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A Lumen Segmentation Method in Ureteroscopy Images based on a Deep Residual U-Net architecture

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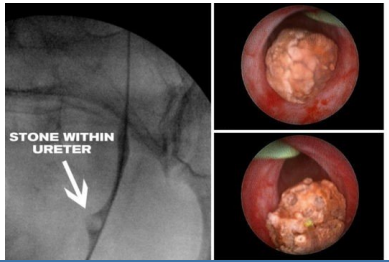
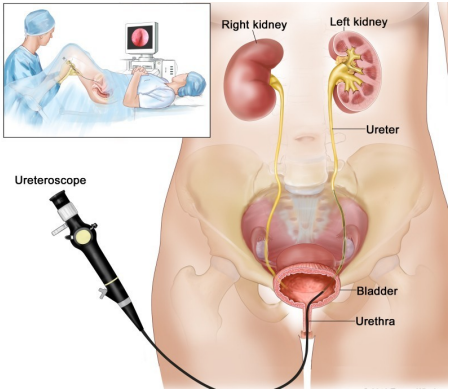
Clinical background: Ureteroscopy

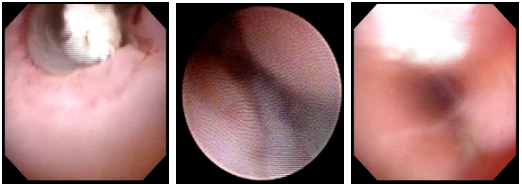
- Ureteroscopy is an examination of the upper urinary tract.
- Treatment of urinary disorders such as **kidney stones** and **urothelial carcinoma**
- Major complications found **[de la Rosette et al, 2006]**:
  - Avulsion
  - Major and minor perforation
  - Mucosal abrasion
  - Stricture

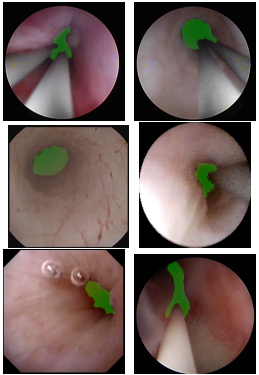




Ureteroscopy: Current Challenges

- Lack of public available and annotated datasets
- The anatomical variability
- Image arifacts, speculatrities, blur specularities, etc.
- The position and orientation at which the image is captured
- The variability among different patients-data

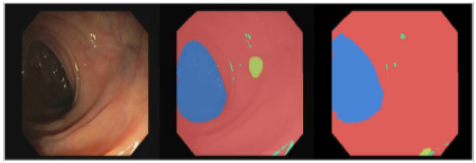




Aim

To develop an image segmentation system capable to be used in endoscopic procedures which can highlight relevant information to the operators during the procedures.

- The hollow lumen
- Relevant information about the tissue



Methodology: Dataset

For this project images obtained at the European Institute of Oncology (IEO) for upper tract carcinoma removal procedures and kidney stone removal respectively were manually annotated.

Video No.	No. of annotated frames	Image Size (pixels)	Patient No.
1	7	356x256	1
2	80	256x266	1
3	462	296x277	2
4	245	256x257	3
5	148	256x257	3
6	168	256x257	3
7	235	256x262	4
Total	1,445	-	-

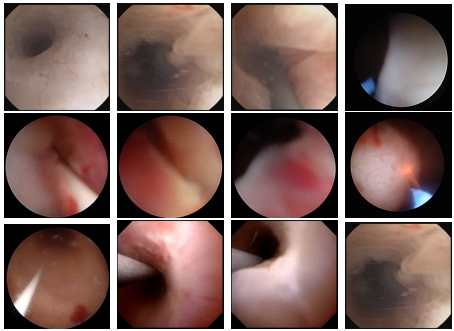
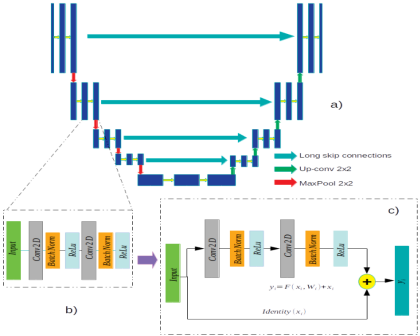


Figure: Samples of the images in the dataset

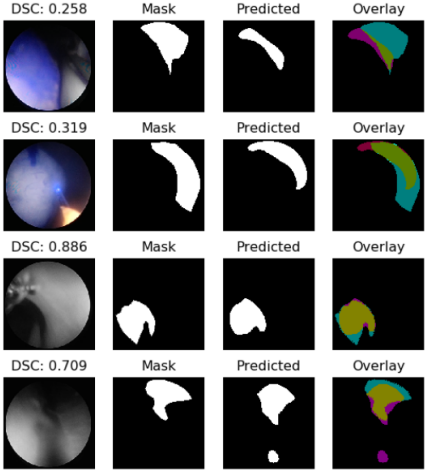
Methodology

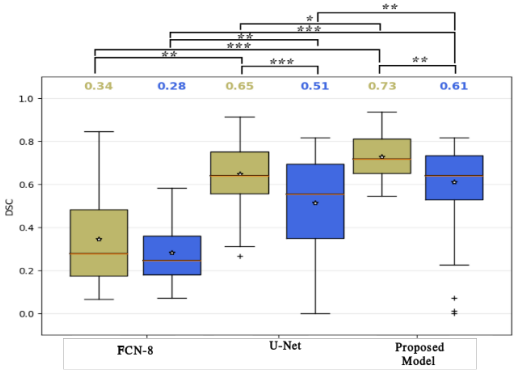
- Exploit the specific nature of the data
  - Use of different color spaces to reduce the dimensionality to speed up computation
  - Use of Batch Normalizaton (BN) for faster convergence
  - The loss function used in this implementation was based on the Dice similarity coefficient (L_{DSC}) defined as:

$$L_{DSC} = 1 - \frac{2TP}{2TP + FN + FP} \qquad (1)$$



Preliminary Results





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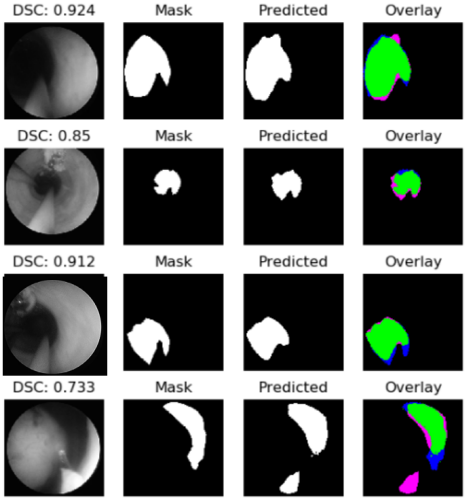

Model	*DSC*	*Prec*	*Rec*	*Acc*
U-Net	0.67 ± 0.01	0.57 ± 0.01	0.69 ± 0.03	**0.94 ± 0.02**
U-Net	0.55 ± 0.09	0.43 ± 0.11	0.57 ± 0.07	0.87 ± 0.17
Residual U-Net	**0.68 ± 0.05**	**0.58 ± 0.01**	**0.78 ± 0.03**	0.92 ± 0.10
Residual U-Net	0.59 ± 0.15	0.49 ± 0.03	0.63 ± 0.13	0.94 ± 0.01
FCN-8	0.36 ± 0.08	0.25 ± 0.09	0.64 ± 0.01	0.78 ± 0.07
FCN-8	0.23 ± 0.04	0.19 ± 0.03	0.52 ± 0.10	0.64 ± 0.15

- In general it has been reported that short skip connections are efficient to deal with the vanishing gradient problem
- The spatial information propagates without degradation and in general thanks to the short-skip connections
- We observed that with the use of residual blocks a better delineation of the borders of the lumen was obtained

Conclusions and Discussion

- The methods analyzed show promising results but need to be further studied
- Keep increasing the dataset
- Deal with the lumen edge variance in the segmentation process and the fine-grain regions which are currently missing
- Add an extra step for lumen 'identification'
- Use of spatio-temporal data instead of single frames
- Consider advanced data augmentation techniques such as the creation of synthetic data

Thank you for your attention!