Vascular Segmentation of Renal Cell Carcinoma

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Overview

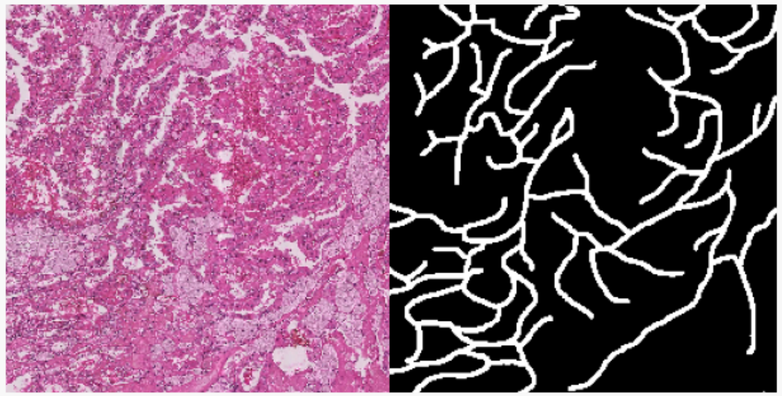
- Dataset analysis and preprocessing tecniques
- Evaluation metrics
- Segmentation models
  - Autoencoder
  - U-Net
  - Pix2Pix GAN
- Results and conclusions
- Next works

Dataset

Composed of 210 histological images (2000x2000) with associated segmentation mask, depicting two types of cancer:

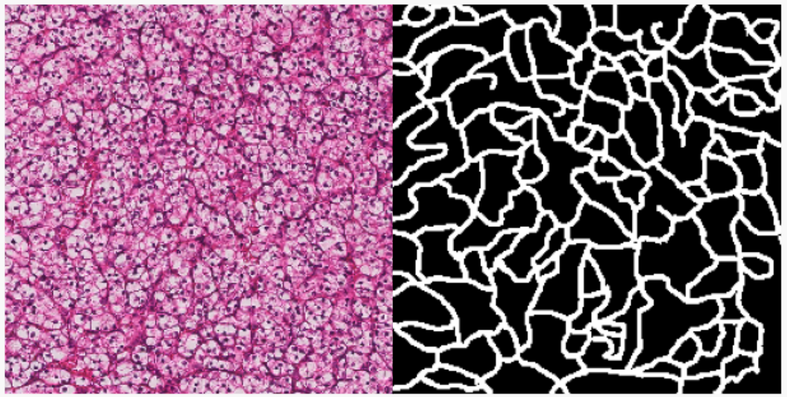
Papillary Renal Cell Carcinoma (pRCC)

TRAIN	TEST
100 images	5 images



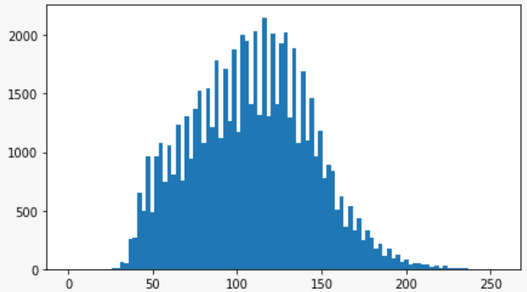
Clear Cell Renal Cell Carcinoma (ccRCC)

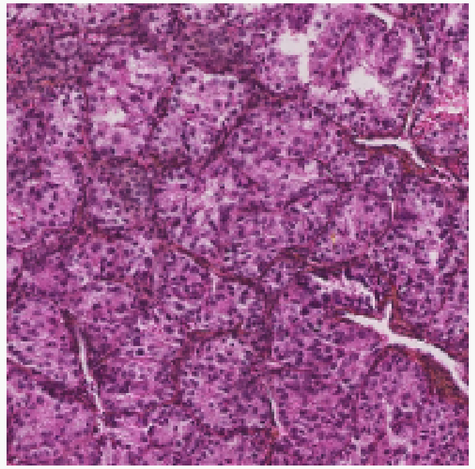
TRAIN	TEST
100 images	5 images



Preprocessing - Contrast

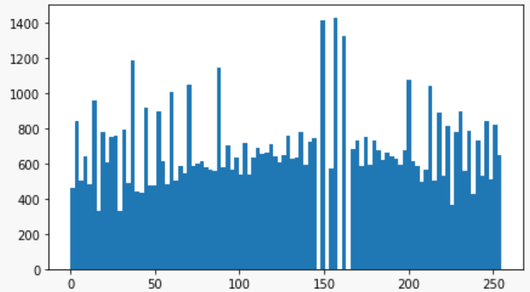
Original Image

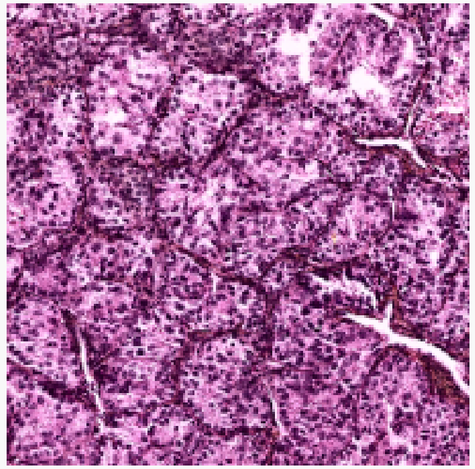




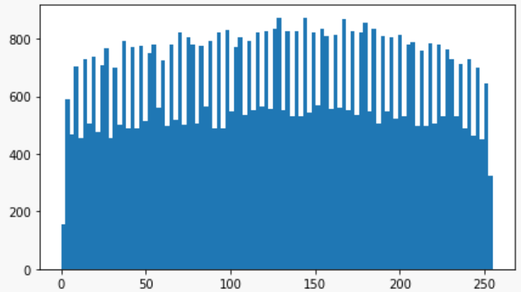
Improve contrast

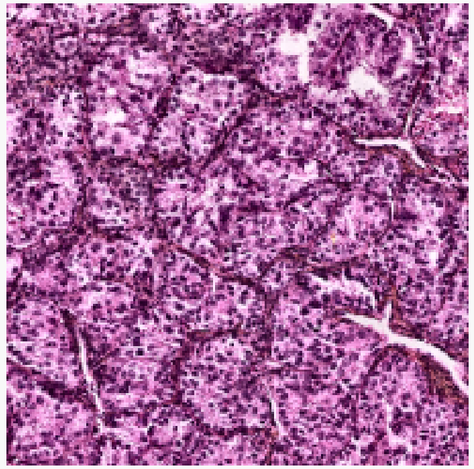
Histogram Equalization





Contrast Limiting Adaptive Histogram Equalization (CLAHE)



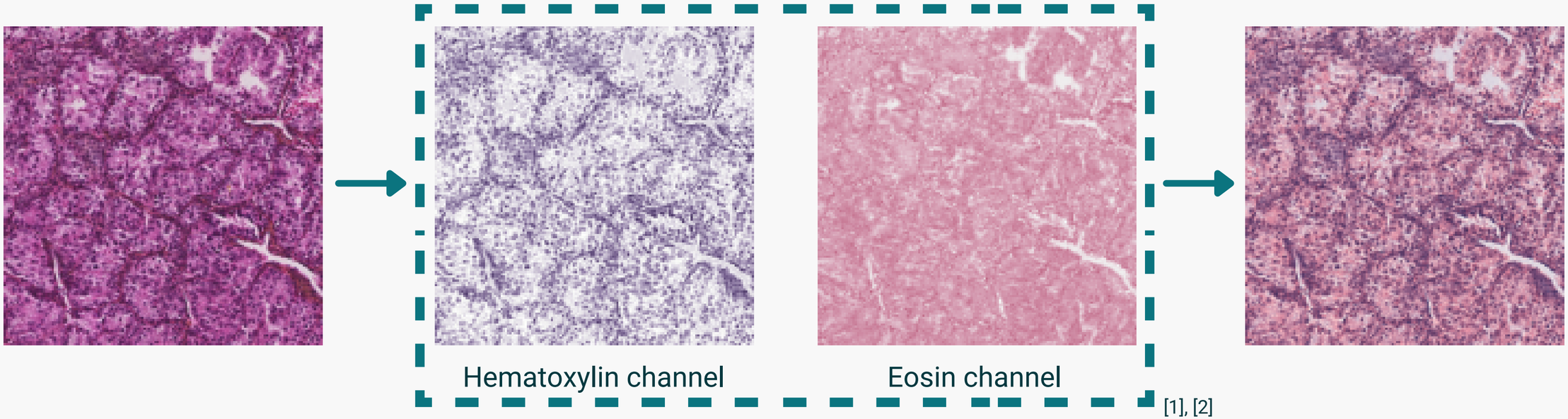


Preprocessing - Stain

Original Image

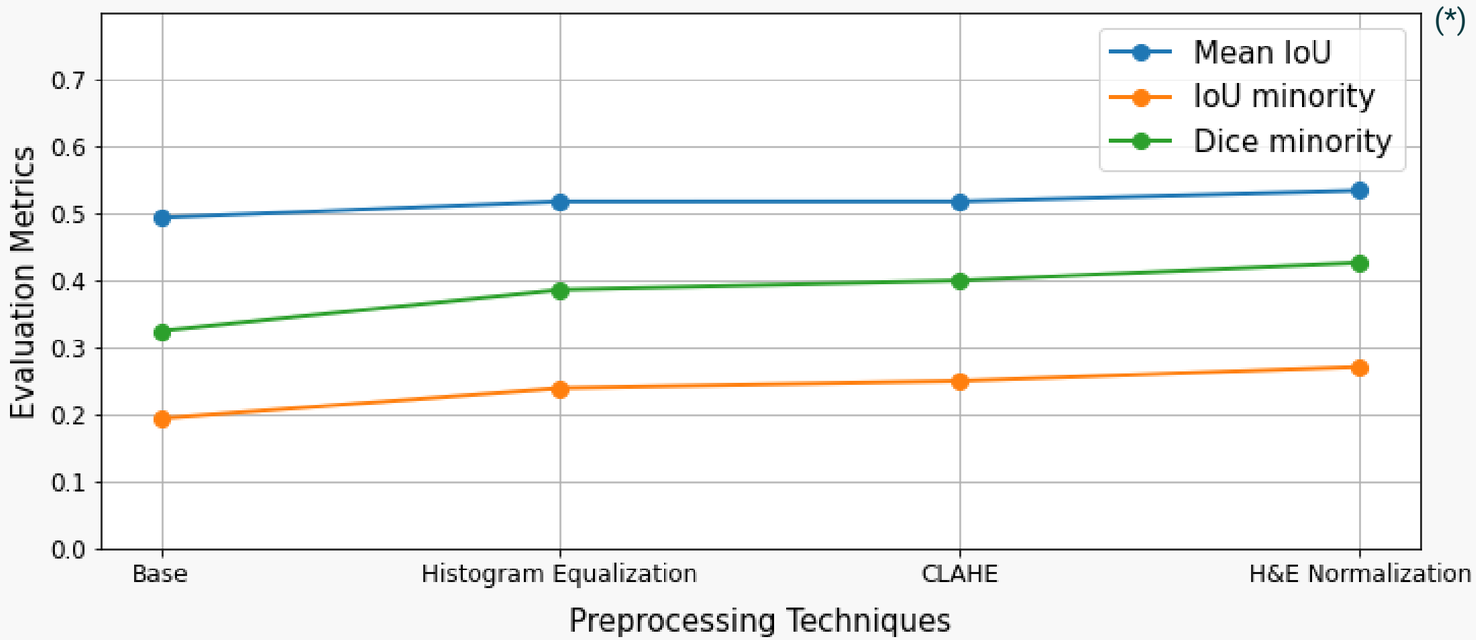
Color normalization after stain separation

Normalized Image



[1], [2]

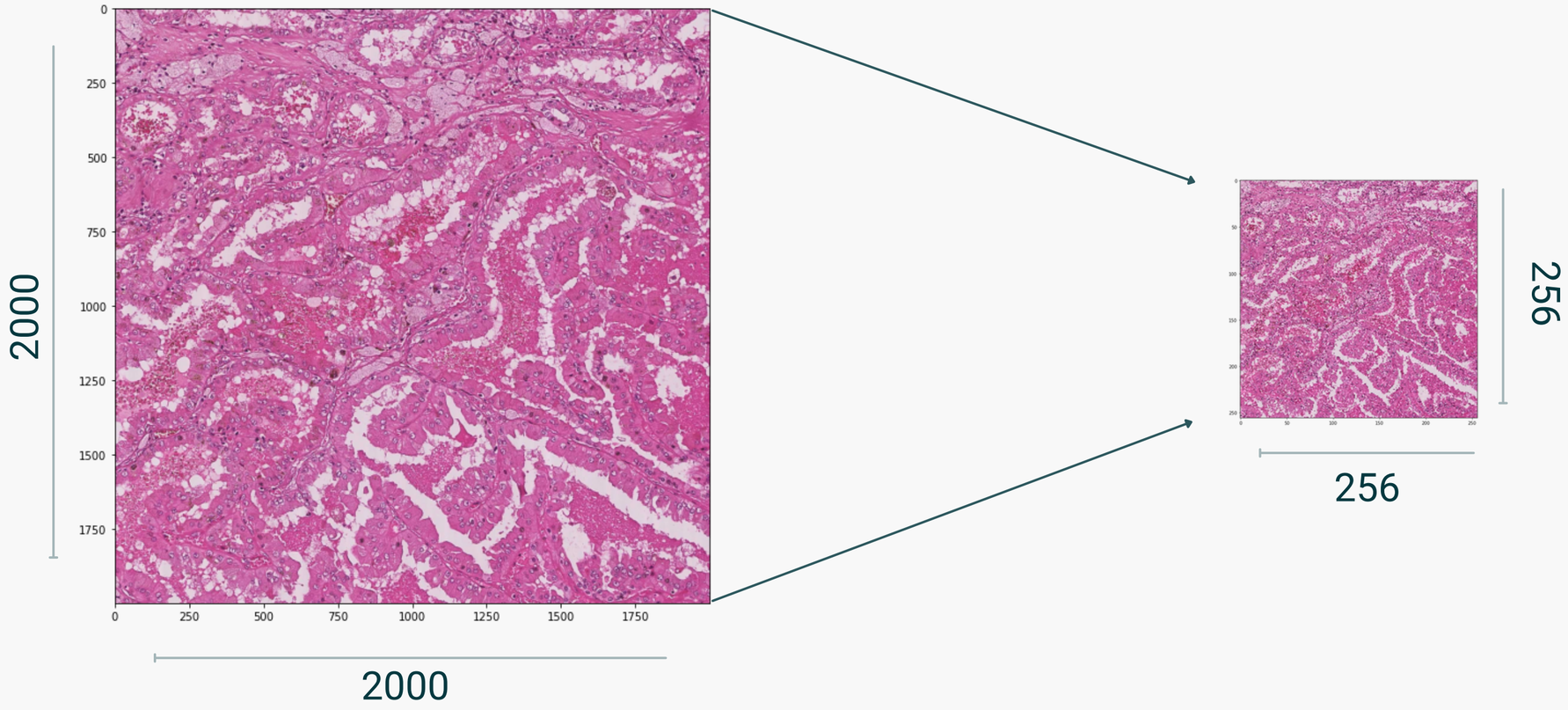
Preprocessing - Results



(*) Results refer to pRCC dataset through Autoencoder

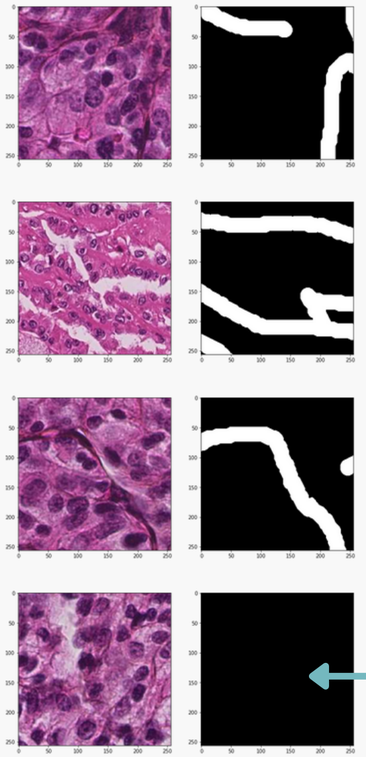
Preprocessing - Resize

1 Resize 256x256



Preprocessing - Patches

2 Patchify

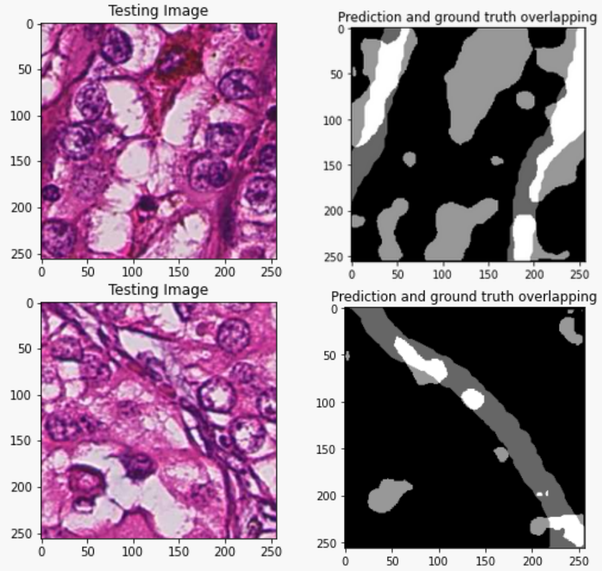


(1*)

From 100 pRCC samples to **4900** pRCC patches

Predict

Totally black
[2]



Dataset	Epochs	Batch size	Learining Rate	Mean IoU	IoU minority	Dice minority
Original pRCC	1000	8	0.001	0.53379	0.27096	0.42638
Patches pRCC	1000	64	0.0001	0.42382	0.15898	0.27434

(2*)

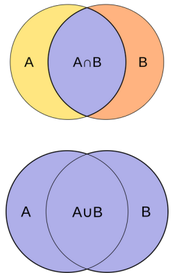
(1*) Patches from pRCC dataset
(2*) Results obtained through Autoencoder

Evaluation Metrics

1 **<u>IoU</u> - Intersection over Union**
Measures similarity between images. It is defined as the area of the intersection divided by the area of the union between predicted and ground truth segmentations.

IoU

$$IoU = \frac{OverlapArea}{UnionArea}$$



IoU - Jaccard coefficient

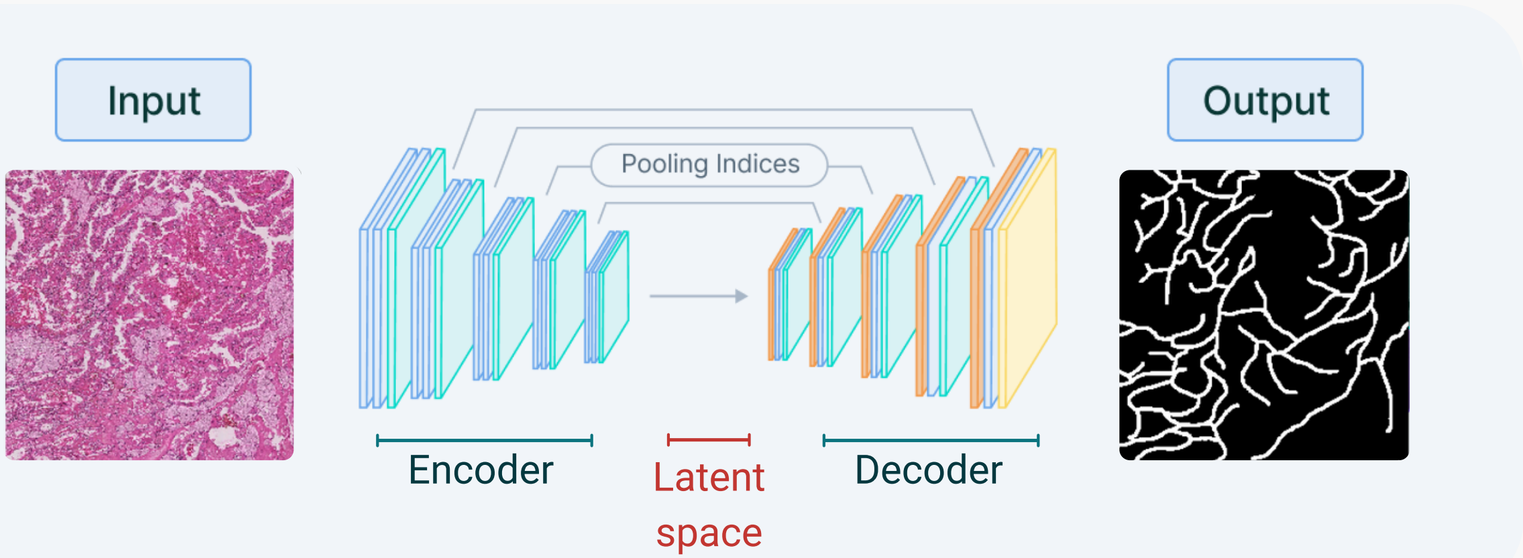
$$IoU = \frac{truePositives}{truePositives + falsePositives + falseNegatives}$$

2 **<u>Dice</u>**
Similar to IoU but composed of the double intersection over the sum between intersection and union.

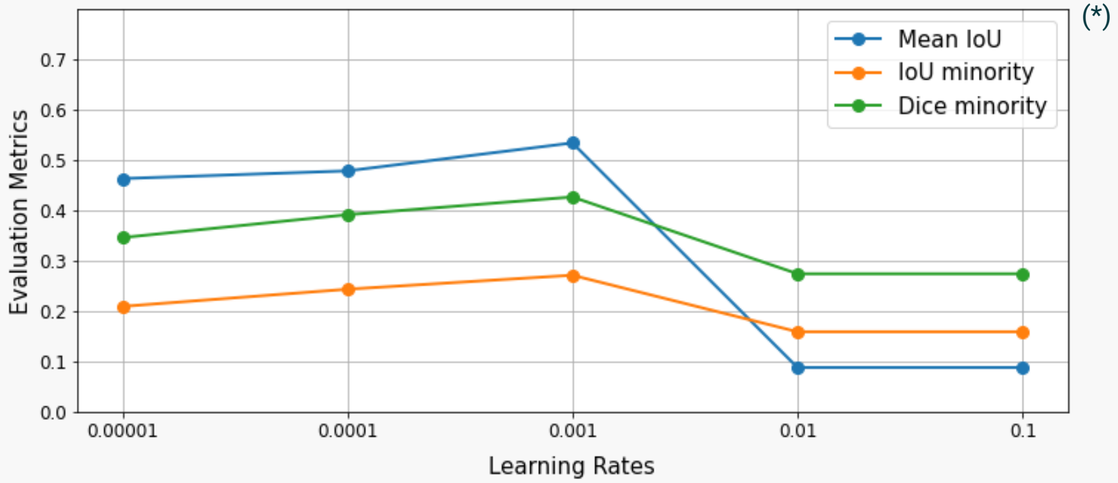
Dice score

$$Dice = 2\frac{truePositives}{(truePositives + falsePositives) + (truePositive + falseNegatives)}$$

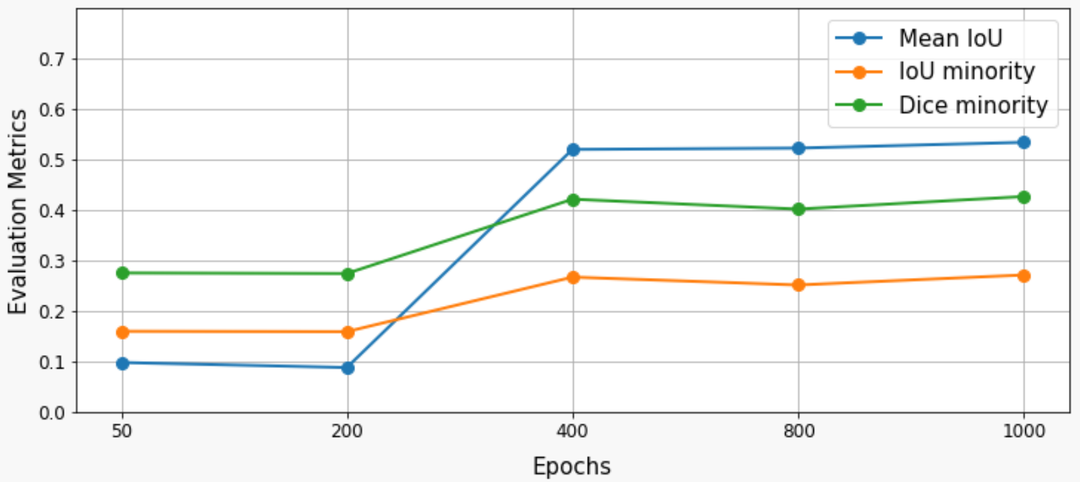
Autoencoder - Structure



Autoencoder - Tuning



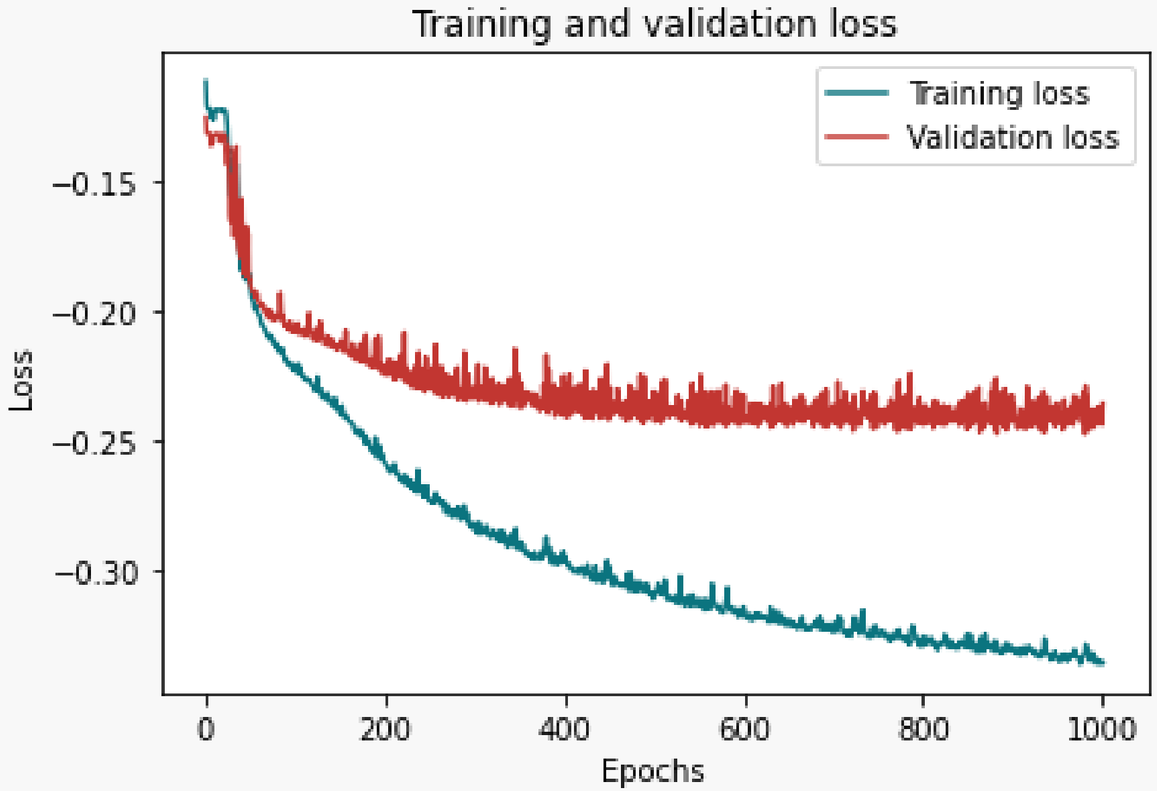
(*)



(*)

(*) Results refer to pRCC dataset

Autoencoder - Loss

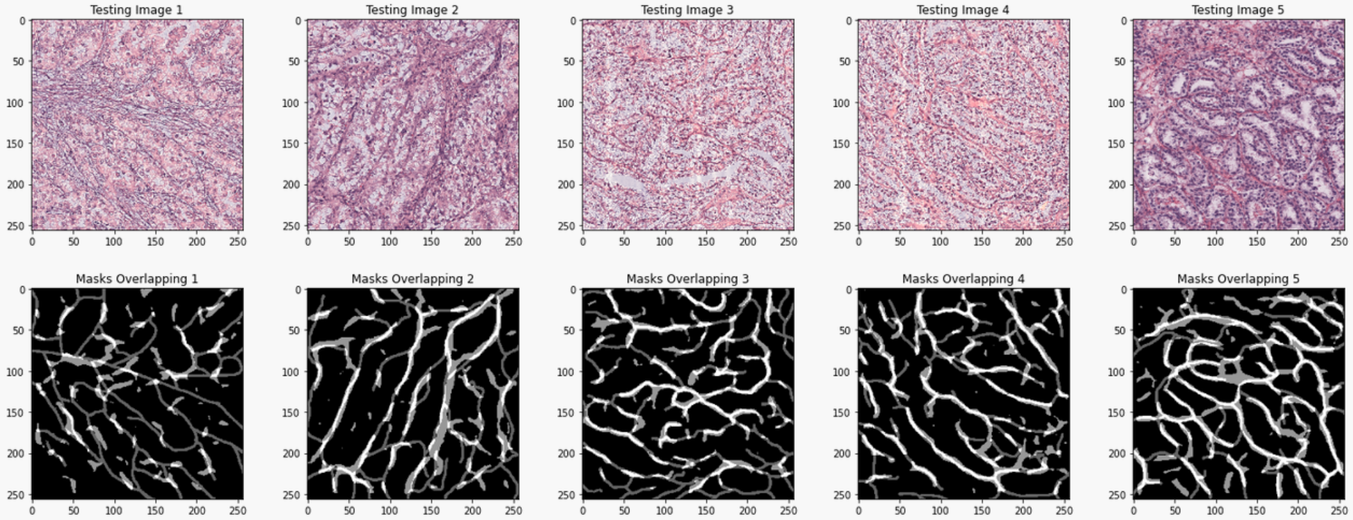


DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-3
BATCH: 8
TEST MEAN IOU: 0.5338

Loss Score

$$IoU_{Loss} = -\sum_{n=1}^{N} \frac{\hat{y_n} y_n}{\hat{y_n} + y_n - (\hat{y_n} y_n)}$$

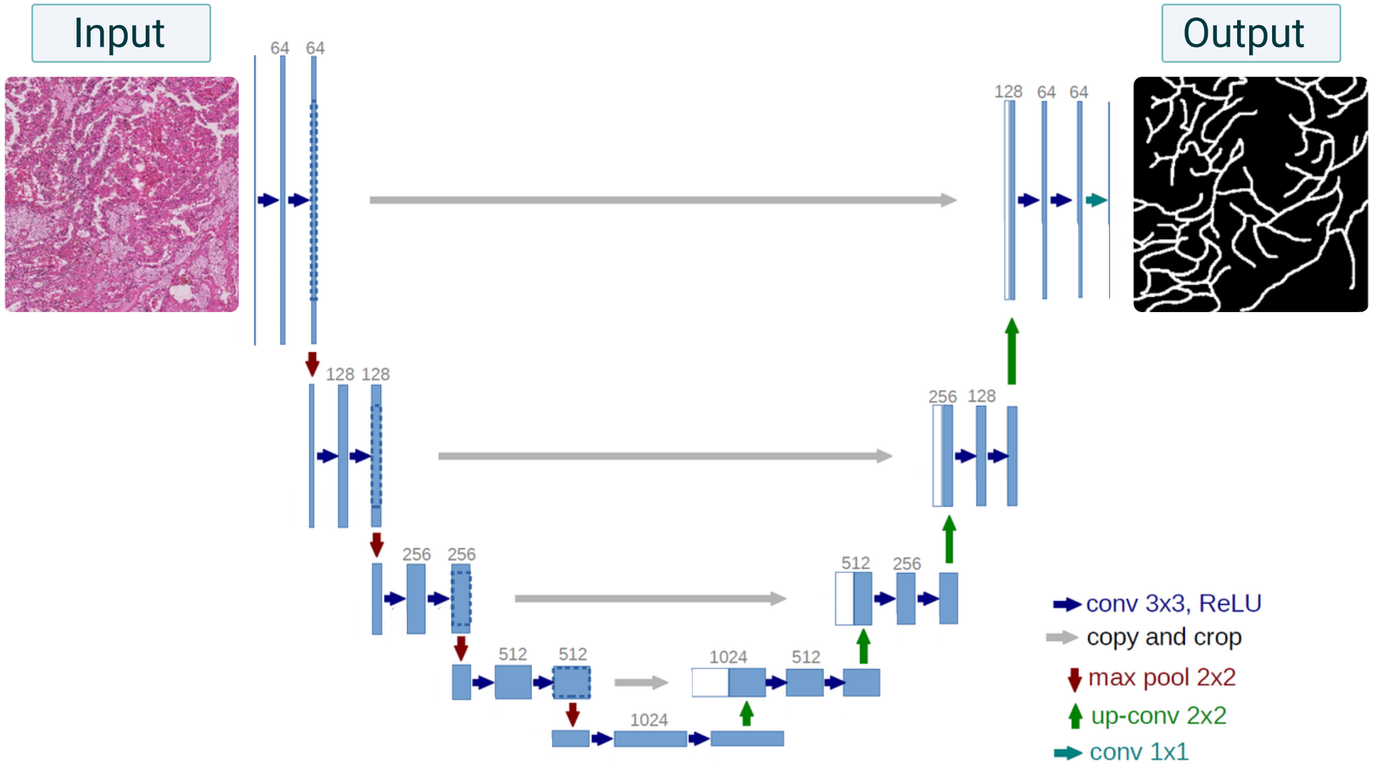
Autoencoder - Best Results



DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-3
BATCH: 8
LOSS: Jaccard Loss

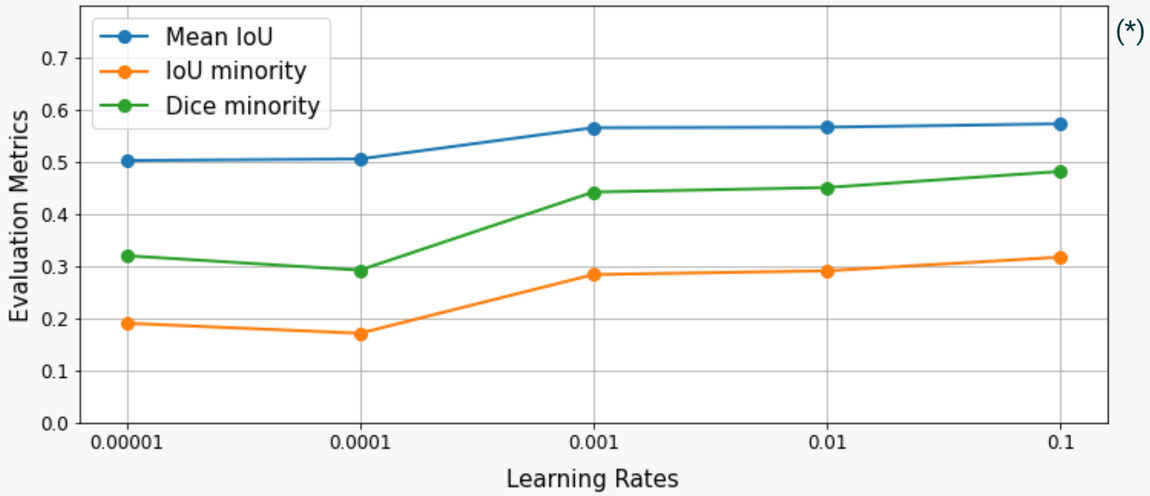
Dataset	Mean IoU	IoU Minority	Dice Minority
pRCC	0.53378814	0.2709558996564221	0.4263812768478744
ccRCC	0.5476335	0.37982286231997253	0.5505385838894643
pRCC+ccRCC	0.3365001	0.2234816844656442	0.36532085000234366

U-Net - Structure

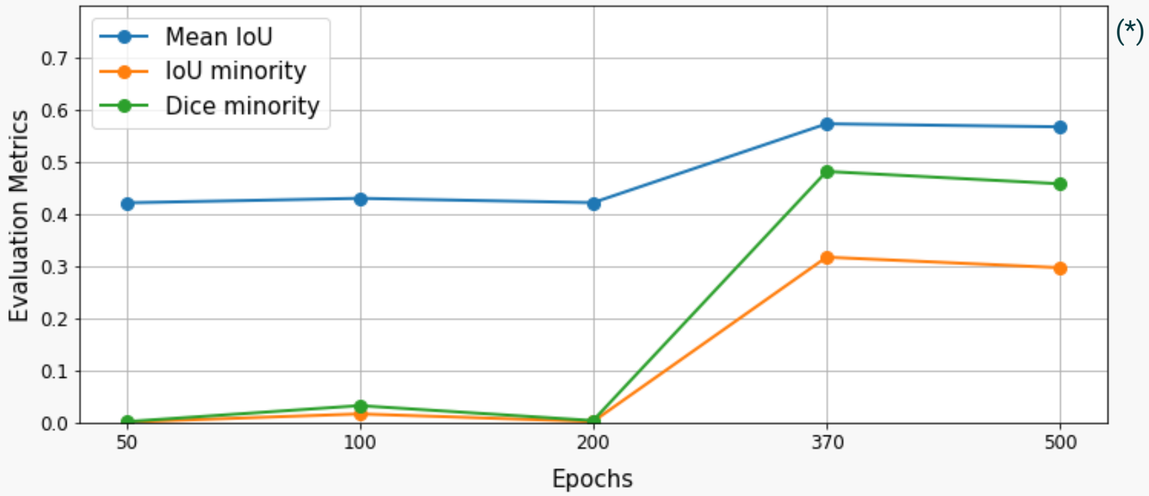


[3]

U-Net - Tuning



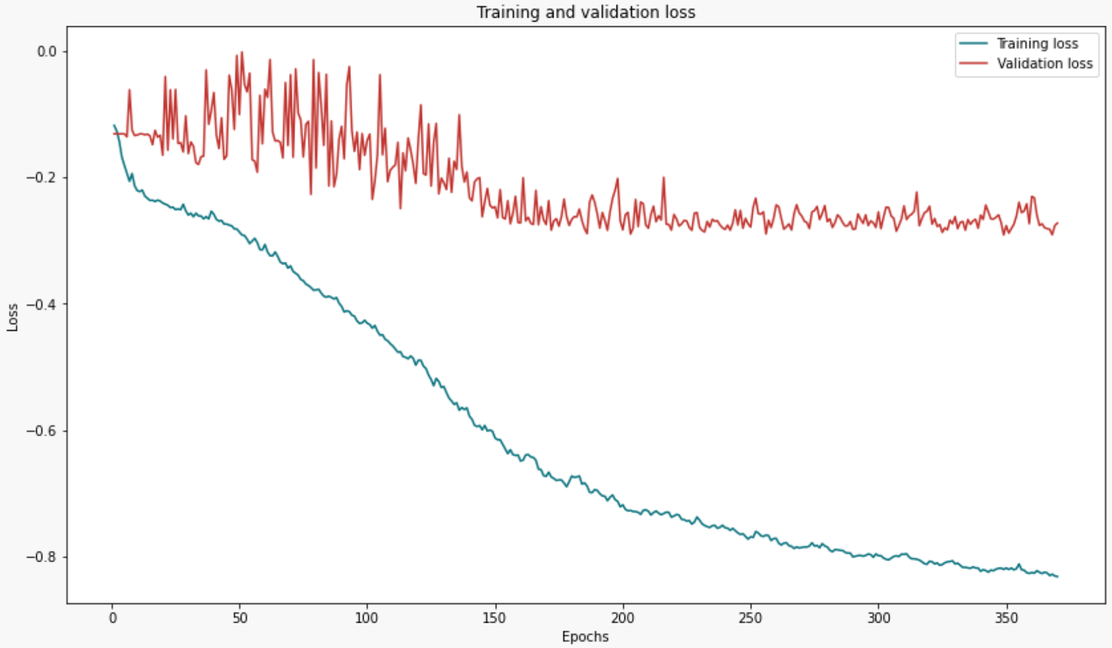
(*)



(*)

(*) Results refer to pRCC dataset

U-Net - Loss

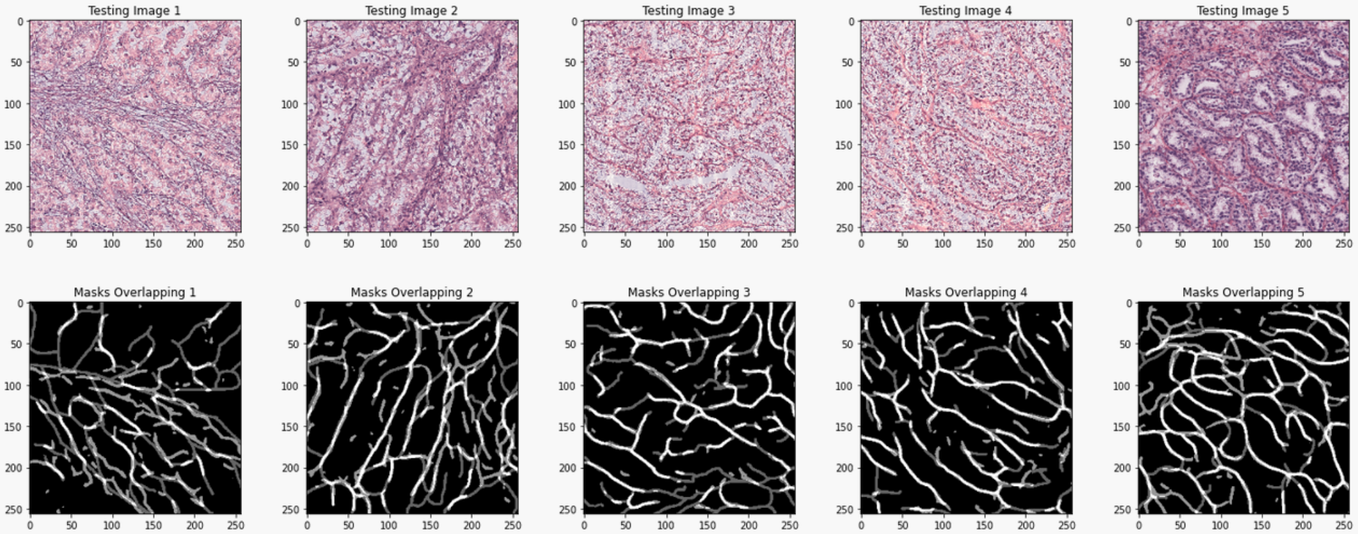


DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-1
BATCH: 16
TEST MEAN IOU: 0.5730

Loss Score

$$IoU_{Loss} = -\sum_{n=1}^{N} \frac{\hat{y_n} y_n}{\hat{y_n} + y_n - (\hat{y_n} y_n)}$$

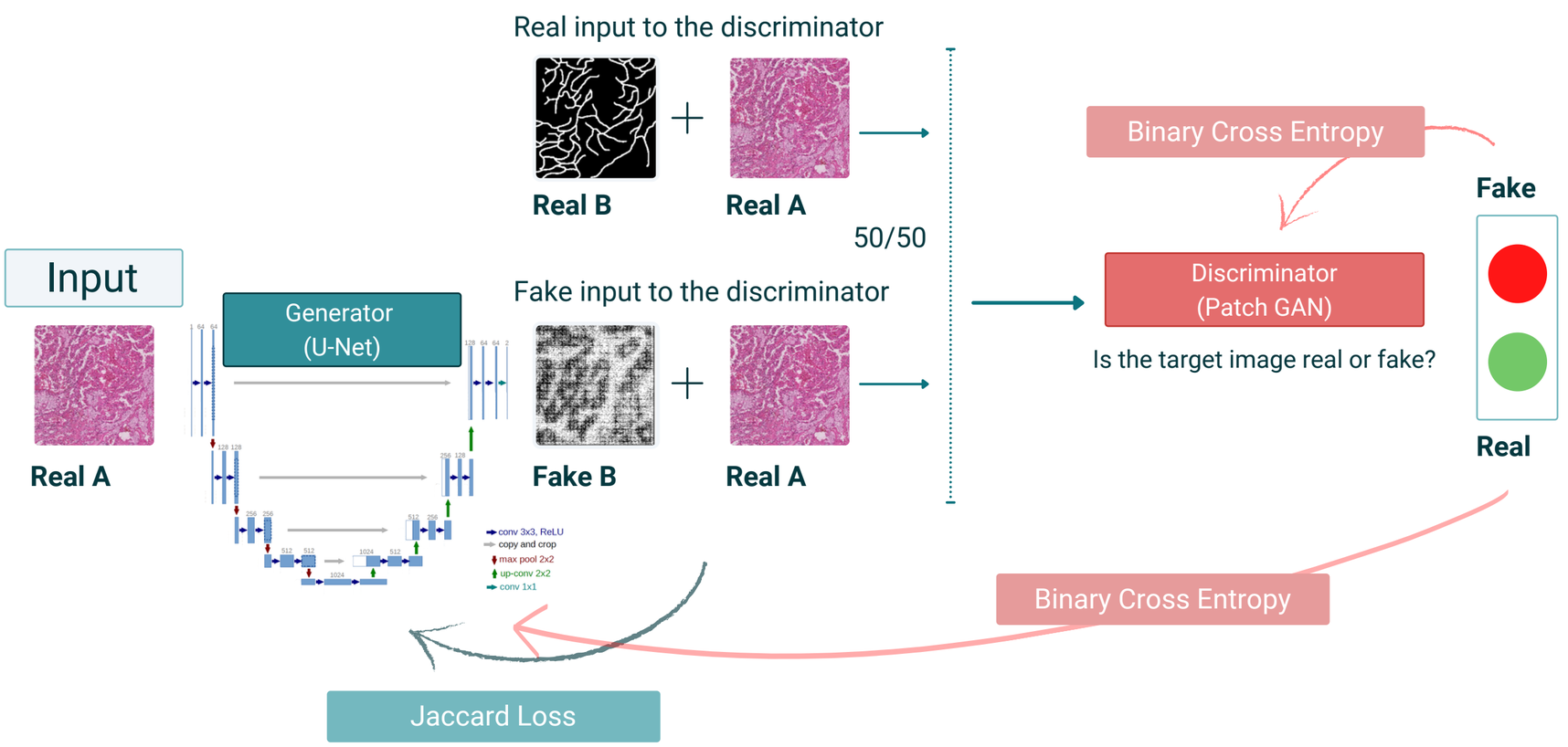
U-Net - Best Results



DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-1
BATCH: 16
LOSS: Jaccard Loss

Dataset	Mean IoU	IoU Minority	Dice Minority
pRCC	0.5730026	0.3171680532008569	0.4815908682724352
ccRCC	0.5610693	0.3882488006888351	0.5593360505641207
pRCC+ccRCC	0.55349886	0.28494036	0.4435075454438602

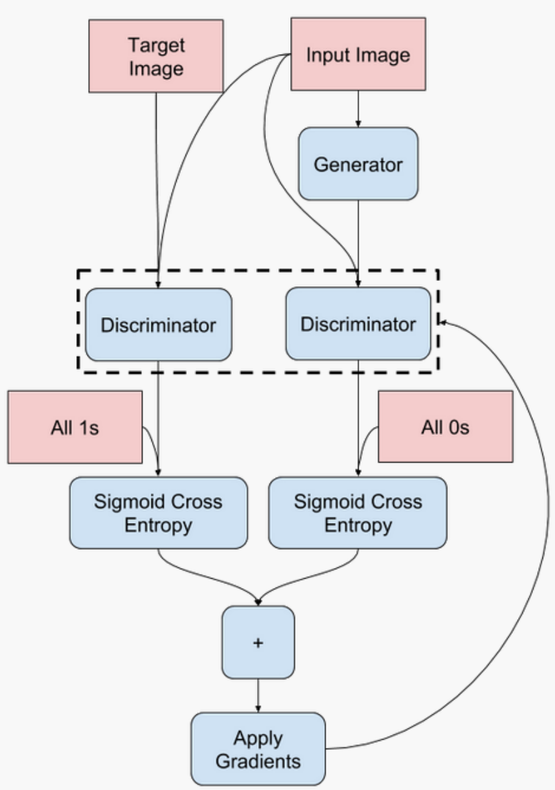
Pix2Pix GAN - Structure



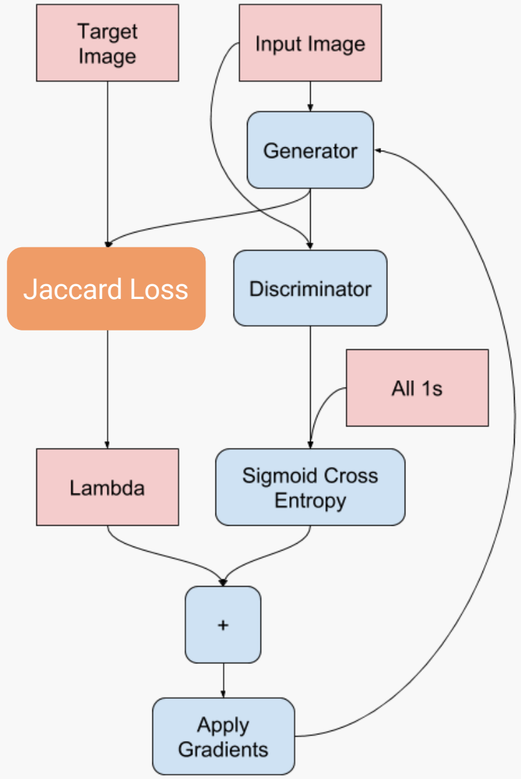
[4]

Pix2Pix - Adversarial loss

Discriminator Updating



Generator Updating



Binary cross entropy

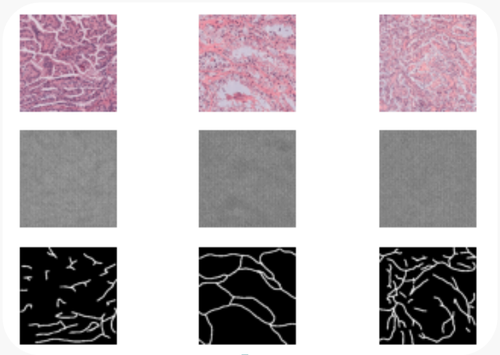
$$BCE_{Loss} = -\sum_{n=1}^{N}[y_n log(\hat{y_n}) + (1 - y_n) log(1 - \hat{y_n})]$$

Jaccard Loss

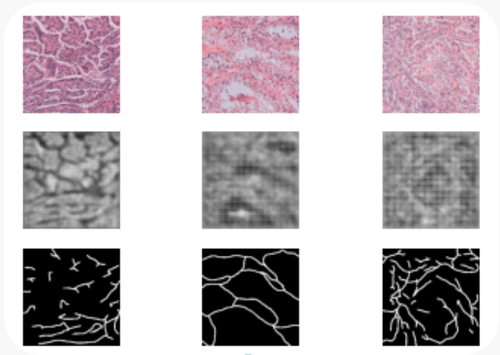
$$IoU_{Loss} = -\sum_{n=1}^{N}\frac{\hat{y_n} y_n}{\hat{y_n} + y_n - (\hat{y_n} y_n)}$$

Originally L1 loss was used by Pix2Pix paper. After some experiments, it has been decided to use the Jaccard Loss and also to have a Sigmoid activation function instead of a Tanh activation function.

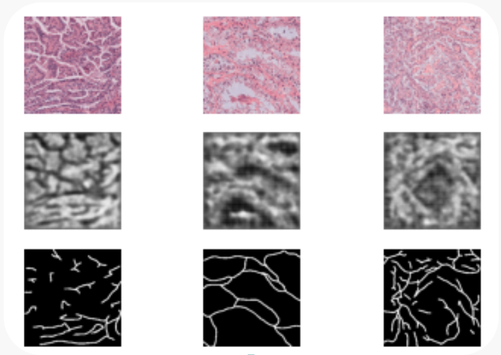
Pix2Pix - Training



10 Epochs

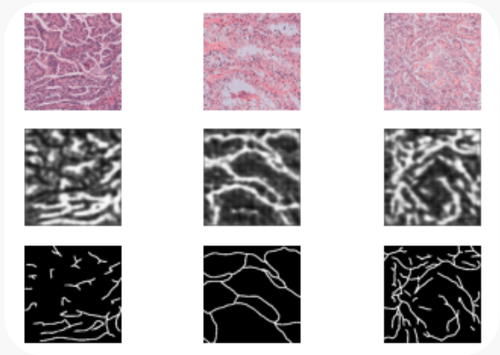


100 Epochs

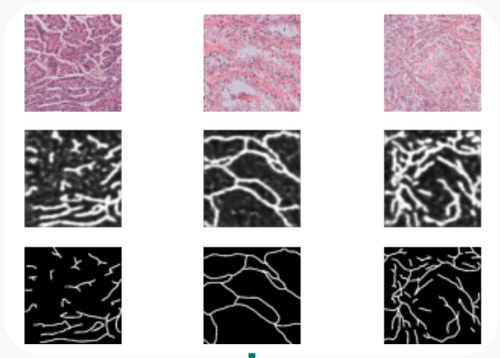


200 Epochs

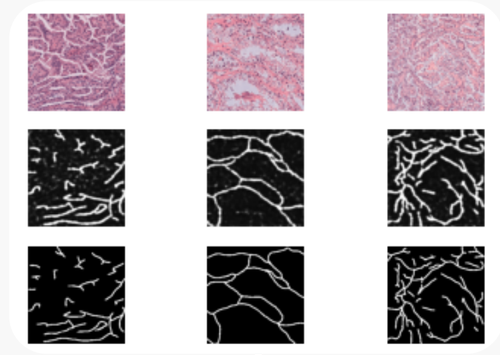
DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-5
BATCH: 64



400 Epochs

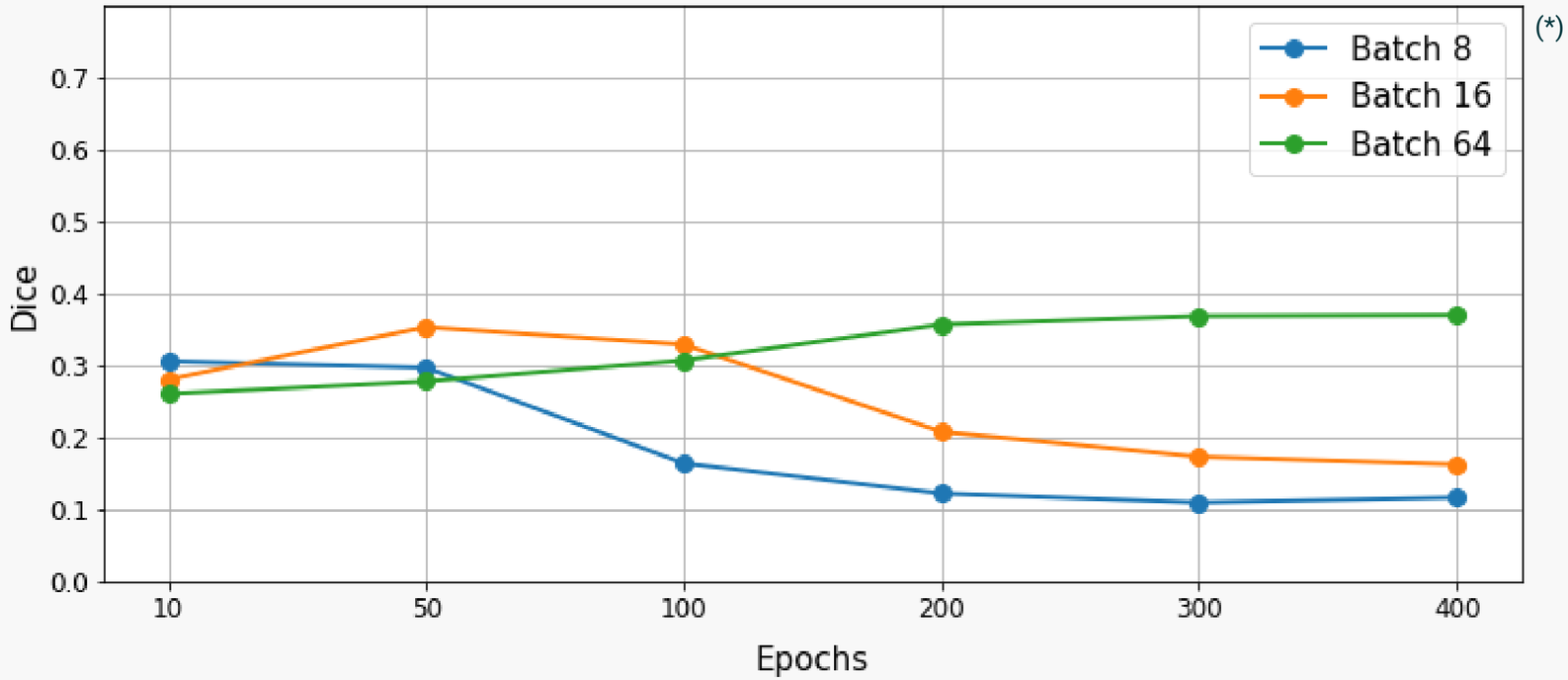


600 Epochs



1000 Epochs

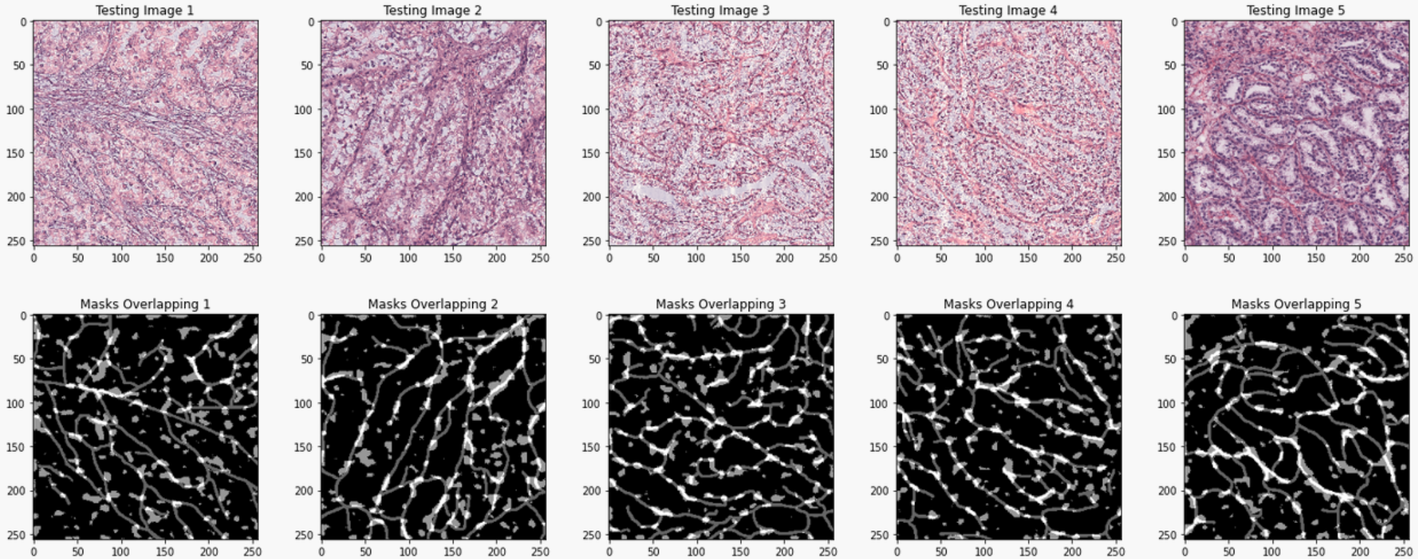
Pix2Pix - Tuning batch size



(*)

(*) Results refer to pRCC dataset with LR 1e-5

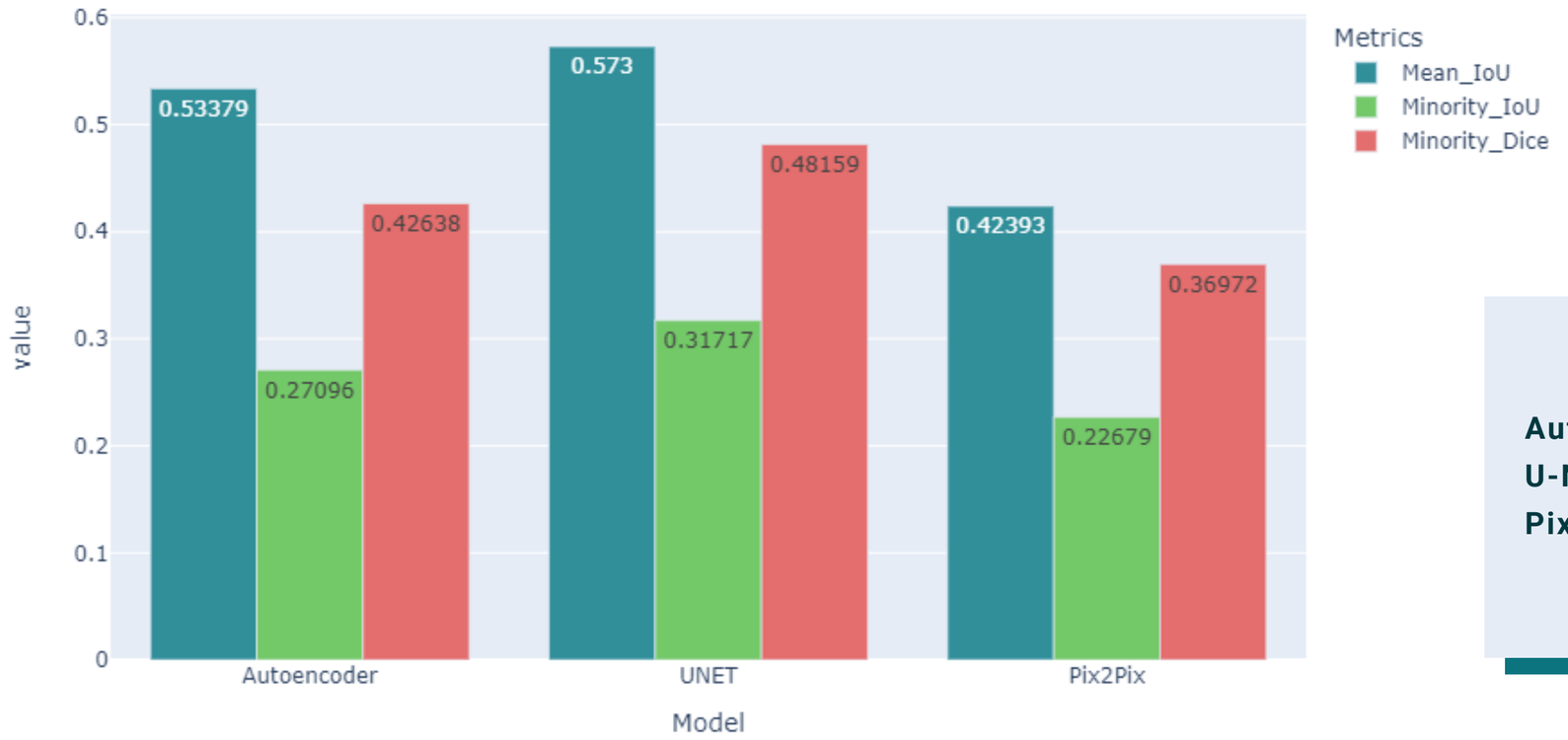
Pix2Pix - Best Results



DATASET : pRCC - resize
PREPROCESSING: H&E norm
LR: 1e-5
BATCH: 64

Dataset	Mean IoU	IoU Minority	Dice Minority	Epochs
pRCC	0.42393038	0.226787	0.3697257	400
ccRCC	0.37890804	0.297376	0.458426	400
pRCC+ccRCC	0.43870416	0.2272085	0.370285	300

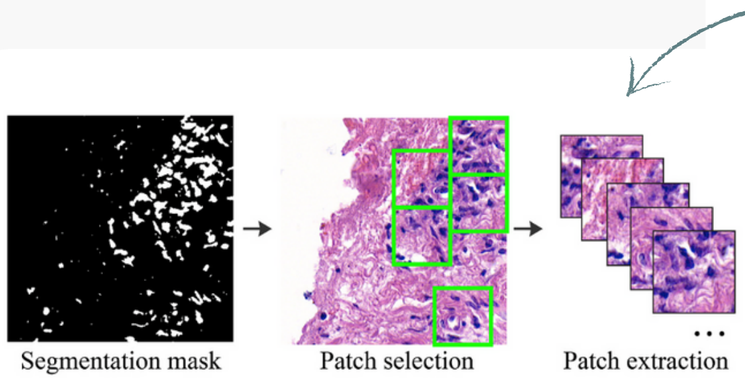
Conclusion



Autoencoder: baseline
U-Net: best performing model
Pix2Pix: requires more data

(*) Results refer to pRCC dataset

Next Works



- Perform classification before segmentation
- Increase samples maintaining vascular network information
- Patch Smart Sampling
- Remove noise (e.g. through hematoxylin channel)

References

[1] A method for normalizing histology slides for quantitative analysis. *Marc Macenko, Marc Niethammer, J. S. Marron, David Borland, John T. Woosley, Xiaojun Guan, Charles Schmitt, Nancy E. Thomas*

[2] Impact of stain normalization and patch selection on the performance of convolutional neural networks in histological breast and prostate cancer classification. *Massimo Salvi, Filippo Molinari, U Rajendra Acharya, Luca Molinaro, Kristen M Meiburger*

[3] U-Net: Convolutional Networks for Biomedical Image Segmentation. *Olaf Ronneberger, Philipp Fischer, and Thomas Brox*

[4] Image-to-Image Translation with Conditional Adversarial Networks. *Phillip Isola, Jun-Yan Zhu, Tinghui Zhou, Alexei A. Efros*

Thank you for your attention!

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