RenderToolbox

A MATLAB Toolkit for Hyperspectral Rendering with Radiance and PBRT

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RenderToolbox
Acknowledgements

RenderToolbox
Goals

- To produce stimuli for psychophysical experiments which are accurately derived from the physical properties of lights and surfaces.

- We are "consumers" of renderers, so we would like to better understand their performance.

- To produce these stimuli without the user needing to be an expert in Radiance/PBRT or even MATLAB.
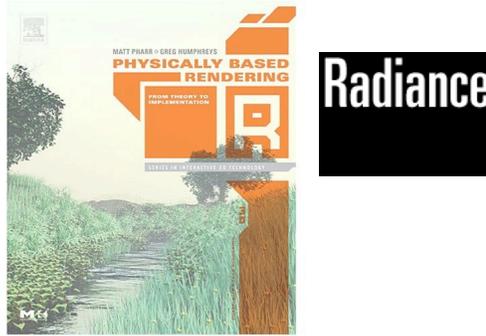
RenderToolbox
Design

- RenderToolbox acts as a wrapper around extant renderers, enabling them to render hyperspectrally. This provides color accuracy, which is important in our lab.

- The toolbox is designed to allow easy comparison of the variations between renderers.
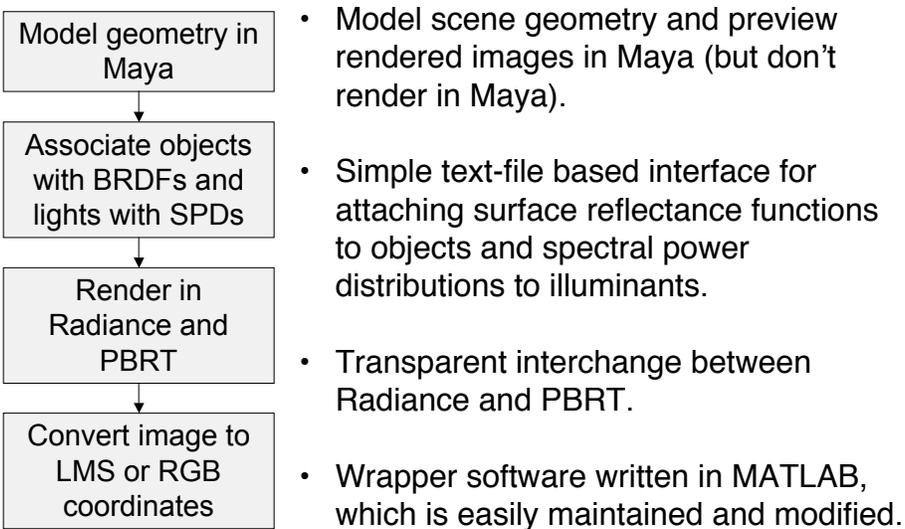
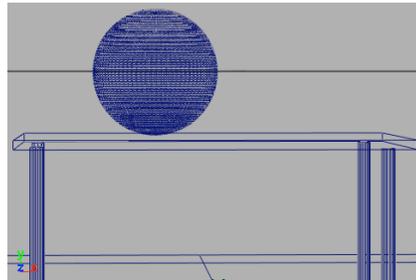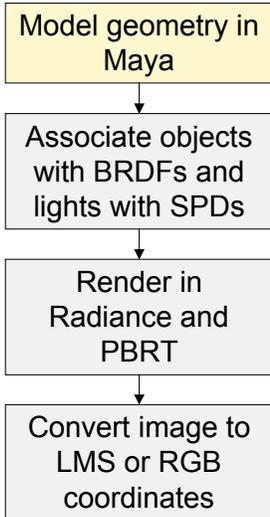# Radiance and PBRT

Both renderers have 2 important features:

- They are designed to simulate the physical flow of light through scenes

- They are freely and publicly available.

Ease of Use

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates

- Model scene geometry and preview rendered images in Maya (but don't render in Maya).

- Simple text-file based interface for attaching surface reflectance functions to objects and spectral power distributions to illuminants.

- Transparent interchange between Radiance and PBRT.

- Wrapper software written in MATLAB, which is easily maintained and modified.

Software: Geometry in Maya

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates
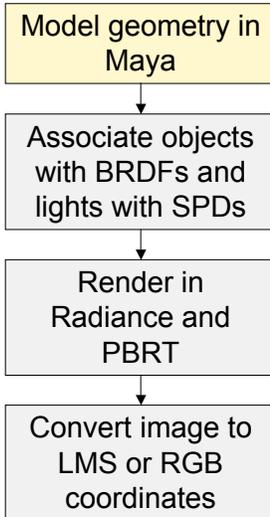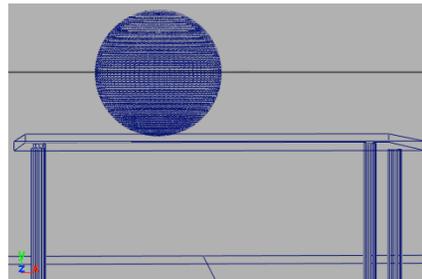

- Maya is a commercial program that lets you design 3D scenes.

- A plugin allows you to export objects into Radiance .obj format.

- A modified public domain plugin allows you to export objects into PBRT format.

Software: Geometry in Maya

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates
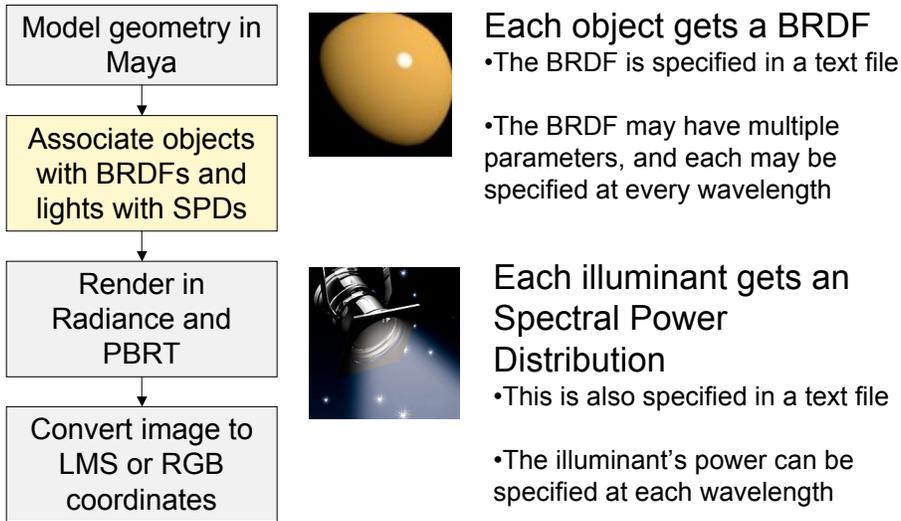
Output from Maya to Radiance and PBRT

plugin ↓ Radiance format

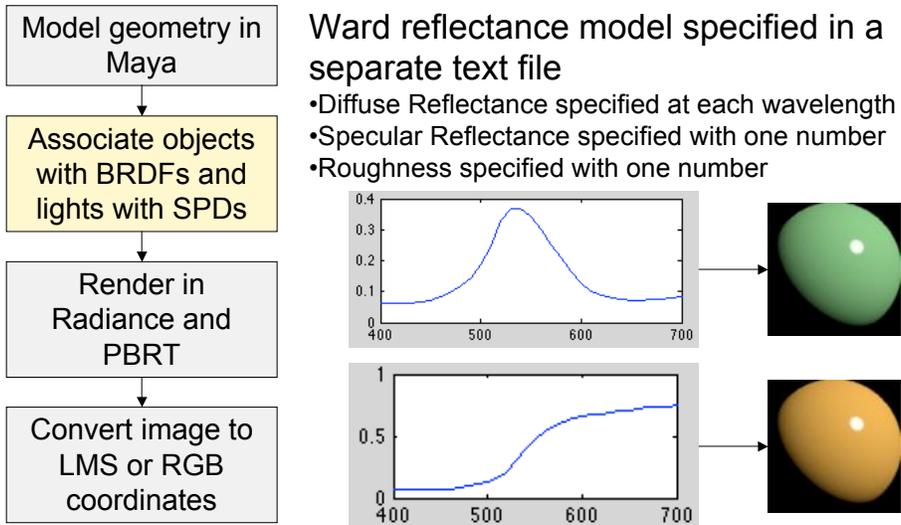plugin ↓ PBRT format

(Also support native .rad and .pbrt format)
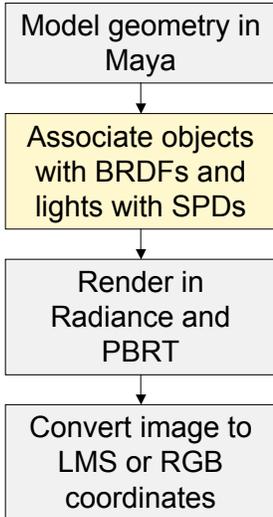
RenderToolbox

Software: Hyperspectral BRDFs & SPDs

Model geometry in Maya	
↓	
Associate objects with BRDFs and lights with SPDs	
↓	
Render in Radiance and PBRT	
↓	
Convert image to LMS or RGB coordinates	

Each object gets a BRDF
•The BRDF is specified in a text file

•The BRDF may have multiple parameters, and each may be specified at every wavelength

Each illuminant gets an Spectral Power Distribution
•This is also specified in a text file

•The illuminant's power can be specified at each wavelength

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Software: BRDF example

Model geometry in Maya	
↓	
Associate objects with BRDFs and lights with SPDs	
↓	
Render in Radiance and PBRT	
↓	
Convert image to LMS or RGB coordinates	

Ward reflectance model specified in a separate text file
•Diffuse Reflectance specified at each wavelength
•Specular Reflectance specified with one number
•Roughness specified with one number

Software: SPD example

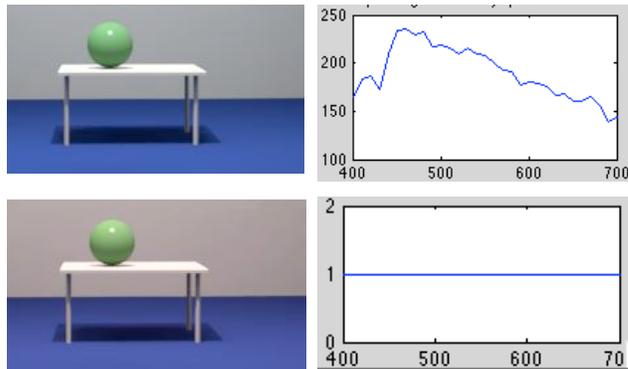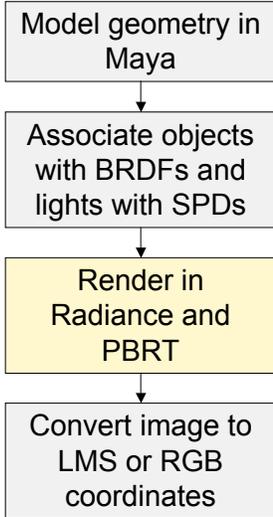| Model geometry in Maya |
| Associate objects with BRDFs and lights with SPDs |
| Render in Radiance and PBRT |
| Convert image to LMS or RGB coordinates |

Daylight illuminant spectrum specified in a text file

•Power is specified at each wavelength in Watts/Steradian

Software: Rendering
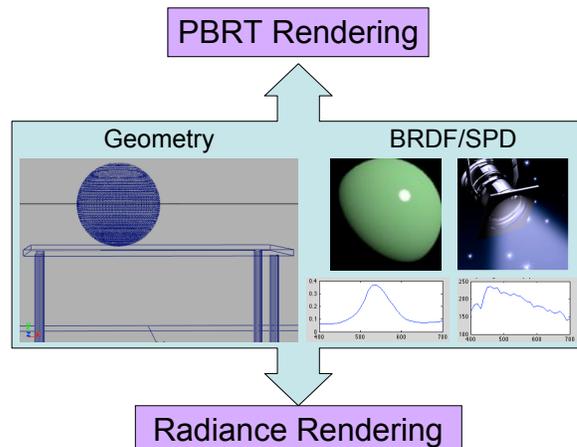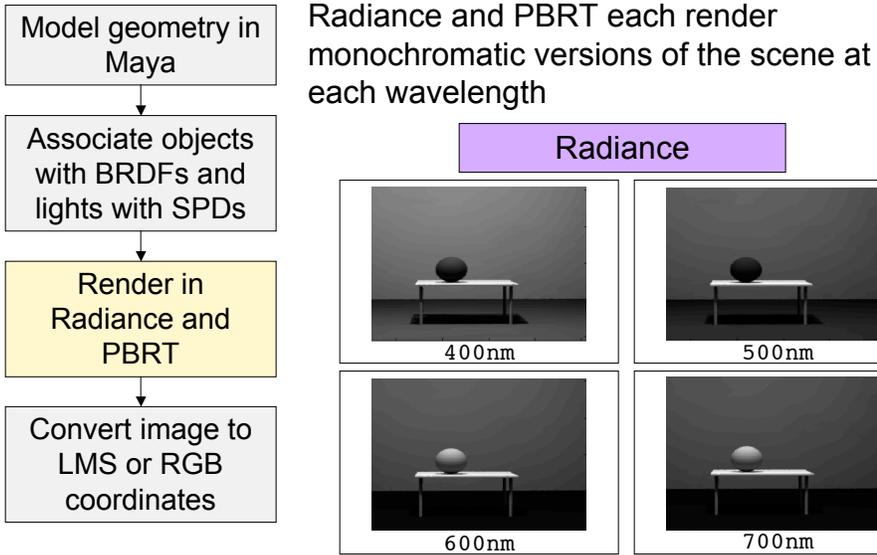
| Model geometry in Maya |
| Associate objects with BRDFs and lights with SPDs |
| Render in Radiance and PBRT |
| Convert image to LMS or RGB coordinates |

Geometry from Maya, and object BRDFs and illuminant SPDs passed to both the PBRT and Radiance renderers.

PBRT Rendering

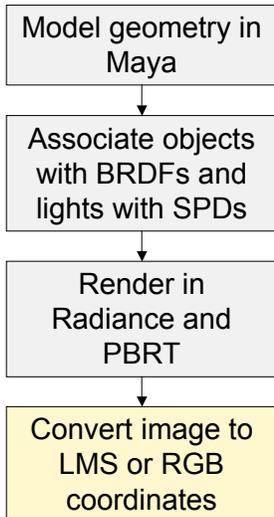| Geometry | BRDF/SPD |

Radiance Rendering

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Software: Rendering

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates

Radiance and PBRT each render monochromatic versions of the scene at each wavelength

Radiance

400nm

500nm

600nm

700nm

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Software: LMS and RGB coordinates

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates

Hyperspectral color data is useful, but we've provided tools to convert the image to an LMS cone image and a RGB monitor image.

Cone image in LMS   Monitor image in RGB
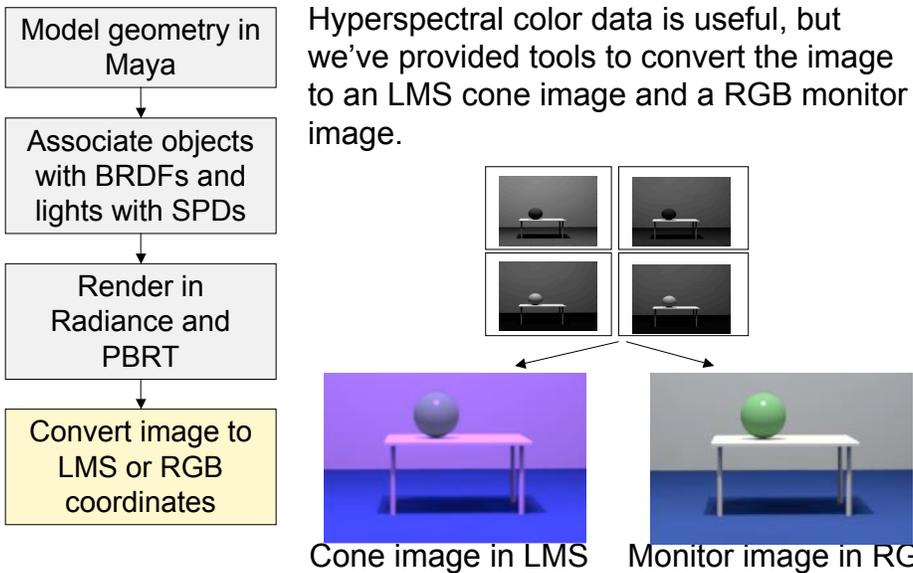
RenderToolbox

Software: Tonemapping and Calibration

Model geometry in Maya

↓

Associate objects with BRDFs and lights with SPDs

↓

Render in Radiance and PBRT

↓

Convert image to LMS or RGB coordinates

The RGB monitor image can be tonemapped and calibrated to a specific monitor. It is easy to write your own tonemapping algorithm.


Tonemapped and calibrated image in RGB

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Additional Features

•The toolbox is configured to compute in a parallel computing environment, specific to our lab, but easily adaptable.
•Also configured to render multiple versions of the same scene with different BRDFs and SPDs, as well as different rendering properties.

•The package is written so that it's easy to use for someone who's not an expert in Radiance or MATLAB.
•The toolbox is available as a beta version online at http://www.rendertoolbox.org.
•We're still working on the documentation but we're happy to help you set it up.

Comparison of the two renderers

•PBRT doesn't natively support the ward model, but we've included a ward shader for PBRT which we found on the internet and modified.

•As this example of an arbitrary scene illustrates, the difference between Radiance and PBRT's output is small. Comparing the two is simply a matter of replacing 'radiance' with 'pbrt' in a conditions file.

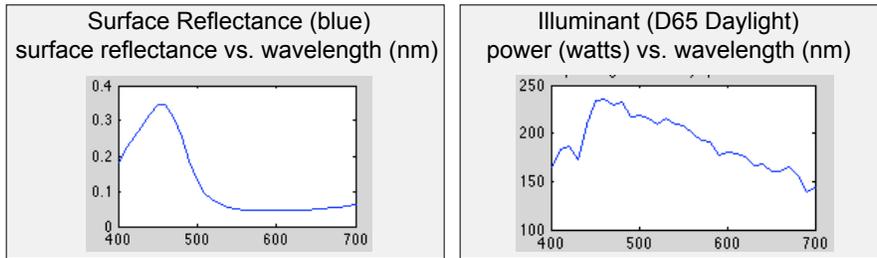| Radiance image | - | PBRT image | = | Difference |
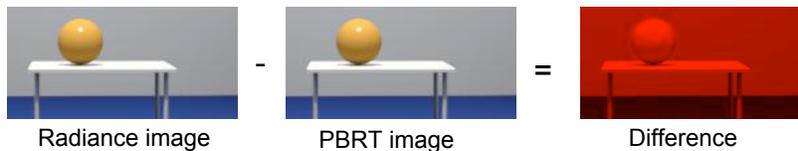
Examples

•RenderToolbox includes two examples that demonstrate its function and compare specific elements of Radiance and PBRT's performance.
•We choose to use simple scenes for which we could compute features of the rendered image from first principles.
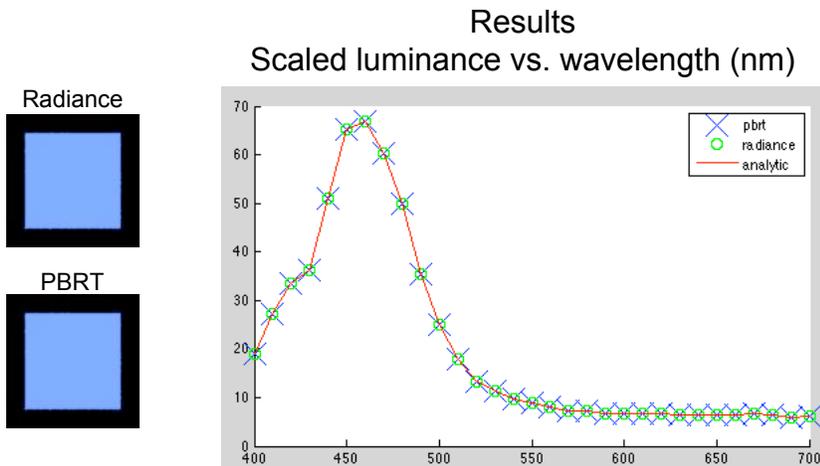
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Example: Simple Square

•This is the simplest scene possible.
•This example demonstrates that the spectral features of the whole package works correctly and that we correctly wrote our software.

Scene characteristics

Surface Reflectance (blue) surface reflectance vs. wavelength (nm)	Illuminant (D65 Daylight) power (watts) vs. wavelength (nm)

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Example: Simple Square

Results
Scaled luminance vs. wavelength (nm)

Radiance

PBRT

Example: Sphere with Point Light

•This scene includes a sphere and distant pointlight in an orthogonal projection.
•Computing the luminance for the sphere and pointlight with the ward model is straightforward, so we generated an image of the same configuration from first principles.
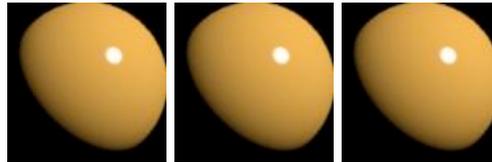
Radiance   PBRT   Analytic

•The images are very similar. We attribute subtle differences in geometry to changes that occur during the export from Maya.
•We didn't write a perspective projection, but the Radiance and PBRT images match each other very closely, which increases our confidence that they are both doing the right thing.

Example: Sphere with Point Light

Scaled Luminocity vs. Vertical Location Along Column in Image

Measure along a vertical slice of the sphere

top   bottom
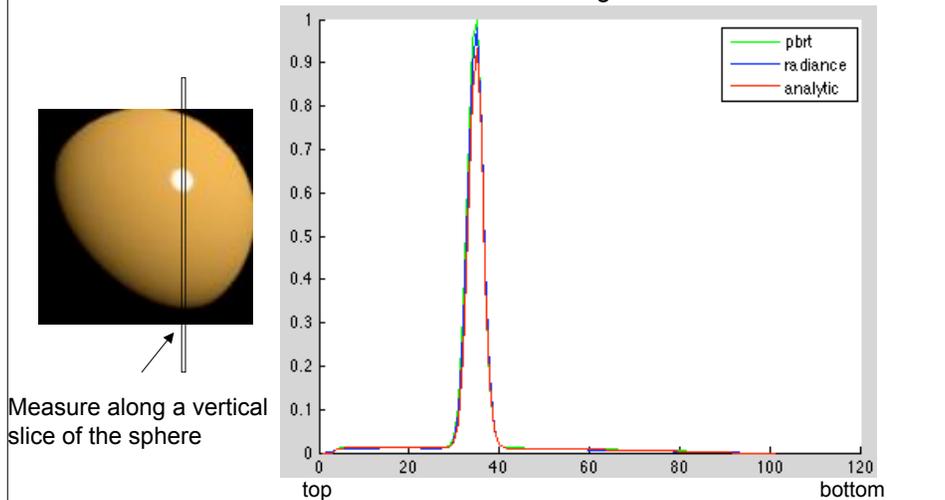
RenderToolbox

Summary

•Plan to include another example to test the renderers' performance with secondary bounces.

•RenderToolbox provides a simple interface to Radiance and PBRT, especially for use in psychophysics.

•Comparison of rendered images from the two renderers for simple cases indicates good agreement and increases our confidence that these renderers are appropriate for use in generating experimental stimuli.

•Beta version available here:

http://www.rendertoolbox.org