Low-Cost Diagnostics

Mohit Jain

Microsoft Research India

Access to Health

Skewed Doctor-to-Patient ratio

Unskilled healthcare workers

Long waiting

Transportation

Loss of income

…

Vision

To develop low-cost smartphone-based diagnostic tools

with AI assistant

to enable CHWs, teachers, primary clinicians, etc.

to perform preliminary screening with minimal training.

Keratoconus

Evaluation
Advanced stage

IMWUT'21
EMBC'22
WACV'24

Ref Error

Evaluation
Advanced stage

IMWUT'22

Dry Eye

Evaluation
Early Stage

IMWUT'25

Lung Disease

Open-sourced

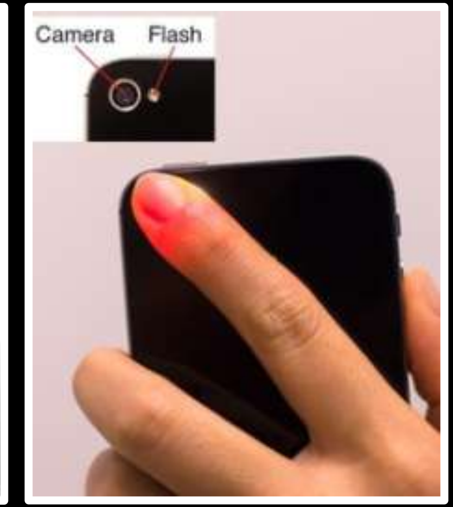
EMBC'21

Height

Working
Early Stage

EMBC'21

BP



Developing
Early Stage

Nature Scientific Reports '25

Collaborators: Sankara Eye Hospital, WeltHungerHilfe

Dry Eye Detection

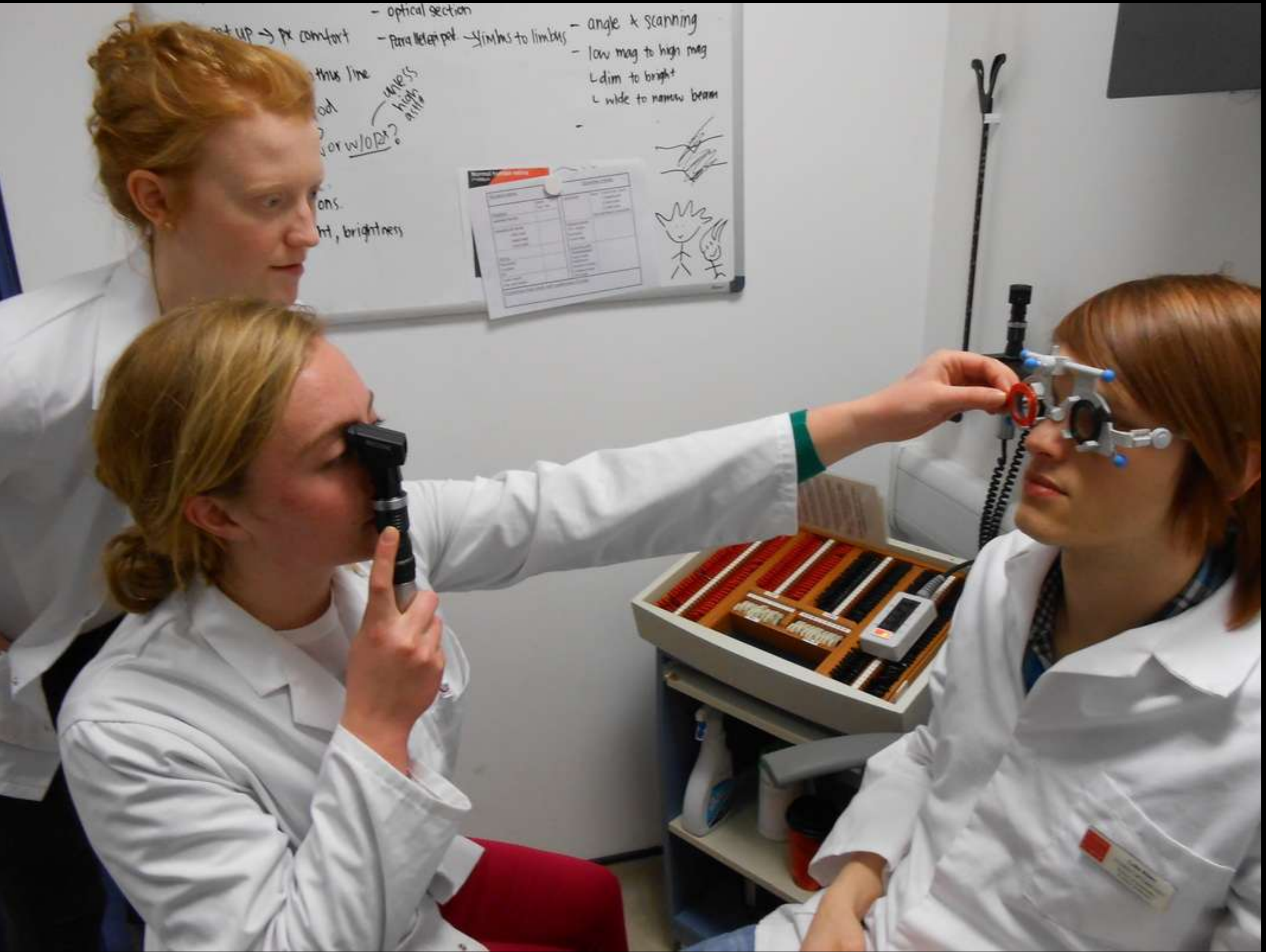
Collaborator: Sankara Eye Hospital

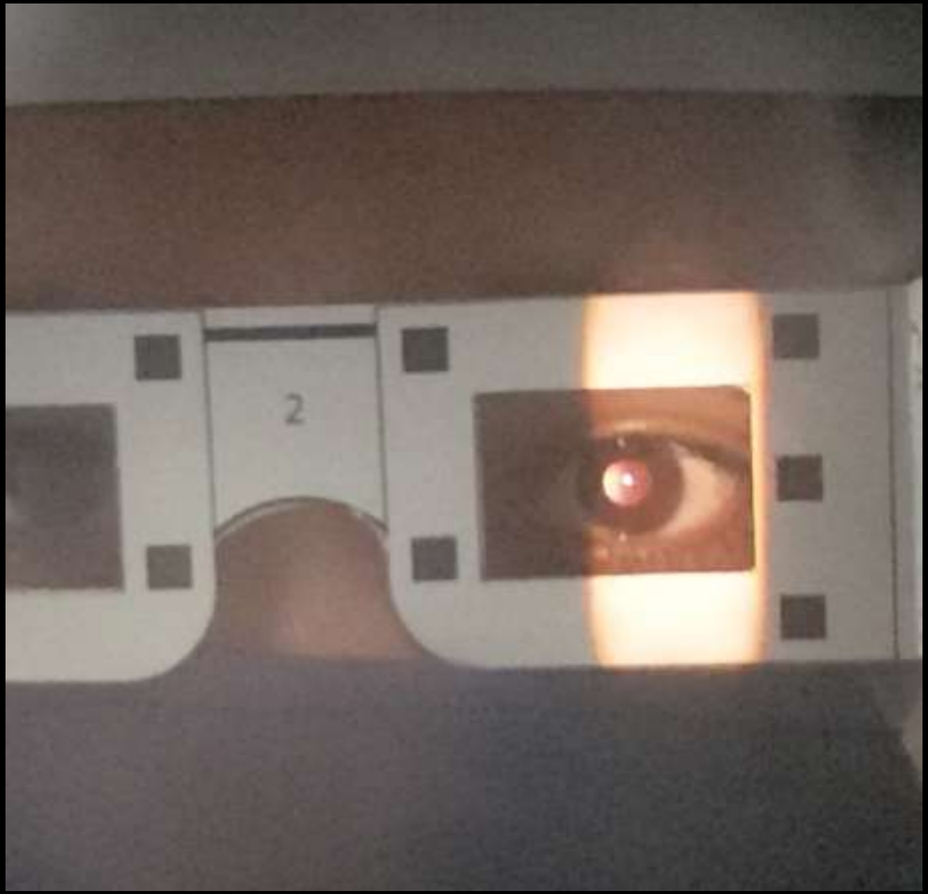
Normal Eye

Dry Eye

Refractive Error Estimation

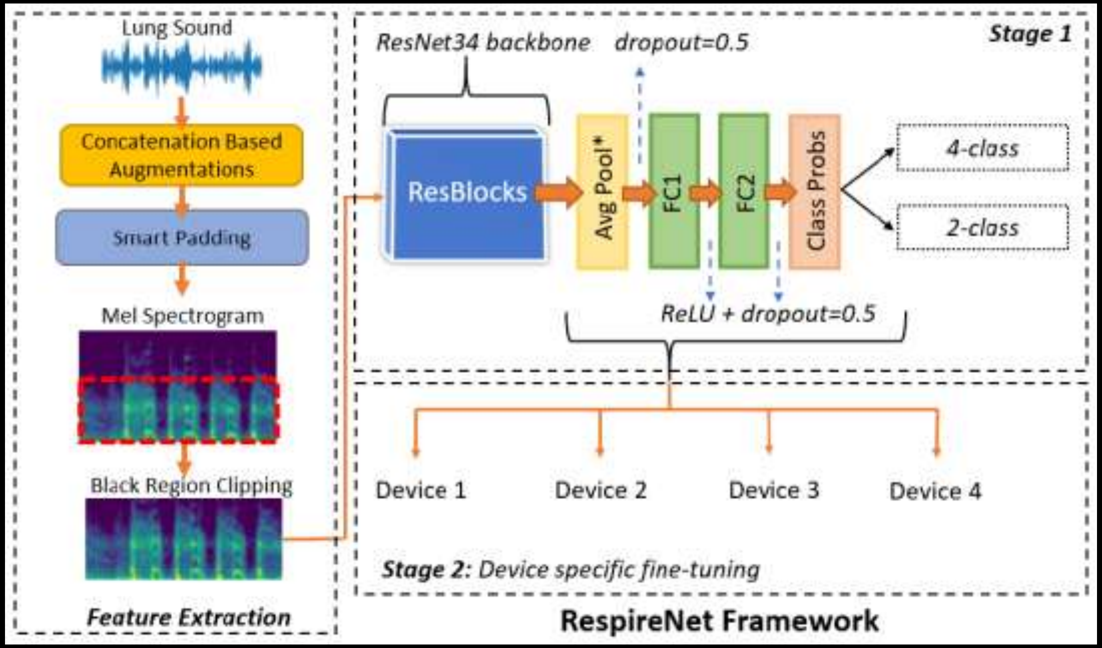
Collaborator: Sankara Eye Hospital

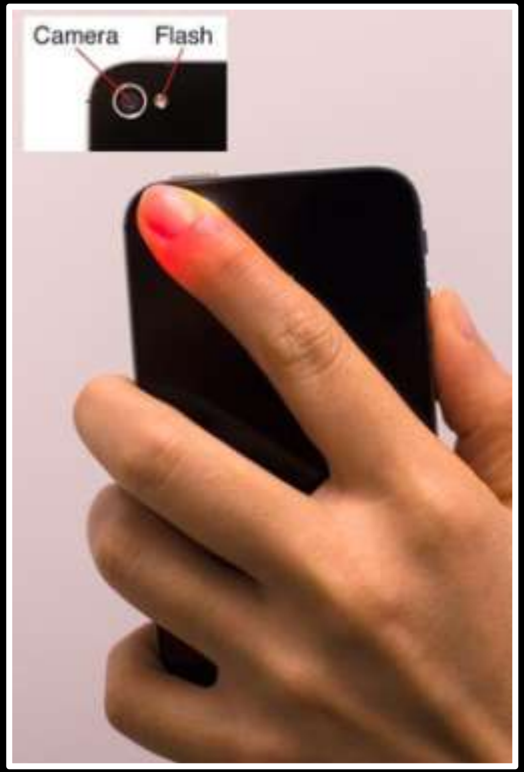




Estimation: Lung Disease, Height, and BP

Collaborator: WHH





SmartKC

Past, Present, Future

Mohit Jain, Nipun Kwatra
RF: Siddhartha Gairola (past), Vaibhav Ganatra (present)
In collaboration with doctors at **Sankara Eye Hospital**
Microsoft Research India

SmartKC

Smartphone-based Corneal Topographer for Keratoconus Diagnosis

Mohit Jain, Nipun Kwatra

RF: Siddhartha Gairola (past), Vaibhav Ganatra (present)

In collaboration with doctors at **Sankara Eye Hospital**

Microsoft Research India

Keratoconus Disease

Distorts cornea into a cone-like shape

Impact teens

Causes (partial) blindness

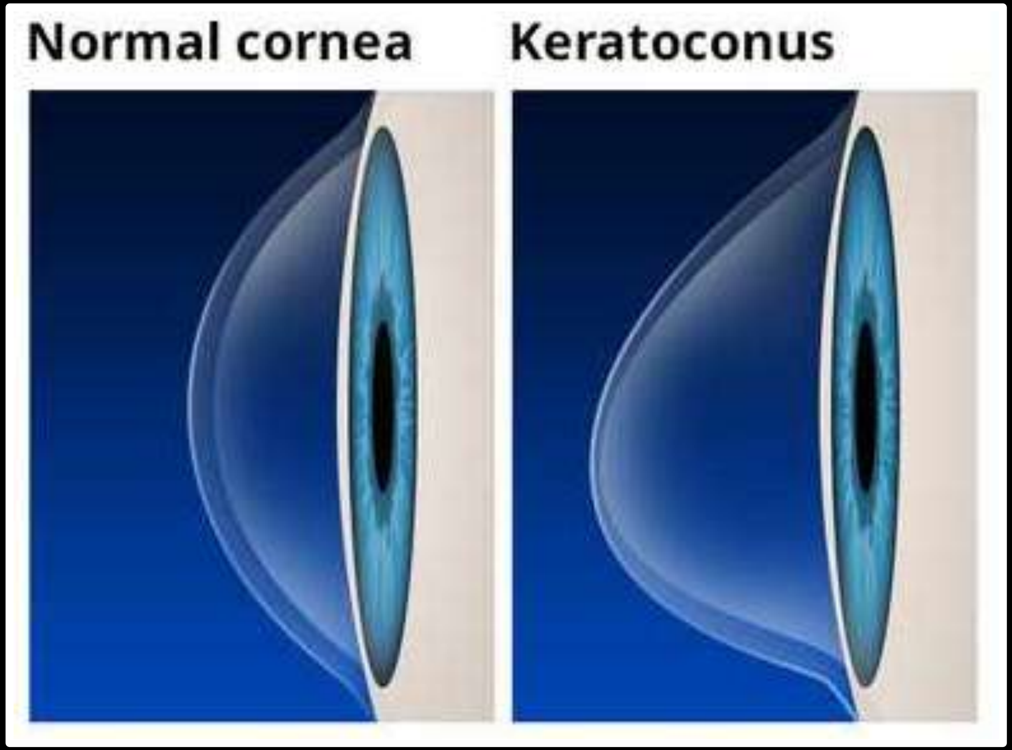
Affects 2.3% people in India

Treatment:

→ Contact lenses

→ Corneal cross-linking

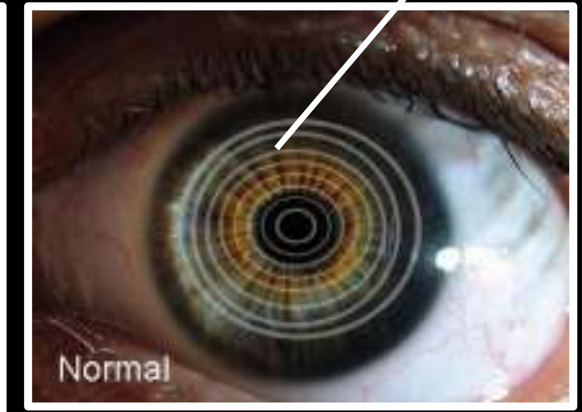
→ Corneal transplant

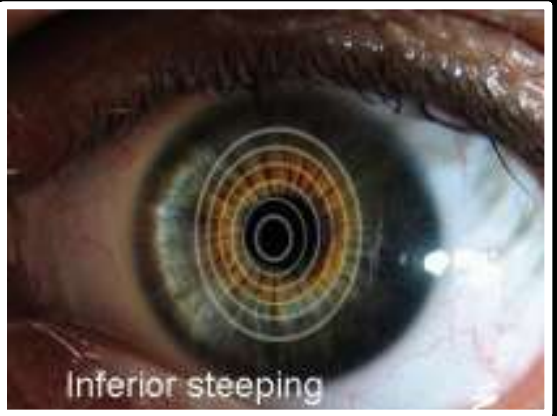


Early Diagnosis is the Key!

Diagnostics: Placido Disc

Mires





Placido

Cheap | Doctor needed | Low accuracy

Diagnostics: Corneal Topographers

Optikon Keratron

Medmont E 300

Zeiss Atlas 9000

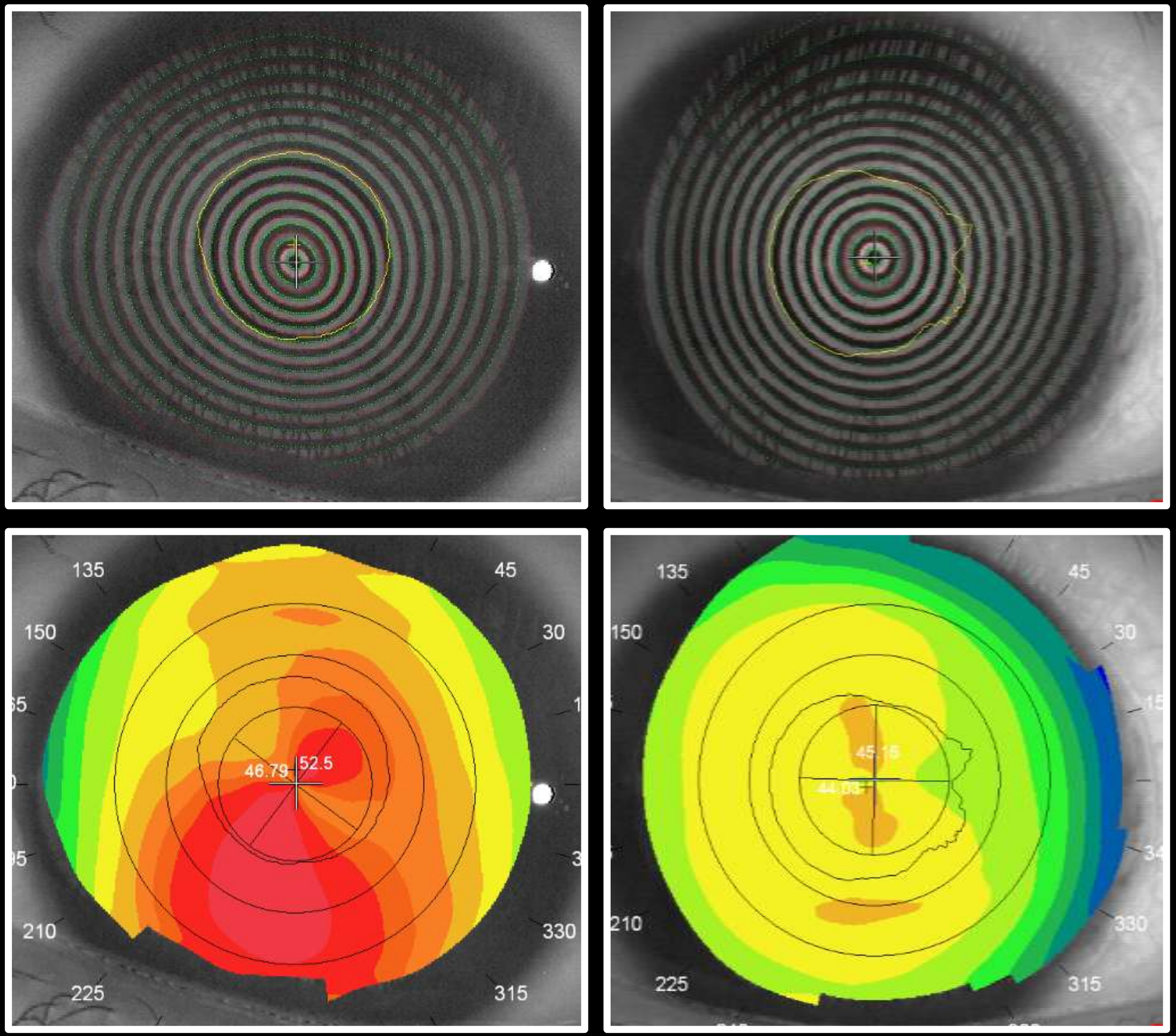
NIDEK Scan III

Expensive | No doctor needed | High accuracy

Curvature (Axial and Tangential) Map,

sim-K1 (steepest),

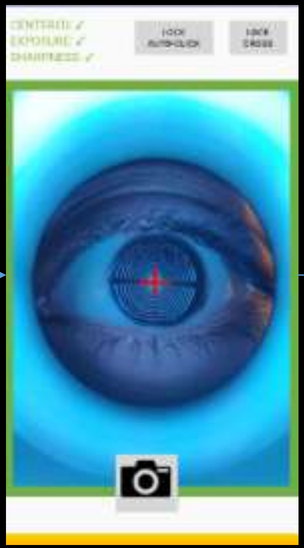
sim-K2

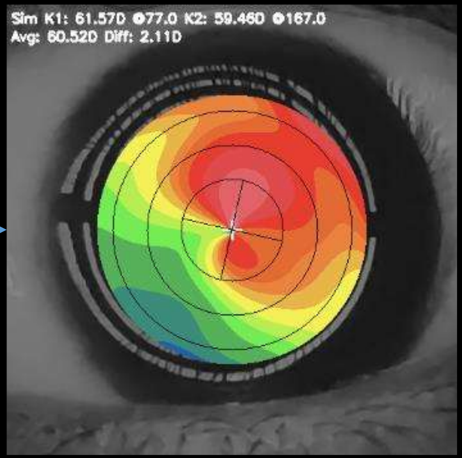


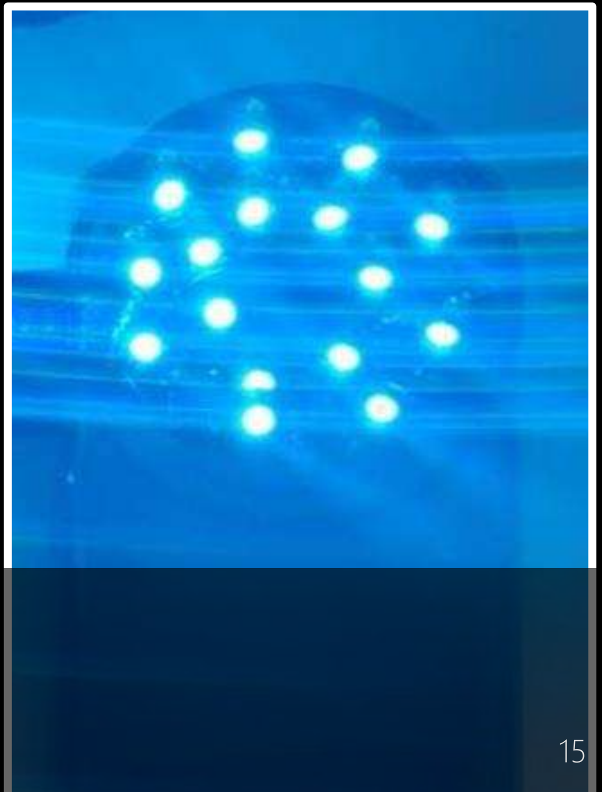
Dioptres (D)	9	14	19	24	29	33	37	38.5	40	41.5	43	44.5	46	47.5	49	51.4	55.5	60.5	65.5	70.5	75.5	80.5	85.5	90.5	95.5	100.5
R (mm)	40.6	24.9	18.1	14.2	11.7	10.0	9.1	8.8	8.4	8.1	7.9	7.6	7.3	7.1	6.9	6.6	6.1	5.6	5.2	4.8	4.5	4.2	4.0	3.7	3.5	3.4

Goal

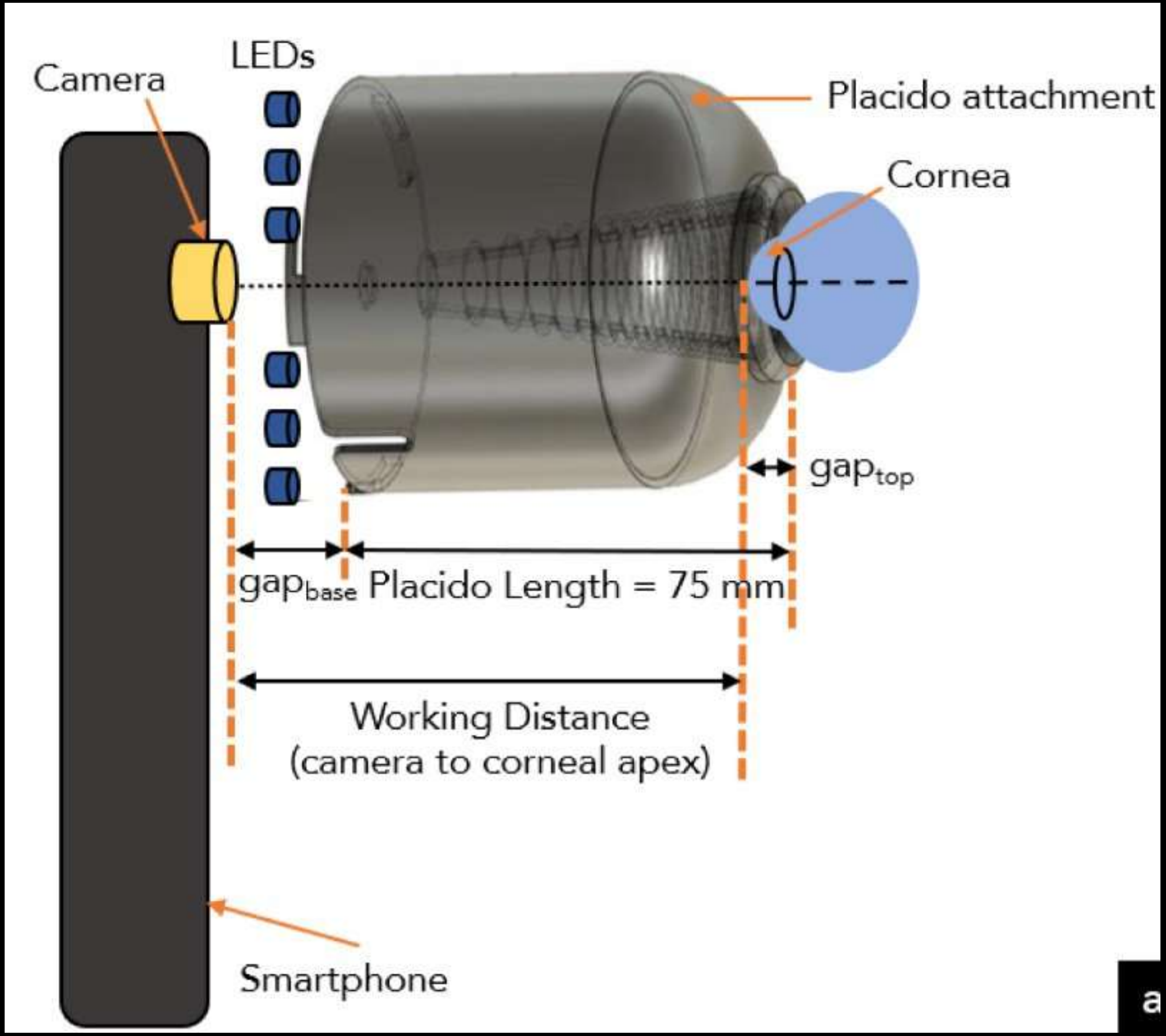
To develop a **low-cost portable** corneal topographer, which **captures the mire image** and **outputs curvature maps**.







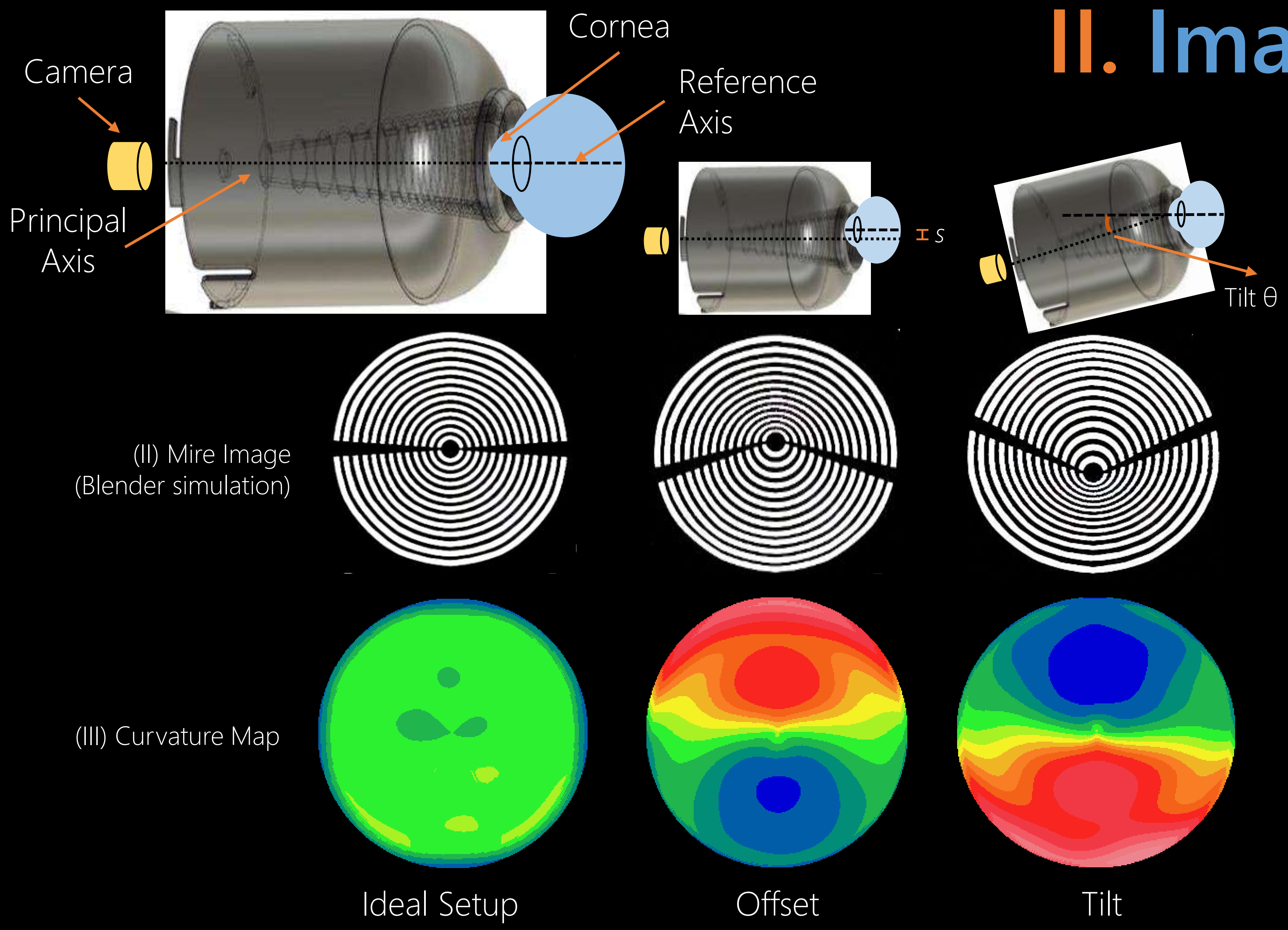
I. Placido Disc

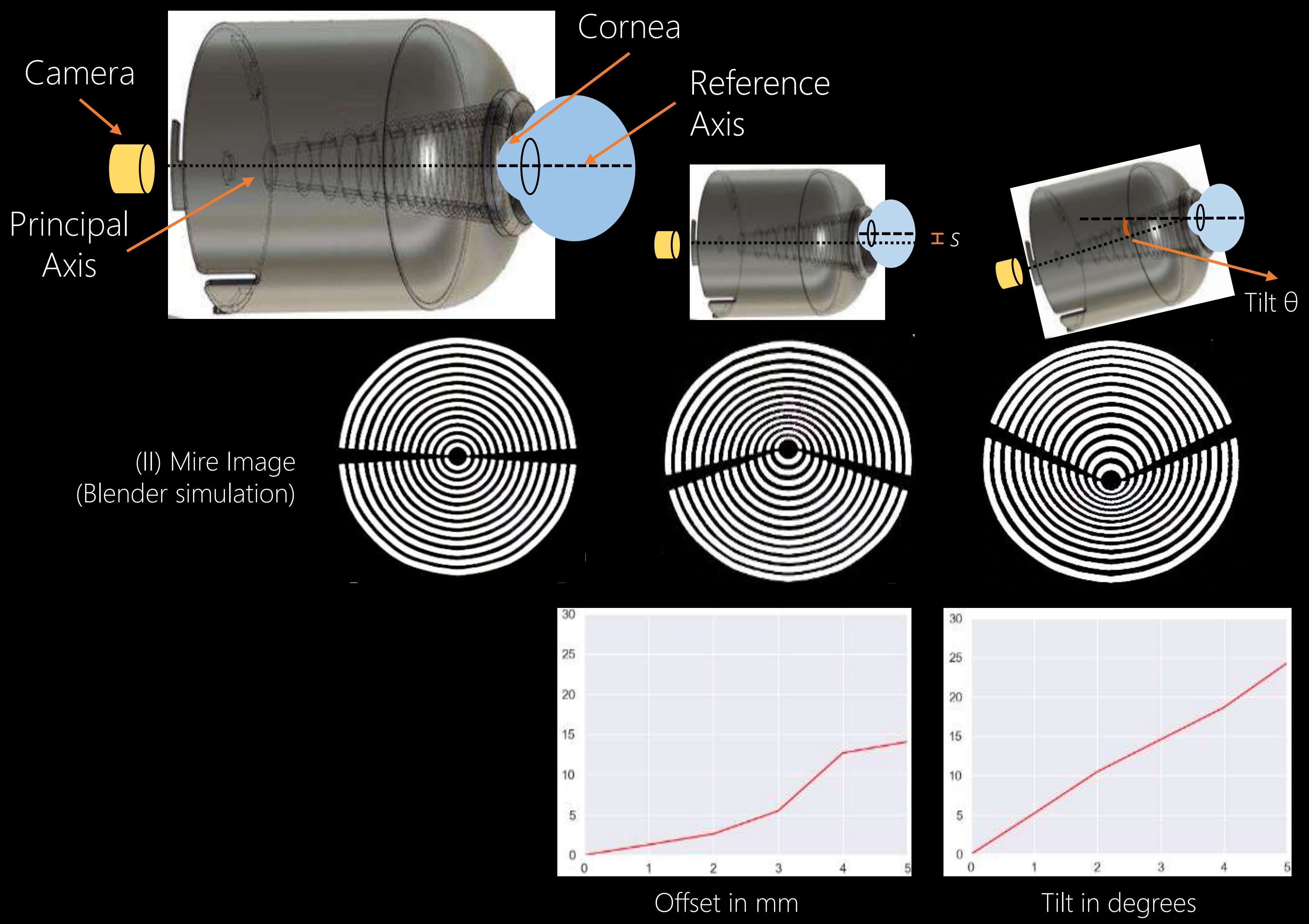


I. Placido Disc

Weighs: 140 grams | Costs: Rs 2500 ($33)

II. Image Quality




Cornea
Camera
Reference Axis
Principal Axis
s
Tilt θ
(II) Mire Image (Blender simulation)
30
25
20
15
10
5
0
0
1
2
3
4
5
Offset in mm
Tilt in degrees

Real-time on-device Image Processing

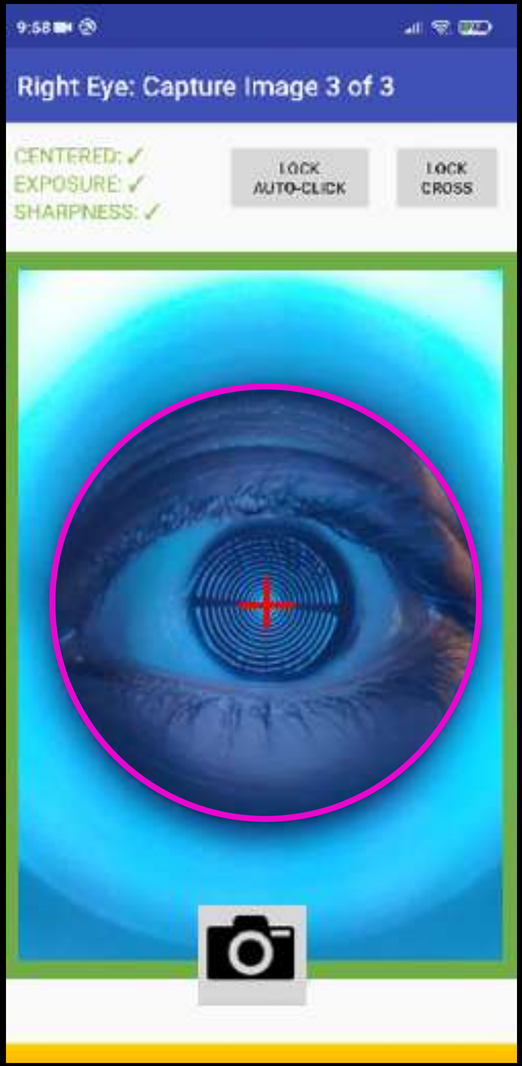
AI assisted app

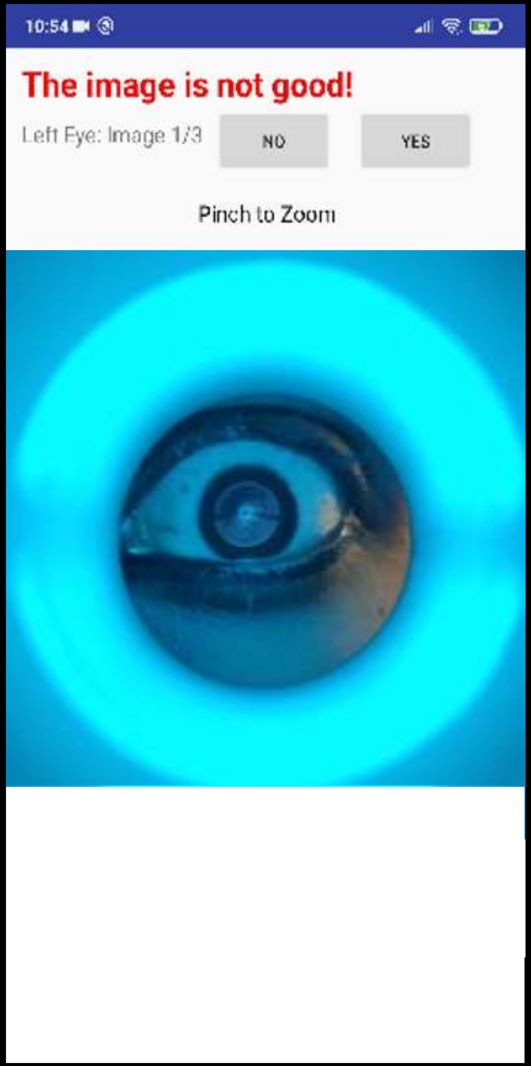
Real-time Checks:

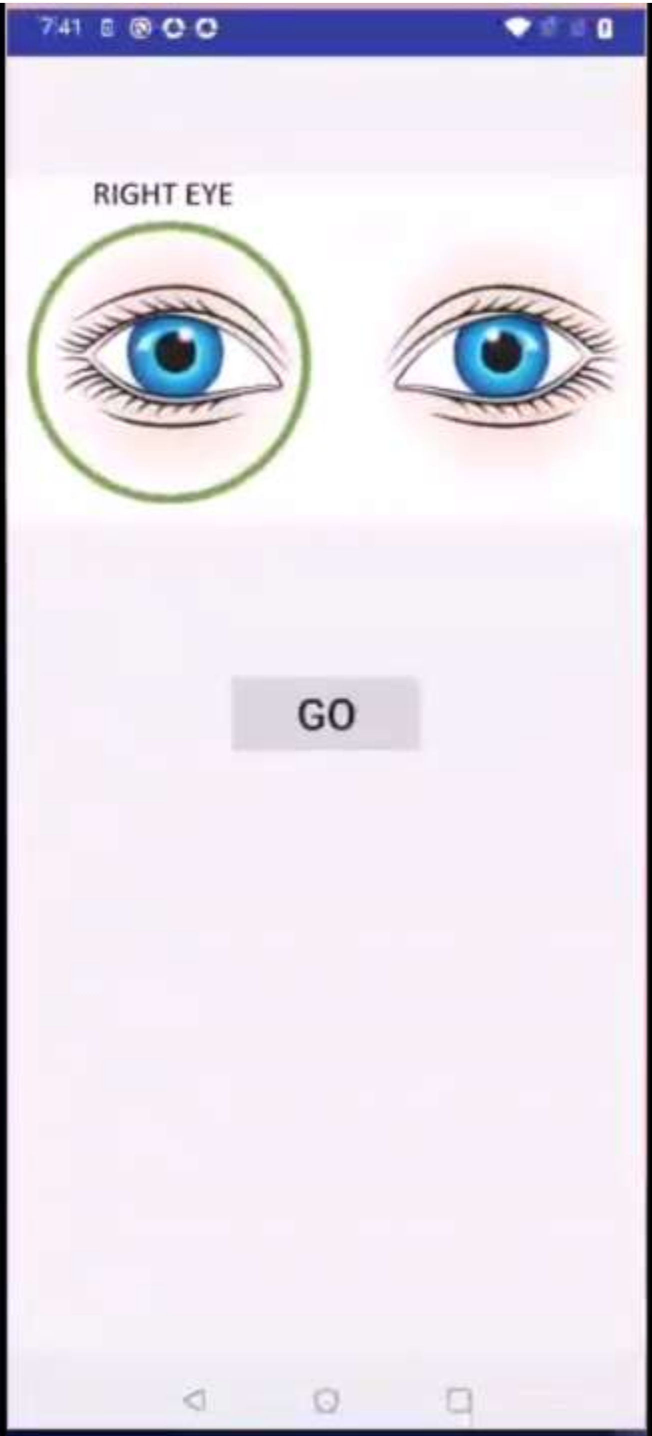
- Exposure
- Sharpness

Center alignment

Auto-capture






7:41
RIGHT EYE
GO

III. Heatmap Generation: Image Processing

Attachment + Smartphone

Captured Image

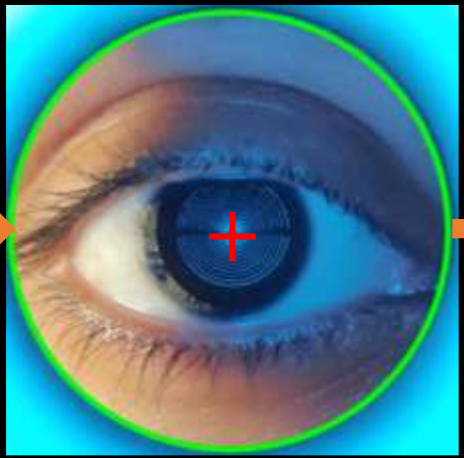
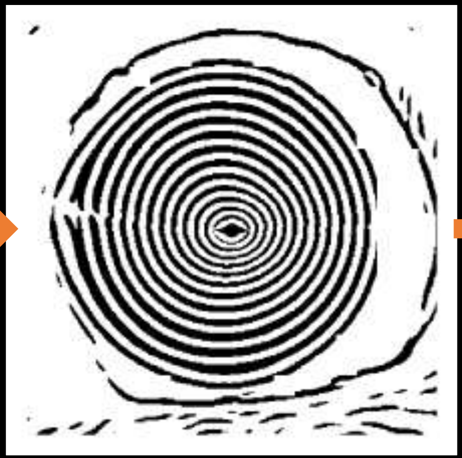
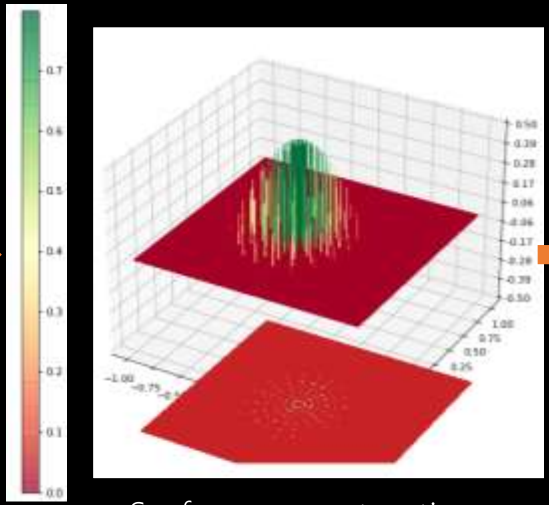


Image Cropping, Centering

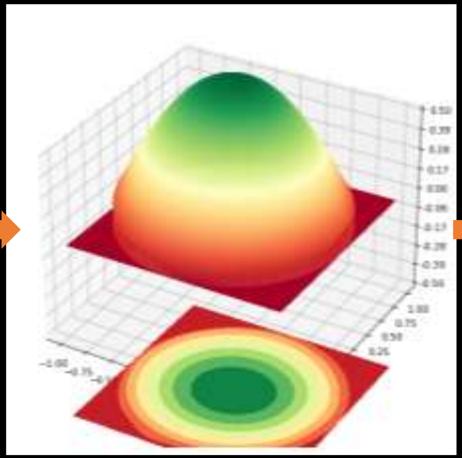
Image Enhancement



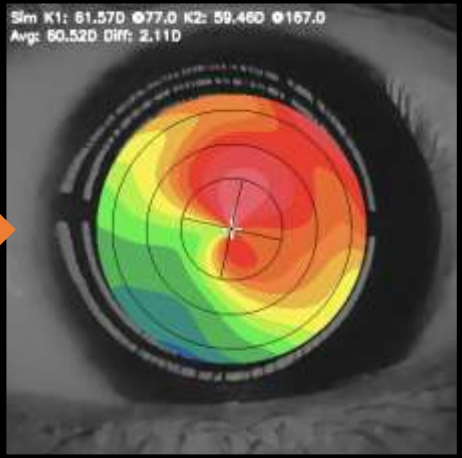
Mire Detection, Labelling



Surface reconstruction using Arc-Step method

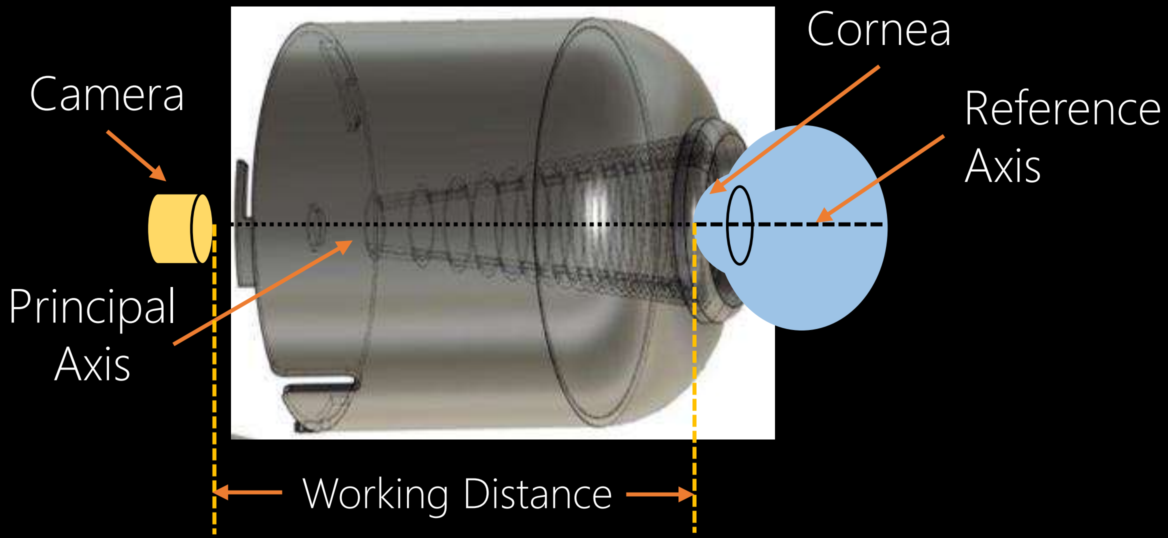


Surface after Zernike fitting



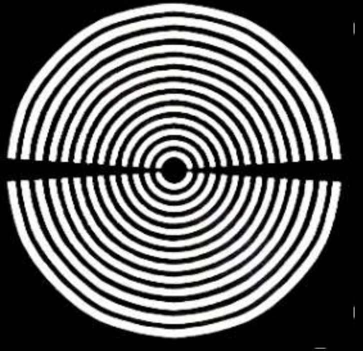
Corneal Topography Curvature Map

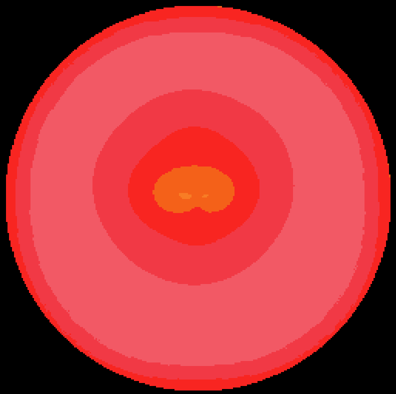
Working Distance error

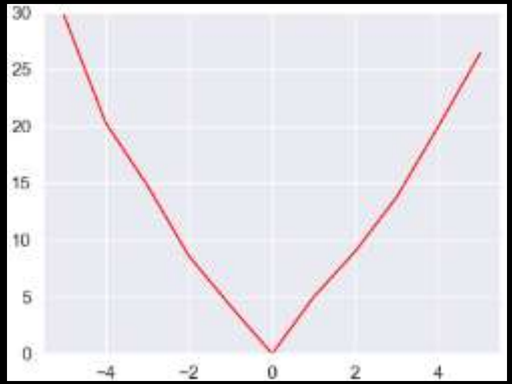


Deep Seat Eye

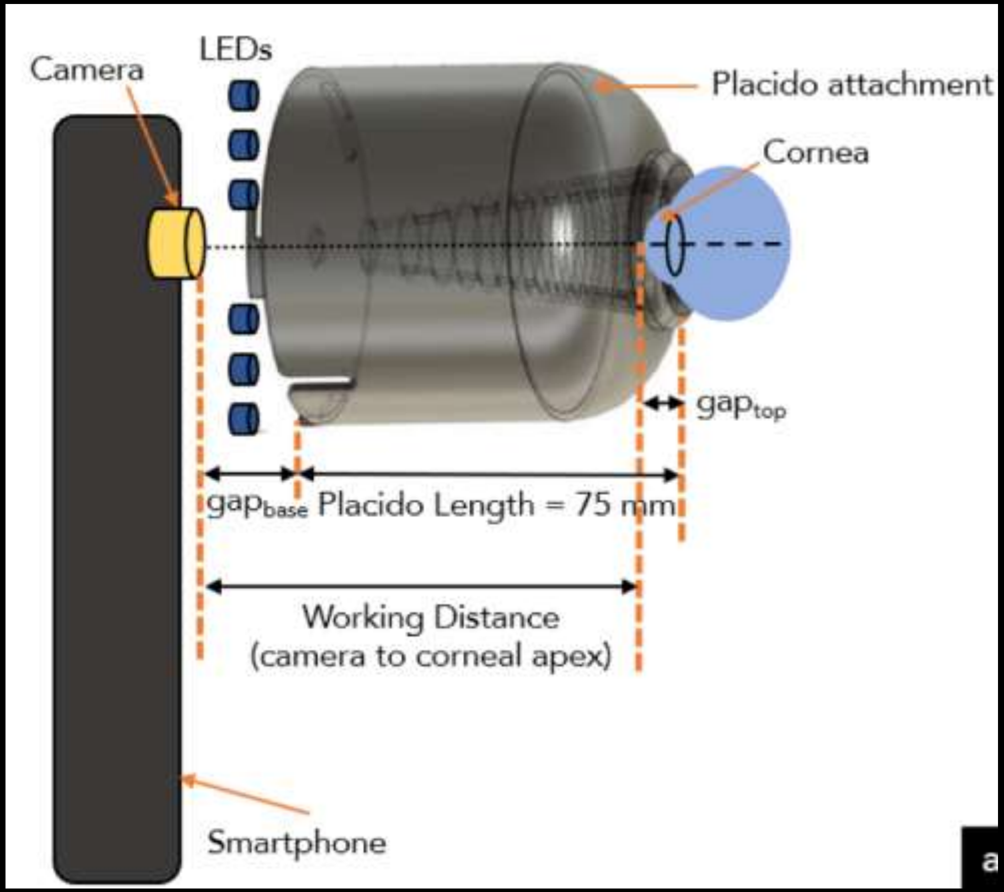
Protruding Eye







Working Distance Computation



Working distance = gap_{base} + placido_length + gap_{top}

Two eye properties:

- the radius of the human cornea is similar (7.79±0.27mm),
- the shape of the cornea is distorted mainly in the central region

For a given gap_{top}, the radius of the mire reflections in the outer region is same across patients.

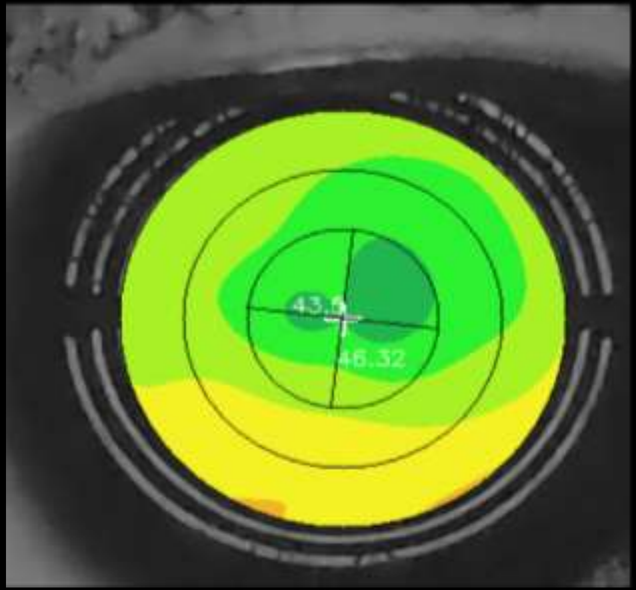
Simulation environment followed by a simple regression model to learn mapping between gap_{top} and radius of the outer mire.

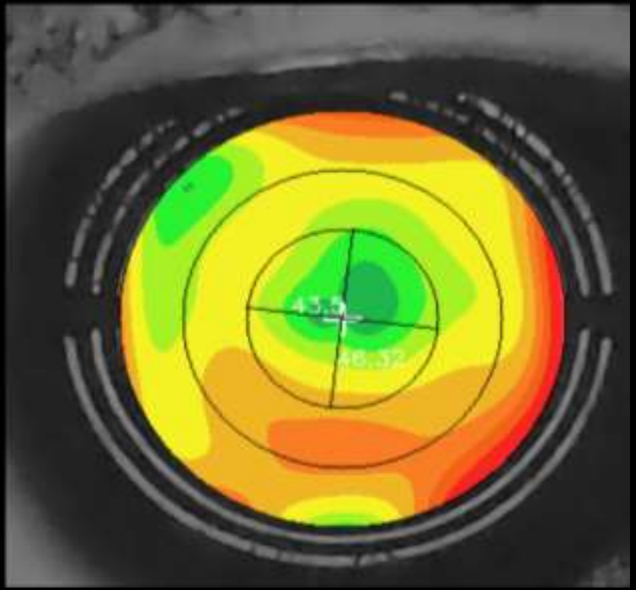
Data and Evaluation

57 patients (35 female, 22 male), age=23.7±7.6 years

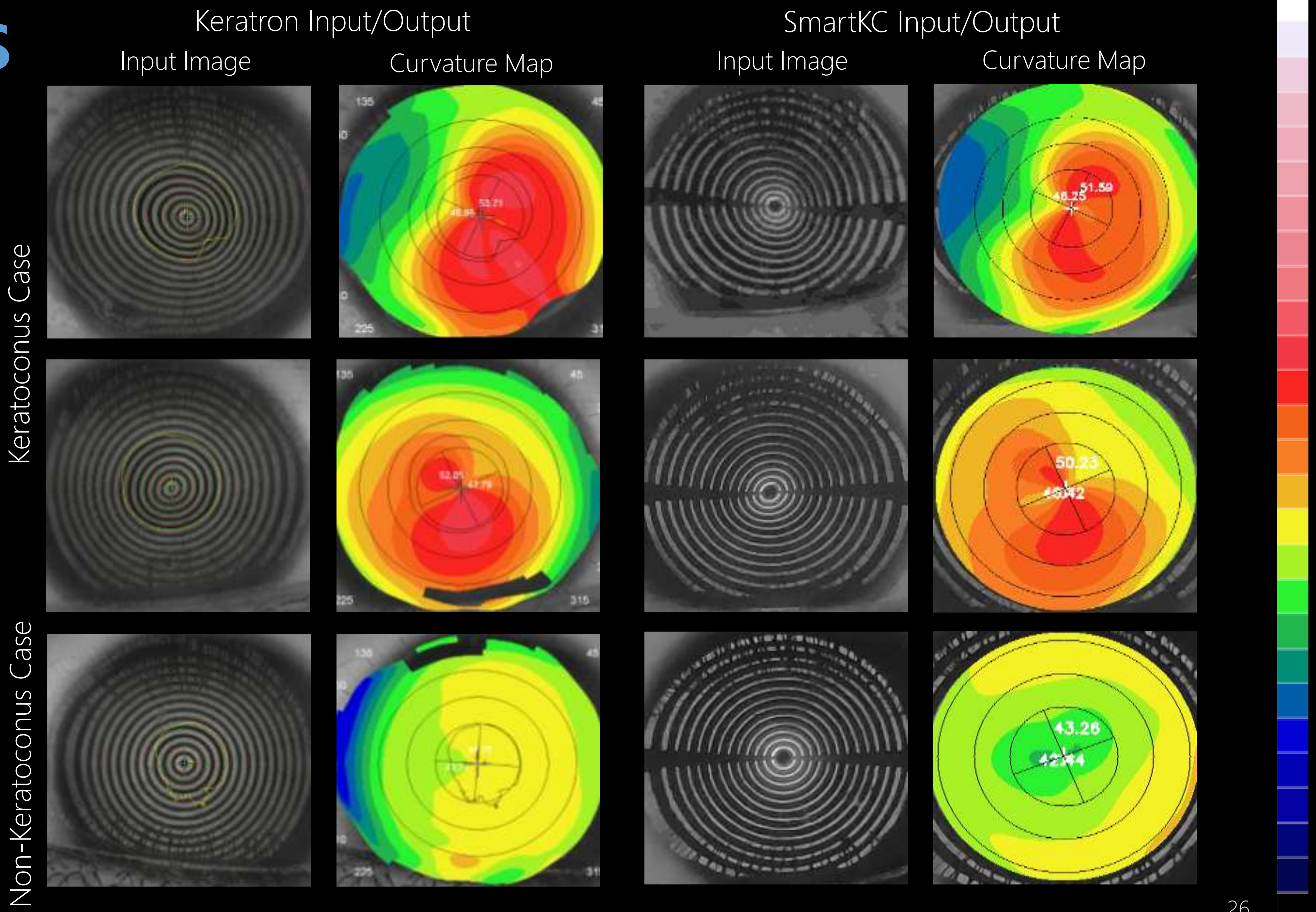
101 eyes [67 non-keratoconus and 34 keratoconus]

4 doctors rating: non-keratoconus, keratoconus, retake





Results



Keratron Input/Output
SmartKC Input/Output
Input Image
Curvature Map
Input Image
Curvature Map
Keratoconus Case
Non-Keratoconus Case
51.59
46.25
50.23
45.42
43.26
42.44

Results

	Device	Sensitivity	Specificity
Doctor 1	Keratron	100.0%	65.8%
	SmartKC	93.5%	95.9%
Doctor 2	Keratron	100.0%	93.3%
	SmartKC	92.3%	100.0%
Doctor 3	Keratron	94.1%	52.6%
	SmartKC	93.7%	100.0%
Doctor 4	Keratron	100.0%	53.8%
	SmartKC	94.1%	100.0%
Overall	Keratron	100.0%	64.5%
	SmartKC	94.1%	100.0%

Sensitivity: **92.3 - 94.1%**

To correctly identify people **with** Keratoconus.
Sensitivity = TP/(TP+FN)

Specificity: **95.9% - 100.0%**

Test to correctly identify people **without** Keratoconus.
Specificity = TN/(TN+FP)

What Next?

Medical Device	SmartKC++	DEDector	Pachymetry
Obvious next step to productize SmartKC	To improve image processing pipeline	A new use case for the Placido attachment	To detect very early cases of keratoconus
Remidio	**WACV'25**	**IMWUT'24**	**ongoing**

What Next?

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Universities and Orgs Reached

Universities

- Duke University
- Stanford University
- University of California, SF
- University of Utah

Ophthalmologist

- US, Canada, Morocco, France, Bangladesh and Pakistan

Research Orgs

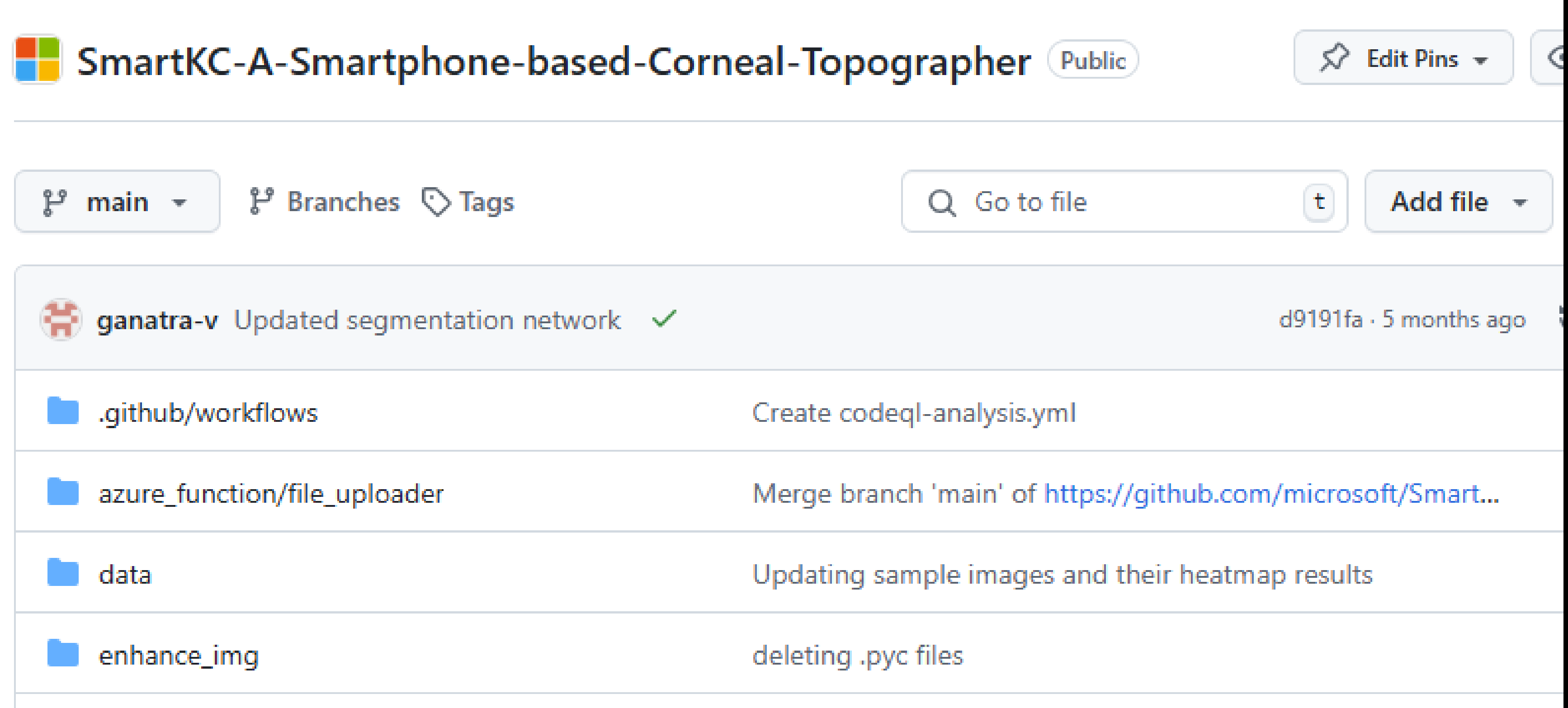
- LVPEI

Device Manufacturers

- Remidio
- Glaukos
- Scott Lewis
- Etc.

CELA

Thought Leader



Disclaimer

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InstaKC by Remidio

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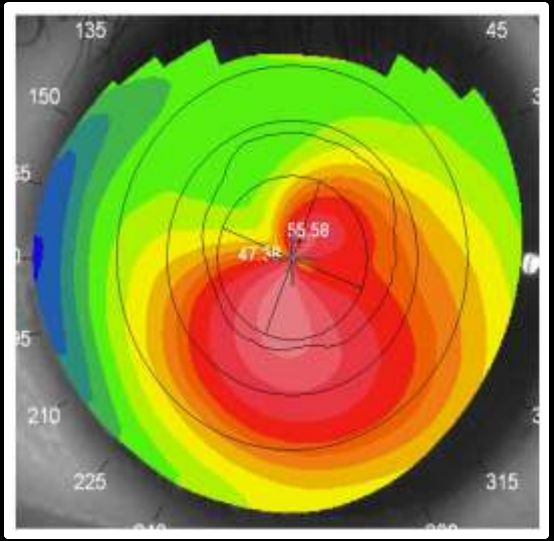
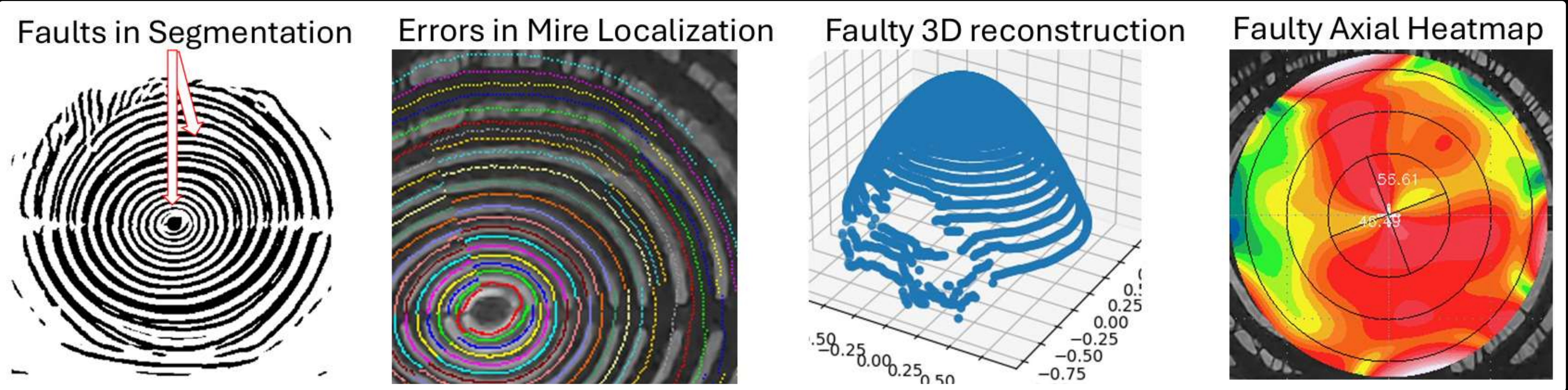
Improving Performance of Smartphone-based Corneal Topographers

Limitations

1. Curvature underestimation in severe cases: **Improper mire segmentation**
2. Curvature overestimation in normal/mild cases: **Incorrect mire localization** due to missing mire segments
3. Errors compounded in 3D reconstruction (**Arc-Step**)

Gold Standard





Solution 1

U-Net based Mire Segmentation

Existing: Image-processing based fingerprint-detection algo.

Limitation: Assumed mires to be circular, leading to underestimation in severe cases.

Solution: Trained a U-Net for mire segmentation.

- Combined data augmentation and pseudolabels from existing algorithm for training
- Manually filtered out erroneous cases for training (shown)

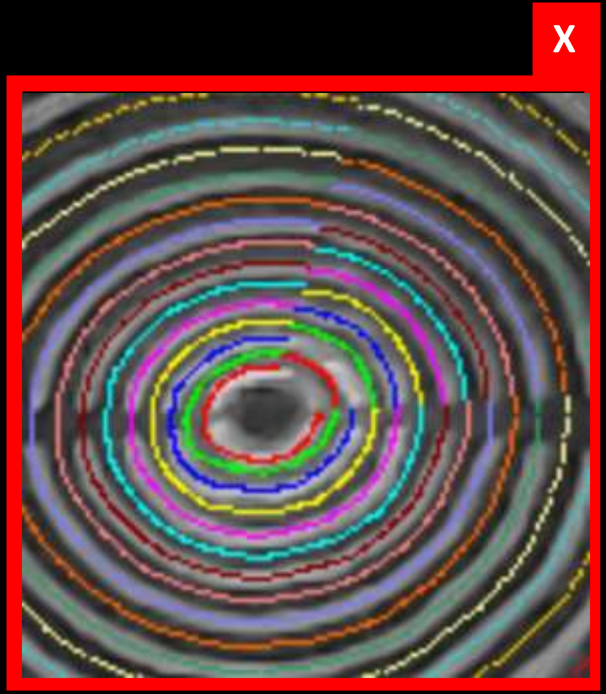
Solution 2

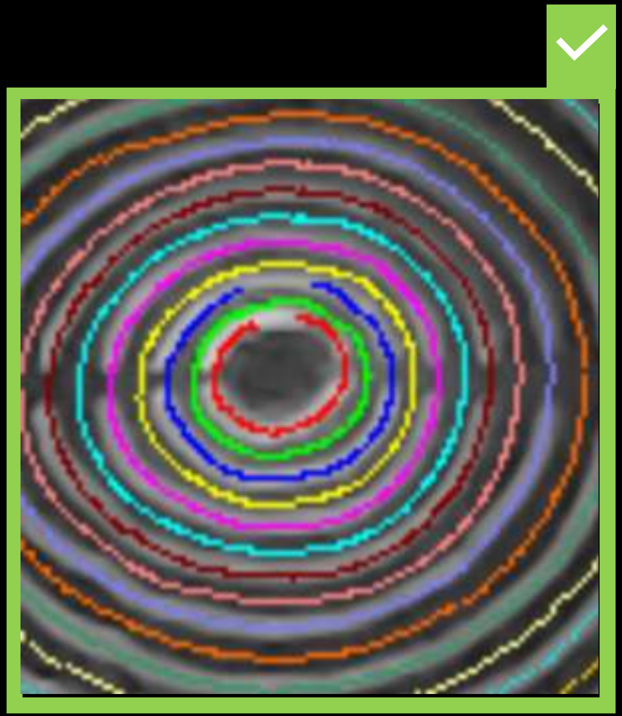
Graph based Mire Localization

Existing: Radial Scanning algorithm.

Limitation: Assumed mires to be complete – did not account for broken mire segments. This led to mire shifts and artifacts in the heatmaps.

Solution: Use spatial information from the neighbourhood to identify broken mire segments and correct mire shifts.





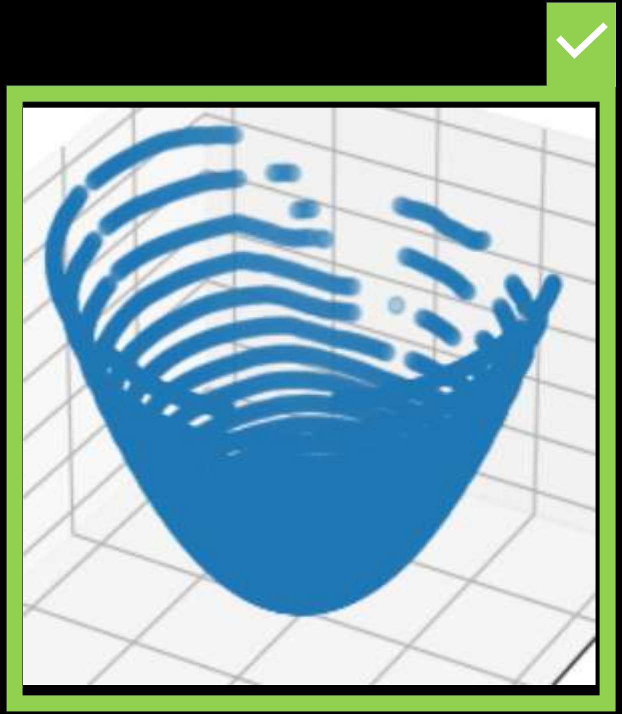
Solution 3

Robust 3D Reconstruction

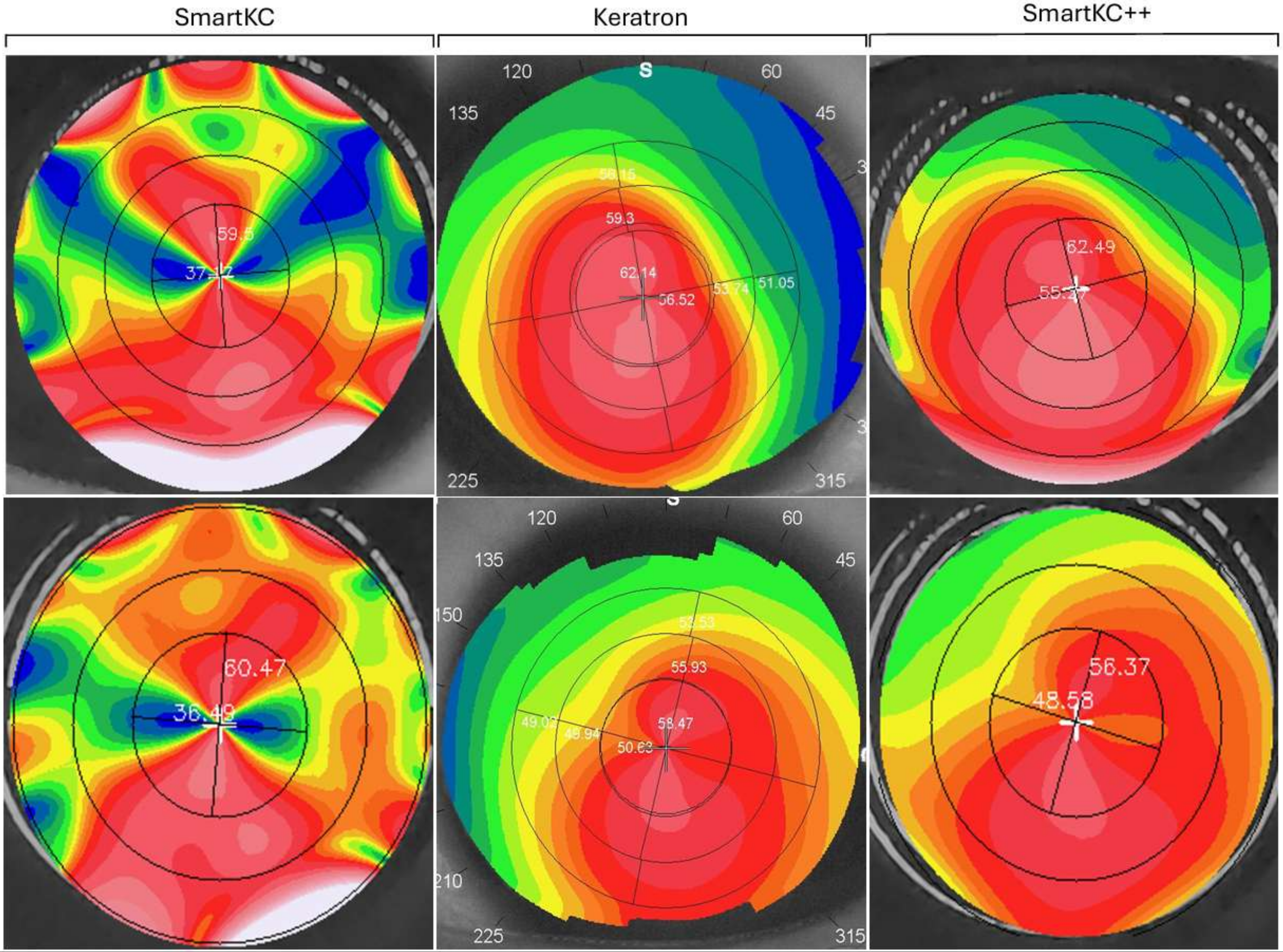
Existing: Arc-Step

Limitation: Assumed mires to be complete – not compatible with broken mire segments; requires interpolation in 2D space.

Solution: Enable compatibility with broken mires to allow interpolation in 3D space



Results



SmartKC
Keratron
SmartKC++
59.5
62.14
56.52
59.3
56.15
53.74
51.05
62.49
120
60
135
45
225
315
S
60.47
36.49
55.93
58.47
50.63
48.94
49.03
56.37
48.58
150
210

Results: Sim-K and Keratoconus

		Sim-K1			Sim-K2		
		MAE	MAPE	Corr.	MAE	MAPE	Corr.
Success Set	SmartKC	**1.29**	**2.64**	0.89	2.25	4.82	0.066
	SmartKC++	1.33	2.72	**0.92**	**1.38**	**3.04**	**0.78**
Failure Set	SmartKC	4.22	7.49	0.62	8.22	16.15	-0.25
	SmartKC++	**1.78**	**3.03**	**0.925**	**2.01**	**3.94**	**0.928**

SmartKC++ exhibits similar performance on both success and failure sets

Device	KT Condition	Acc.	Sens.	Spec.	Prec.	Recall	F1
Keratron	K1 >46.995 or (K1 - K2) >1.523	80.37	85.71	70.27	84.51	85.71	85.11
SmartKC	K1 >44.35 or K1-K2 >2.644	81.32	87.27	72.22	82.76	87.27	84.96
SmartKC++		**89.01**	**87.27**	**91.67**	**94.12**	**87.27**	**90.57**

SmartKC++ **outperforms** SmartKC on Automated Keratoconus Detection

What Next?

Medical Device	SmartKC++	DEDector	Pachymetry
Obvious next step to productize SmartKC	To improve image processing pipeline	A new use case for the Placido attachment	To detect very early cases of keratoconus
Remidio	**WACV'25**	**IMWUT'24**	**ongoing**

Smartphone-based Non-Invasive Screening of Dry Eye Disease

Tear Breakup Time

Break Types

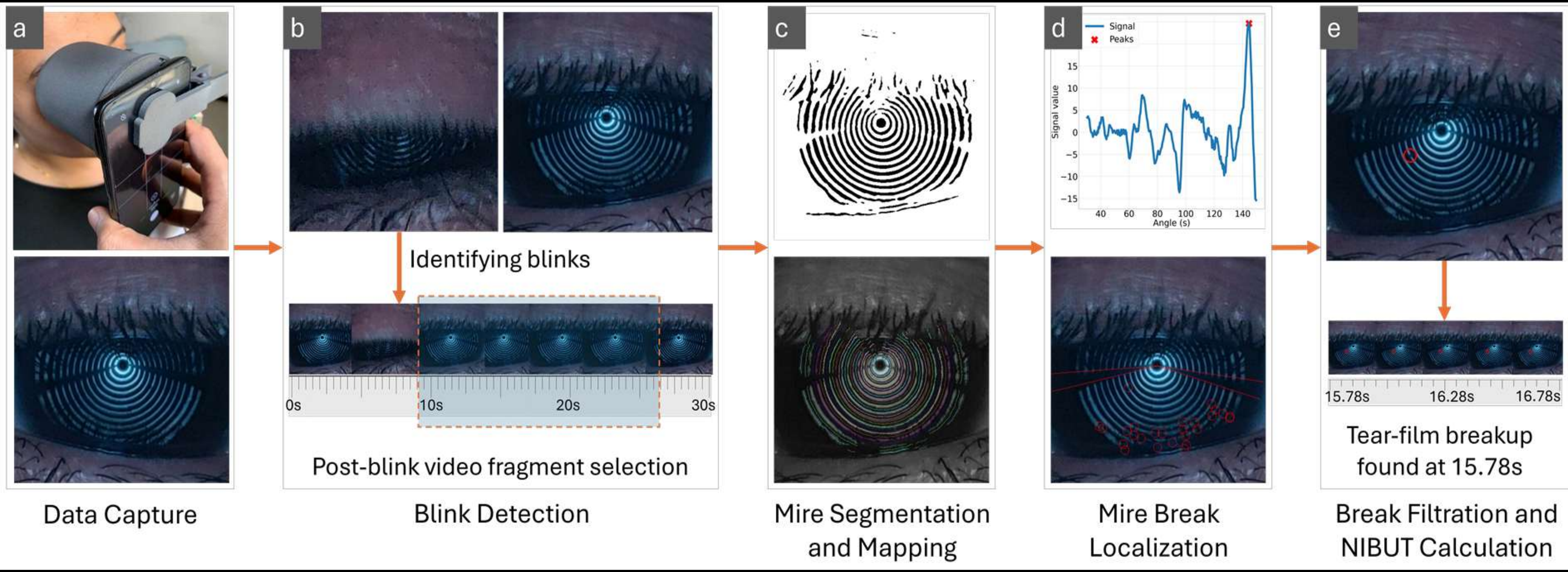
Line Break

Merge Break

Out-of-shape Break

Distortion Break

Video Processing Pipeline



Results

Comparison with medical devices

Device	**Threshold** (s)	**Sensitivity** (%)	**Specificity** (%)
Tomey RT-7000 Keratometer	5	82	60
IDRA Plus	7.75	**89**	69
Oculus Keratograph 5M	6.69	80	67.59
***DEDector* – Auto (ours)**	10	77.78	**78.57**

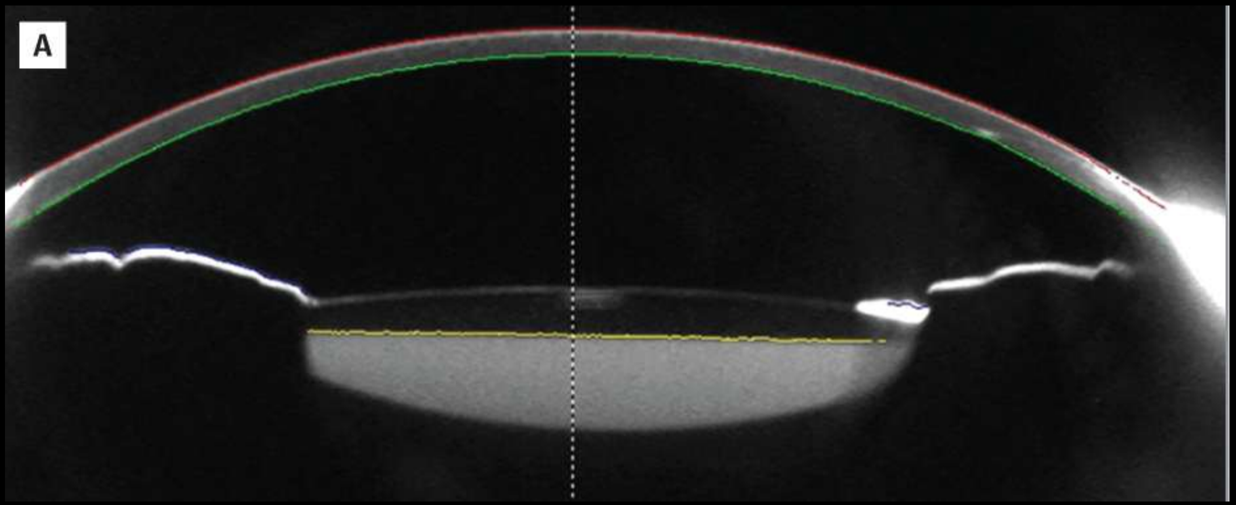
Comparison with other screening tools

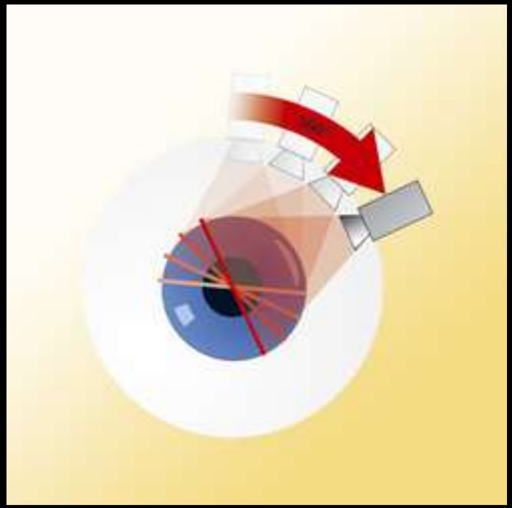
Method	**Phone**	**Eval Set Size**	**Acc.**	**Sens.**	**Spec.**
DryEyeRhythm	Yes	82 (42 DED)	71.95	50.00	**95.00**
DEvice©(AI, Rome, Italy)	No	40 (20 DED)	77.50	60.00	**95.00**
DEDector - Manual (ours)	Yes	46 (18 DED)	**80.43**	**77.78**	82.14
DEDector - Auto (ours)	Yes	46 (18 DED)	78.26	**77.78**	78.57

What Next?

Medical Device	SmartKC++	DEDector	Pachymetry
Obvious next step to productize SmartKC	To improve image processing pipeline	A new use case for the Placido attachment	To detect very early cases of keratoconus
Remidio	**WACV’25**	**IMWUT’24**	**ongoing**

Keratoconus: Corneal Tomographer



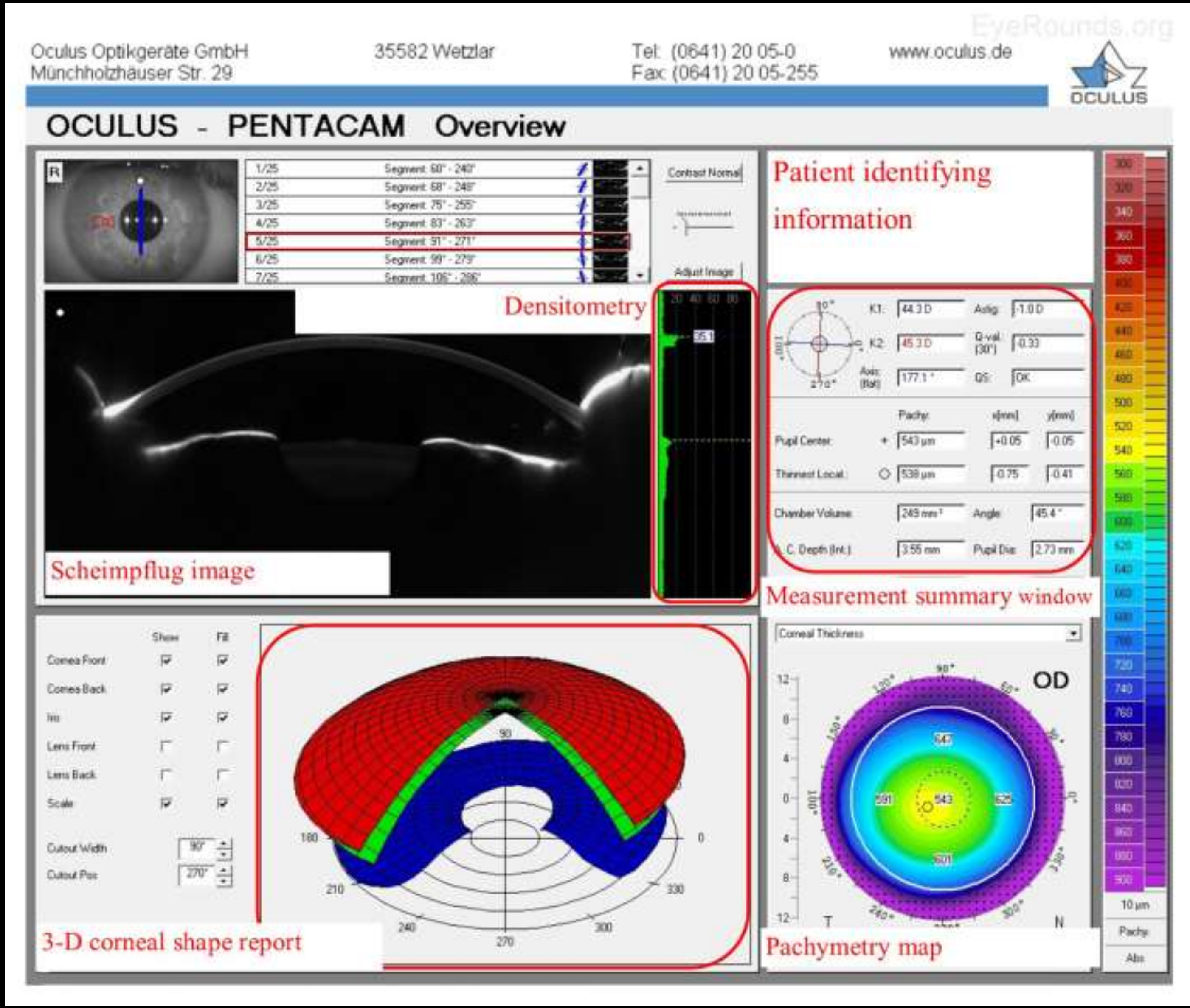


- Keratoconus manifests on the posterior corneal surface
- **Corneal Tomographer** captures individual cross-sections of the cornea

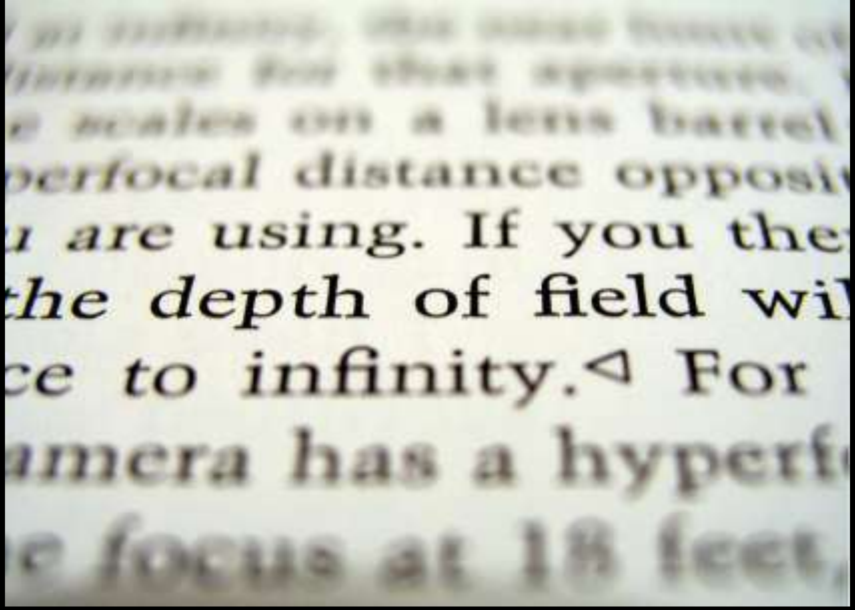
  → Consolidate information for 3D reconstruction

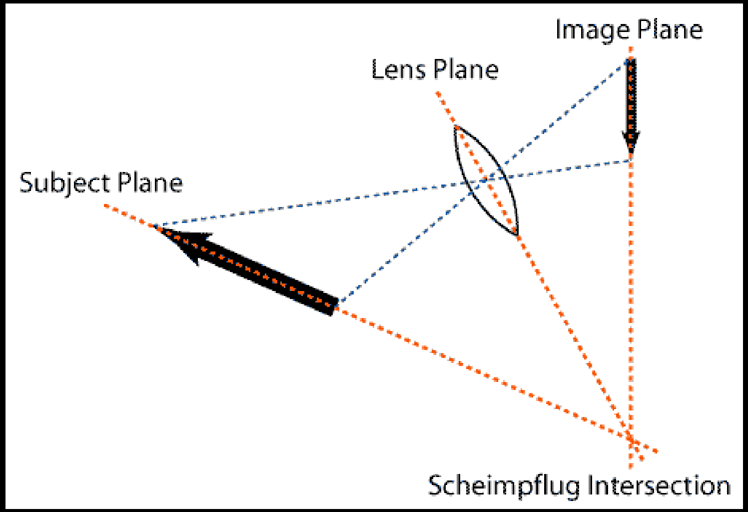
  → Generate **Pachymetry map**

Pentacam Report



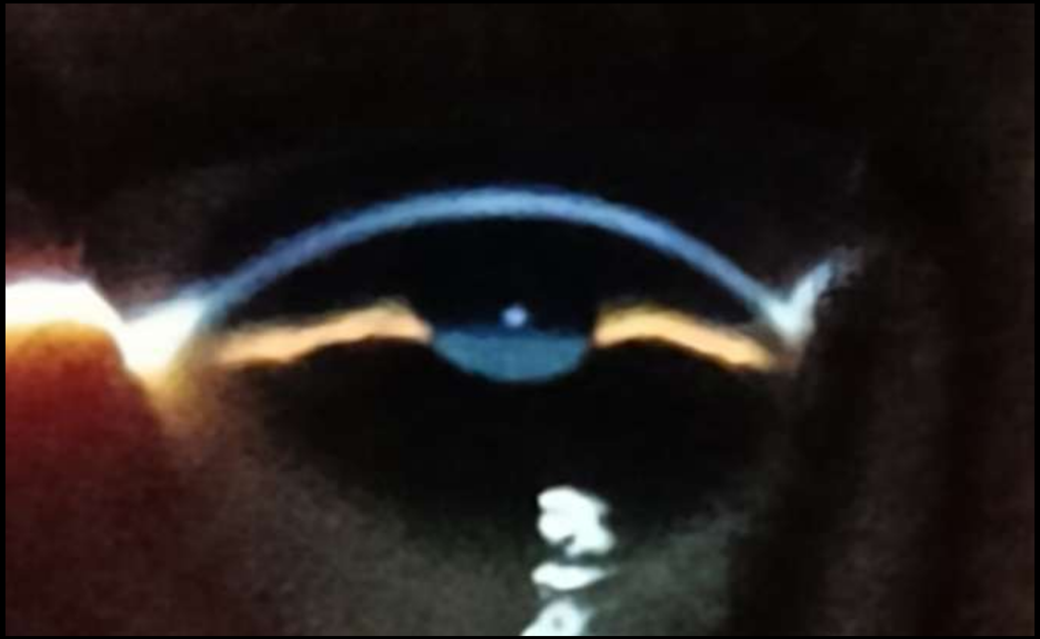
Scheimpflug Principle

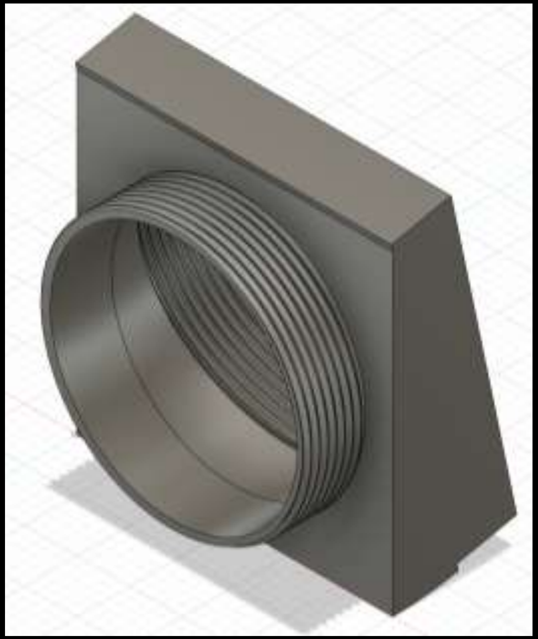


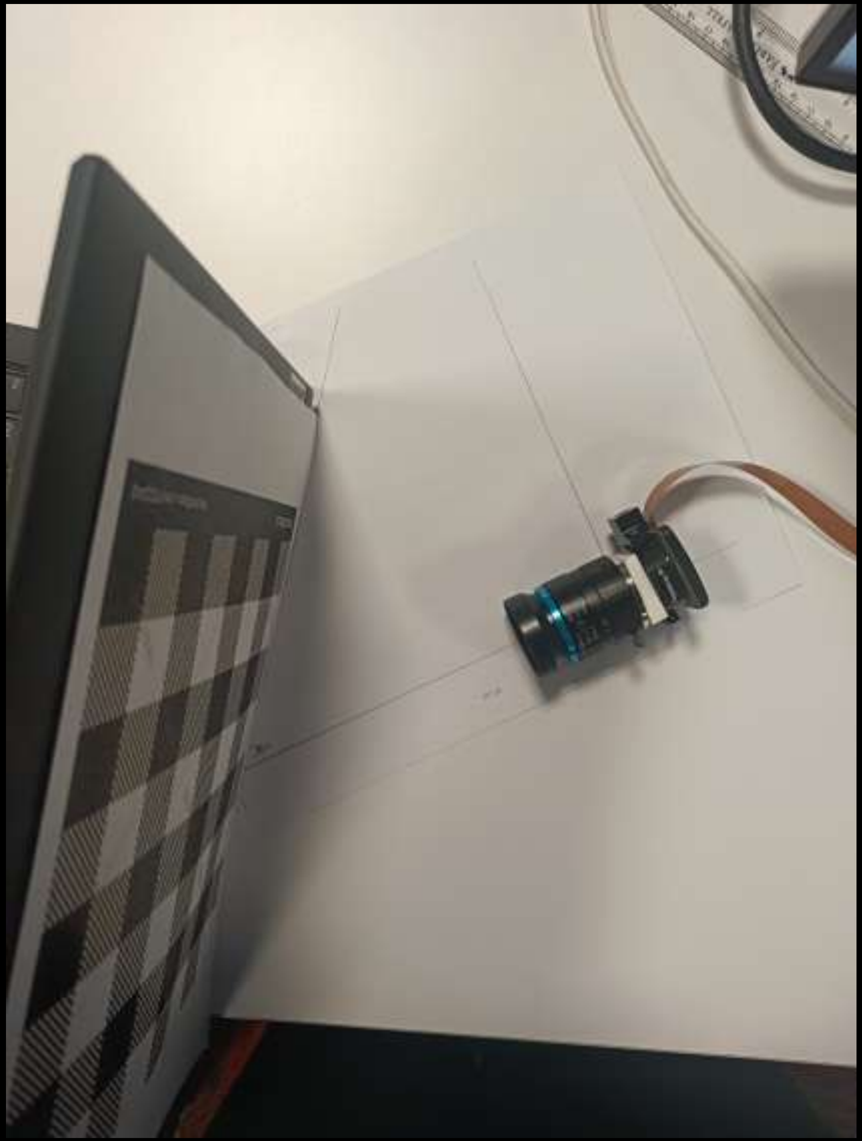


Our Approach

- Involves a tilt between three planes:
  - Object, Lens, and Image.
- To focus on a tilted object w.r.t the lens plane







Conclusion

- Diagnostics device research is complex, takes time
- But its highly rewarding and impactful!
- Interdisciplinary collaboration is critical for success
- One research thread often branches into multiple new research opportunities
- Real-world deployments provide valuable insights

Thank You!

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