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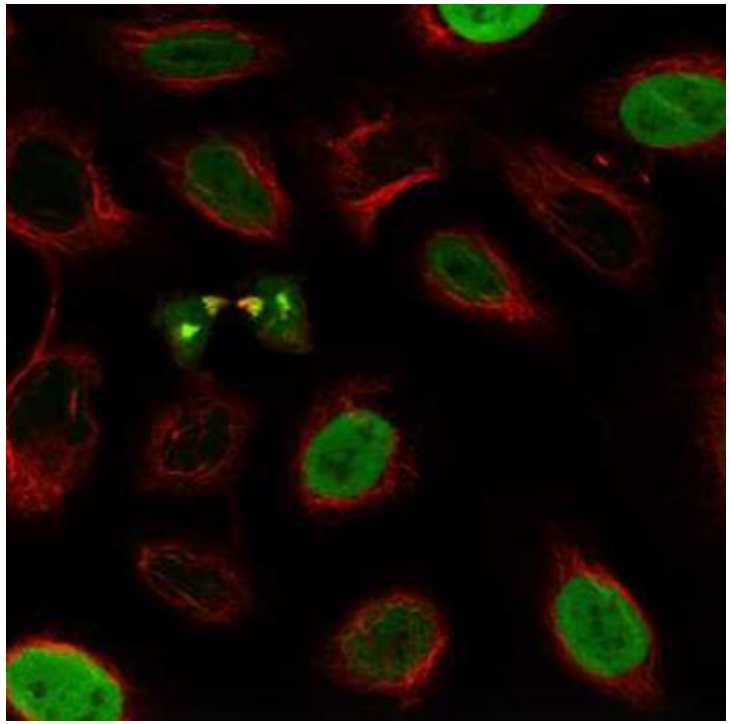
Human Protein Atlas - Single Cell Classification

Weakly Instance segmentation for proteins
Metric: mAP for 19 proteins

Input:
1728x1728 ~ 3072x3072
4ch cell image



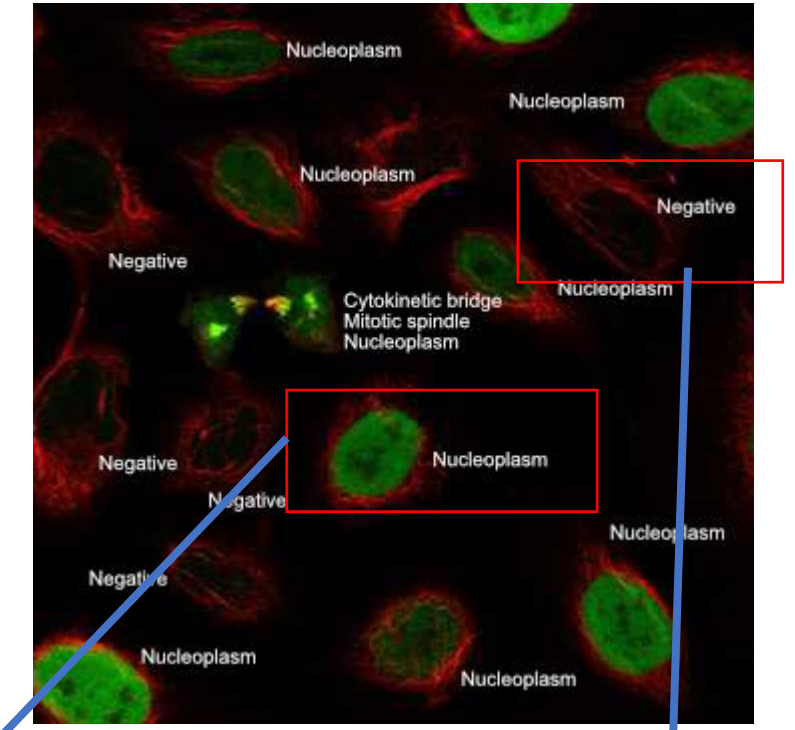
Provided label:
Image level class label

"Nucleoplasm",

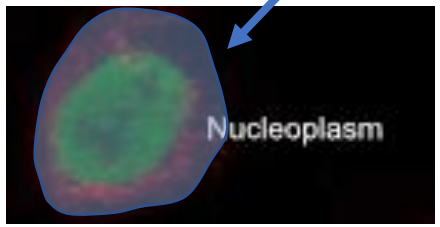
"Cytokinetic bridge",

"Mitotic spindle"

Required Prediction:
Cell instance mask and its class label



Mask & Label



Mask & Label

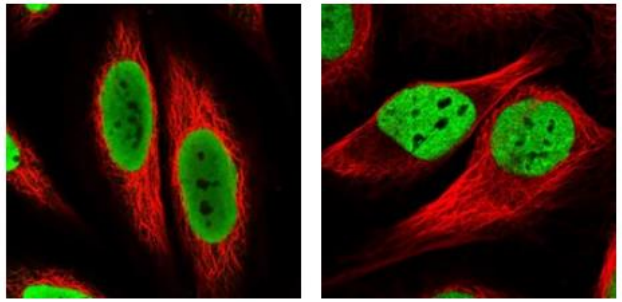
Figures from
https://www.kaggle.com/lnhtrang/single-cell-patterns/notebook

Human Protein Atlas - Single Cell Classification

Protein Class: 19 classes
For more details about protein
please check -> https://www.kaggle.com/lnhtrang/single-cell-patterns/notebook

0. Nucleoplasm

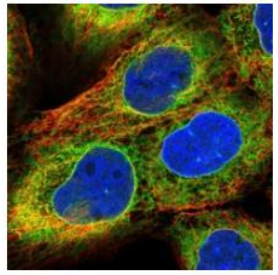
The nucleus is found in the center of cell and can be identified with the help of the signal in the blue nucleus channel. A staining of the nucleoplasm may include the whole nucleus or of the nucleus without the regions known as nucleoli (Class 2).



More examples

6. Endoplasmic reticulum

The endoplasmic reticulum (ER) is recognized by a network-like staining in the cytosol, which is usually stronger close to the nucleus and weaker close to the edges of the cell. The ER can be identified with the help of the staining in the yellow ER channel.

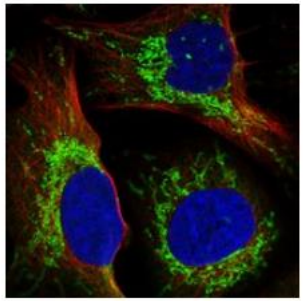


More examples

Figures from
https://www.kaggle.com/lnhtrang/single-cell-patterns/notebook

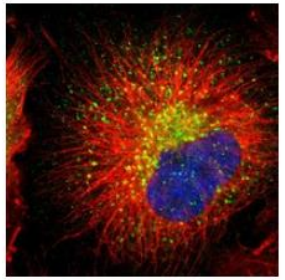
14. Mitochondria

Mitochondria are small rod-like units in the cytosol, which are often distributed in a thread-like pattern along microtubules.



17. Vesicles and punctate cytosolic patterns

This class includes small circular compartments in the cytosol: Vesicles, Peroxisomes (lipid metabolism), Endosomes (sorting compartments), Lysosomes (degradation of molecules or eating up dead molecules), Lipid droplets (fat storage), Cytoplasmic bodies (distinct granules in the cytosol). They are highly dynamic, varying in numbers and size in response to environmental and cellular cues. They can be round or more elongated.



Vesicles | Peroxisomes | Endosomes | Lysosomes | Lipid droplets | Cytoplasmic bodies

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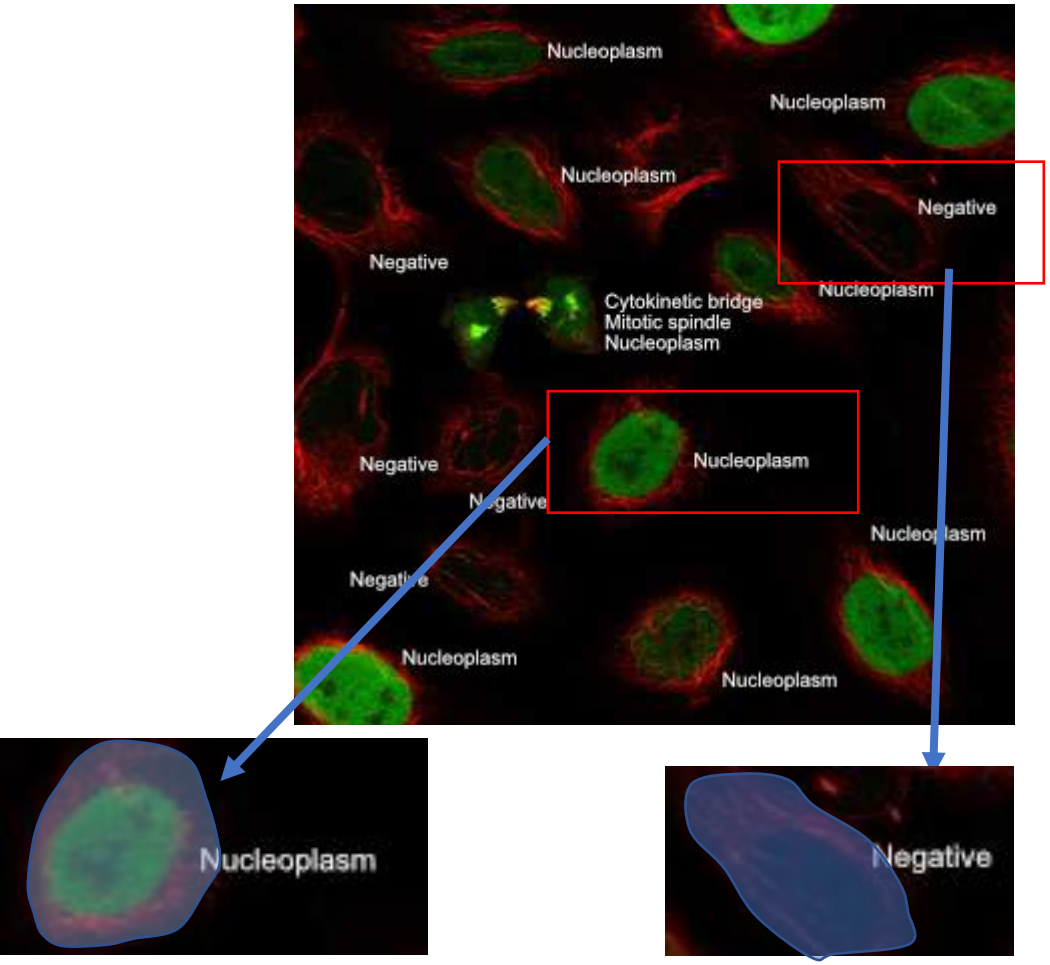
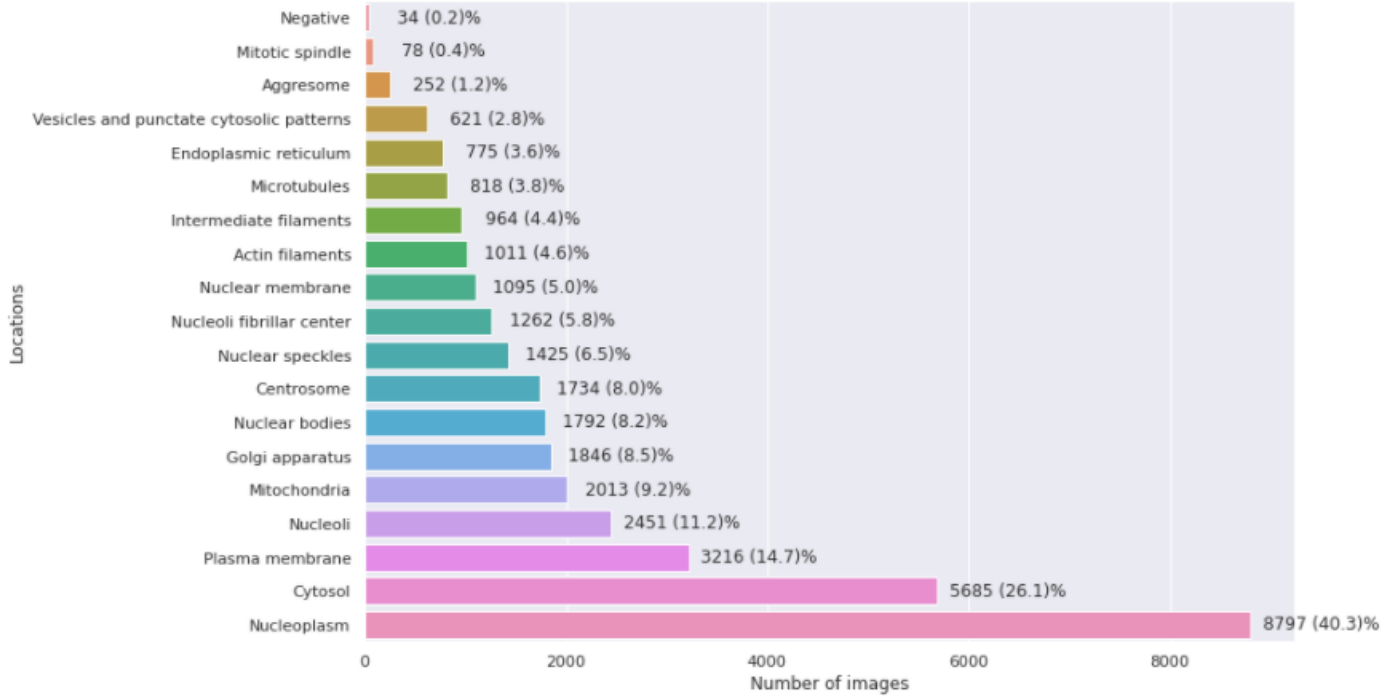
Main challenges

1. Weakly Instance segmentation. Few research papers.
2. Large image size, 1728x1728 ~ 3072x3072
3. Unbalanced class dataset

Required Prediction:
Class for each cell and cell instance mask



Class distribution

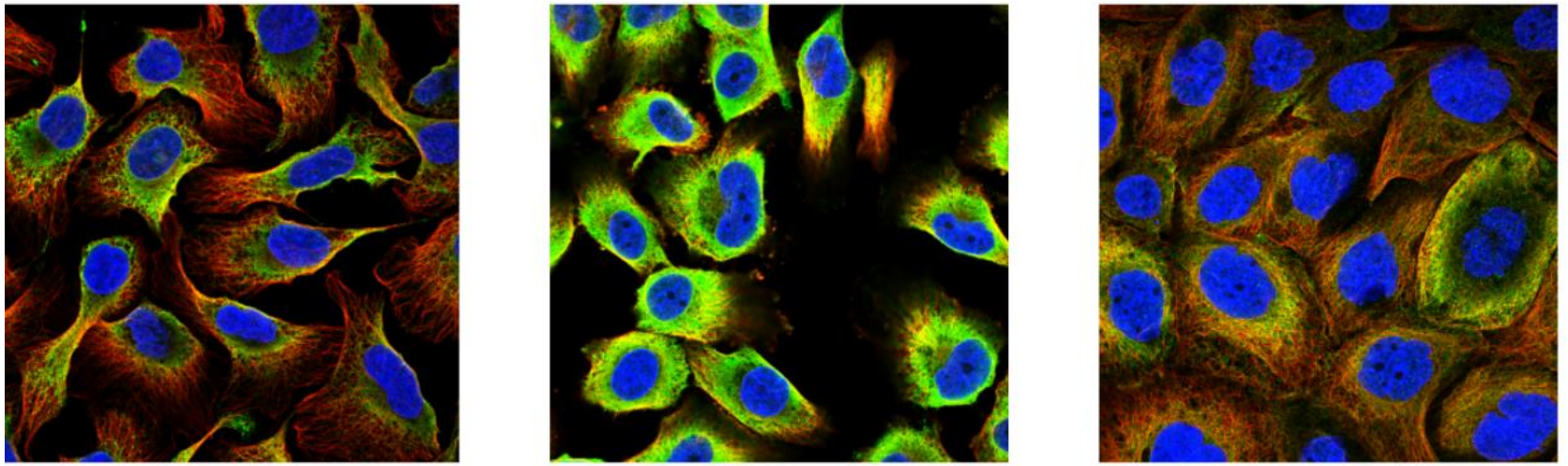


From https://www.kaggle.com/lnhtrang/single-cell-patterns/notebook#Label-distribution-in-the-training-set

Available Tool : HPA-Cell-Segmentation

Good cell instance segmentation model is available.
https://github.com/CellProfiling/HPA-Cell-Segmentation
-> We can focus on protein classification for each mask from this tool.

Input:



HPA-Cell-Segmentation:

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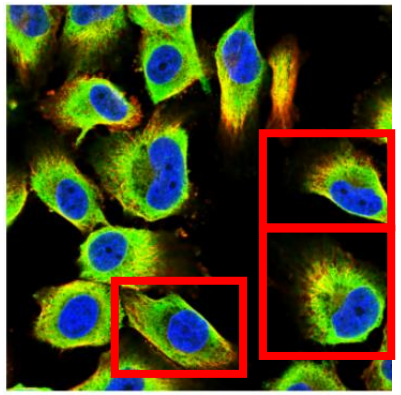
Two major approaches at Kaggle

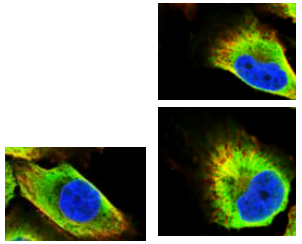
Kaggle public approaches disclosed during this competition.

1. Cellwise Approach, Public score ~ mAP 0.35
2. Class Activation Map, CAM, Public score ~ mAP 0.34

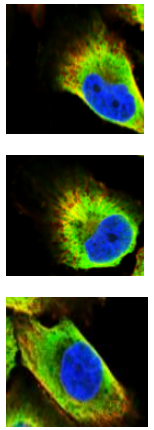
Cellwise Approach



Crop



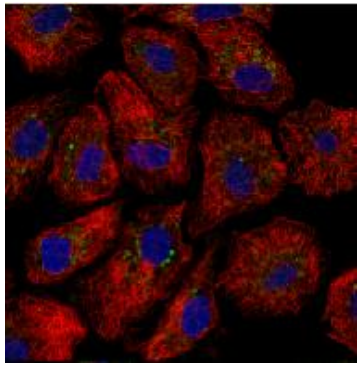
Resize~224x224

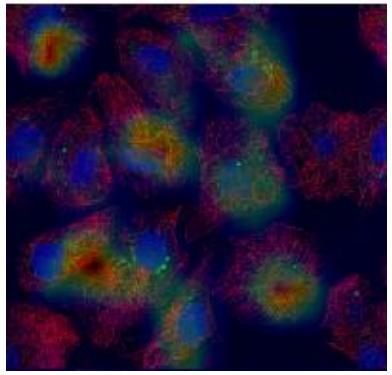


Cell Dataset

CNN classification

Class Activation Maping, CAM:



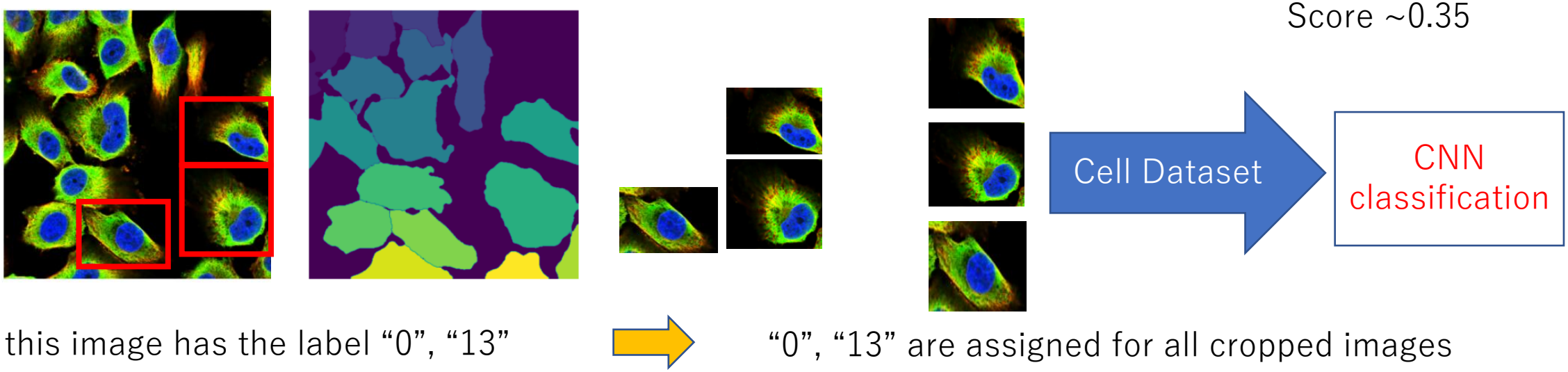


1. Cellwise Approach

Pros:
- easy to train
- keep fine resolution with cropping.
  Original input size is ~ 2048x2048 and really hard to train as it is.

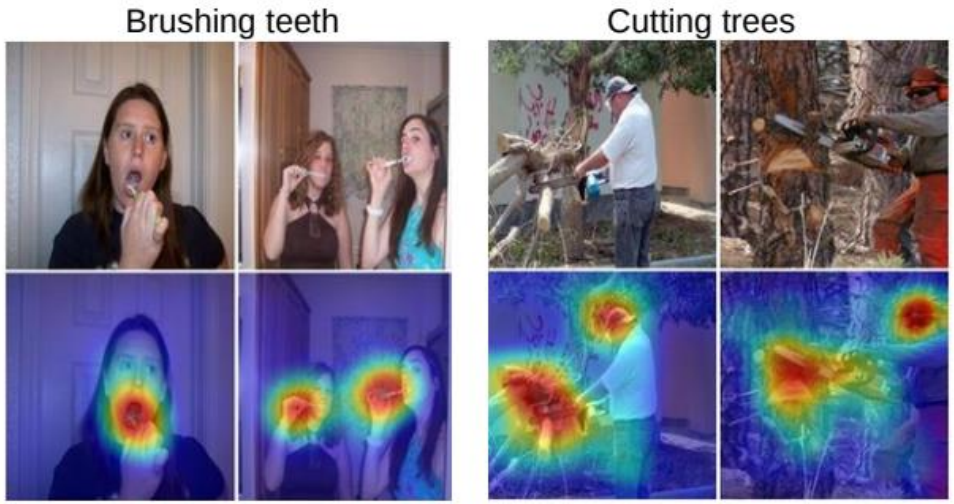
Cons:
- noisy label assignment for multi labeled image.
  We have only image level class label, so after cropping we cannot avoiding labeling all crop images with the same image label.

Cellwise Approach



2. CAM Approach: CAM?

Class Activation Mapping, CAM
https://arxiv.org/abs/1512.04150
Object localization method with image level class label
-> but at this method, only focus discriminative part not whole part



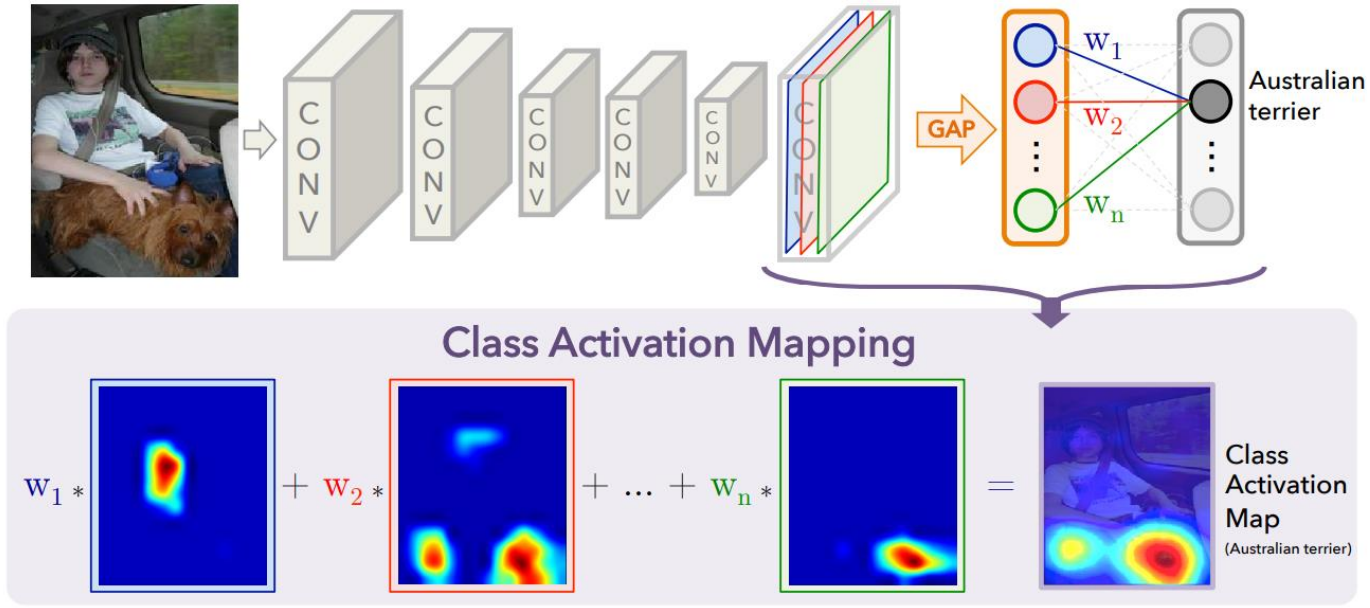


Figure 2. Class Activation Mapping: the predicted class score is mapped back to the previous convolutional layer to generate the class activation maps (CAMs). The CAM highlights the class-specific discriminative regions.

2. CAM Approach: Puzzle CAM

Puzzle-CAM: Improved localization via matching partial and full features
https://arxiv.org/abs/2101.11253

Splitting input image like tile, and training each split images and original image with reconstruction loss .

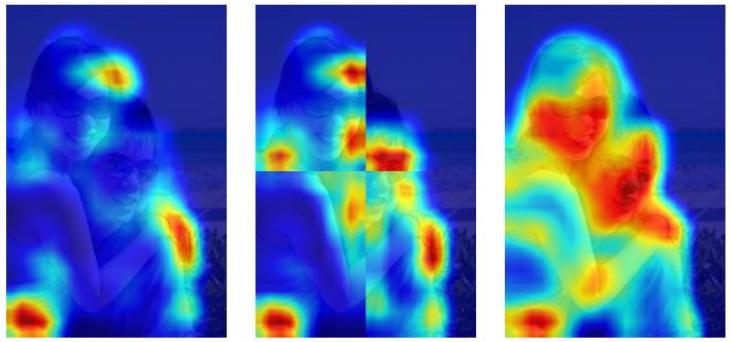


Fig. 1: CAMs generated from tiled and original images: (a) conventional CAMs from the original image, (b) generated CAMs from the tiled images, and (c) predicted CAMs by the proposed Puzzle-CAM.

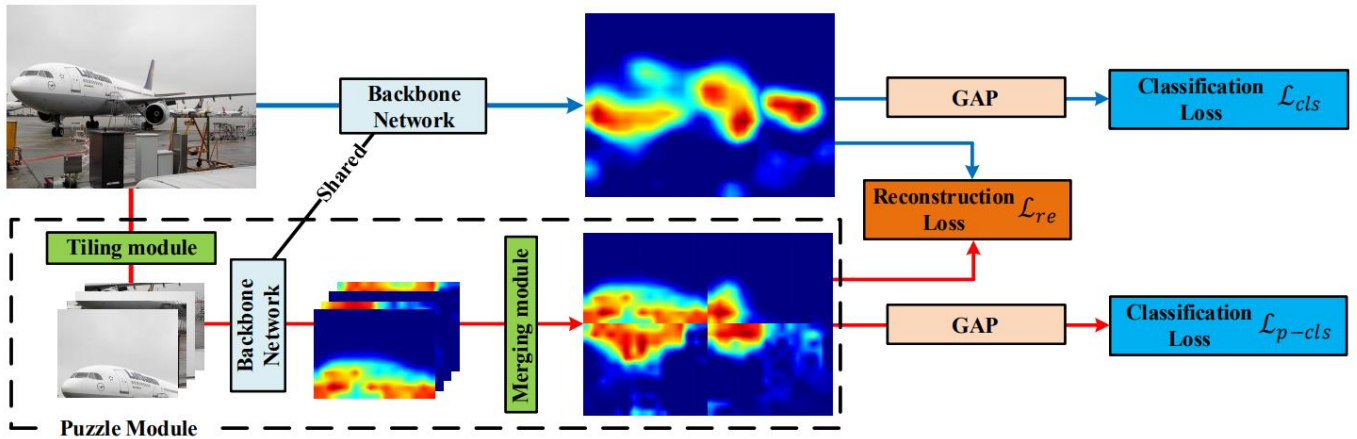


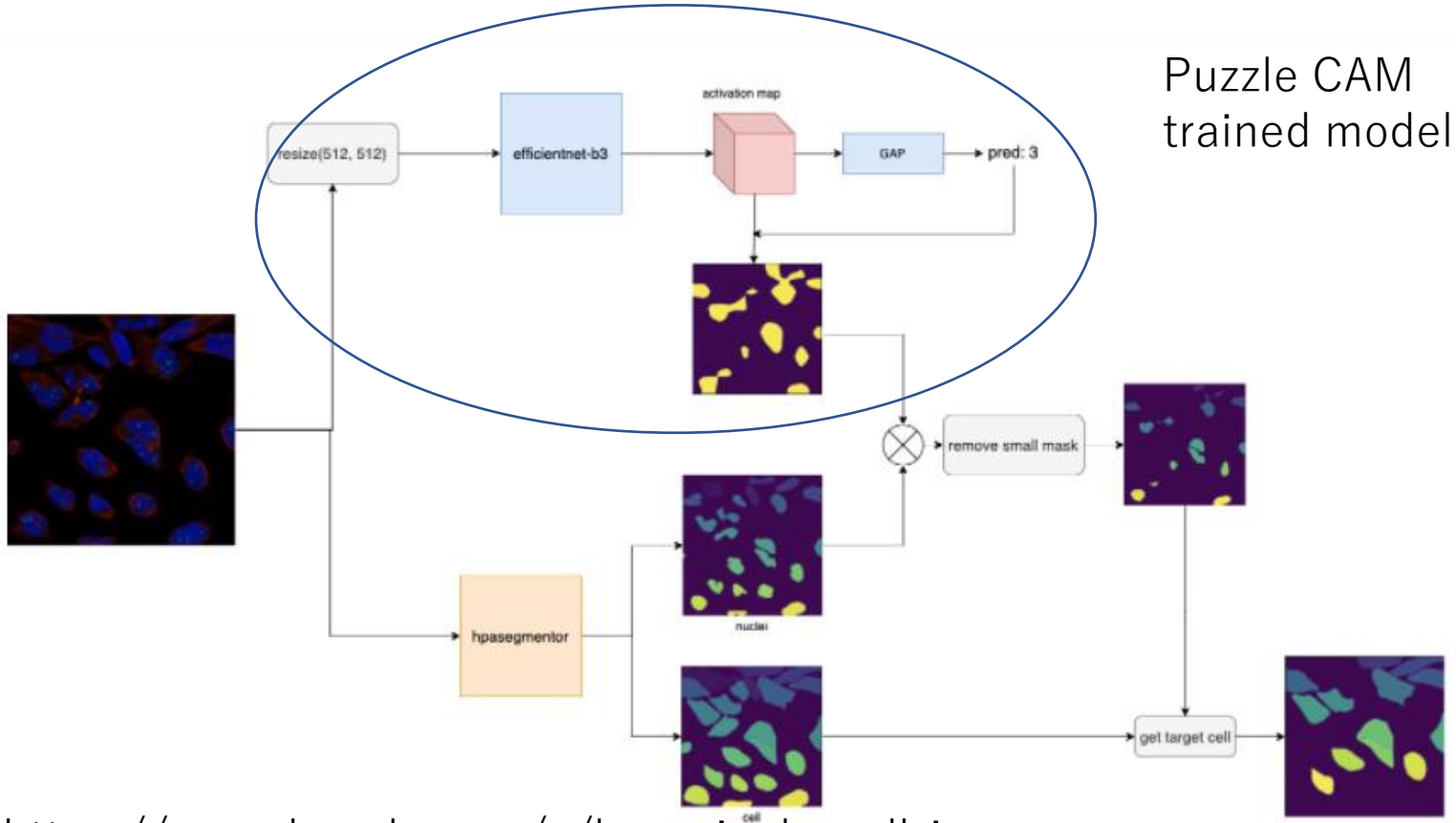
Fig. 2: The overall architecture of the proposed Puzzle-CAM showing the integration of reconstructing regularization and the puzzle module.

from https://arxiv.org/abs/2101.11253

2. CAM Approach: Puzzle CAM

Pros:
- no any noise at training

Cons:
- does not keep original resolution ~2048x2048
- Puzzle CAM is still not perfect for localization.



Puzzle CAM trained model

Score ~0.34

From https://www.kaggle.com/c/hpa-single-cell-image-classification/discussion/217395

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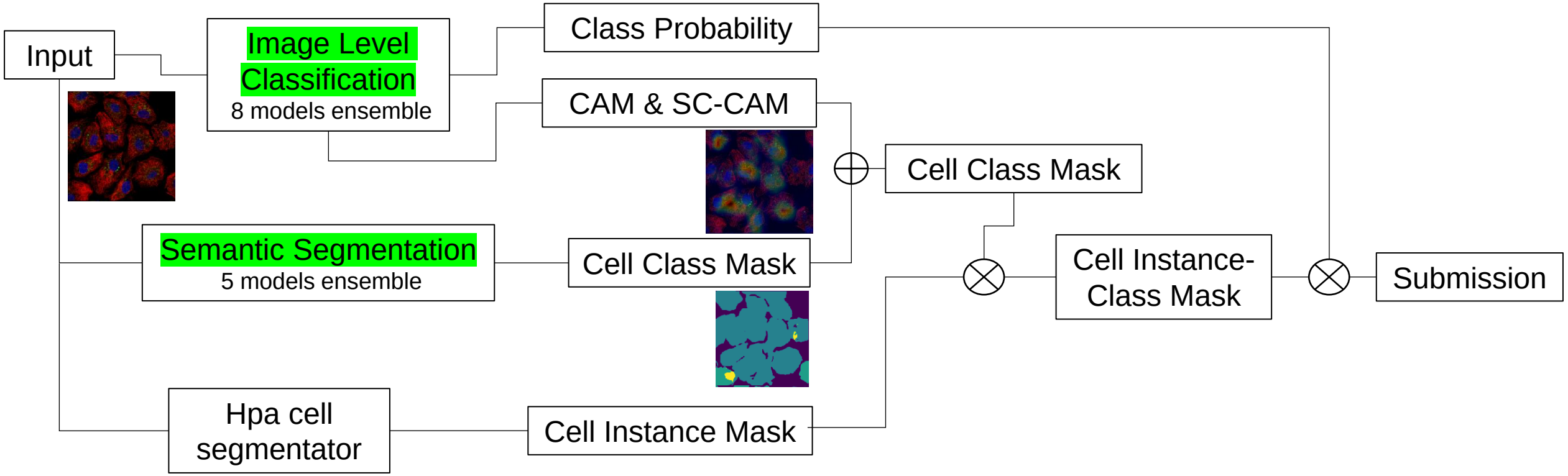
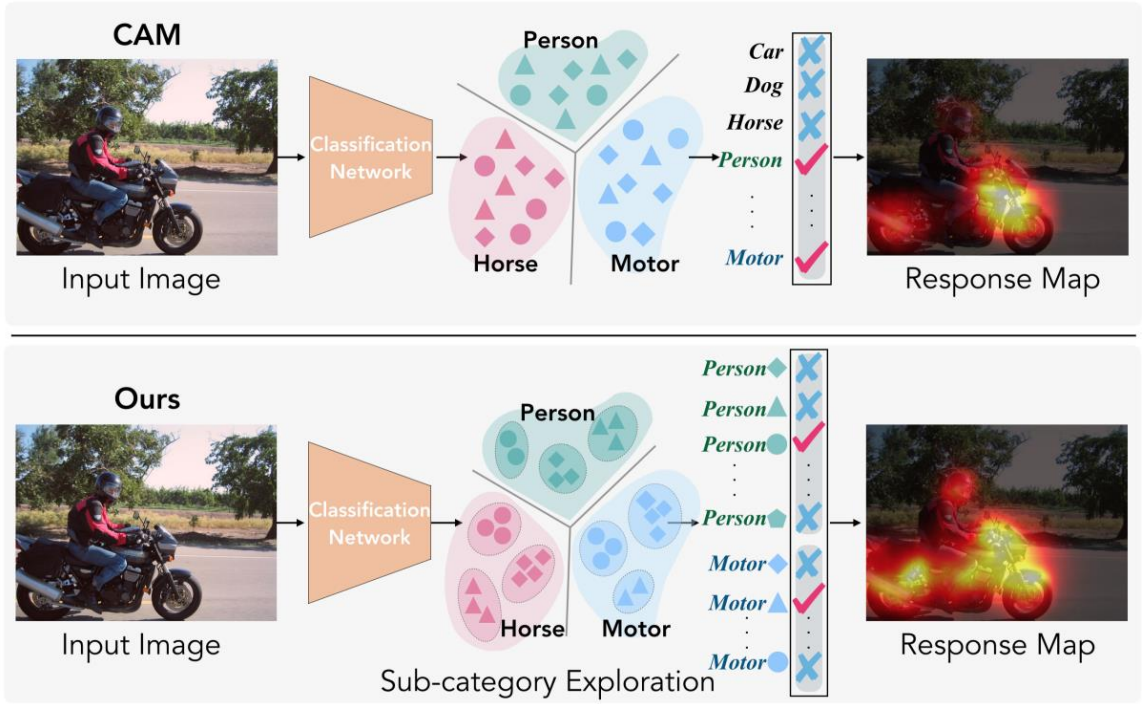
My plan

1. CAM, SC-CAM x Puzzle CAM
   Puzzle CAM: localization improvement for CAM
   Subcenter CAM, SC-CAM: differentiate intra-class. -> expecting additional improvement
   https://arxiv.org/pdf/2008.01183.pdf
2. Semantic Segmentation with pseudo label by CAM



My plan : SC-CAM

SC-CAM: Sub category CAM
1.Introducing sub category from a clustering of CNN feature.
2. This sub category is contributed to differentiate intra-class variation
   -> extend the area of CAM
3. This improvement may independent from Puzzle CAM which focus on spatial feature.
   -> Puzzle CAM x SC-CAM should be the best ! !



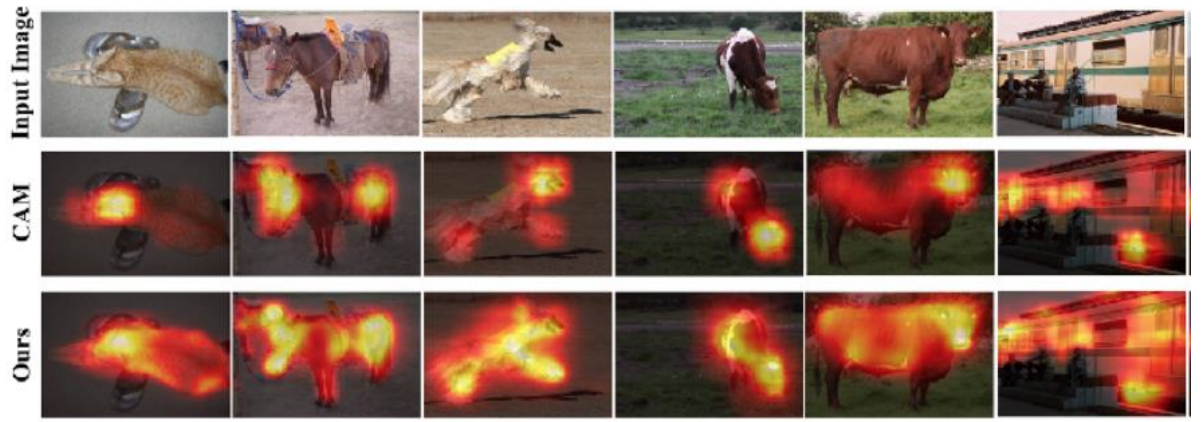


Figure 3: Sample results of initial responses. Our method often generates the response map t
object (i.e., attention on the body of the animal), while the response map produced by CAM
discriminative parts.

From https://arxiv.org/abs/2008.01183

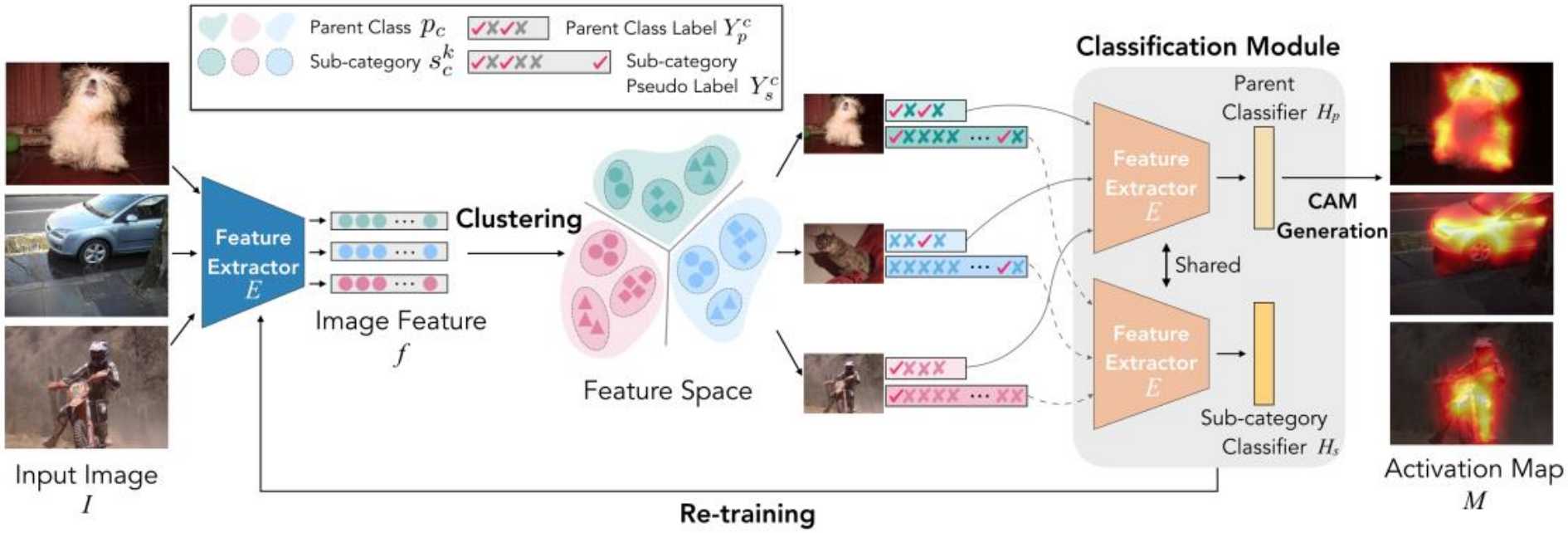
My plan : SC-CAM training procedure

SC-CAM
- multi rounds training.
- original SC-CAM uses 3 rounds but at this task 1 round is enough.

SC-CAM round 0 train
normal label 19 classes

Sub category label generation
CNN feature & k-means

SC-CAM round 1 train
normal label 19 classes
+ sub category label 19x10 classes



From https://arxiv.org/abs/2008.01183

My plan : training procedure

2 stages
- 1st stage: CAM x SC-CAM generation
- 2nd stage: Semantic Segmentation with the pseudo label from CAM

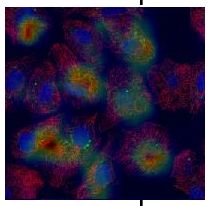
1st stage

Image Classification

Puzzle CAM x SC-CAM round 0 train
normal label 19 classes

Sub category label generation
CNN feature & k-means

Puzzle CAM x SC-CAM round 1 train
normal label 19 classes
+ sub category label 19x10 classes



CAM

Hpa cell segmentator

Pseudo Semantic Segmentation Label generation

2nd stage

Semantic Segmentation

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0.40050

Results for image classification part SC-CAM and Puzzle CAM

Sadly SC-CAM x Puzzle CAM does not work.
- separate use is better,
- SC-CAM is better than Puzzle CAM at my experiment

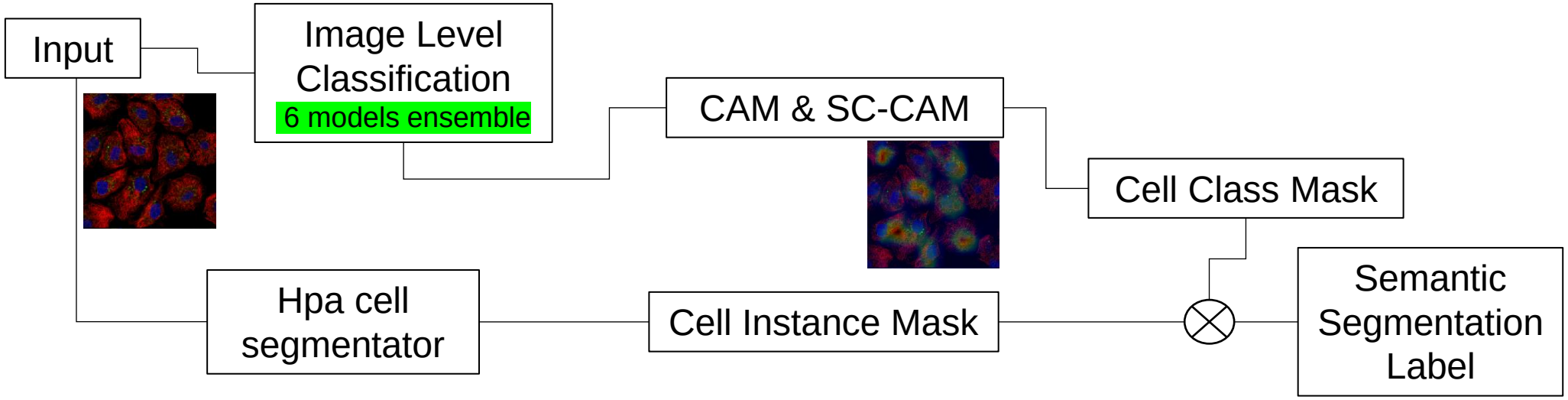
SC-CAM worked only for image size 512x512

Image size	External Data	SC-CAM	Puzzle-CAM	Public mAP
512				0.334
512		✓		0.373
512			✓	0.352
512		✓	✓	0.360
512	✓			0.381
512	✓	✓		**0.404**
768	✓			**0.423**
768	✓	✓		0.399
1280	✓			**0.429**

Resnet50 is used for all runs
“External data” with dropping frequent class

Semantic Segmentation

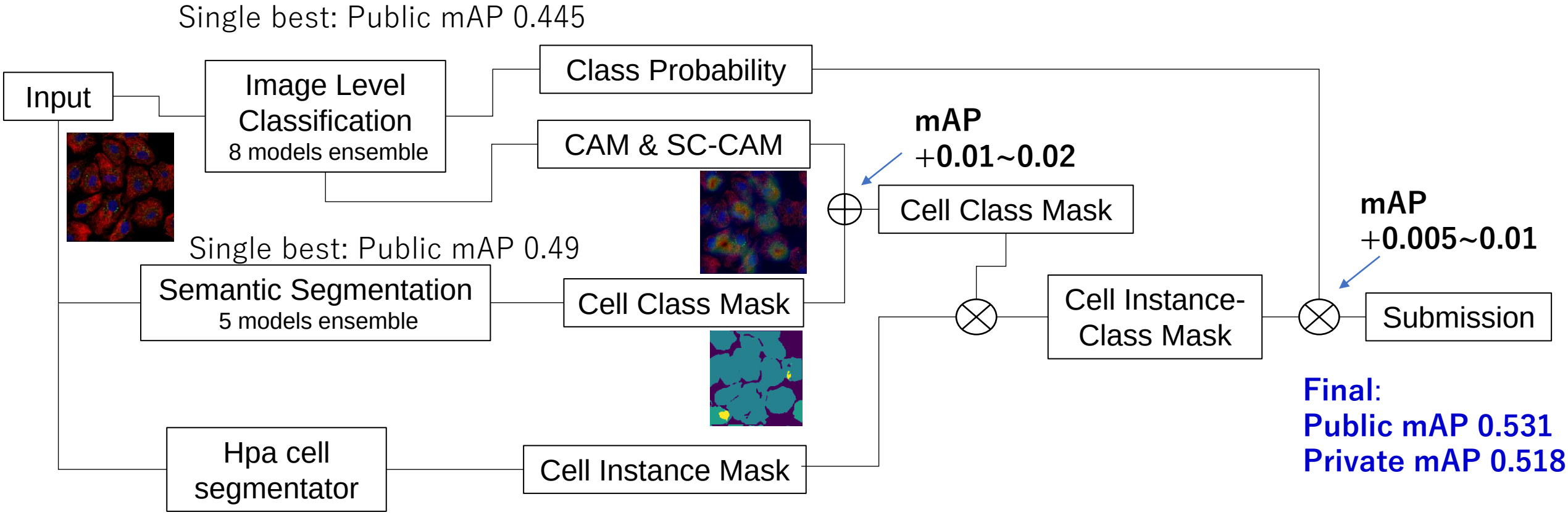
Heavy ensemble pseudo labeling.
-> 0.02 improvement
Using hard label:
-> but the threshold was really sensitive. I choose 0.225 based on public mAP score.



Only one CAM model pseudo label: mAP 0.47
6 different model {resnet, resnest, effcientnet} : mAP 0.49

Final Submission

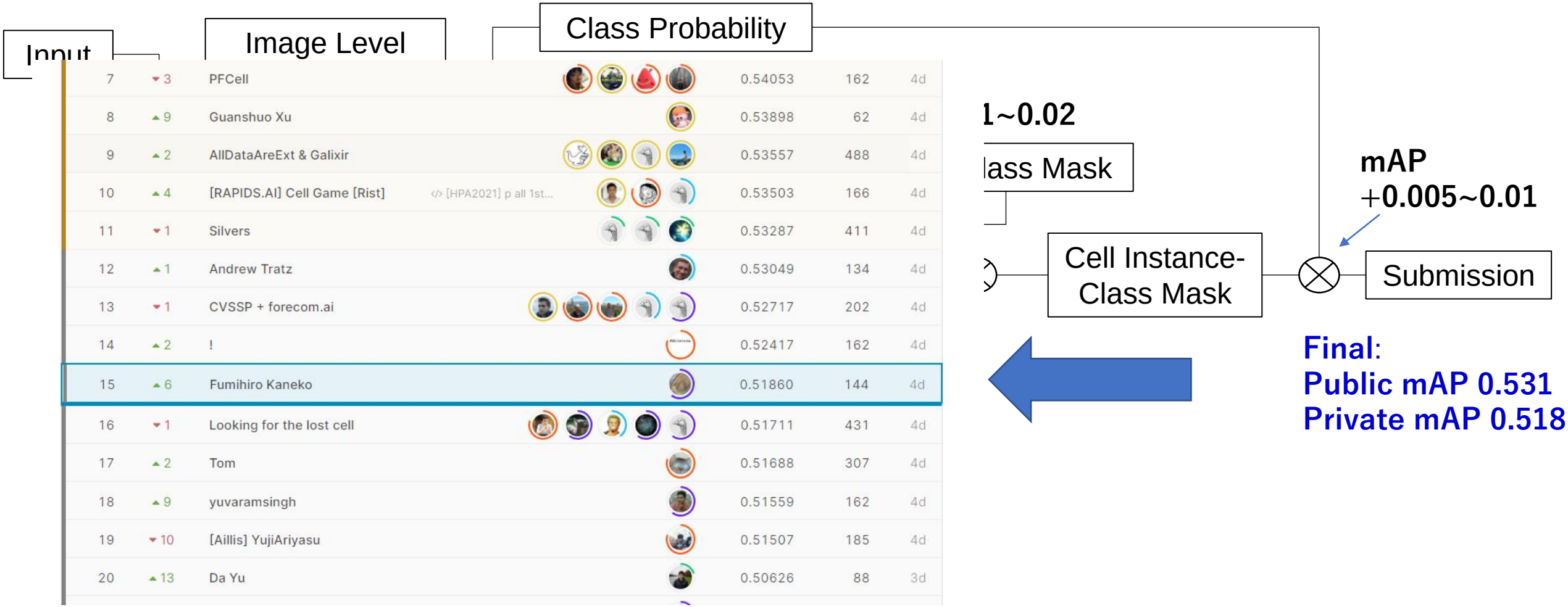
+ CAM&SC-CAM, Semantic Segmentation and HPA cell segmentator
+ Image Level Classification was trained for pseudo semantic segmentation label,
  But it contributed to the score, approximately mAP 0.01~0.02.



Final Submission

+ CAM&SC-CAM, Semantic Segmentation and HPA cell segmentator
+ Image Level Classification was trained for pseudo semantic segmentation label,
  But it contributed to the score, approximately mAP 0.01~0.02.

Single best: Public mAP 0.445



7	▼3	PFCell		0.54053	162	4d
8	▲9	Guanshuo Xu		0.53898	62	4d
9	▲2	AllDataAreExt & Galixir		0.53557	488	4d
10	▲4	[RAPIDS.AI] Cell Game [Rist]	</> [HPA2021] p all 1st...	0.53503	166	4d
11	▼1	Silvers		0.53287	411	4d
12	▲1	Andrew Tratz		0.53049	134	4d
13	▼1	CVSSP + forecom.ai		0.52717	202	4d
14	▲2	!		0.52417	162	4d
15	▲6	Fumihiro Kaneko		0.51860	144	4d
16	▼1	Looking for the lost cell		0.51711	431	4d
17	▲2	Tom		0.51688	307	4d
18	▲9	yuvaramsingh		0.51559	162	4d
19	▼10	[Aillis] YujiAriyasu		0.51507	185	4d
20	▲13	Da Yu		0.50626	88	3d

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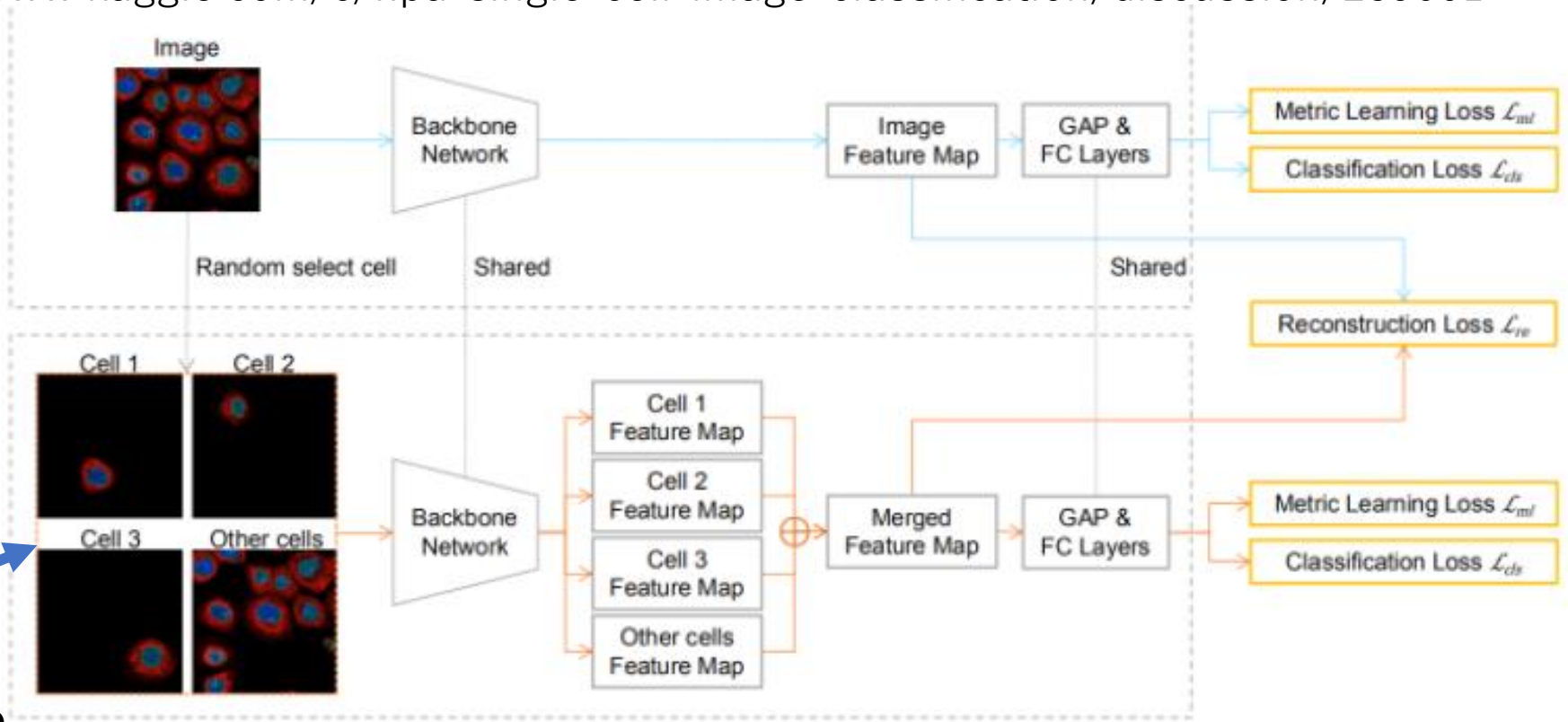
Top solution: “bestfitting”

2 stages approach
1st stage: Extend Puzzle CAM -> Fair Cell Activation Network
2nd stage: Cell wise pseudo leveled label by 1st stage
5 levels label: [1.0, 0.75, 0.5, 0.25, 0.0]
normal label : [1.0, 0.0]

1st stage

https://www.kaggle.com/c/hpa-single-cell-image-classification/discussion/239001

Fair Cell Activation Network



Best single model
Public mAP: 0.565
Private mAP: 0.547

Final ensemble 6 models
Public mAP: 0.590
Private mAP: 0.566

Replace the split of the Puzzle CAM with cell mask

Summary

1. I used 2 stages approach

   1st : image classification for getting CAM

   2nd : Semantic segmentation with pseudo label from 1st stage CAM

2. My initial plan SC-CAM x Puzzle CAM did not work.

3. Successfully train 2nd stage semantic segmentation

4. Compared to the TOP 1 solution

   - use the same 2 stages pseudo label approach

   - but each stage for TOP 1 solution got much better score.

     TOP 1 solution was evolving a research result for this cell problem.

Appendix

Model and other details

Image Level Classification
- model: resnest50, resnet50, resnet200d, effb3
- Input size: 512x512 ~ 1280x1280
- Loss: focal loss
- Learning rate scheduler: Cosine Annealing

Semantic Segmentation
- model: Unet{resnest50, resnet50, resnext50}
- Input size: 512x512 ~ 768x768
- Loss: focal loss
- Learning rate scheduler: Cosine Annealing

Other Tips
- Training speed : NGC container x Channel Last for pytorch memory format
  + following the benchmark result at timm, my resnet training time reduced by 40% from my initial configuration. Also effb training reduced by 20 or 30%.

- TTA, Test time augmentation
  h/vflip, image scale { x1.2, x1.4} improve the CAM model score by 0.01~0.03