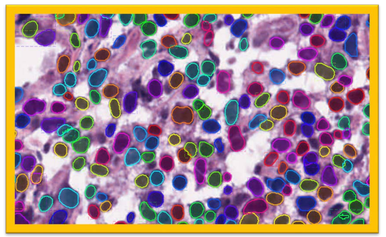
MEDICAL UNIVERSITY OF VIENNA

Improved Mask R-CNN for Nuclei Segmentation in Histologic Images



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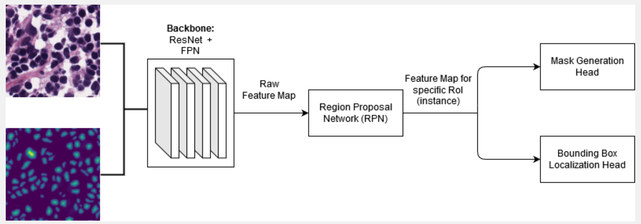
Introduction

- Digital pathology supports pathologists' workflows
- Nuclei instance segmentation is a key step for quantitative analysis in digital pathology
- Most current image processing-based and machine learning-based methods separate touching or overlapping nuclei in post-processing
- Detection-based models such as Mask R-CNN [1] aim to overcome this challenge in a unified manner and have rarely been explored
- We therefore propose to use Mask R-CNN for nuclei instance segmentation and perform analysis on the impact and potential of possible improvements

Methods

◇ Proposed modified Mask R-CNN architecture adapted for binary instance segmentation with distance maps



- 4-channel inputs (raw RGB images + distance maps) are fed to the model (refer to the example for details)
- Feature Pyramid Network in ResNet performs feature extraction
- Region Proposal Network (RPN) then implements binary classification as well as Region of Interest (RoI) estimation
- RoIs are aligned with their features using the RoI-Align algorithm for final instance features
- Features within each RoI (= instance) get passed to the second stage and mask generation and localization are performed

◇ Datasets used

- Kumar et al. (2017) dataset [2]: used for training (16 images) and test performance (14 images)
- PanNuke dataset [3]: used for pre-training

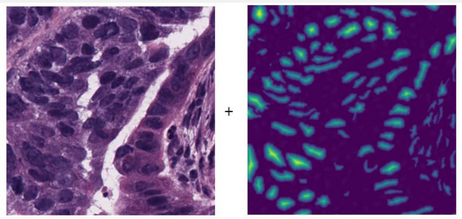
Stats	Kumar	PanNuke
Nr. of Image tiles	30	7901
Image Size	1000x1000	256x256
Nr. of annotated nuclei	21,625	205,343
Nr. of tissue types	7	19
Annotation type	Manual binary	Semi-Automatic classified

◇ Evaluation Metrics

- Aggregate Jaccard Index (AJI) [2] and Panoptic Quality (PQ) [4]

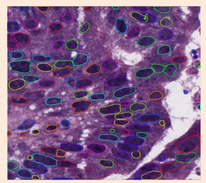
◇ Explored adaptation methods

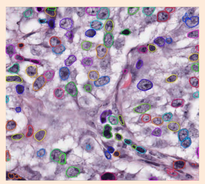
- 4-fold ensembling: merging multiple models trained on folds of the training set
- Test-time augmentation (TTA): using flips and color disturbances in the inference phase
- Transfer learning: using pretraining on the PanNuke Dataset
- Model adaptations: include distance map information as an extra input channel
- **Example of 4-channel input (RGB image on the left + distance map derived from the binary masks on the right)**

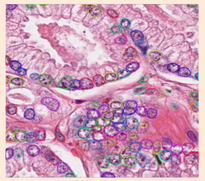


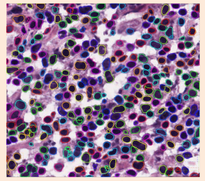
Results

◇ Visual evaluation of the test results from the best approach


Colon


Liver


Prostate


Stomach

◇ Quantitative average results on the Kumar et al. (2017) test set

Adaptation	Ensemble	TTA	PanNuke Pretrain	Distance maps	AJI (%)	PQ (%)
Mask R-CNN [5]	-	-	-	-	49.2	50.5
Mask R-CNN +	✓	-	-	-	52.2	52.6
	-	✓	-	-	53.5	53.1
	-	-	✓	-	52.1	52.9
	-	-	-	✓	55.2	51.9
	✓	✓	-	-	50.6	48.2
	✓	-	✓	-	53.3	52.4
	✓	-	-	✓	55.9	52.4
	-	✓	-	✓	55.6	52.7
	-	✓	✓	-	56.5	55.2
	-	-	✓	✓	56.2	52.5
	✓	✓	✓	-	55.8	53.1
	-	✓	✓	✓	56.2	52.3
	✓	-	✓	✓	55.9	52.8
	✓	✓	-	✓	56.3	52.7
	✓	✓	✓	✓	**56.7**	**53.1**

Conclusion and future work

- Mask R-CNN can perform high quality instance segmentation on crowded nuclei
- Adaptations to the baseline architecture improve the segmentation performance
- Not all combinations of modifications are beneficial

◇ Next:

- Use customized inference strategy to minimize image border region detections
- Explore alternatives and extensions to the RPN stage
- Change model architecture to incorporate distance masks
- Implement algorithm to merge instances

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Contact

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[3] Gamper, et al., PanNuke Dataset Extension, Insights and Baselines, https://arxiv.org/abs/2003.10778
[4] Kirillov, et al., Panoptic Segmentation, Proceedings on the IEEE/CFV International Conference on Computer Vision and Pattern Recognition (CVPR), 2019, pp. 9404-9413
[5] Reference implementation from: https://github.com/matterport/Mask_RCNN