NEW DEVELOPMENTS IN MATERIALX
MATERIALX AT THE ASWF

- MaterialX joined the Academy Software Foundation this year
- Opportunities for additional teams to collaborate on its development
- Steering meetings are open to the entire community
MaterialX Session Schedule

**Introduction**

**MaterialX in Hydra** - Karen Lucknavalai (Pixar)

**Shader Translation Graphs** - Jonathan Stone (ILM)

**MaterialX Shader Generation** - Bernard Kwok & Ashwin Bhat (Autodesk)

**MaterialX in MayaUSD** - Krystian Ligenza (Autodesk)

**MaterialX in Houdini** - Mark Elendt (SideFX)

**The Adobe Standard Material Model** - Paul Edmondson (Adobe)

**Adding MaterialX Closures to OSL** – Chris Kulla (Epic Games)
MaterialX in Hydra

How to use MaterialX within Hydra?

1. Attach a MaterialX file to a USD object through the `materialBinding`

2. Run a MaterialX file through `usdcat` to generate a USD version of the mtlx file and use as usual

Both these methods translate the MaterialX network into UsdShade

```python
#usda 1.0
def Sphere "sphere" {
  rel material:binding = </MaterialX/Materials/USD_Default>
}
def Scope "MaterialX" {
  references = [
    @/usd_preview_surface_default.mtlx@</MaterialX>,
  ]
}
```
MaterialX in Hydra - Lights

Just add lights to your USD file as usual!

Support for:

- Indirect lights → environment lights
- Direct lights → point lights
MaterialX in Hydra - Lights
MaterialX in Hydra
MaterialX in Hydra - Textures

```xml
<nodegraph name="NG_Brass">
  <geompropvalue name="stcoords" type="vector2">
    <input name="geomprop" type="string" value="st" />
  </geompropvalue>
  <tiledimage name="image_color" type="color3">
    <input name="file" type="filename" value="brass_color.jpg" />
    <input name="uvtiling" type="vector2" value="1.0, 1.0" />
    <input name="texcoord" type="vector2" nodename="stcoords" />
  </tiledimage>
  <tiledimage name="image_roughness" type="float">
    <input name="file" type="filename" value="brass_roughness.jpg" />
    <input name="uvtiling" type="vector2" value="1.0, 1.0" />
    <input name="texcoord" type="vector2" nodename="stcoords" />
  </tiledimage>
  <output name="out_color" type="color3" nodename="image_color" />
  <output name="out_roughness" type="float" nodename="image_roughness" />
</nodegraph>
```

standard_surface_brass_tiled.mtlx
MaterialX in Hydra - Textures

```xml
<!-- NodeGraph using a geompropvalue for the primvar name -->
<nodegraph name="NG_Brass">
    <geompropvalue name="stcoords" type="vector2">
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        <input name="texcoord" type="vector2" nodename="stcoords"/>
    </tiledimage>
    <output name="out_color" type="color3" nodename="image_color"/>
    <output name="out_roughness" type="float" nodename="image_roughness"/>
</nodegraph>
```

standard_surface_brass_tiled.mtlx
MaterialX in Hydra - Textures

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    <input name="uvtiling" type="vector2" value="1.0, 1.0" />
    <input name="texcoord" type="vector2" nodename="stcoords" />
  </tiledimage>
  <tiledimage name="image_roughness" type="float">
    <input name="file" type="filename" value="brass_roughness.jpg" />
    <input name="uvtiling" type="vector2" value="1.0, 1.0" />
    <input name="texcoord" type="vector2" nodename="stcoords" />
  </tiledimage>
  <output name="out_color" type="color3" nodename="image_color" />
  <output name="out_roughness" type="float" nodename="image_roughness" />
</nodegraph>
```

standard_surface_brass_tiled.mtlx
MaterialX in Hydra - Textures

<!-- NodeGraph using a geompropvalue for the primvar name -->
<nodegraph name="NG_Brass">
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    </geompropvalue>
    <tiledimage name="image_color" type="color3">
        <input name="file" type="filename" value="brass_color.jpg" />
        <input name="uvtiling" type="vector2" value="1.0, 1.0" />
        <input name="texcoord" type="vector2" nodename="stcoords" />
    </tiledimage>
    <tiledimage name="image_roughness" type="float">
        <input name="file" type="filename" value="brass_roughness.jpg" />
        <input name="uvtiling" type="vector2" value="1.0, 1.0" />
        <input name="texcoord" type="vector2" nodename="stcoords" />
    </tiledimage>
    <output name="out_color" type="color3" nodename="image_color" />
    <output name="out_roughness" type="float" nodename="image_roughness" />
</nodegraph>
MaterialX in Hydra - Textures
MaterialX in Hydra - Storm and Prman
Thank you

More information at the USD, Hydra BOF at SIGGRAPH:
Wed August 11, 2pm-4pm
SHADER TRANSLATION GRAPHS

JONATHAN STONE – INDUSTRIAL LIGHT & MAGIC
PHYSICALLY BASED SHADING NODES

- Standard building blocks for composing shading models
- Existing graph definitions for Autodesk Standard Surface and UsdPreviewSurface
- New graph definitions for the MaterialX Lama nodes
GRAPH BASED SHADING MODELS

- High-level definition of shading model behavior
- Maintains independence from renderer-specific choices
- Allows more natural comparison of differences between models
SHADER TRANSLATION GRAPHS

- Graph based definitions of translations between shading models
- MaterialX shader generation can be applied to both content and translation
- Translations can remain “live” as graphs or be baked to flat textures
NEW DEVELOPMENTS

BB-8 AT SIGGRAPH 2019
ILM began refining the technique for use in production

Translation becomes data-driven and automated

Extended to include dual specular lobes, anisotropy, and other techniques
NEW DEVELOPMENTS

ILM PRODUCTION TESTS

ILM UNIFIED

STANDARD SURFACE
NEW DEVELOPMENTS

ILM PRODUCTION TESTS

ILM UNIFIED

STANDARD SURFACE
NEW DEVELOPMENTS

EXAMPLE TRANSLATION GRAPH

- A first example translation graph has been added to MaterialX
- Translates from Standard Surface to UsdPreviewSurface
NEW DEVELOPMENTS

EXAMPLE TRANSLATION GRAPH

- **UsdPreviewSurface** has a smaller feature set, so some techniques are omitted.
- Anisotropic roughness is averaged.
- Sheen, thin film, and subsurface effects are ignored.
NEW DEVELOPMENTS

EXAMPLE TRANSLATION GRAPH

- For a Python example, see translateshader.py in the Scripts folder
- For a C++ example, see Viewer.cpp in the MaterialXView project
- Shader translation has been added to render tests in GitHub Actions
THANKS TO...

Doug Smythe
Madeleine Yip
André Mazzone
Karen Lucknavalai
Bernard Kwok
Krystian Ligenza
Paul Edmondson
Mark Elendt
Chris Kulla

Eoghan Cunneen
Emma Holthouser
David Meny
George ElKoura
Ashwin Bhat
Zap Andersson
David Larsson
Lee Kerley
Adrien Herubel

Roger Cordes
François Chardavoine
Rob Bredow
Nick Porcino
Niklas Harrysson
Eric Bourque
Guido Quaroni
Mark Tucker
Larry Gritz
MaterialX Shader Generation

Bernard Kwok and Ashwin Bhat
bernard.kwok@autodesk.com
ashwin.bhat@autodesk.com
1.38.x Updates
Shading Graph Configurability

- Consistent and robust compound and functional graph support
- Improved traversal logic for node and graph interface connections
- New: Nodegraph-to-nodegraph connections, Translation graph support.
- Improved namespace, version, target support
- Improved input value resolution to handle: inheritance, interface connections, geometry and filenames (incl. tokens)
- Improved ability to code generate for individual nodes, and sub-graphs.
Improved light injection and geometry stream bindings

Improved uniform injection including layout support

Improved reflection for resource binding and transparency heuristics

Improved image format and texturing support
Rendering validation (Intel OpenSWR)

MaterialX Web: WASM generation and Github pages hosting.

Goal: support fully automated code generation / rendering validation
Color Management

OCIO v2 Integration

- Challenges:
  - ACEScg color space naming consistency
  - Code generation targets: GLSL, OSL, MDL, ESSL
  - Deployment flexibility: pre-compute, function generation, full shader, reference definition
  - OCIO enhancements for uniform injection / format control
SPIRV Code Generation Overview

- Use `mx::GlslResourceBindingContext`
- Generate SPIRV compatible GLSL. 
  E.g., use `#extension GL_ARB_shading_language_420pack`
- Explore and improve KhronosGroup/SPIRV-Tools to provide per target Shader Reflection.

Image credit: 3ds Max: Open Standards & Next Generation Viewport Framework (SIGGRAPH 2020 Autodesk Vision Series)
MaterialX for Web

MaterialX JavaScript library

- **In progress project** for upcoming release.

- Components:
  - JavaScript Bindings + Web Assembly.
  - CodeGen for OpenGL ES 3.0.
  - Web Viewer Sample Application [https://autodesk-forks.github.io/MaterialX/](https://autodesk-forks.github.io/MaterialX/)

- Fully compatible with current GLSL implementation.

- Supported Browsers Chrome, Firefox, Edge, Safari*

- Supports material shading graphs and pattern graphs (textures, procedurals)

- Framework agnostic.
MaterialX for Web

Deployment options (framework agnostic)

- **Browser** deployment using JavaScript Bindings
  - Three.js
  - Babylon.js

- **Server** based deployment using Native or WASM
  - WebGL
  - Autodesk Forge
MaterialX API in JavaScript, using GL ES Shader Generator

```javascript
let gen = new mx.EsslShaderGenerator();
let genContext = new mx.GenContext(gen);
let stdlib = mx.loadStandardLibraries(genContext);
doc.importLibrary(stdlib);

// Load material
if (mtlxMaterial)
  await mx.readFromXmlString(doc, mtlxMaterial);
else
  FallbackMaterial(doc);

let elem = mx.findRenderableElement(doc);

// Handle transparent materials
const isTransparent = mx.isTransparentSurface(elem, gen.getTarget());
genContext.getOptions().hwTransparency = isTransparent;

// Load lighting setup into document
const lightRigDoc = mx.createDocument();
await mx.readFromXmlString(lightRigDoc, loadedLightSetup);
doc.importLibrary(lightRigDoc);

// Register lights with generation context
const lights = (O, helper_js__WEBPACK_IMPORTED_MODULE_0__.findLights)(do
const lightData = (O, helper_js__WEBPACK_IMPORTED_MODULE_0__.registerLig

let shader = gen.generate(elem.getNamePath(), elem, genContext);

// Get GL ES shaders and uniform values
let vShader = shader.getSourceCode("vertex");
let fShader = shader.getSourceCode("pixel");
```
Future Work
NVIDIA MDL Updates

- Forthcoming MDL 1.7 release will have better alignment with MaterialX (e.g., sheen layer, unbound mixer nodes)

- End of year target to have MaterialX import for Omniverse
  - Background improvements in MDL generation and consumption (E.g., resource path handling)

- See SIGGRAPH 2021 updates from NVIDIA.
void NG_ramp4_color3(color valuetl, color valuetr, color valuebl, color valuebr, vector2 texcoord, output color out)
{
    vector2 N_txclamp_color3_low_tmp = vector2(0, 0);
    vector2 N_txclamp_color3_high_tmp = vector2(1, 1);
    vector2 N_txclamp_color3_out = clamp(texcoord, N_txclamp_color3_low_tmp, 
    N_txclamp_color3_high_tmp);
    float N_t_color3_out = 0.0;
    NG_extract_vector2(N_txclamp_color3_out, 1, N_t_color3_out);
    float N_s_color3_out = 0.0;
    NG_extract_vector2(N_txclamp_color3_out, 0, N_s_color3_out);
    color N_mixbot_color3_out = mix(valuebl, valuebr, N_s_color3_out);
    color N_mixtop_color3_out = mix(valuetl, valuetr, N_s_color3_out);
    color N_mix_color3_out = mix(N_mixtop_color3_out, N_mixbot_color3_out, 
    N_t_color3_out);
    out = N_mix_color3_out;
}
### Generation Optimization

- **Performance optimizations** for language / platform / workflow
  - Optimize at code, node, and/or definition level
  - Repackaging of resources: baking, packing, access atlas / arrays (e.g. UDIMs), alternate formats (e.g. IBL cubemaps)

```c
void NG_ramp4_color3_slow(color valuetl, color valuetr, color valuebl, color valuebr, vector2 texcoord, output color out)

vector2 N_txclamp_color3_low_tmp = vector2(0, 0);
vector2 N_txclamp_color3_high_tmp = vector2(1, 1);
vector2 N_txclamp_color3_out = clamp(texcoord, N_txclamp_color3_low_tmp, N_txclamp_color3_high_tmp);
float N_t_color3_out = 0.0;
NG_extract_vector2(N_txclamp_color3_out, 1, N_t_color3_out);
float N_s_color3_out = 0.0;
NG_extract_vector2(N_txclamp_color3_out, 0, N_s_color3_out);
color N_mixbot_color3_out = mix(valuebl, valuebr, N_s_color3_out);
color N_mixtop_color3_out = mix(valuetl, valuetr, N_s_color3_out);
color N_mix_color3_out = mix(N_mixtop_color3_out, N_mixbot_color3_out, N_t_color3_out);
out = N_mix_color3_out;
```

```c
void NG_ramp4_color3_fast(color valuetl, color valuetr, color valuebl, color valuebr, vector2 texcoord, output color out)

{ out = fast_code; }
```
• Publishing for reuse, produce reference libraries (e.g. OSL reference library)

• Realtime Updates:
  • Observability
  • Change management
  • Diagnostics / Feedback

```c
void NG_ramp4_color3_fast(color valuetl, color valuetr, color valuebl, color valuebr, vector2 texcoord, output color out) {
    vector2 N_txclamp_color3_low_tmp = vector2(0, 0);
    vector2 N_txclamp_color3_high_tmp = vector2(1, 1);
    vector2 N_txclamp_color3_out = clamp(texcoord, N_txclamp_color3_low_tmp, color N_mixtop_color3_out =
      mix(valuetl, valuetr, N_s_color3_out);
      color N_mix_bot_color3_out = mix(N_mixtop_color3_out, N_mixbot_color3_out, N_t_color3_out);
      out = N_mix_color3_out;
}
```
## Credits

<table>
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MaterialX in MayaUSD and ArnoldUSD

Krystian Ligenza
Software Architect | krystian.ligenza@autodesk.com
Safe Harbor Statement

During the course of this presentation, we may make statements regarding future events and/or statements regarding planned or future development efforts for our existing or new products and services.

We wish to caution you that such statements reflect our current expectations, estimates and assumptions based on factors currently known to us and that actual events or results could differ materially. Also, these statements are not intended to be a promise or guarantee of future delivery of products, services or features but merely reflect our current plans, which may change.

Purchasing decisions should not be made based upon reliance on these statements. The statements made in this presentation are being made as of the time and date of its live presentation. We do not assume any obligation to update any statements we make to reflect events that occur or circumstances that exist after the date of this presentation.
Level-set on **MayaUSD**
Closed pull requests: 1086
Closed issues: 266 (customer reported)
Stars: 422
Forks: 124
Releases: 11
Total downloads: 13,877
MayaUSD | Workflows

- Import/Export
- Direct Editing
- Visualization
MayaUSD | Interop via UsdShade + PreviewSurface


Custom translation with plugin architecture
MaterialX in MayaUSD
MaterialX | Phase 1 Workflows

Import/Export

Visualization
MaterialX | Interop via UsdShade + MaterialX

Asset source: https://github.com/KhronosGroup/gltf-Sample-Models
We are using the hdMtlx translation framework, which is also in use for hdStorm and hdPrman, and using the same GLSL code generator as hdStorm.
MaterialX | Visualization in Maya's Viewport

Problem: USD refers to texture coordinates by name, but MaterialX defaults to index

Solution: Modify MaterialX GLSL codegen for geompropvalue to emit varying inputs
Modify MaterialX document in-flight to remap indexed UV streams to USD named streams

```xml
<!-- Direct connection by name -->
<image name="BB8_color" type="color3">
  <input name="file" type="filename" value="BB8_color.png" />
  <input name="texcoord" type="vector2" nodename="st_dirtmap" />
</image>
<geompropvalue name="st_dirtmap" type="vector2">
  <input name="geomprop" type="string" value="dirtmap" />
</geompropvalue>

<!-- Implicit connection to UV0 -->
<image name="BB8_roughness" type="float">
  <input name="file" type="filename" value="BB8_roughness.jpg" />
</image>

<!-- Explicit connection to UV1 -->
<image name="BB8_normals" type="vector3">
  <input name="file" type="filename" value="BB8_normals.jpg" />
  <input name="texcoord" type="vector2" nodename="st_UV1" />
</image>
<texcoord name="st_UV1" type="vector2">
  <input name="index" type="integer" value="1" />
</texcoord>

<!-- Automatically added for UV0 -->
def Mesh "BB8" ()
{
  rel material:binding = </Looks/BB8Surface>
texCoord2f[] primvars:st = [...] 
texCoord2f[] primvars:st1 = [...] 
texCoord2f[] primvars:dirtmap = [...] 
}

<!-- Automatically added for UV1 -->
<geompropvalue name="auto_UV0" type="vector2">
  <input name="geomprop" type="string" value="st" />
</geompropvalue>
<geompropvalue name="auto_UV1" type="vector2">
  <input name="geomprop" type="string" value="st1" />
</geompropvalue>
```
Problem: MaterialX did not interact with Maya’s scene lights
Solution: Modify the Maya light code generator to provide GLSL entry points to query Maya light information directly from MaterialX light loop
Problem: A single instance of a standard surface material can take seconds, and each material generated its own shader
Solution: Computing the minimal topologically equivalent Hydra material
Opportunities & References

Opportunities / future investigations

- Render context
- More material translators
- Direct material binding and graph & parameters authoring
- Color Management
- ArnoldUSD

Useful links:

- [https://github.com/autodesk-forks/MaterialX](https://github.com/autodesk-forks/MaterialX)
- [https://github.com/Autodesk/maya-usd/](https://github.com/Autodesk/maya-usd/)
- [https://github.com/Autodesk/maya-usd/discussions](https://github.com/Autodesk/maya-usd/discussions)
Sneak-peek: MaterialX in ArnoldUSD
Sneak-peek: MaterialX in ArnoldUSD

BB-8 and R2-D2 © & ™ Lucasfilm LTD.
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MaterialX in Houdini

Mark Elendt
Usd 21.05/Houdini ???.

- Usd 21.05 added support for MaterialX 1.38
  - MaterialX networks can be loaded as Usd Shade nodes
  - Shade nodes are passed through Hydra (available to all render delegates)

- Houdini/Solaris
  - Read .mtlx directly into LOPs (free with Usd 21.05)
  - New set of MaterialX nodes in the shader editor
  - Usd tools/workflows/edits
  - Houdini tools/workflows/edits
standard_surface_brass_tiled.mtlx: Storm
standard_surface_brass_tiled.mtlx: Karma
Building shader networks
Thank You
MaterialX and the Adobe Standard Material Model

Paul Edmondson
Senior Graphics Engineer, Adobe
Adobe and 3D

- Adobe has a long history of forays into 3D
  - Photoshop, After Effects, Dimension(s), Aero
- Allegorithmic and Medium teams joined Adobe in 2019
- Substance 3D Collection released in 2021:
  - Designer
  - Painter
  - Sampler
  - Stager
  - Modeler (beta)
The Adobe Standard Material

• A common, unified basis for material interchange between tools
• Not a shader to end all shaders, but a model for data-driven look alignment

• Goals:
  • Support for use by raster-based and traced renderers
  • Backward compatibility with materials in existing tools
  • Maximal interoperability between apps for most materials
  • Emphasis on art-directability and ease of use where possible
  • Not bound to any single language or file format
  • Don’t reinvent the wheel
Version 4 Features

- Expanded metal/roughness PBR model
- Native material model for Substance 3D Stager via MDL and SBSAR
- Compatibility with Substance 3D Assets, Painter, and Designer
- Technical specification to be posted in coming weeks
- Translatable with minimal loss to/from Disney PBR, glTF, USD Preview Surface, Autodesk Standard Surface, etc. for supported features
Why we didn’t use ___________

• The Adobe Standard Material (ASM) model is not meant to supplant all other material models
• The Substance 3D tools continue to support many alternate models
• We needed something that could represent the intersection of our toolsets with minimal loss of information
• We also wanted to support interchange with external DCC tools
MaterialX Prototype

• Eventual support of MaterialX was always planned for
• Only prototype stage at present, but with eye toward future
• Relatively easy to get reasonable results with standard PBR nodes
• Some BxDFs will require customization down the line for full visual fidelity
ASM in MaterialXView
ASM in MaterialX + USD
Next Steps

• Finish prototype with standard node support of all properties
• Translation support to other common models like Standard Surface
• Support of additional targets
• Share!

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MaterialX

OpenShadingLanguage

Adding MaterialX closures to OSL

Chris Kulla (OSL TSC Chair)
About Me

• Chris Kulla
  • Principal Rendering Engineer at Epic Games
  • Previously at Sony Imageworks
  • Chair of the Technical Steering Committee for OpenShadingLanguage
• OSL TSC meets every other week to discuss the evolution of the open source library
How are MaterialX and OSL related?

- MaterialX
  - Represents shading networks without being tied to a particular renderer
  - Can *generate* OSL code directly (among other backends)
- OpenShadingLanguage
  - A programming language for shading calculations
  - A compiler and execution framework to run efficiently on CPU & GPU
  - Primarily used by production path tracers
- MaterialX sits **outside** the renderer, OSL lives **inside** the renderer
What is missing from OSL backend in MaterialX?

• MaterialX has supported OSL for a long time already
  • But recent addition of PBR nodes could not be expressed directly
• OSL thinks about surface/light interaction in abstract terms to provide flexibility to the implementation
  • Details of how light paths are sampled and traced left up to renderer
  • All BxDF, EDF, VDF definitions abstracted as closures to be defined
  • OSL specification had an outdated set of recommended standard closures (most implementations defined their own)
• We have decided to adopt MaterialX’s PBR nodes as the canonical set of OSL closures!
What does this mean concretely?

1. Update OSL spec to refer to MaterialX’s PBR shading nodes
2. Ship a header definition of the expected MaterialX closures
3. Add a reference implementation to OSL’s testrender
4. Integrate with MaterialX unit tests
What have we done so far?

1. Update OSL spec to refer to MaterialX’s PBR shading nodes
2. Ship a header definition of the expected MaterialX closures
3. Add a reference implementation to OSL’s testrender
4. Integrate with MaterialX unit tests
What do the closures look like?

// Constructs a diffuse reflection BSDF based on the Oren-Nayar reflectance model.

//

// \param N Normal vector of the surface point being shaded.

// \param albedo Surface albedo.

// \param roughness Surface roughness [0,1]. A value of 0.0 gives Lambertian reflectance.

// \param label Optional string parameter to name this component. For use in AOVs / LPEs.

//

closure color oren_nayar_diffuse_bsdf(normal N, color albedo, float roughness) BUILTIN;
What about layering?

// Vertically layer a layerable BSDF such as dielectric_bsdf, generalized_schlick_bsdf or
// sheen_bsdf over a BSDF or VDF. The implementation is target specific, but a standard way
// of handling this is by albedo scaling, using "base*(1-reflectance(top)) + top", where
// reflectance() calculates the directional albedo of a given top BSDF.

//
// \param top Closure defining the top layer.
// \param base Closure defining the base layer.
closure color layer(closure color top, closure color base) BUILTIN;
Conclusion

- Provide a specification for OSL to express the same set of material properties as MaterialX documents
- Provide a reference implementation of these ideas
- Iterate with the community on the more subtle details of efficient layering, IOR and medium tracking, and other conventions and best practices
Thank you!

Questions?