(MP58-06) Automated Staging of T1 Bladder Cancer Using Digital Pathologic H&E Images: A Deep Learning Approach

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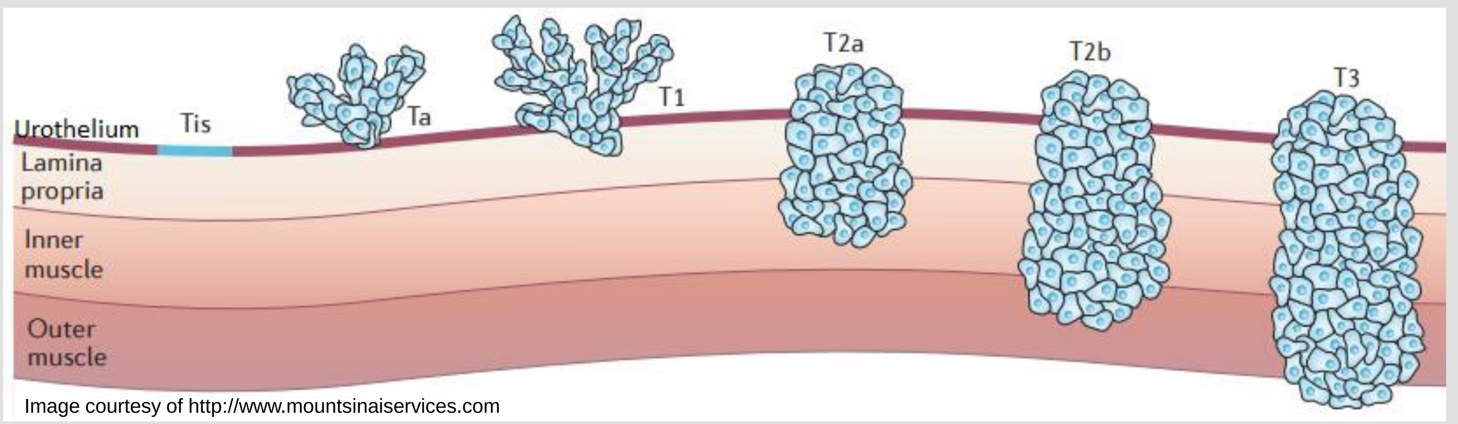
Introduction

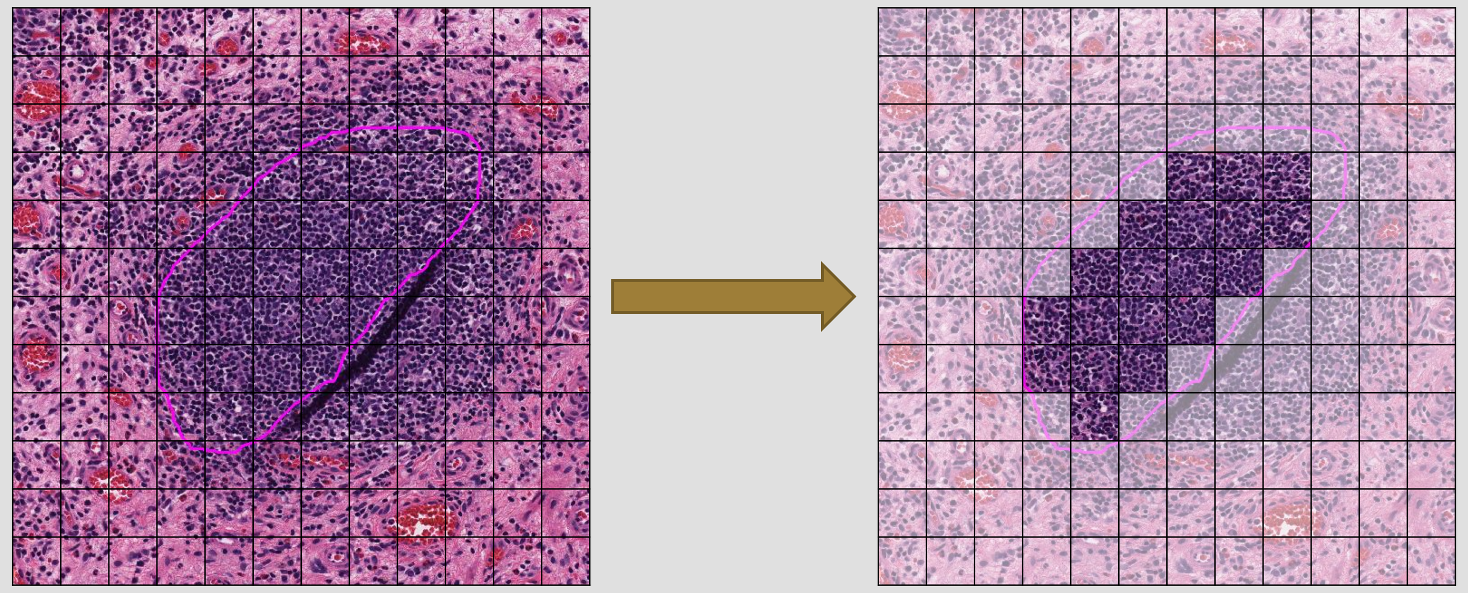
Normal bladder mucosa is comprised of urothelium (U), resting at the basement of the membrane, lamina propria (LP), deep to U, and muscularis propria (MP), adjacent of LP.



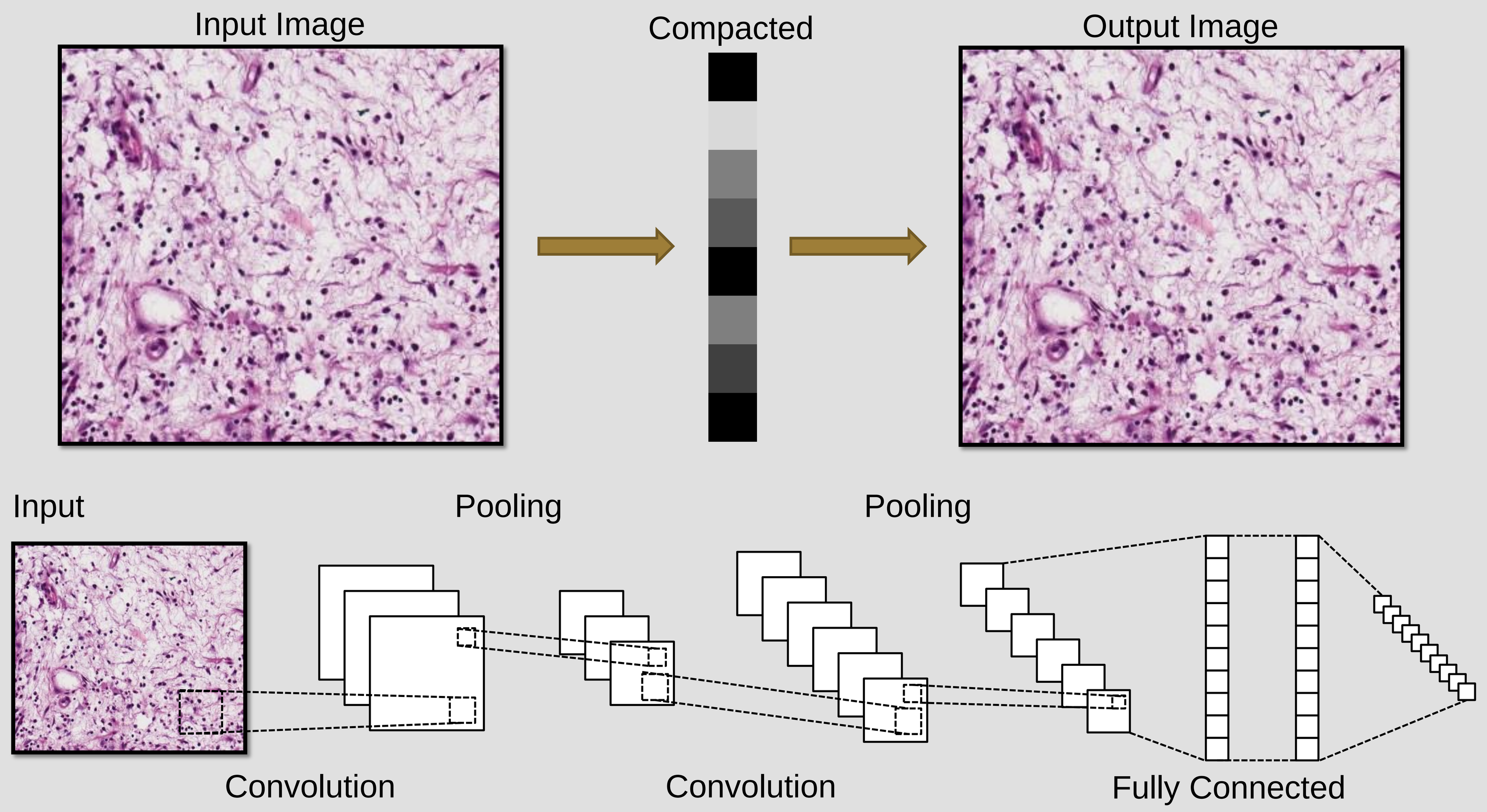
T1 bladder cancer is defined as the invasion of tumor cells into LP. Studies have shown that depth of tumor invasion into LP is correlated with worse prognosis (more recurrence and higher rates of progression) [1]. Yet, prevailing literature suggests that pathologists struggle to recognize LP invasion accurately from H&E bladder biopsies [2]. To enhance pathologic interpretation, we are developing a deep learning method to identify bladder layers (U, LP, MP) from H&E tissue biopsies and to measure the extend of LP invasion.

Materials and Methods

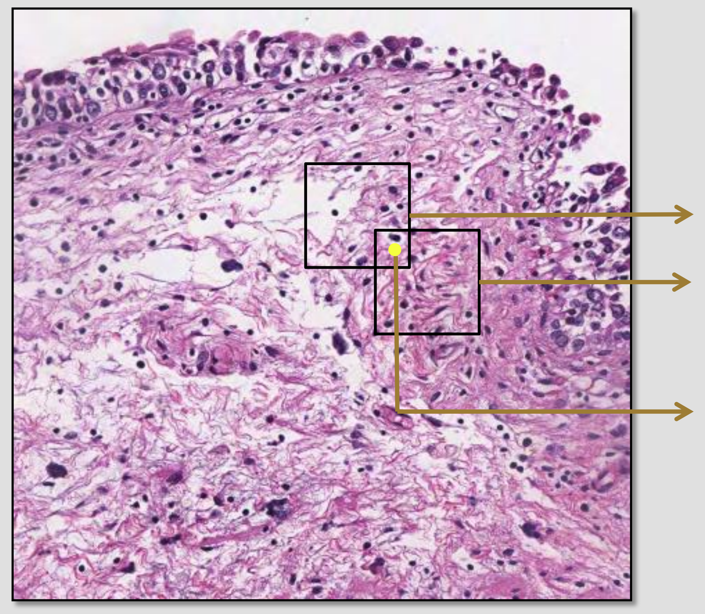
Our database consists of 86 whole slide H&E images of bladder biopsies scanned at 40x magnification using a high resolution scanner and was annotated for U, LP, MP, cauterized tissue, red blood cells (RBCs), and inflammation by an expert pathologist.



Each annotation was automatically sampled for 64x64-pixel tiles at 10x magnification using an overlaid regular grid. Finally, 86 distinct datasets were created from the pre-processing results, each withholding tiles from 1 of 86 whole slide images. We explored two deep learning paradigms for the identification of bladder layers – convolutional networks (CNNs), trained via transfer learning, and autoencoders, trained from scratch. Two different CNN architectures were used – AlexNet [3], which was fine-tuned, and Inception v3 [4], which was used as a feature extractor.



As an unlabeled image is presented to the system, a 64x64 pixel window slides over the image with step size of 8 pixels. Each resulting window is classified by the deep learning system and produces a vector of probabilities for each class. These probabilities are accumulated on respective class 'probability maps' on a pixel-by-pixel basis, which when fused and thresholded, produce masks for U, LP, and MP.



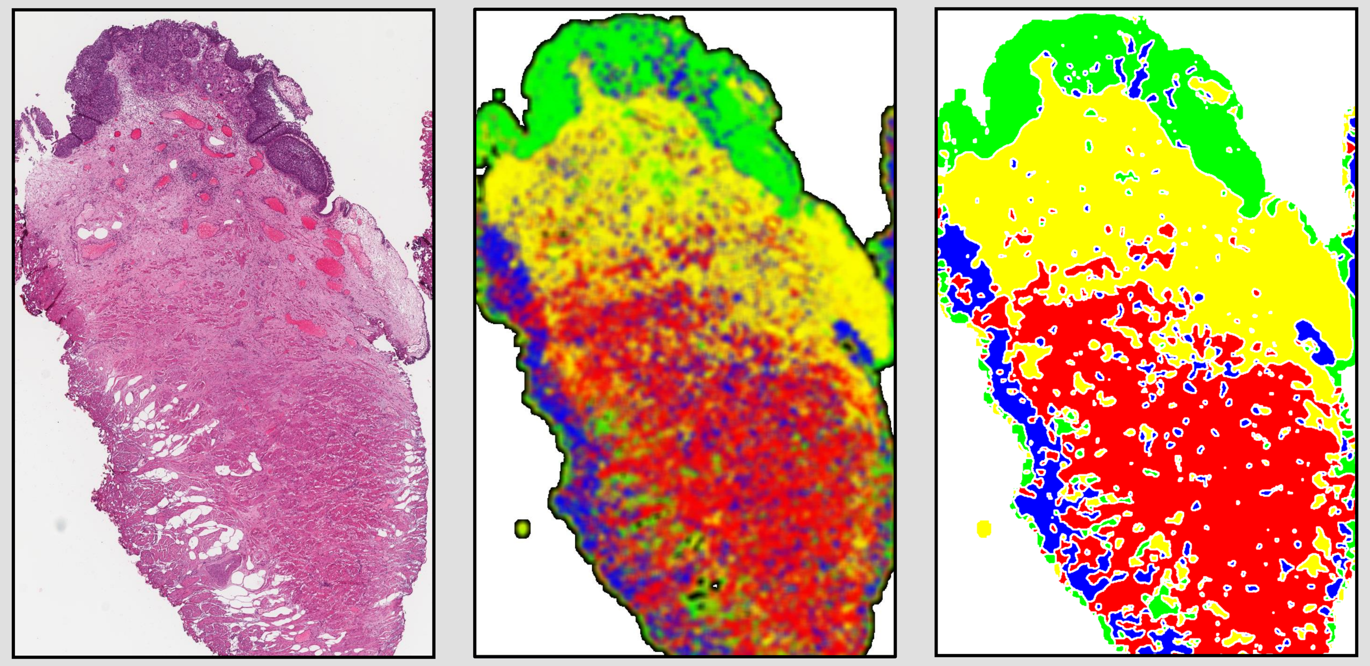
	LP	MP	U	C	I	RBC
	< 0.9	0.03	0.03	0.1	0.02	0.01 >
	< 0.9	0.01	0.03	0.03	0.02	0.01 >
Sum	< 1.8	0.04	0.06	0.04	0.04	0.02 >
Avg.	< 0.9	0.02	0.03	0.03	0.02	0.01 >

Results

When validated on LP and MP tiles, Inception has 96% accuracy, AlexNet 97%, and autoencoders 88%. When tested, Inception performs at 97% accuracy, AlexNet at 88%, and autoencoders at 80%. When formed into a two-class problem (U vs. LP/MP), Inception has 96% testing accuracy. When segmentation of bladder layers on 37 test images was evaluated by an expert pathologist (0-5 rating, step size 0.5), the proposed method resulted in an average score of 4.6 (+/- 0.6).

Alexnet		Predicted Class LP	Predicted Class MP	
Actual Class	LP	6513	1088	86%
	MP	1651	4549	73%
		80%	81%	80%
Inception		**Predicted Class LP**	**Predicted Class MP**	
Actual Class	LP	7953	178	98%
	MP	211	5459	96%
		97%	97%	97%
Autoencoders		**Predicted Class LP**	**Predicted Class MP**	
Actual Class	LP	6992	609	92%
	MP	1029	5134	83%
		87%	89%	88%

Below is a sample segmentation produced by the model. Green represents U, yellow represents LP, red represents MP, and blue represents cautery artifacts.



Conclusions

The results suggest that it is possible to transfer knowledge between recognition tasks, i.e. use discernable features learned from non-pathology images to recognize bladder layers using deep learning. Each model achieved high accuracy on both validation and testing sets. When given a set of tumor nuclei, the system is capable of determining the depth of invasion. A relationship between this measurement and patient prognosis has yet to be determined.

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References

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