Leiden University Medical Center

C.J. Gorter MRI Center

Peripheral image scaling of fundus photographs and their implications in ocular oncology

EVER 2025 – Course PO 69

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LEIDEN UNIVERSITY MEDICAL CENTER

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Disclosures

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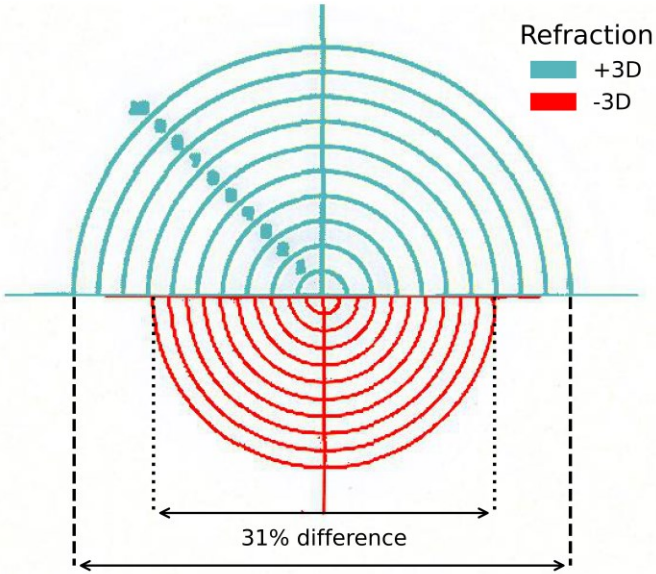
- This project received research support from RaySearch Laboratories

Recap: central magnification differences

- Anatomical differences affect the magnification of fundus photographs [1]
- Accurate measurements require correction for these differences
- Only **central magnification** has been considered



Is the magnification the same in the **periphery**?

[1] Pors et al. (2024). Correction Method for Optical Scaling of Fundoscopy Images: Development, Validation, and First Implementation. *IOVS*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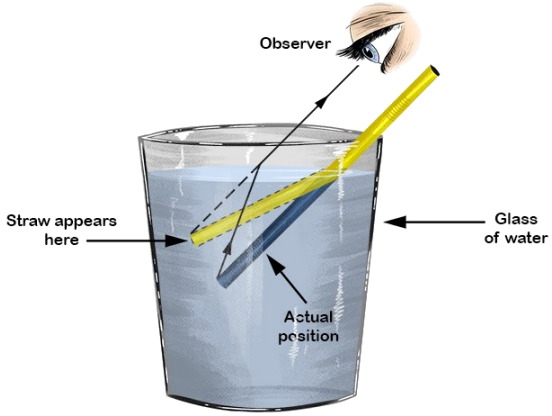
Aberrations in fundus photographs

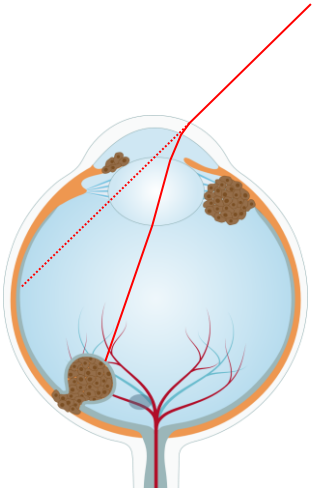
Geometrical: 2D images of a 3D ellipsoid [1-3]

List of map projections. (2023). *Wikipedia*

Optical: refraction by the eye's cornea and lens



Refraction and straws. (n.d.). *Mammoth Memory*



Jager et al. (2020). *Nat. Rev. Dis. Primers*

[1] Dobler et al. (2002). Precise modelling of the eye for proton therapy of intra-ocular tumours. *Phys. Med. Biol.*
[2] Daftari et al. (2010). Fundus image fusion in EYEPLAN software: An evaluation of a novel technique for ocular melanoma radiation treatment planning. *Med. Phys.*
[3] Via et al. (2022). MRI and FUNDUS image fusion for improved ocular biometry in Ocular Proton Therapy. *Radiother. Oncol.*

Aberrations in fundus photographs

Geometrical: 2D images of a 3D ellipsoid [1-3]

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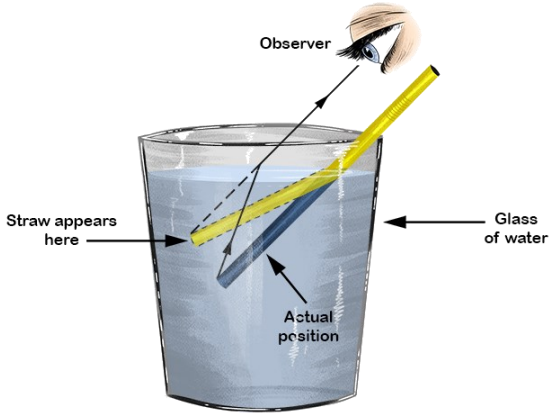

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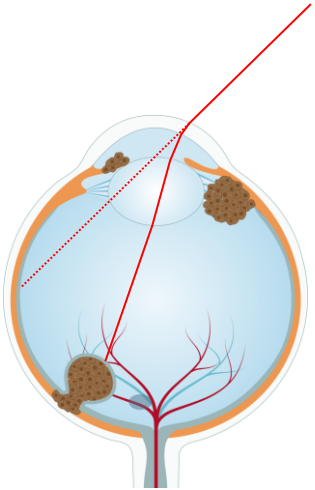


Jager et al. (2020). *Nat. Rev. Dis. Primers*

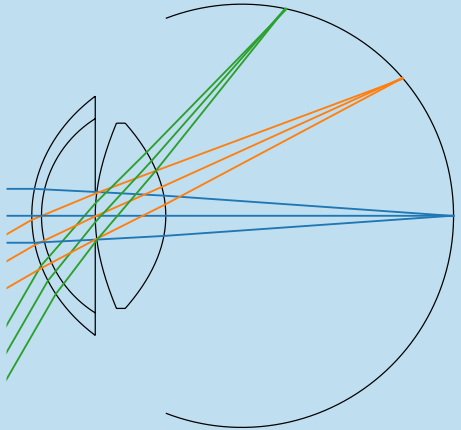
Peripheral aberrations result in an **inhomogeneous magnification** throughout the fundus photograph

Example: uveal melanoma on an Optos image

- Assumption: same scaling throughout the image
- Based on the optic disk size, the tumor has a diameter of about 20 mm
- This means the tumor should completely fill the eye

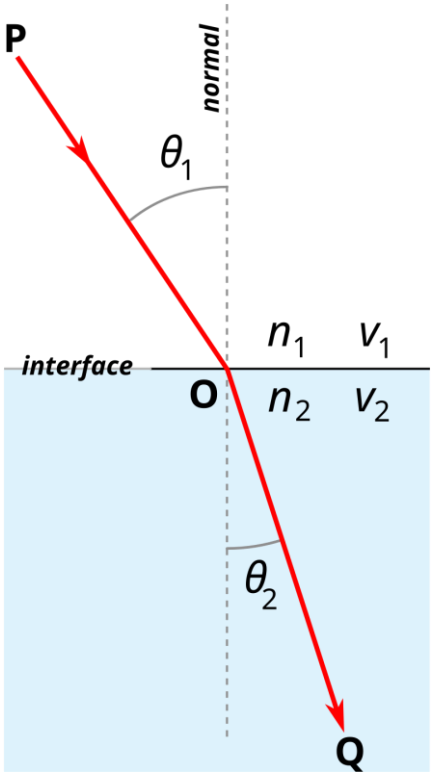
Choroidal Melanoma. (2019). *Retina Image Bank*.

Characterizing peripheral deformations



Using ray tracing to characterize deformations

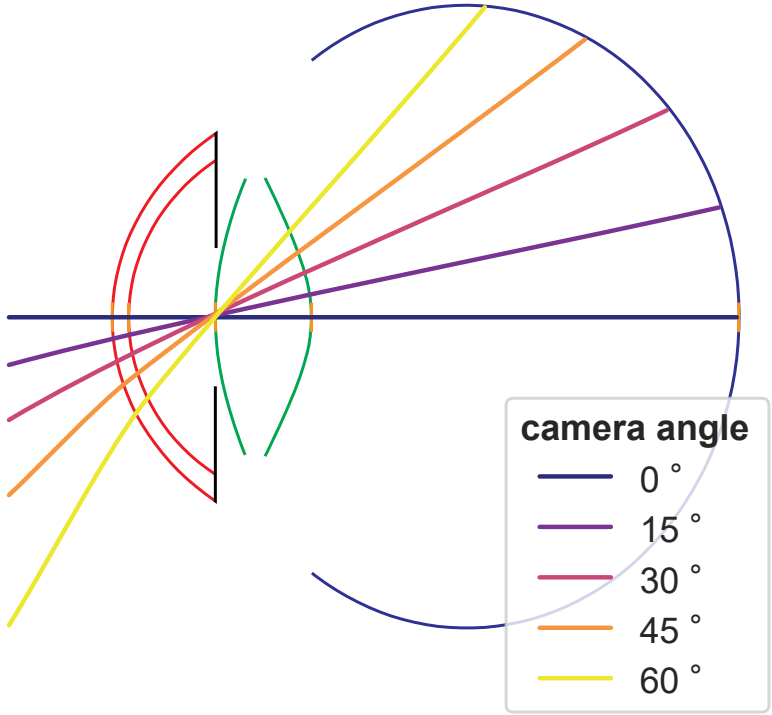
- Light rays are refracted at interfaces between two materials (e.g. air-cornea)
- **Ray tracing**: calculate the path of a light ray between two points
- Commonly used for refractive surgery and visual optics research



Snell's Law. (2025). *Wikipedia*

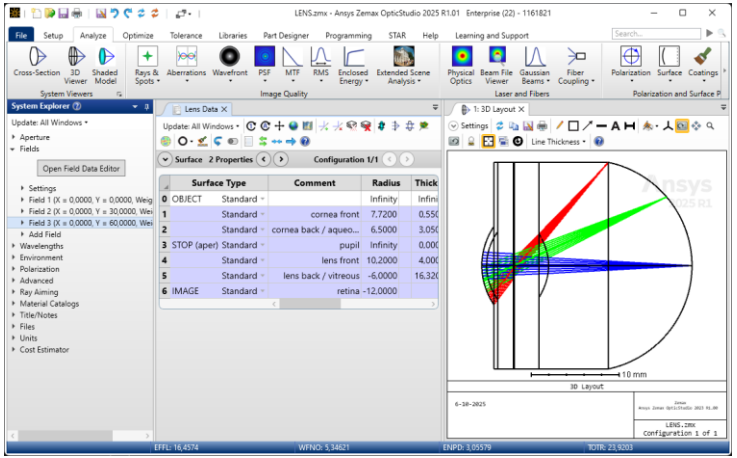
Optical models of the eye

- **Patient-specific eye models** based on
  - corneal topography
  - refractometry
  - biometry
  - MRI
- Use ray tracing to establish a relation between locations on the fundus photograph and the retina



Intermezzo: optical simulations with Visisipy

- Ray tracing simulations are commonly performed in Ansys OpticStudio
- Visisipy (**Vis**ion **Si**mulations in **Py**thon) is an **open-source** library to perform these simulations in Python



Intermezzo: optical simulations with Visisipy

- Free and open-source
- Accessible
- Multiple ray-tracing backends
  - OpticStudio
  - Optiland
- Runs in your browser

Code: github.com/MREYE-LUMC/visisipy

Docs: visisipy.readthedocs.io

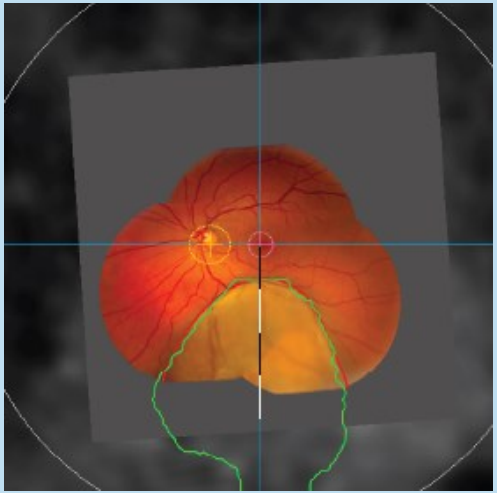
Demo: demo.mreye.nl/visisipy

```python
import visisipy

model = visisipy.EyeModel()

visisipy.analysis.raytrace(
    model,
    coordinates=[(0, y) for y in range(0, 90, 5)]
)
```

Correcting for peripheral deformations

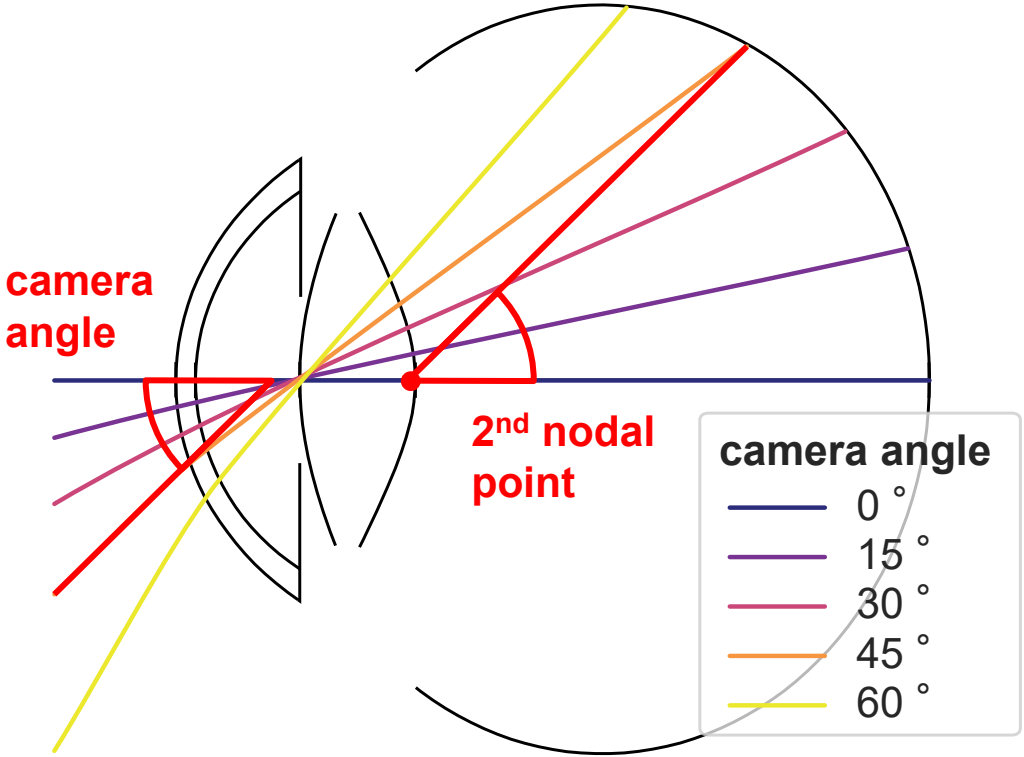


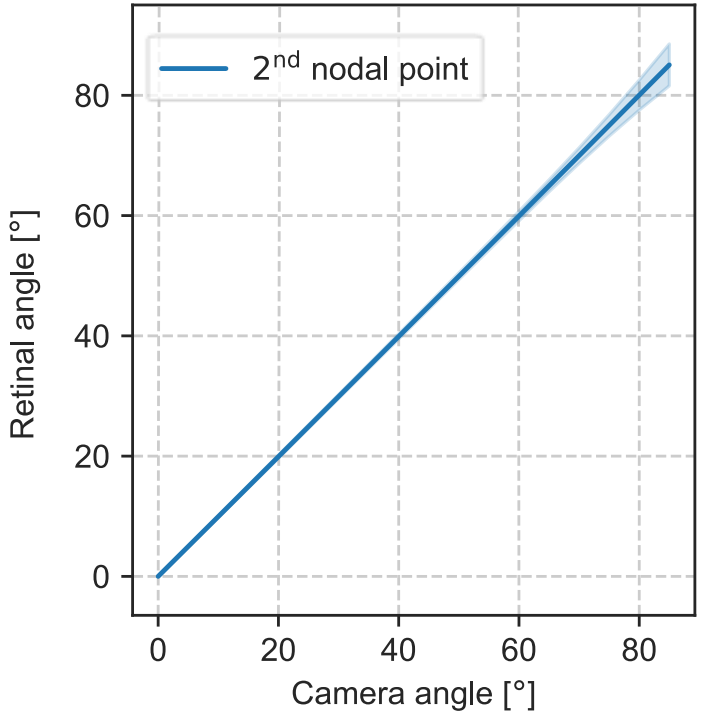
Methods

- Use ray tracing to develop a **mapping between fundus photographs and 3D imaging**
- Simulations on 27 subject-specific eye models

	IQR
Spherical Equivalent [D]	-6.88 - 0.25
Axial length [mm]	22.44 - 26.39
Medial retinal radius [mm]	8.96 - 14.30
Transversal retinal radius [mm]	10.95 - 12.43
Corneal thickness [mm]	0.47 - 0.59
Anterior chamber depth [mm]	2.79 - 3.77
Lens thickness [mm]	3.17 - 4.19
Anterior corneal curvature [mm]	7.23 - 8.13
Anterior corneal asphericity [-]	0.14 - 0.74
Posterior corneal asphericity [-]	-0.12 - 0.61

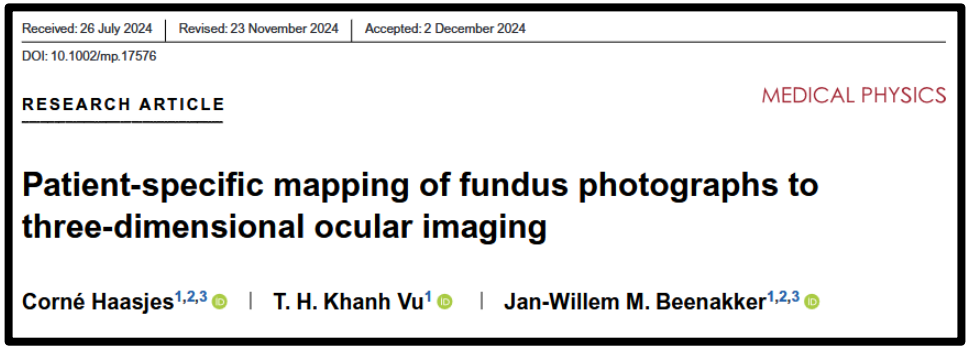
Results


camera angle
2nd nodal point
camera angle
0 °
15 °
30 °
45 °
60 °


2nd nodal point
Retinal angle [°]
Camera angle [°]
0
20
40
60
80

Nodal point mapping

- Also works for Optos cameras, which scan a laser ray through a point behind the cornea



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RESEARCH ARTICLE

MEDICAL PHYSICS

Patient-specific mapping of fundus photographs to three-dimensional ocular imaging

Corné Haasjes[1,2,3] | T. H. Khanh Vu[1] | Jan-Willem M. Beenakker[1,2,3]

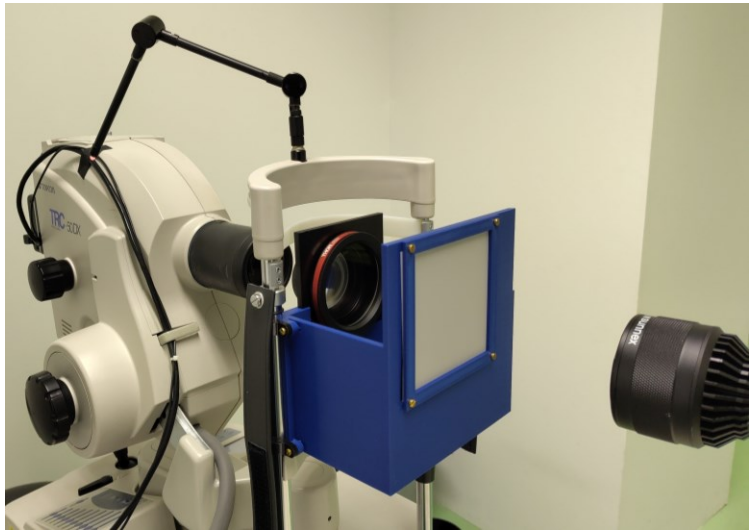
Measuring camera aberrations

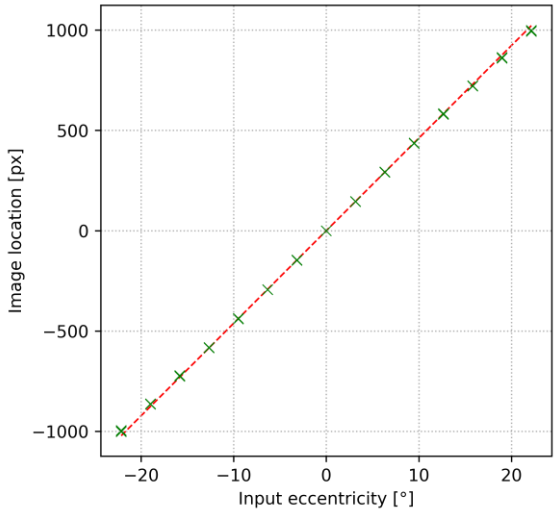
How about the fundus camera?

- Until now, we only considered the optics of the eye
- The fundus camera is also an optical system, so it can introduce deformations

Peripheral fundus camera calibration

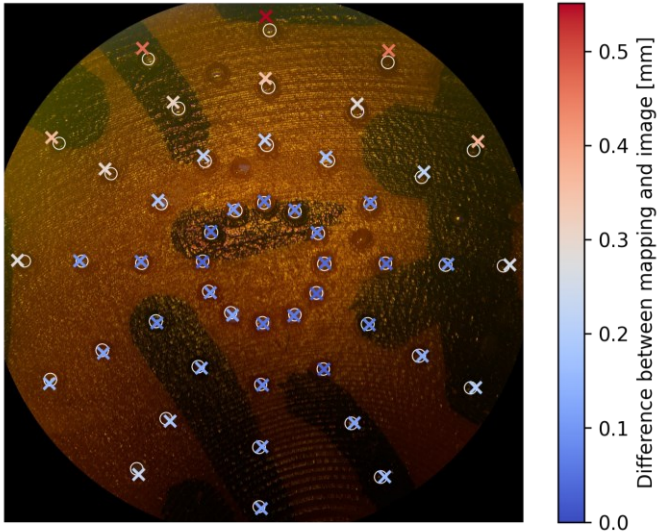
- Phantom to map **input eccentricities** (camera angles) to **image locations**
- **Linear relation** → deformations are minimal for the Topcon TRC50 DX





End-to-end validation on an eye phantom

- OEMI-7 ocular imaging eye model (Ocular Inc) with custom retinas [1]
- **Predict locations** of markers in fundus photographs using the **nodal point method** [2]

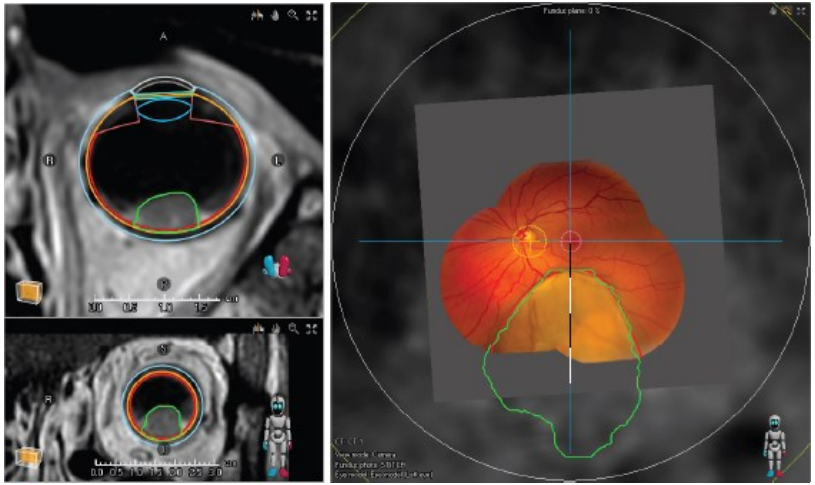


Mean error: 0.3 mm @ 21°

[1] Ocular Imaging Eye Model. https://ocularinc.com/ocular-imaging-eye-model.html
[2] Haasjes et al. (2024). Patient-specific mapping of fundus photographs to three-dimensional ocular imaging. *Med. Phys.*

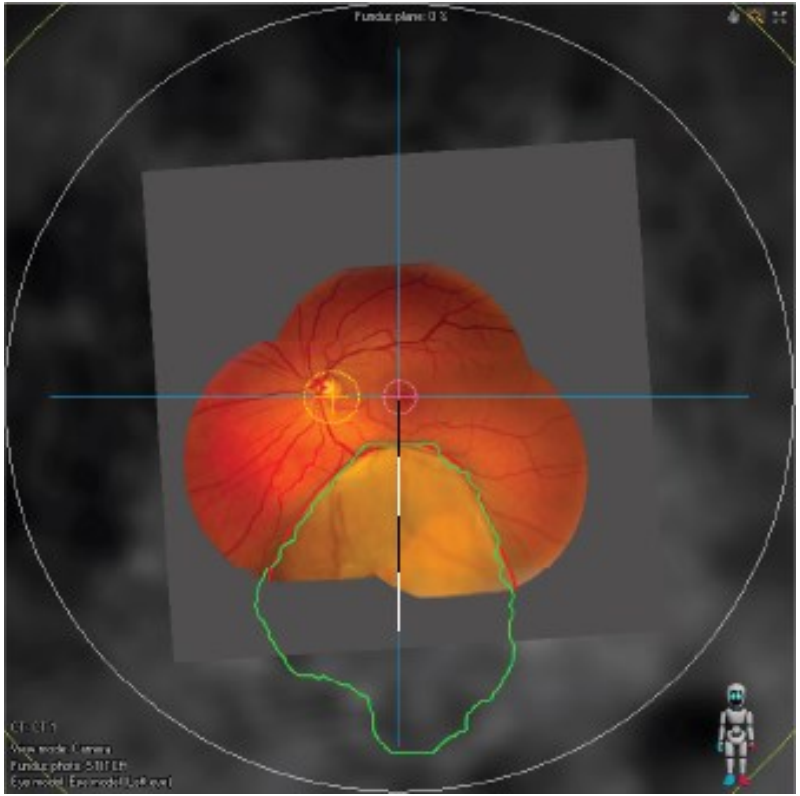
Clinical example

- Combination of **nodal point method** [1] and **linear camera behaviour**
- **Green**: MR-based contour, **red**: fundus-based contour



[1] Haasjes et al. (2024). Patient-specific mapping of fundus photographs to three-dimensional ocular imaging. *Med. Phys.*

- Combination of **nodal point method** [1] and **linear camera behaviour**
- **Green**: MR-based contour, **red**: fundus-based contour
- Difference: median 0.2 mm, maximum 0.5 mm



[1] Haasjes et al. (2024). Patient-specific mapping of fundus photographs to three-dimensional ocular imaging. *Med. Phys.*

Conclusions

The patient-specific scaling of fundus photographs is inhomogeneous: it is different for the peripheral retina

Optical ray tracing can be used to characterize and correct for these deformations

These methods can be applied in ocular oncology to combine information from fundus photographs and MR images

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Want to know more?

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