Imaged Area of the Retina

Alastair Atkinson, BSc, MSc, MIEE, CEng
Christophe Mazo, BSc, MSc, MPhil

1. Introduction

An important question that is frequently asked of Optos is "how much of the retina can I see on an Optomap® Image"? Typically this question is answered by reference to fields of view quoted as a function of angles – either internal or external. The implications of a field of view angle that quoted as a figure of merit for retinal imaging devices are not easily understood. This paper seeks to improve this understanding by converting the field of view angle figure into something that is perhaps more digestible – the percentage of retina visible.

2. Calculations

In Appendix A, a formula is derived that calculates the partial area of a sphere as shown by the colored area in the diagram below for an angle θeye. Most fundus cameras are specified by their *external* angle (θexternal). We must allow for the refractive index of the materials of the eye to convert from an *external* angle to the *internal* angle, hence:

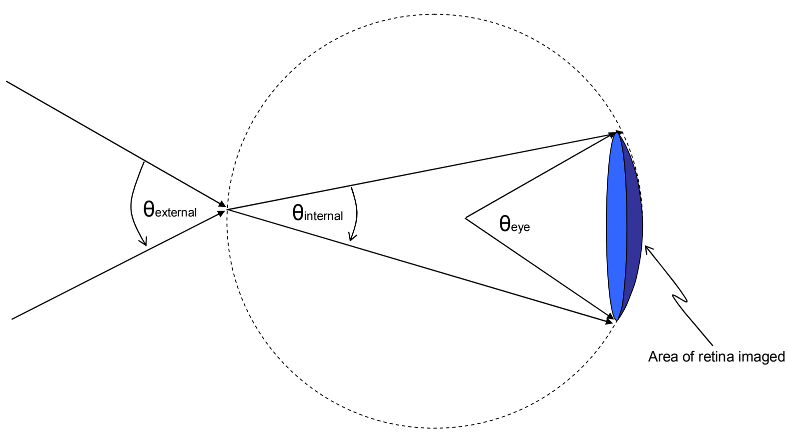

Figure 1: Relationship of internal, external and center of eye angles

Equation 1: $A = R^2 \cdot 2\pi \cdot \left(1 - \cos\left(\frac{\theta_{eye}}{2}\right)\right)$ where R is the radius of the sphere.

Most fundus camera manufacturers use an external angle to quote their field of view. Therefore to use the above equation, we must convert from an external to an internal angle. This is done by:

Equation 2: $\theta_{eye} = 0.74 \cdot 2 \cdot \theta_{external}$ which is derived from the refractive properties of the materials of the eye (as shown in Figure 1 above).

Assumptions (refer to references in Appendix B):

1. Radius of the eye = 11mm
2. The ora serrata is located at internal angle of 230°

From the above assumptions, and equation 1 we can calculate that the total area of the retina = 1081.57 mm^2

This allows us to compute the following table of results for typical imaging devices (undilated pupils unless specifically stated):

Device	**External Angle (degrees)**	**Corresponding Internal Angle (degrees)**	**Corresponding eye angle (degrees)**	**Area of retina visible (sq. mm)**	**Percentage of retina visible**
Direct ophthalmoscope	5	3.7	7.4	1.6	0.1%
Welch Allyn Panoptic	12	8.9	17.8	9.1	0.8%
Visual Pathways Inc ARIS	30	22.2	44.4	56.4	5.2%
Canon CF60DSi Fundus camera	40	29.6	59.2	99.2	9.2%
Canon CR-Dgi	45	33.3	66.6	124.8	11.5%
Zeiss Meditec Visucam Pro	45	33.3	66.6	124.8	11.5%
Kowa NONMYD7	45	33.3	66.6	124.8	11.5%
Nidek NM1000	45	33.3	66.6	124.8	11.5%
Topcon TRC-NW200	45	33.3	66.6	124.8	11.5%
Topcon TRC501X	50	37.0	74.0	153.1	14.2%
optomap			200.0	892.3	82.5%
ora seratta			230.0	1081.6	100.0%

3. Conclusions

Using the assumptions listed above, the P200 device with an eye angle of 200° captures approximately 82% of the retina with each image, in comparison with a typical fundus camera at 11%.

Appendix A – Formula Derivation.

Representing the eye in terms of spherical co-ordinates:
radius, r (mm)
Φ subtended angle from center (radians)
θ angle of rotation through 2Π radians

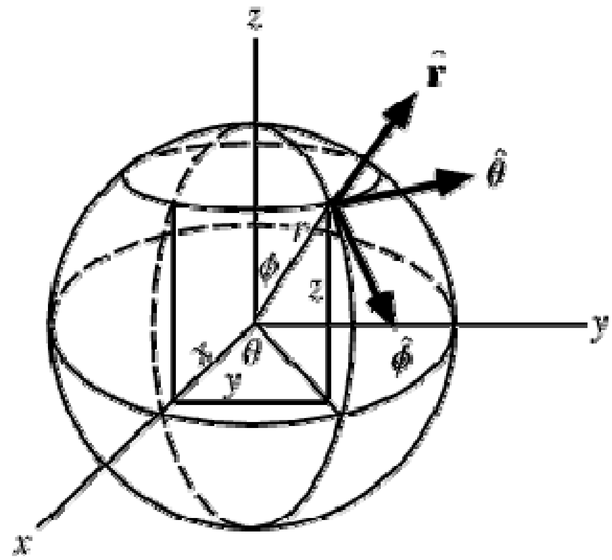

Figure 1 : Spherical Co-ordinates

Then to calculate the area of the surface of the sphere create by *r*, *θ* and *Φ*, integrate a surface area element given by the area element:
$dA = r^2 \cdot \sin(\phi) \cdot d\phi \cdot d\theta$ (See Figure 1)

Therefore the area of a full surface, as *θ* and *Φ* are allowed to vary:

$\phi \in [0 \quad \phi_{\max}]$

$\theta \in [0 \quad 2\pi]$

Area of the scan :

$$A = \int_{\phi=0}^{\phi=\phi_{\max}} \int_{\theta=0}^{\theta=2\pi} dA = \int_{\phi=0}^{\phi=\phi_{\max}} \int_{\theta=0}^{\theta=2\pi} r^2 \cdot \sin(\phi) \cdot d\phi \cdot d\theta$$

$$A = r^2 \cdot [\theta]_{\theta=0}^{2\pi} \cdot \int_{\phi=0}^{\phi=\phi_{\max}} \sin(\phi) \cdot d\phi = r^2 \cdot 2\pi \cdot [-\cos(\phi)]_{\phi=0}^{\phi=\phi_{\max}}$$

$$A = r^2 \cdot 2\pi \cdot (1 - \cos(\phi_{\max}))$$

Since *Φ* in the above derivation is equal to half the eye angle θ_{eye}:

Equation 1: Retinal area $= A = R^2 \cdot 2\pi \cdot \left(1 - \cos\left(\frac{\theta_{eye}}{2}\right)\right)$

Appendix B – Assumptions

There are two assumptions used in the paper, namely the radius of the eye and position of the ora serata. Clearly both of these physical dimensions vary from one person to the next – the values used in the calculations were derived from the following internet sources:

http://webvision.med.utah.edu/sretina.html
http://www.harcourt-international.com/e-books/viewbook.cfm?ID=222
http://webvision.med.utah.edu/Facts.html

It is important to note however, that the calculations are performed for each of the devices and their respective field of views using the same assumptions. Small variations in these dimensions will not make a significant impact on the results.