How to Work with the Programmable Interface & Example (Spherical Surface)
Abstract

Providing maximum versatility for your optical simulations is one of our most fundamental objectives. In this document we show you how to program custom surfaces: that is, how to define a height function $h(x, y)$ that describes a 3D surface with respect to the $x, y$ coordinates which span the parametrization plane. These surfaces can then be used to configure the optical components in your system. Conical surfaces, being some of the most fundamental, are of course provided as a default template in VirtualLab; in this tutorial, however, we use a spherical surface as a simple programming example.
Where to Find the Programmable Interface: Catalog

Hint: you can save your customized interface in the Interfaces Catalog (as User Defined) for later use.
Where to Find the Programmable Interface: Components
Writing the Code

• The panel on the right shows a list of available independent parameters.
• $x$ and $y$ represent the independent variables, the 2D coordinates spanning a plane.
• The interval where $x$ and $y$ are defined is given by $\text{ApertureDiameterX}$ and $\text{ApertureDiameterY}$ (both of them determined in the general configuration dialog of the interface).
• The code in the Main Function must return a double value per $x$, $y$ point. This value represents the height at that point. The set of all these height values defines a 3D surface.
• Use the Snippet Body to group parts of the code in support functions.
Definition of the Surface Gradient

- An accurate calculation of the gradient of the interface is fundamental in an optical simulation.

- The Programmable Interface in VirtualLab allows for two different modes of definition of the gradient: numerical, with adjustable accuracy (automatically carried out by the software) or analytical (programmed additionally by the user).
User-Defined Surface Gradient

• The panel on the right shows the same list of available independent variables.

• This time, the code in the Main Function must return a VectorD—a vector with two double (real-valued) coordinates. Use the Snippet Body to group parts of the code in support functions.

• Using the analytical definition of the gradient where possible makes for the more accurate alternative. The consistency of the code is checked by the software, but the user must make sure that the function entered for the gradient coincides with the corresponding interface!
Output of the Programmable Interface

- The output is a 3D surface which can be used to define the interface of an actual optical component in a system.
- The custom interface can be programmed directly within the real component where it is required.
- Or, alternatively, it can be saved in the catalog for later use.
Programming a Spherical Surface
The Spherical Surface

A sphere is defined as the locus of all the points \( x, y, z \) located at the same distance \( R \) from a common centre (which we shall place at the origin)

\[
x^2 + y^2 + z^2 = R^2.
\]  

(1)

Then, to transform Eq. (1) into an expression that generates the height function \( h(x, y) \) of a spherical surface

\[
h(x, y) = \pm \sqrt{R^2 - (x^2 + y^2)}.
\]  

(2)

It is also possible to straight-forwardly compute the gradient of the surface

\[
\frac{\partial h(x, y)}{\partial x} = \mp x \left[R^2 - (x^2 + y^2)\right]^{-1/2} \quad \text{and} \quad \frac{\partial h(x, y)}{\partial y} = \mp y \left[R^2 - (x^2 + y^2)\right]^{-1/2}
\]  

(3)
Where to Find the Programmable Interface: Catalog
Where to Find the Programmable Interface: Components
Setting Up the Area of Definition of the Surface

• In the configuration dialog previous to entering the programming interface, the user can define the shape and size of the area of definition (parametrization) of the surface.

• In this example we use a circular aperture.

• Bear in mind that there is a natural limit to the area of definition of a spherical surface, given by its diameter, outside of which the surface is not defined!
Entering the Programming Interface
Programmable Interface: Global Parameters

• Once you have triggered open the Edit dialog (Source Code Editor), go to the Global Parameters tab.

• There, Add and Edit one parameter:
  
  − *double* Radius = 10 mm (-1 m, 1 m): the radius of curvature of the spherical surface.

• Use the button with the small “notes” icon to add some explanation to your custom global parameters.

*Hint:* it is possible to add some clarifying text to each global parameter to facilitate use of the snippet for other users!
Optional: you can use the Snippet Help tab to write instructions, clarifications, and some additional data associated to your snippet.

This option is very helpful to keep track of your progress with a programmable element.

It is especially useful when the programmable element is later disseminated to be handled by other users!
Programmable Interface: Snippet Help

Custom Spherical Surface

Version: 1.0
Last Modified: Wednesday, August 29, 2018

This snippet generates a spherical surface. The user can input the desired radius of curvature, with both positive and negative values allowed to account for convex and concave surfaces.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius</td>
<td>The radius of curvature of the spherical surface. It can be positive or negative to define a convex or a concave surface respectively.</td>
</tr>
</tbody>
</table>
Offset the height function so that \( h(0, 0) = 0 \). Even if this is not implemented in the code, the surface will still be automatically offset to fulfil this condition!
Programmable Interface: User-Defined Gradient

Eq. (3)
You can modify the value of the global parameters you defined here.

You can modify the area of definition (aperture) of your surface. Bear in mind possible constraints (as already pointed out in the case of the spherical surface).

You can view the surface you have defined here.

Modify your snippet by clicking on Edit.

With respect to which reference point in the surface is the surrounding plane defined? And what happens when a part of the EM field meets this surrounding plane?
The surface is defined completely analytically by the code—full accuracy (up to double precision)
Saving the Custom Interface to the Catalog

Hint: if you used the Catalog to define your custom interface, you will be automatically prompted to save your work to the catalog.
Troubleshooting Tips

Do you see strange border effects in the 3D visualization of your custom surface?
The area of definition you have entered for the surface is larger than mathematically possible!
In this particular example, make sure you have selected an “Elliptic” shape, or reduce the size of the area of definition.

The area of definition you have entered for the surface is larger than mathematically possible!

Do you see strange border effects in the 3D visualization of your custom surface?
double height = 0.0;

height = (Radius / Radius.Abs()) * // Use correct sign.
   Math.Sqrt((Radius * Radius) - (x * x) - (y * y));
height = height - Radius; // Offset surface so that central point is at zero height.

// Hint: an alternative way to compute the sign is to use
// MathFunctions.Sign(Radius) instead of (Radius / Radius.Abs()).

return height;
Test the Code!

Main Function (Gradient)

```csharp
VectorD gradient = new VectorD();

gradient.X = -(Radius / Radius.Abs()) * (x) /
    (Math.Sqrt((Radius * Radius) - (x * x) - (y * y)));
gradient.Y = -(Radius / Radius.Abs()) * (y) /
    (Math.Sqrt((Radius * Radius) - (x * x) - (y * y)));

// Hint: an alternative way to compute the sign is to use
// MathFunctions.Sign(Radius) instead of (Radius / Radius.Abs()).

return gradient;
```
<table>
<thead>
<tr>
<th>title</th>
<th>How to Work with the Programmable Interface &amp; Example (Spherical Surface)</th>
</tr>
</thead>
<tbody>
<tr>
<td>document code</td>
<td>CZT.0096</td>
</tr>
<tr>
<td>version</td>
<td>1.0</td>
</tr>
<tr>
<td>toolbox(es)</td>
<td>Starter Toolbox</td>
</tr>
<tr>
<td>VL version used for simulations</td>
<td>7.4.0.49</td>
</tr>
<tr>
<td>category</td>
<td>Feature Use Case</td>
</tr>
<tr>
<td>further reading</td>
<td>- <a href="#">Customizable Help for Programmable Elements</a></td>
</tr>
<tr>
<td></td>
<td>- <a href="#">Programmable Light Source, Function, Interface and Medium</a></td>
</tr>
<tr>
<td></td>
<td>- <a href="#">Programming a Sinusoidal Surface</a></td>
</tr>
</tbody>
</table>