

Creating Klems coordinate system BSDF data files according to WINDOW XML format

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Overview

The complex glazing database contains a lot of XML files with BSDF data in them. This document summarizes different pathways for creating them.

The term BSDF (bi-directional scattering distribution function) is used to describe a lot of different things. Sometimes it is used to denote a file, sometimes it is used as shorthand when talking about a property which could be either BRDF (bi-directional reflectance distribution function) or BTDF (bi-directional transmittance distribution function). It is also used when talking about the discrete matrix representation of the continuous function.

Formatting, storing, and accessing BSDF data in IGSDb and IKDB

File format example

The XML schema holds the formal definition of the file format, but WINDOW and other programs that parse these XML files are not able to handle all possible options so having examples of a

file that works in WINDOW is helpful. Downloading the latest version of CGDB should be a good source for full XML files that can be used by WINDOW.

The schema for the XML format is defined by BSDF-v1.7.7.XSD (or later version).

The header of the file contains information about the product in the following format.

```
<?xml version="1.0" encoding="UTF-8"?>
<WindowElement xmlns="http://windows.lbl.gov" xmlns:xsi=
"http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://windows.lbl.gov BSDF-v1.7.7.xsd">
<WindowElementType>Layer</WindowElementType>
<FileType>BSDF</FileType>
<Optical>
  <Layer>
    <Material>
      <Name>World's best fabric</Name>
      <Manufacturer>World's best company</Manufacturer>
      <Thickness unit="Millimeter">1</Thickness>
      <DeviceType>Woven Shade</DeviceType>
      <ThermalConductivity>0.15</ThermalConductivity>
      <EmissivityFront>0.7</EmissivityFront>
      <EmissivityBack>0.3</EmissivityBack>
      <TIR>0.15</TIR>
      <EffectiveOpennessFraction>0.145</EffectiveOpennessFraction>
      <Color>brown</Color>
      <Comments></Comments>
    </Material>
```

The angle basis is defined after the initial information, the Klems coordinate system that is used in WINDOW would look something like

```
<DataDefinition>
  <IncidentDataStructure>Columns</IncidentDataStructure>
  <AngleBasis>
    <AngleBasisName>LBNL/Klems Full</AngleBasisName>
    <AngleBasisBlock>
      <Theta>0</Theta>
      <nPhis>1</nPhis>
      <ThetaBounds>
        <LowerTheta>0</LowerTheta>
        <UpperTheta>5</UpperTheta>
      </ThetaBounds>
    </AngleBasisBlock>
    <AngleBasisBlock>
      <Theta>10</Theta>
      <nPhis>8</nPhis>
```

```

        <ThetaBounds>
        <LowerTheta>5</LowerTheta>
        <UpperTheta>15</UpperTheta>
    </ThetaBounds>
</AngleBasisBlock>
<!-- and so forth until-->
<AngleBasisBlock>
    <Theta>82.5</Theta>
    <nPhis>12</nPhis>
    <ThetaBounds>
        <LowerTheta>75</LowerTheta>
        <UpperTheta>90</UpperTheta>
    </ThetaBounds>
</AngleBasisBlock>
</AngleBasis>
</DataDefinition>

```

After the header the same style block is repeated for each wavelength band (visible and solar) and property (reflectance/transmittance).

```

<WavelengthData>
    <LayerNumber>System</LayerNumber>
    <Wavelength unit="Integral">Visible</Wavelength>
    <SourceSpectrum>CIE D65 standard illuminant</SourceSpectrum>
    <DetectorSpectrum>CIE 1931 2deg observer Y</DetectorSpectrum>
    <WavelengthDataBlock>
        <WavelengthDataDirection>Reflection
Front</WavelengthDataDirection>
        <ColumnAngleBasis>LBNL/Klems Full</ColumnAngleBasis>
        <RowAngleBasis>LBNL/Klems Full</RowAngleBasis>
        <ScatteringDataType>BTDF</ScatteringDataType>
        <ScatteringData>
        <!-- Data block, i.e. a 145x145 matrix, goes here -->
        </ScatteringData>
    </WavelengthDataBlock>
</WavelengthData>

```

This block will come back in 8 permutation with all possible combinations of three variables

- Wavelength This can be Visible or Solar
- WavelengthDataDirection This has two parts Reflection or Transmission and Front or Back.

For each permutation there will be a 145 by 145 matrix with BSDF values in the data block. Each column corresponds to an incident direction and each row corresponds to the outgoing direction resulting in all specular directions being located on the main diagonal.

The tail of the document only closes the blocks started in the header

```

</Layer>

```

```
</Optical>  
</WindowElement>
```

Considering the time

Converting spectral data to the visible and solar wavelength bands

Spectral data can be used to calculate visible and solar properties according to NFRC 300. The integrated thermal IR emissivity and transmittance are given as integrated values. For shade materials the most common path is to use an emissometer according to AERC 1.1 appendix E.

Radiance genBSDF output

genBSDF can generate Klems XML files as output. These are commonly created where optical properties of the elements are the spectrally integrated visible values. However, genBSDF is agnostic to this and if integrated solar values are used in the input model, the resulting BSDF will be a solar BSDF.

Radiance bsdf2klems output

Radiance can handle an interpolant format where the BSDF is represented by an ensemble of gaussian lobes which can be sampled using bsdf2klems to produce a Klems coordinate system BSDF XML file. Similar to how genBSDF is wavelength agnostic this is also true for bsdf2klems, so the wavelength property of the output data will match that of the input.

One quirk of bsdf2klems is that the sampling of the interpolant is carried out to match the Klems coordinates which does not compress data for symmetric layers. This means that the resulting matrix might have different direct-hemispherical values where you would expect them to be identical. E.g. for an isotropic product where you would expect that for a given incident theta-value, all the incident phi-values would result in identical direct-hemispherical outgoing results, the randomness of sampling the interpolant for each incident direction will result in different values. Post processing the BSDF to match the symmetry of the model or measurement can be helpful for users looking at the final BSDF to understand the symmetry of the product.

Software tools using solar BSDF

WINDOW converts solar data to do multilayer calculations in spectral data bands

The multi-layer calculations with diffuse layers in WINDOW are, by default, carried out at 17 wavelength points (Preferences->Optical calcs->Spectral Data: Condensed spectral data). For the visible data points the visible BSDF is being used. For the other data point a new BSDF matrix is calculated from the visible and solar matrices in the data file so that a solar integration over all these 17 points result in the same direct-hemispherical result as was given for the solar matrix. This is not ideal since the visible values has lost the energy information in the visible range. However, for systems with spectrally selective coatings it is preferable do the multiple bands in this way compared to doing multi-layer calculations simply with only an integrated solar value for each layer.

The wavelengths where calculation is carried out when using the default 5 visible bands and 10 NIR bands of the WINDOW condensed calculation are

300, 380, 460, 540, 620, 700, 780, 952, 1124, 1296, 1468, 1640, 1812, 1984, 2156, 2328, 2500

Use of solar BSDF in EnergyPlus

EnergyPlus does band by band calculation, visible separate from solar and can use XML files with Klems format BSDFs in them for the window layers.

Use of solar BSDF in Radiance

Radiance can parse a XML with a BSDF in Klems format.

Measurement methods to obtain BSDF data (Separate report)

Pathways to measure data that can be converted to BSDF data in different ways is not described in this document.