Automated Surgical Skill Assessment for Cataract Surgery Videos

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Biostatistics & Medical Informatics

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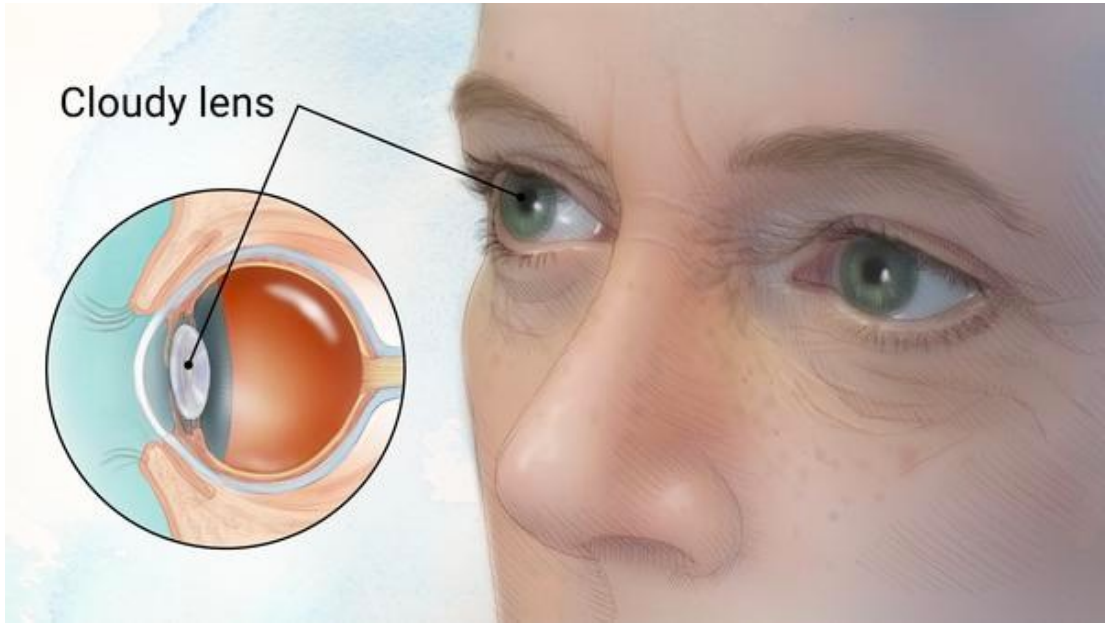
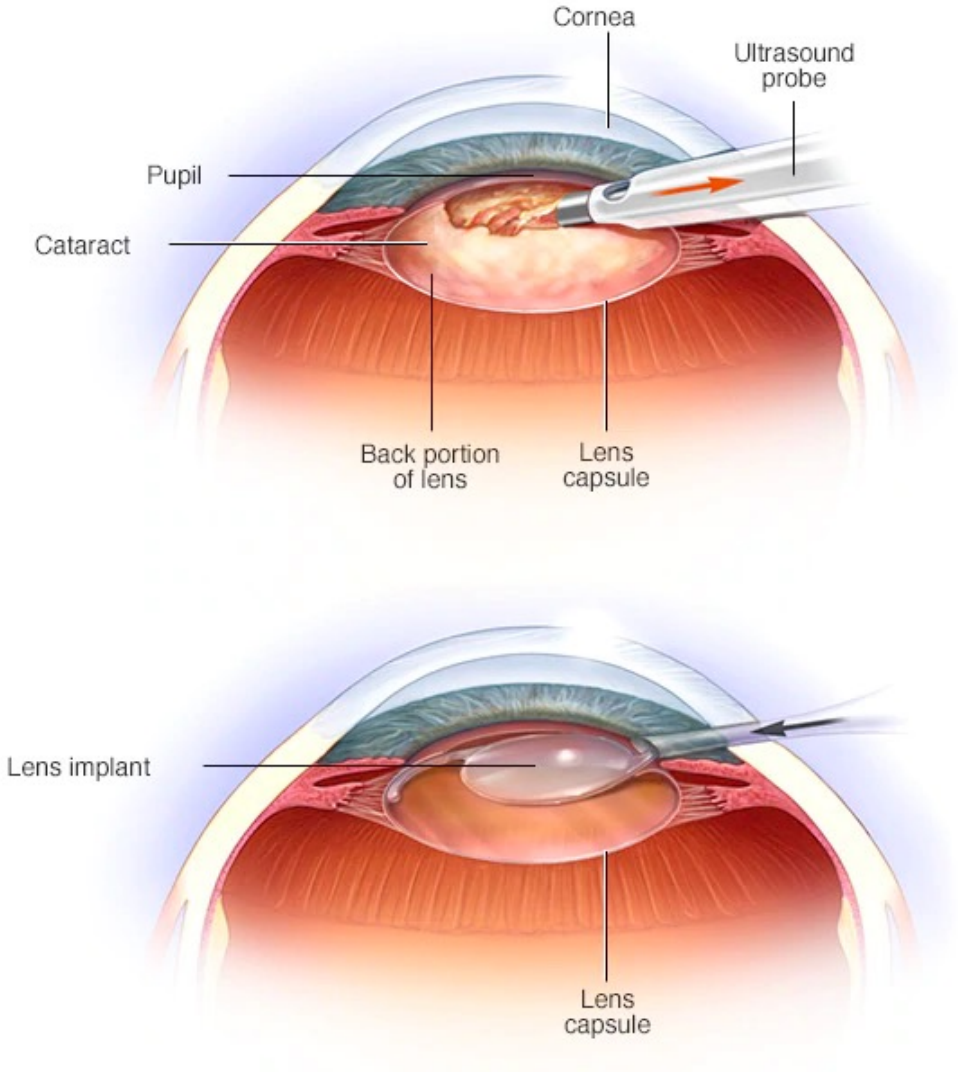
Cataract Surgery

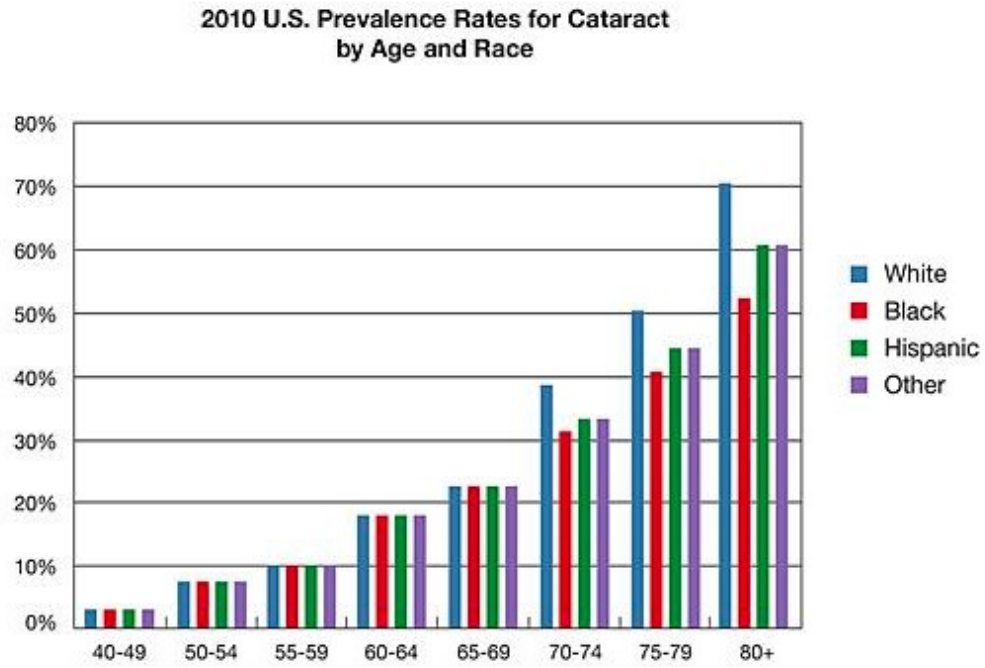




Sources: Mayo Clinic

Motivation

- Leading cause of blindness in the world, according to the World Health Organization.
- Most common surgical interventions performed in the world. (~19M interventions / year)
- Cataract cases are estimated to increase 78% by 2050.
- Ophthalmology residents spend a large portion of their training in learning cataract surgery.
- A key challenge in the training is to develop a systematic and objective assessment of surgical competency of the residents.



Source: National Eye Institute - NIH

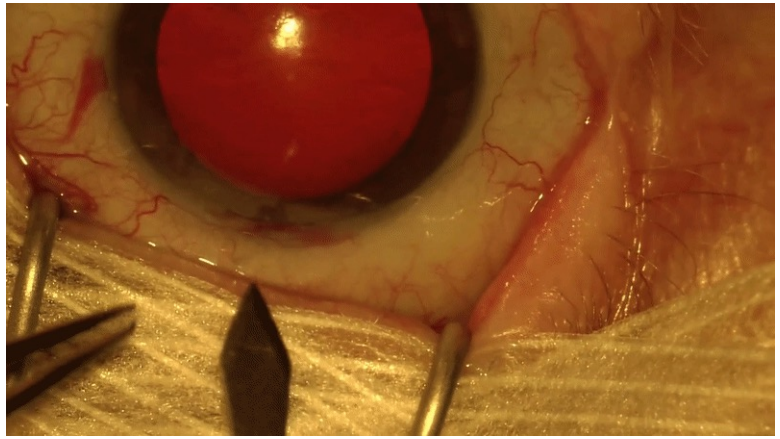
Surgical Skill Assessment

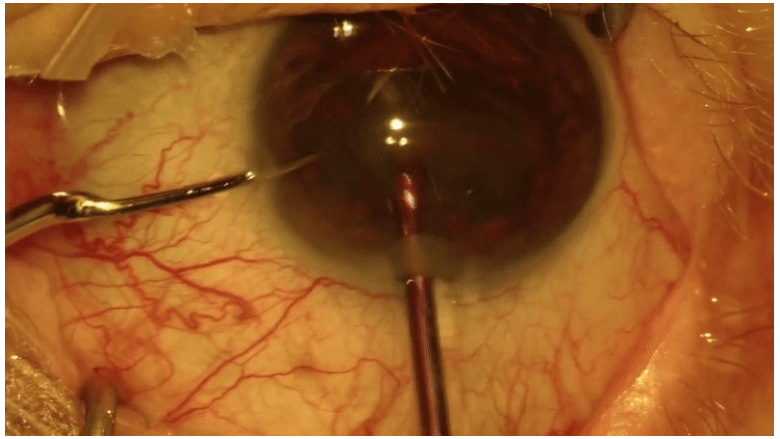
ICO-Ophthalmology Surgical Competency Assessment Rubric: Phacoemulsification (ICO-OSCAR: Phaco)

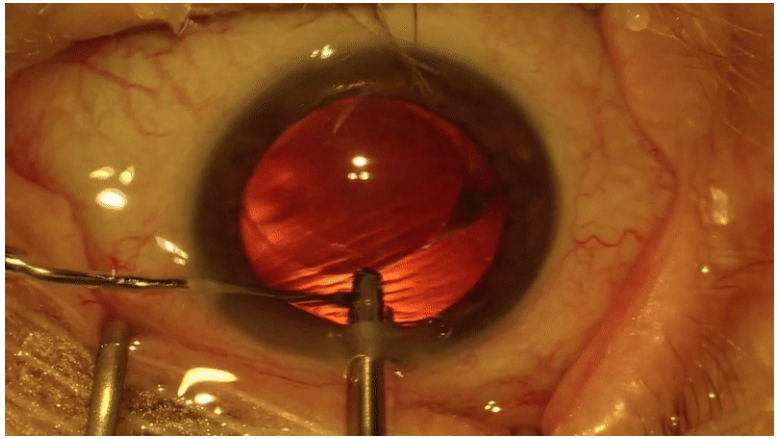
Date _____ Resident _____ Evaluator _____	Novice (score = 2)	Beginner (score = 3)	Advanced Beginner (score = 4)	Competent (score = 5)	Not applicable. Done by preceptor (score= 0)
1 Draping:					
2 Incision & Paracentesis: Formation & Technique					
3 Viscoelastic: Appropriate Use and Safe Insertion					
4 Capsulorrhexis: Commencement of Flap & follow-through.					
5 Capsulorrhexis: Formation and Circular Completion					
6 Hydrodissection: Visible Fluid Wave and Free Nuclear Rotation					
	Global Indices				
15	Wound Neutrality and Minimizing Eye Rolling and Corneal Distortion	Nearly constant eye movement and corneal distortion.	Eye often not in primary position, frequent distortion folds.	Eye usually in primary position, mild corneal distortion folds occur.	The eye is kept in primary position during the surgery. No distortion folds are produced. The length and location of incisions prevents distortion of the cornea.	
16	Eye Positioned Centrally Within Microscope View	Constantly requires repositioning.	Occasional repositioning required.	Mild fluctuation in pupil position.	The pupil is kept centered during the surgery.	
17	Conjunctival and Corneal Tissue Handling	Tissue handling is rough and damage occurs.	Tissue handling borderline, minimal damage occurs.	Tissue handling decent but potential for damage exists.	Tissue is not damaged nor at risk by handling.	
18	Intraocular Spatial Awareness	instruments often in contact with capsule, iris and corneal endothelium', blunt second hand instrument not kept in appropriate position.	Occasional accidental contact with capsule, iris and corneal endothelium, sometimes has blunt second hand instrument between the posterior capsule and the activated phaco tip.	Rare accidental contact with capsule, iris and corneal endothelium. Often has blunt second hand instrument between the posterior capsule and the activated phaco tip.	No accidental contact with capsule, iris and corneal endothelium, when appropriate, a blunt, second hand instrument, is always kept between the posterior capsule and the tip of the phaco when the phaco is activated.	
19	Iris Protection	Iris constantly at risk, handled roughly.	Iris occasionally at risk. Needs help in deciding when and how to use hooks, ring or other methods of iris protection.	Iris generally well protected. Slight difficulty with iris hooks, ring, or other methods of iris protection.	Iris is uninjured. Iris hooks, ring, or other methods are used as needed to protect the iris.	
20	Overall Speed and Fluidity of Procedure	Hesitant, frequent starts and stops, not at all fluid.	Occasional starts and stops, inefficient and unnecessary manipulations common, case duration about 60 minutes.	Occasional inefficient and/or unnecessary manipulations occur, case duration about 45 minutes.	Inefficient and/or unnecessary manipulations are avoided, case duration is appropriate for case difficulty. In general, 30 minutes should be adequate.	

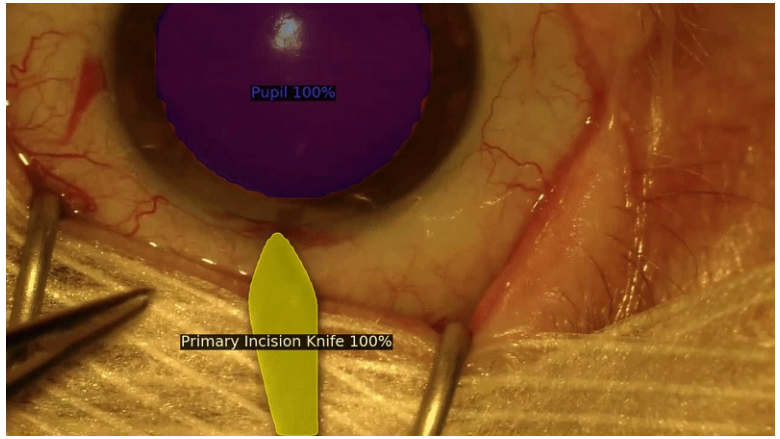
Our Results

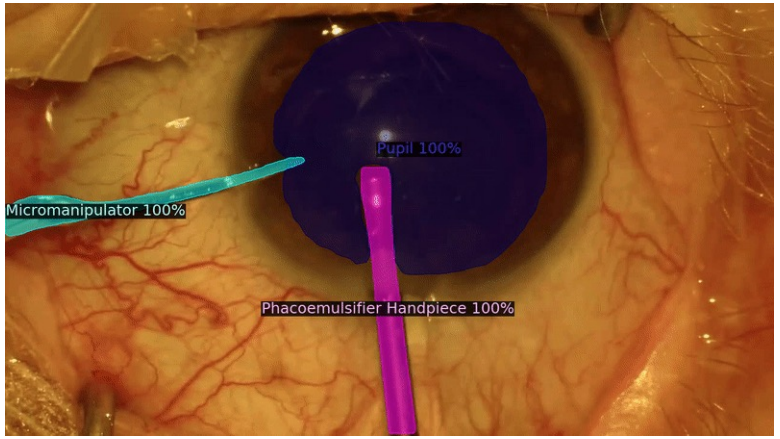
WARNING!

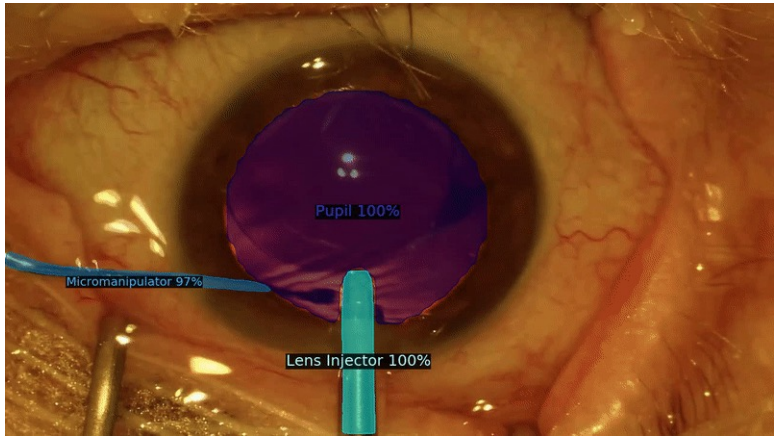




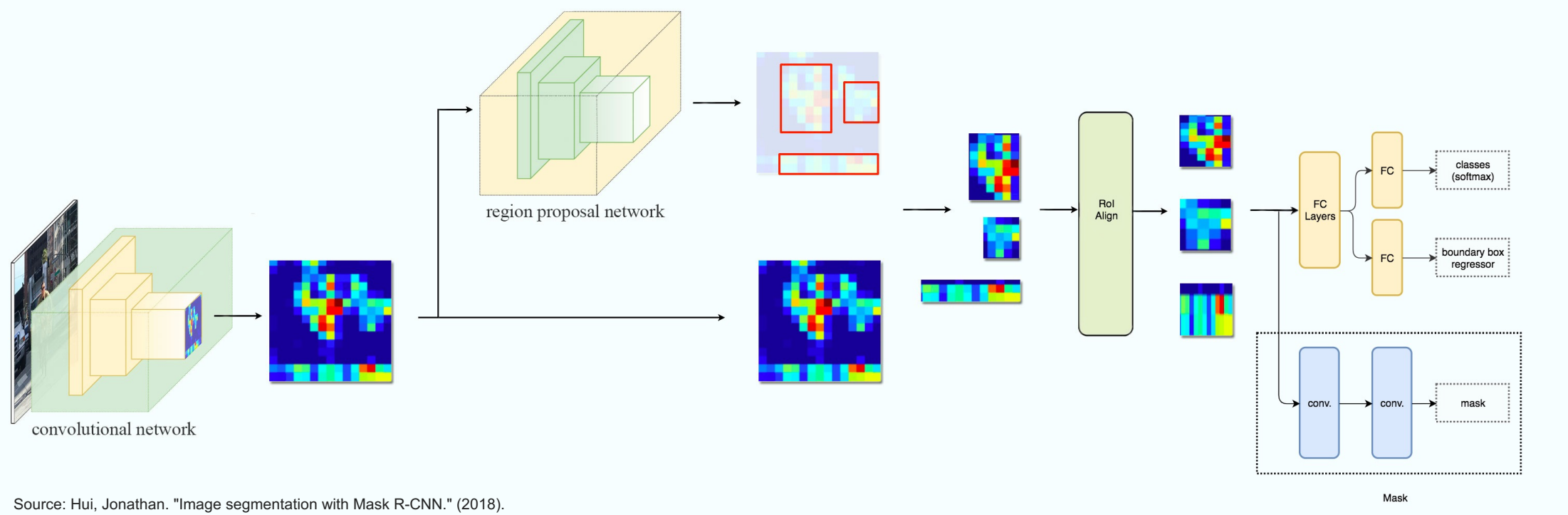








Methods: Mask R-CNN*

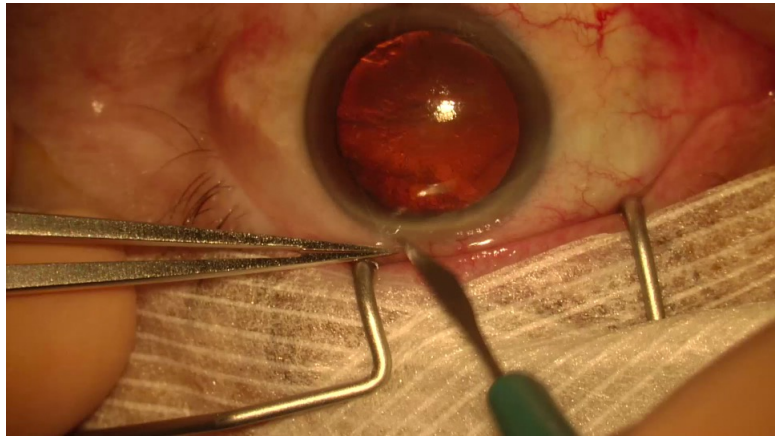


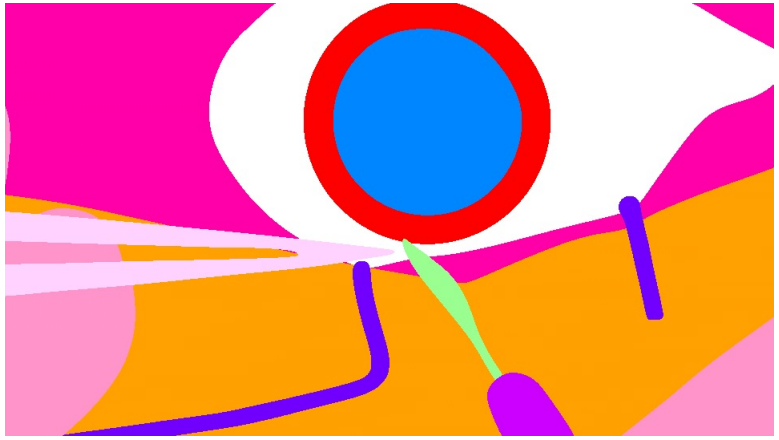
Source: Hui, Jonathan. "Image segmentation with Mask R-CNN." (2018).

* He, Kaiming, et al. "Mask R-CNN." *Proceedings of the IEEE international conference on computer vision*. 2017.

Dataset: CaDIS*

- 4738 images extracted from 25 videos with corresponding semantic annotation.
- Training: 3582, Validation: 542, Testing: 614

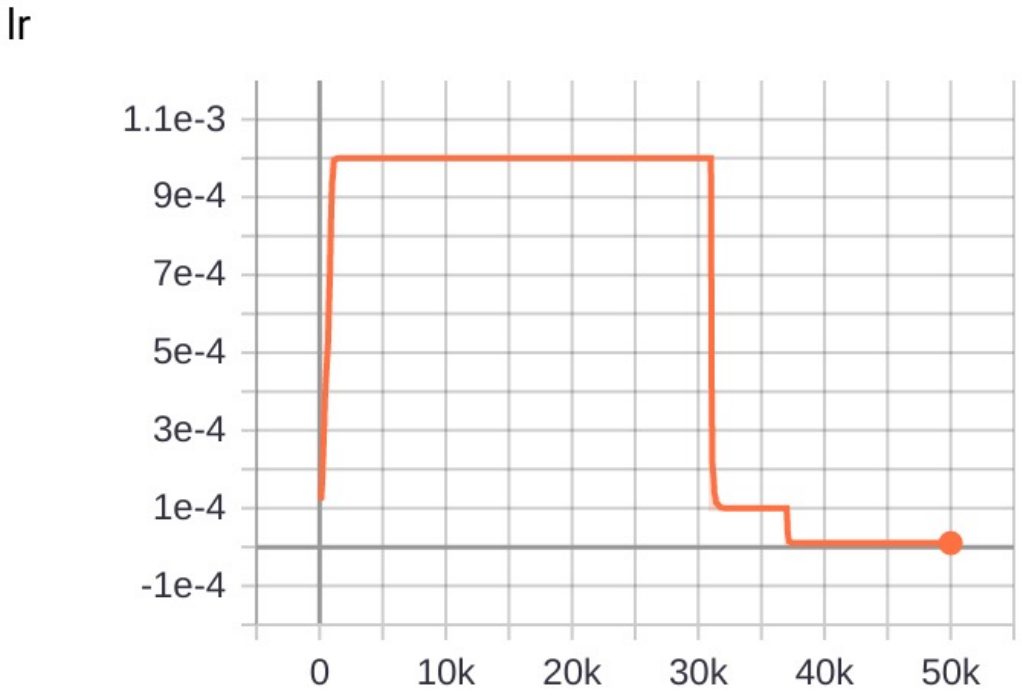


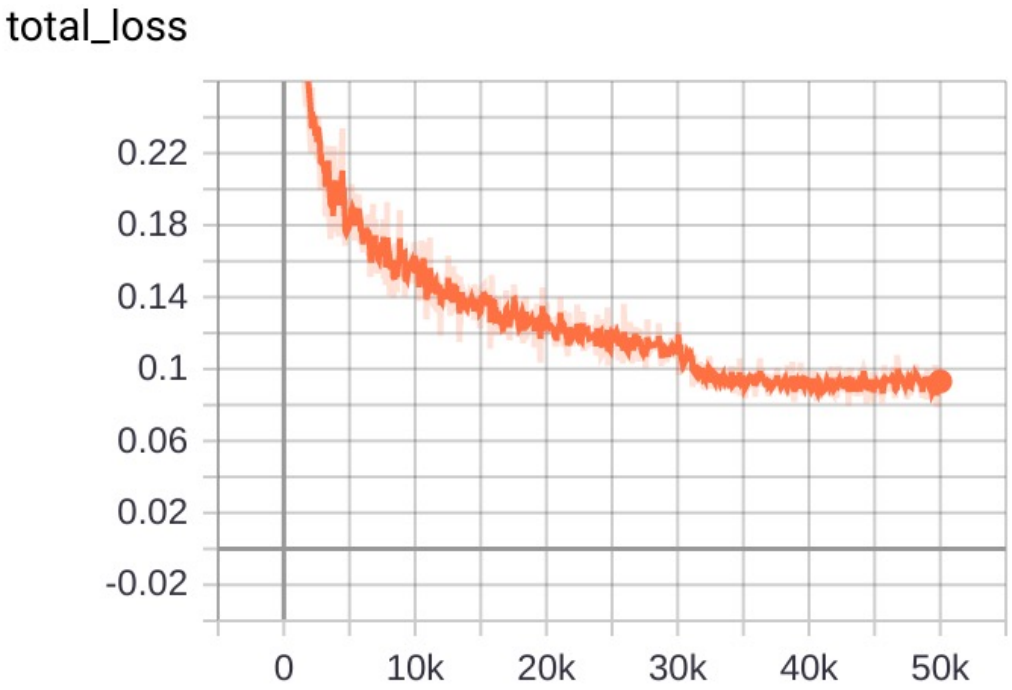


* Flouty, Evangello, et al. "Cadis: Cataract dataset for image segmentation." arXiv preprint arXiv:1906.11586 (2019).

Model Training

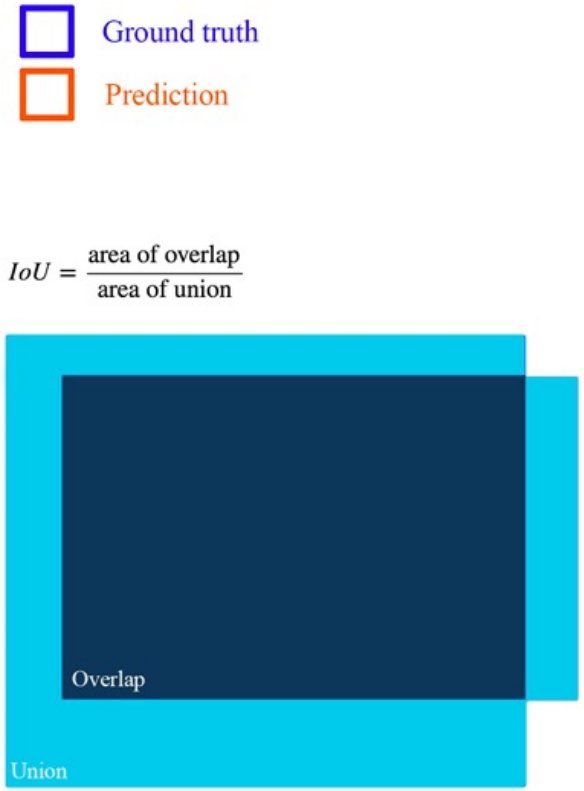
- We use Detectron2* as our training platform.
- 50k iterations (~55.6 epochs, mini-batch size of 4, 3.6k training images).
- A learning rate scheduler is used.





* Wu, Yuxin, et al. "Detectron2." URL: https://github.com/facebookresearch/detectron2

Evaluation Metrics (Average Precision)



$$IoU = \frac{\text{area of overlap}}{\text{area of union}}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

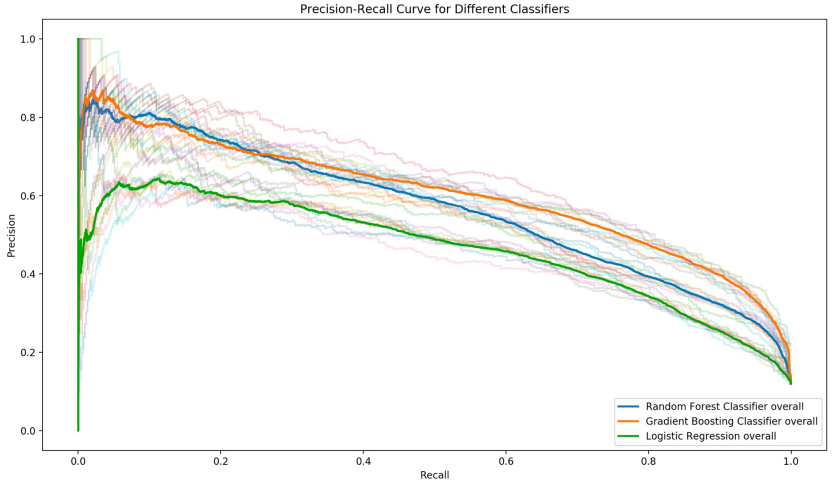
$$F1 = 2 \cdot \frac{precision \cdot recall}{precision + recall}$$

TP = True positive

TN = True negative

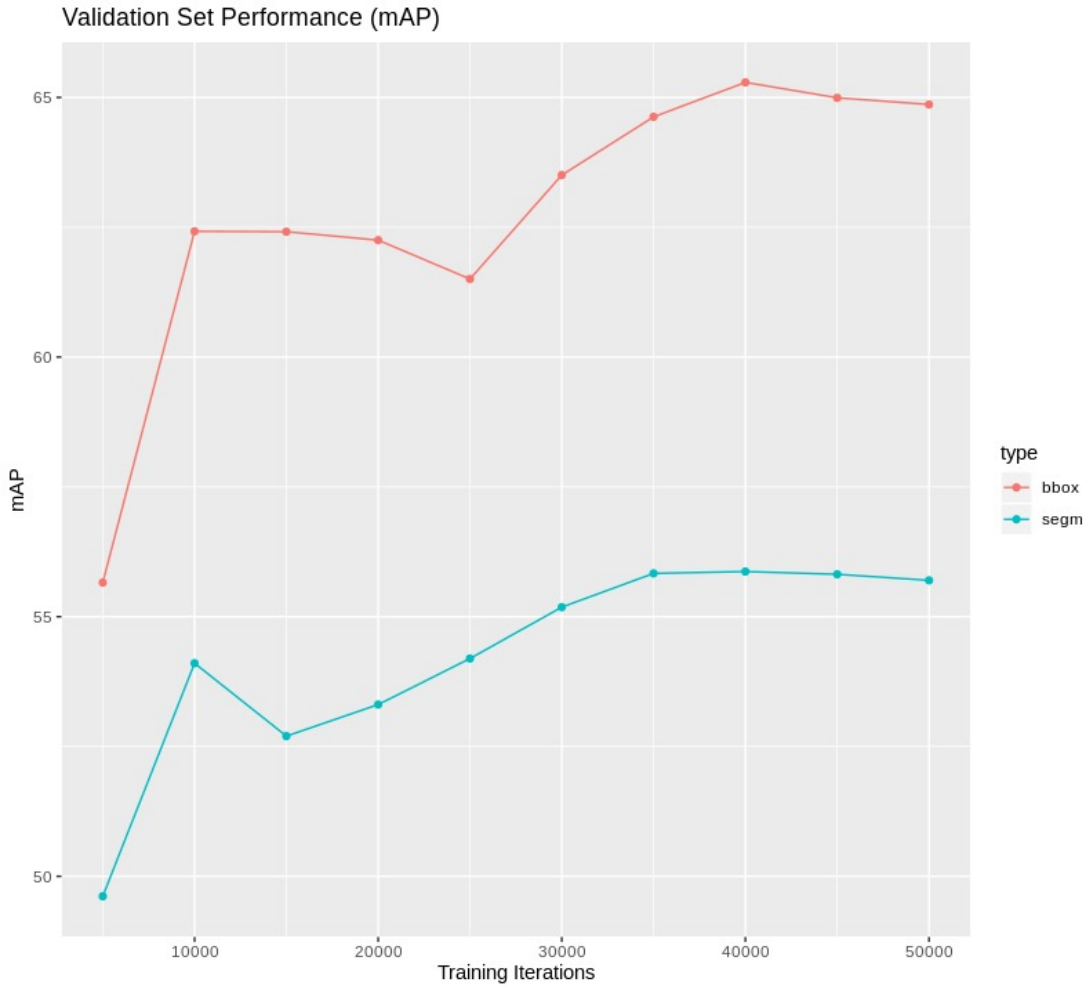
FP = False positive

FN = False negative



Model Validation

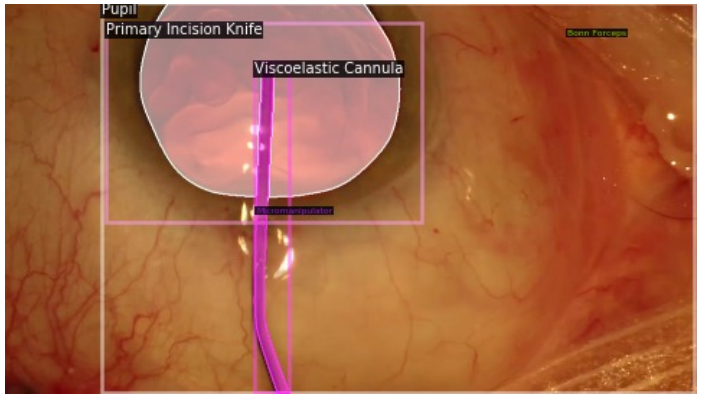
- Validate for every 5k iterations on Average Precision

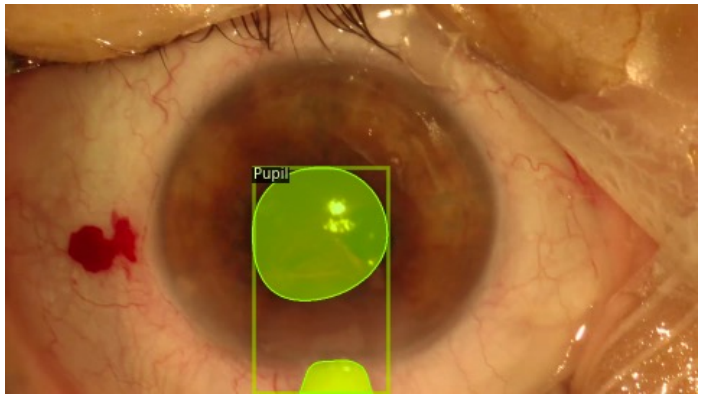


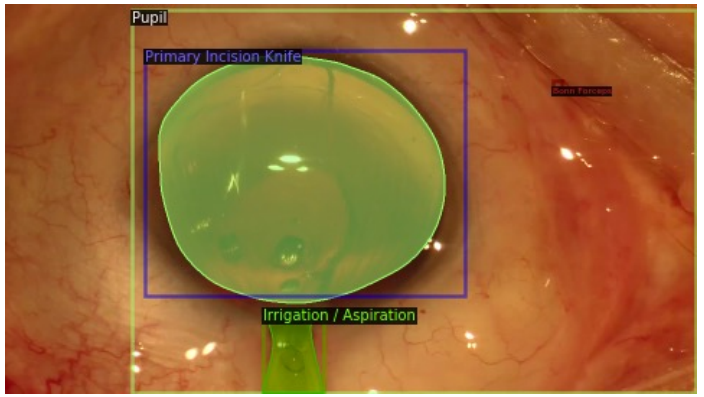
Test Performance

Pupil	mAP (IoU=0.50:0.95)	AP50	AP75
Segmentation	81.13	96.98	86.19

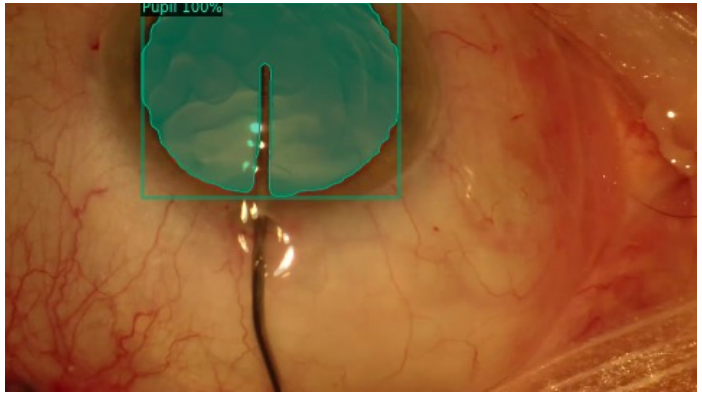
Labeled:

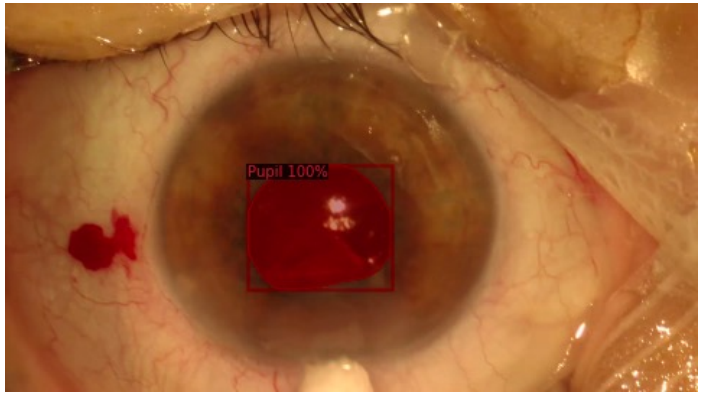


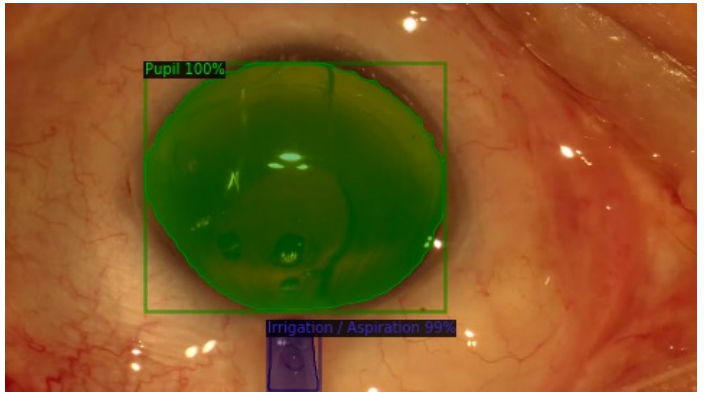




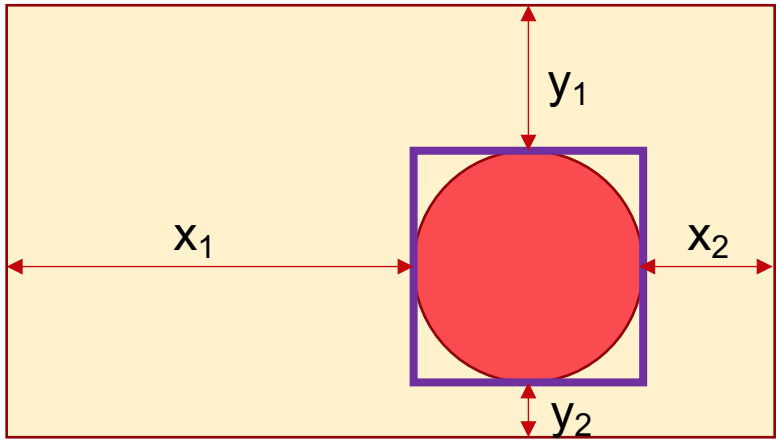
Predicted:



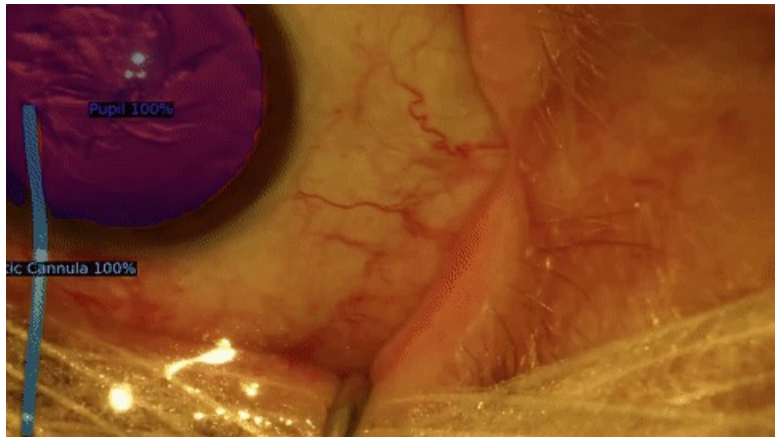


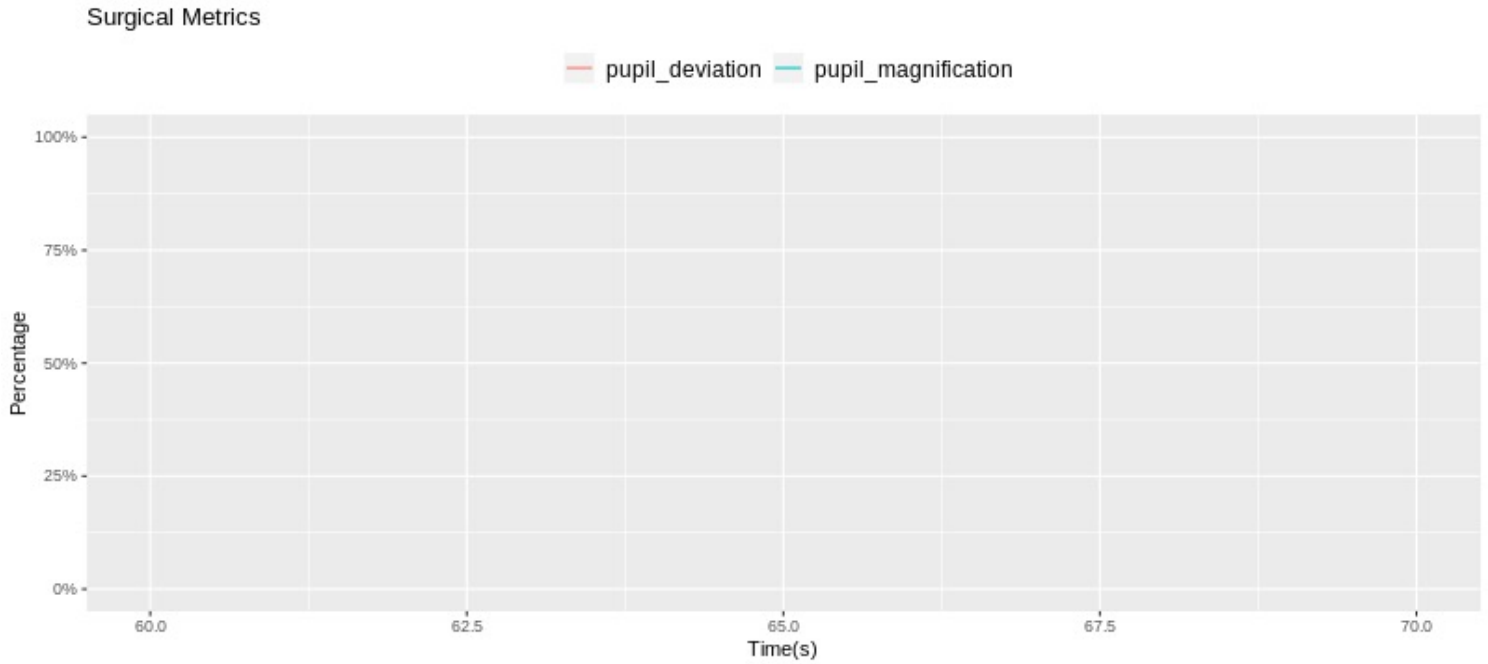


Surgical Metrics



- Pupil Deviation = $\frac{|y_1 - y_2|}{y_1 + y_2}, y_2 = \min(x_1, x_2, y_1, y_2)$
- Pupil Magnification = $\frac{Area(Bounding\ Box\ of\ Pupil)}{Area(Frame)}$





Future Work

DATA

METHODS

SURGICAL ASSESSMENT

Thank you!
Q&A

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