Arizona Eye Model

INTRODUCTION

Optical models of the human eye are used for designing ophthalmic devices and optical systems meant to be used with human eyes. This knowledge base article demonstrates one such model: the Arizona Eye Model, which is described in the SPIE “Field Guide to Visual and Ophthalmic Optics” by Jim Schwiegerling. The AZ eye model matches on and off-axis aberration levels that have been determined based on average clinical data. The FRED file contains the eye model as well as several sources useful for analyzing it. An embedded script is included that can be used to adjust the model based on the desired amount of accommodation.

THE MODEL

The model definition, shown in Table 1, consists of a series of surfaces described by a radius, conic constant, index of refraction ($n_d$), Abbe number ($V_d$), and distance to the next surface. Some of the parameters depend on the accommodation (A) in Diopters.

<table>
<thead>
<tr>
<th>Name</th>
<th>Radius (mm)</th>
<th>Conic Constant</th>
<th>Index of Refraction</th>
<th>Abbe Number</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornea</td>
<td>7.8</td>
<td>-0.25</td>
<td>1.377</td>
<td>57.1</td>
<td>0.55</td>
</tr>
<tr>
<td>Aqueous</td>
<td>6.5</td>
<td>-0.25</td>
<td>1.337</td>
<td>61.3</td>
<td>2.97-0.04A</td>
</tr>
<tr>
<td>Lens</td>
<td>12.0 – 0.4A</td>
<td>-7.52+1.29A</td>
<td>1.42+0.0026A -0.00022A²</td>
<td>51.9</td>
<td>3.77+0.04A</td>
</tr>
<tr>
<td>Vitreous</td>
<td>-5.22+0.2A</td>
<td>-1.35-0.43A</td>
<td></td>
<td>61.1</td>
<td>16.713</td>
</tr>
<tr>
<td>Retina</td>
<td>-13.4</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The model was created in FRED with an accommodation (A) of 0 and a pupil was added just in front of the lens. The materials were generated by creating new materials of the type “Model Material”, whose input parameters are $n_d$ and $V_d$. 
Sources

Multiple sources have been defined to analyze different properties of the model. Figure 1 shows all the sources and suggested purposes they can be used for.

<table>
<thead>
<tr>
<th>Objects</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Sources</td>
<td></td>
</tr>
<tr>
<td>Collimated beam on-axis</td>
<td>random, 3 wavelengths</td>
</tr>
<tr>
<td>Collimated random 20 deg off-axis</td>
<td>random, 3 wavelengths</td>
</tr>
<tr>
<td>Point source at z = -250 mm</td>
<td>4D accommodation</td>
</tr>
<tr>
<td>Point source at z = -1000 mm</td>
<td>10D accommodation</td>
</tr>
<tr>
<td>Letter F at z = -250 mm</td>
<td>4D accommodation</td>
</tr>
<tr>
<td>Sagittal 5</td>
<td>5 degrees off-axis</td>
</tr>
<tr>
<td>Sagittal 10</td>
<td>10 degrees off-axis</td>
</tr>
<tr>
<td>Tangential 5</td>
<td>5 degrees off-axis</td>
</tr>
<tr>
<td>Tangential 10</td>
<td>10 degrees off-axis</td>
</tr>
</tbody>
</table>

Figure 1. Sources and Suggested Uses

All the sources except “Letter F” are defined with the ray positions located at the aperture stop and an added pre-propagation distance of $z = -8$. Although the rays are created at the pupil, the specified direction refers to the rays after the pre-propagation distance. This means that the beams with the direction specified as collimated along the $z$-axis are collimated in front of the eye, not at the pupil.

After the embedded script is used to modify the accommodation to 4 Diopters, the source “Letter F” creates an image of the letter F on the retina. The green rays are very well focused while the red and blue are a bit blurry. Use the Positions Spot Diagram analysis to see this best.

Retinal Scatter

A 72% reflective lambertian scatter model named “Retina surface” is included in the “Scatterers” folder. It provides a rough approximation of retinal scatter. To model scattering from the retina, change the raytrace property of the “Retina” surface part of the “Eye ball” custom element from “Halt All” to “Allow All”. Make the “Plane” in the Geometry traceable and raytrace one of the collimated beams.

Note that the “Retina” surface has a scattering Importance Sampling Specification defined, which is accessed at the bottom of the “Scatter” tab of its Edit dialog. The “towards pupil” specification scatters the rays towards the pupil with a semi-angle of 10 degrees.
THE SCRIPT

The embedded script uses a dialog to prompt the user for an accommodation and pupil diameter. Creating and using dialogs is very easy to do in FRED’s Basic scripting language. Figure 2 shows how to access the user dialog editor, shown in the following figure.

```vba
Sub Main

' Get user inputs from dialog
Begin Dialog UserDialog 320,126,"Input parameters" ' %GRID:10,7,1,1
Text 20,21,190,21,"Accommodation (in Diopters):",Text1,1
OKButton 40,91,90,21
CancelButton 190,91,90,21
Text 20,99,190,94,"Pupil diameter (in mm default):",Text2,1
TextBox 220,49,40,21 File ' Default: 4
End Dialog

Dim dlg As UserDialog
ok = Dialog (dlg)
If ok = 0 Then
    ' cancel button was pressed
    Print "Execution cancelled."
End If

' Assign accommodation and pupil diameters, use defaults if field left empty
If dlg.TextBox1 = "" Then
    A = 0 ' Default accommodation
Else
    A = CDbI(dlg.TextBox1)
End If
If dlg.TextBox2 = "" Then
    pupilDiam = 4 ' Default pupil diameter
Else
    pupilDiam = CDbI(dlg.TextBox2)
End If

End Sub
```

Figure 2. Creating and Editing User Dialogs

Figure 3. User Dialog Editor
The code lines just below the dialog definition check if the “OK” button was pressed, and if it wasn’t the script is terminated. Then the input parameters are assigned to variables and if a field was left blank a default value is used. Therefore, if no values are entered and the “OK” button is pressed, the script runs with an accommodation value of 0 and pupil diameter of 4 mm.

The rest of the script calculates all the parameters that depend on accommodation and modifies the model accordingly.