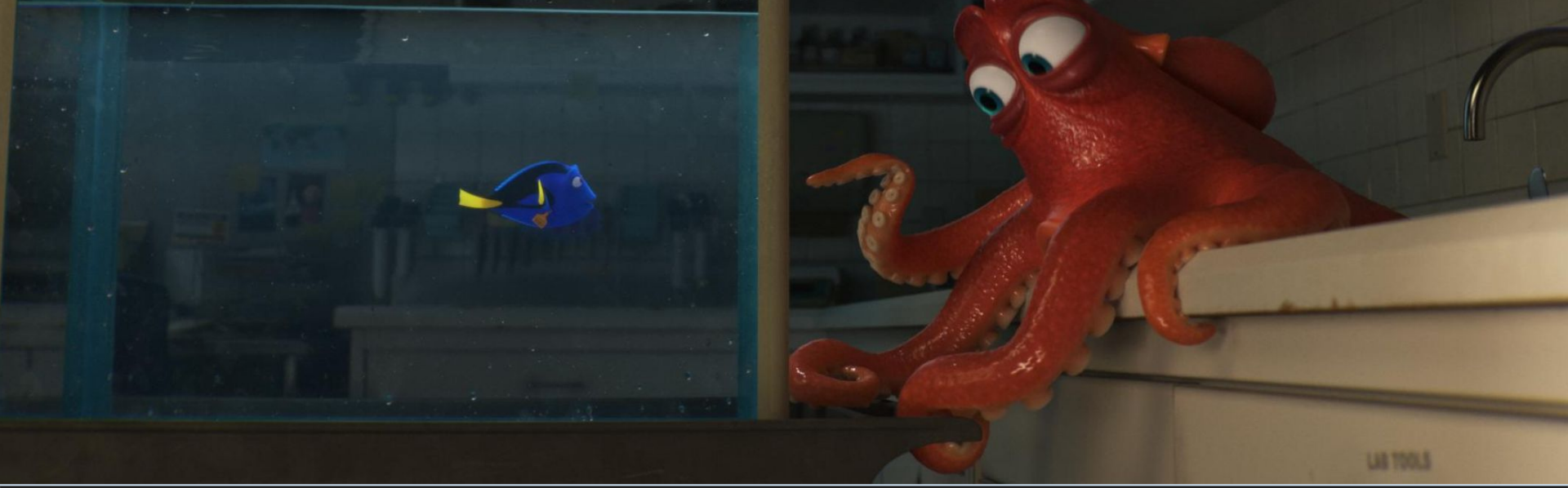


Real-Time Graphics for Feature Film Production

PIXAR

ANIMATION STUDIOS

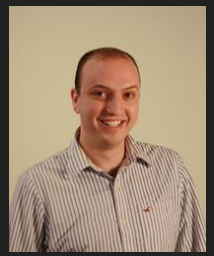
GPU Team

David Yu

Matthew Williams

Pol Jeremias-Vila

Takahito Tejima



George Elkoura

Dirk Van Gelder

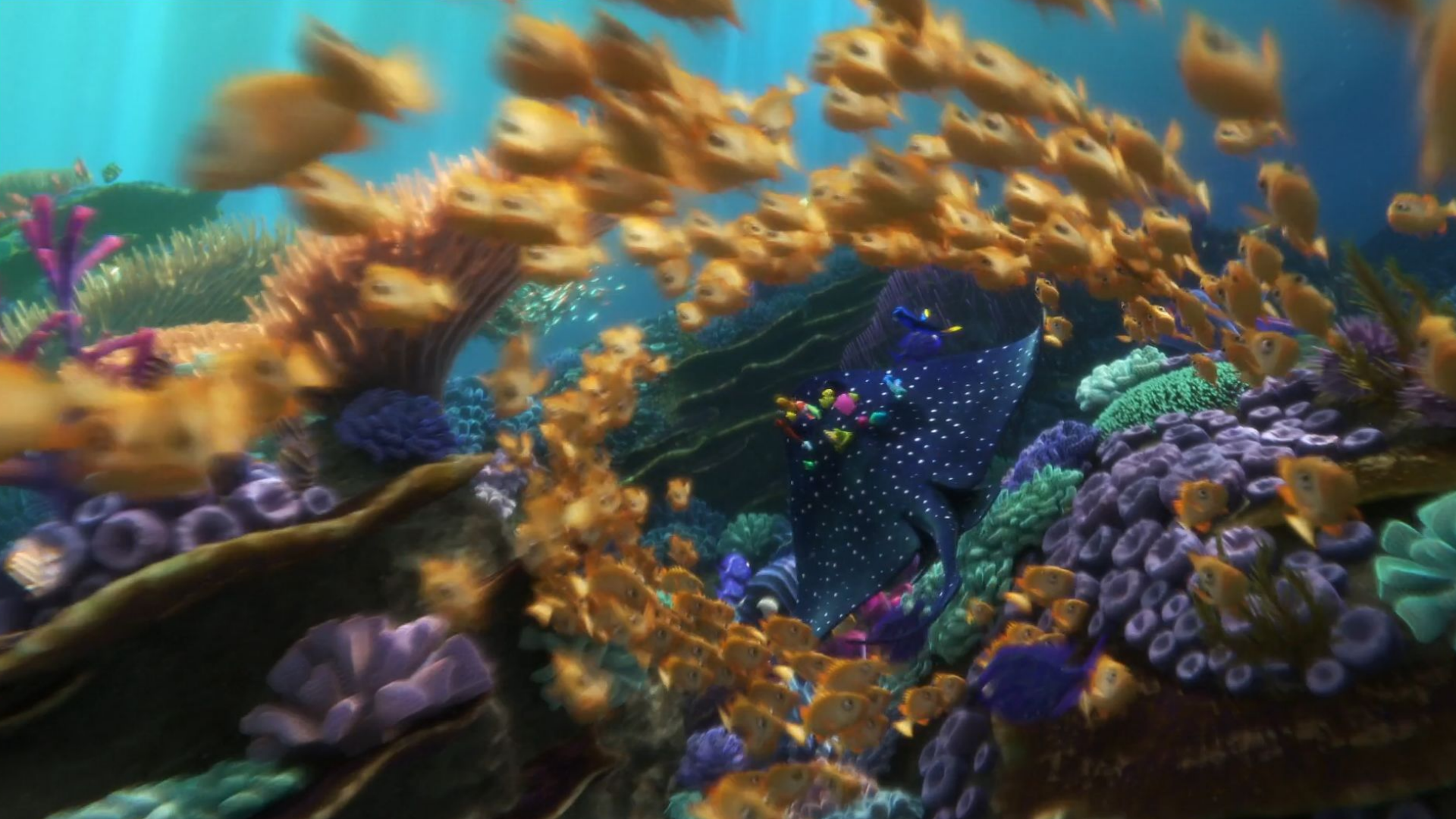
Overview

- Challenges
- Pixar Tech for Real-Time Workflows
- Effects
- Future Work

(clip)

Challenges

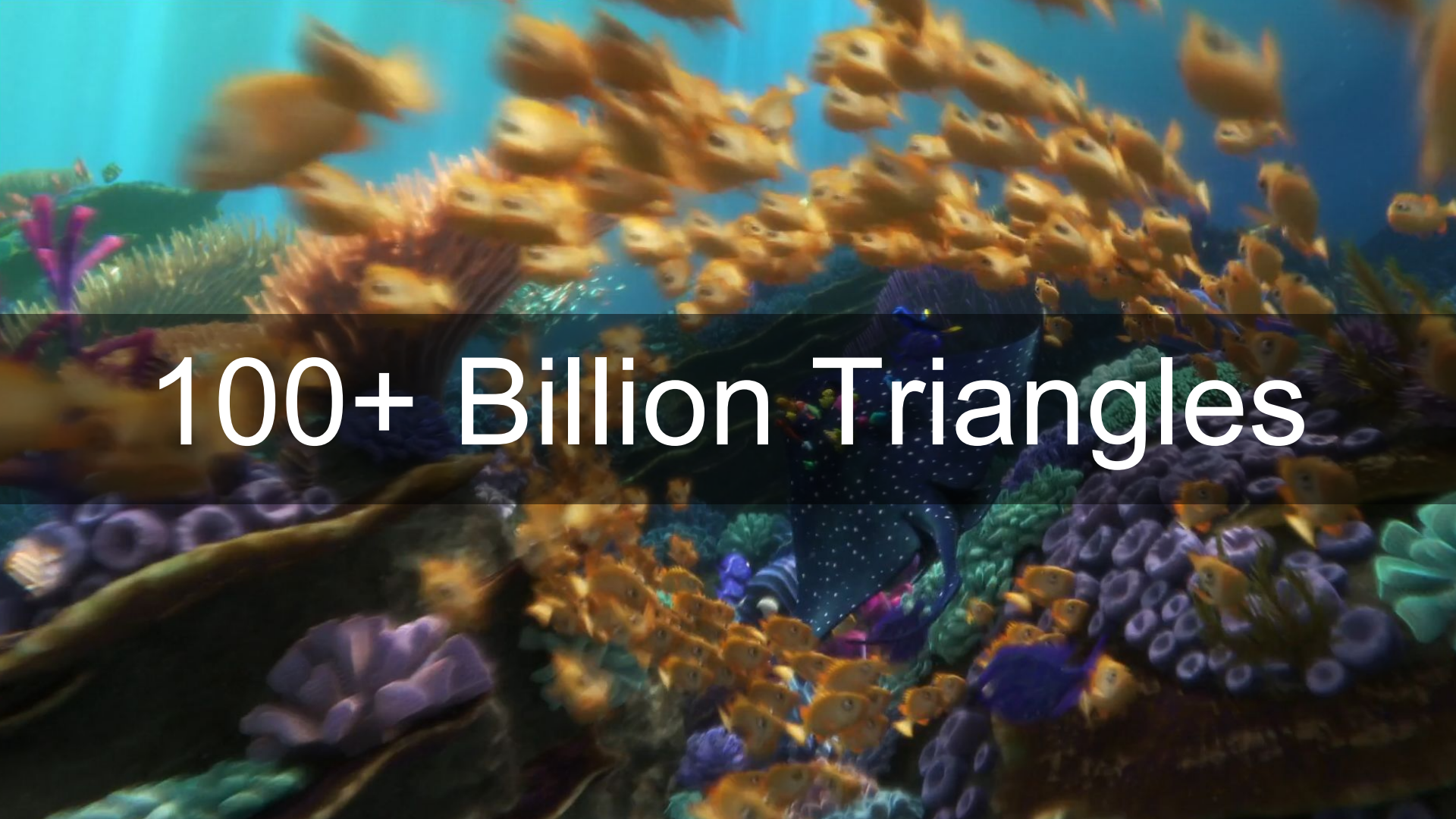
- Production assets
- Optimized for beauty, not real-time rendering
- Average hardware configuration:
  - GPU: 12 GB NVIDIA Quadro M6000
  - CPU: 16-core Intel Haswell @ 2.3GHz
  - RAM: 64 GB



6,000 Meshes

81,000 Instances

52 Million Faces


100+ Billion Triangles

This is a small shot

Heavy Assets

- Fx: millions of instances
- Chars: hundreds of meshes
- Crowds: tens of thousands of chars
- Large sets: billions of polys in frustum
- Subdivision: geometric growth in complexity

PRESTO

ANIMATION SYSTEM

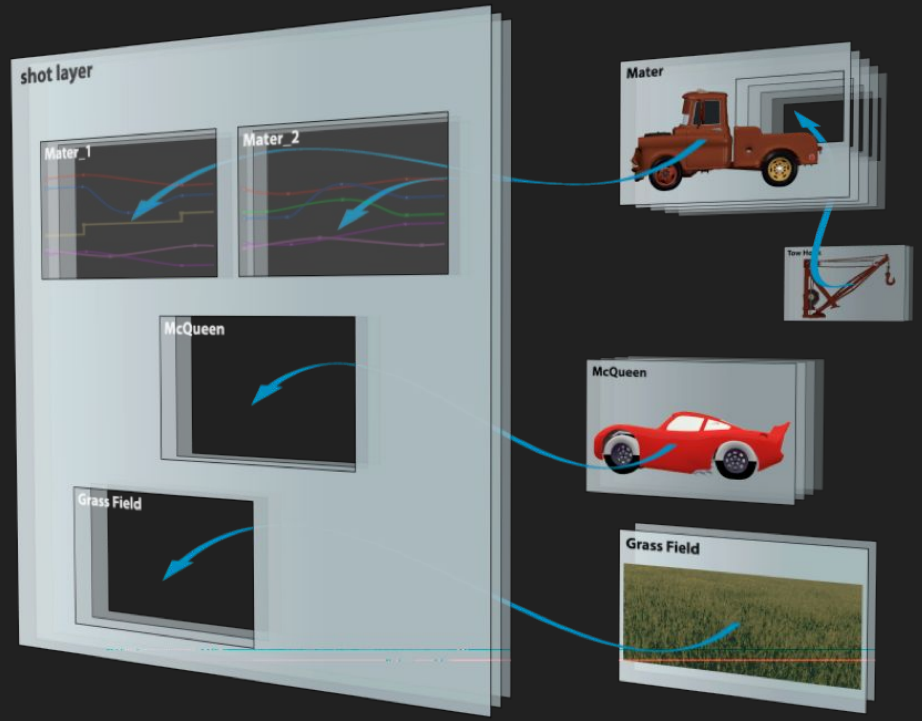
PIXAR

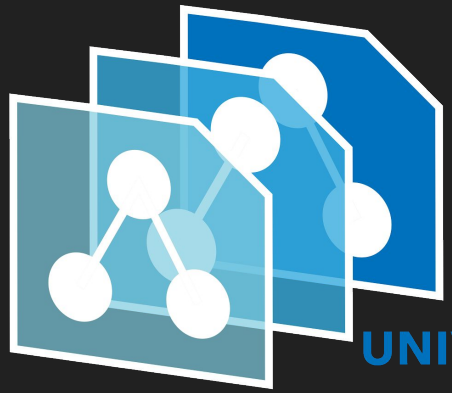
Presto Animation System

- Primary tool for :
  - Previs
  - Layout
  - Simulation
  - Rigging
  - Animation
  - Crowd Animation

PRESTO
ANIMATION SYSTEM

(demo)


shot layer
Mater_1
Mater_2
McQueen
Grass Field
Mater
McQueen
Grass Field



USD

UNIVERSAL SCENE DESCRIPTION

PIXAR

Universal Scene Description

- Deployed on Finding Dory
- Scene described in terms of layers and references
- Designed for multi-user workflows
- DCC Interchange
- Supported by Apple's SceneKit
- Open source release on Github July 26, 2016

```
#usda 1.0

def Cube “HelloCube” {
  double size = 1.0
}
```

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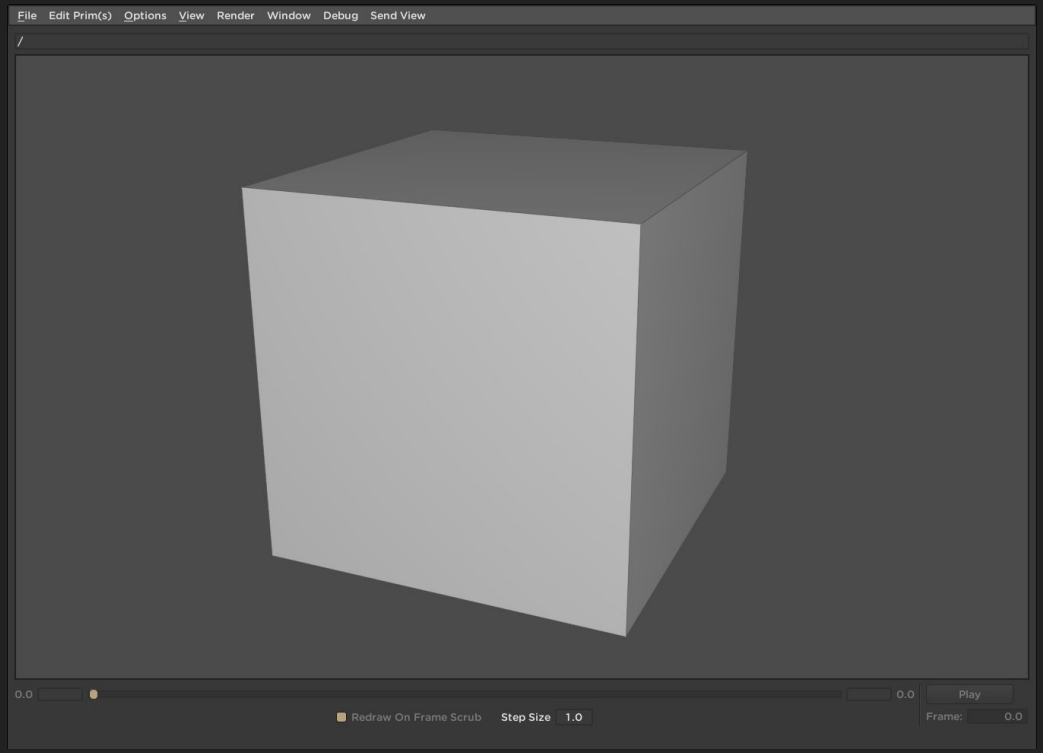
def Cube “HelloCube” {
  double size = 1.0
}
```



```
#usda 1.0

def Cube "Cube" {
    double size = 1.0
}

def "World" {
    over "CubeInstance1" (
        references = </Cube>
        instanceable = true) {
    }
    over "CubeInstance2" (
        references = </Cube>
        instanceable = true) {
    }
}
```

```
#usda 1.0

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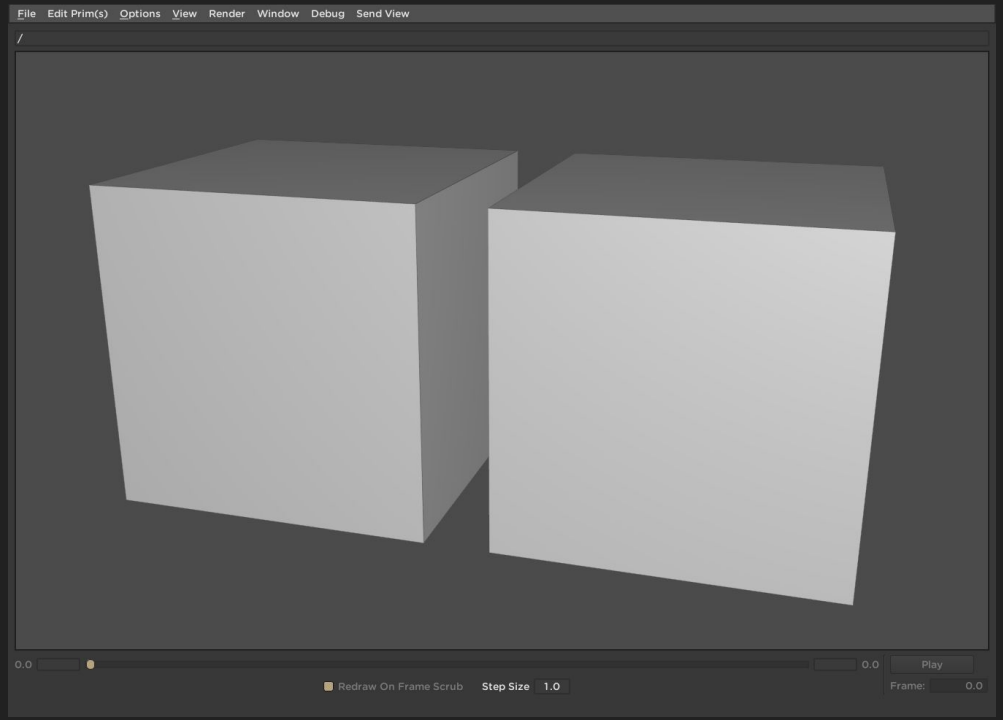
    }
}
```



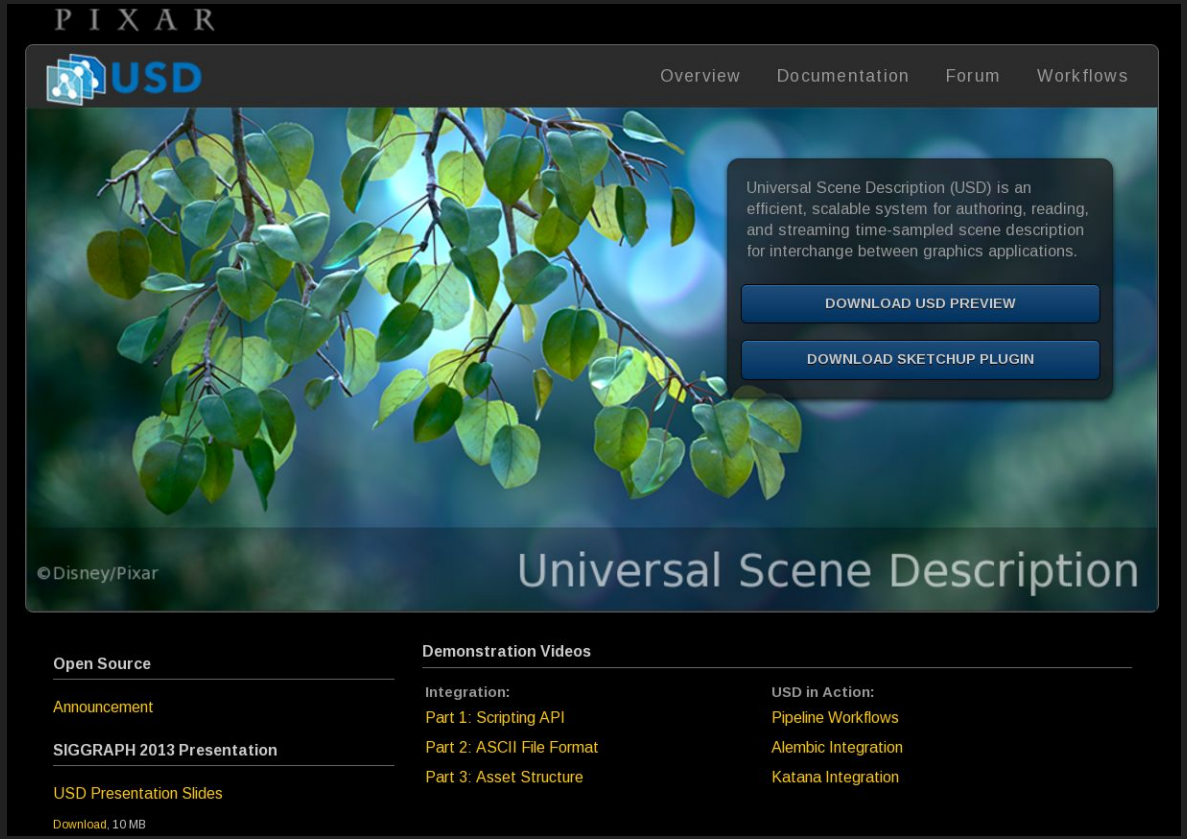
USD Composition Arcs

- Layers
- Inheritance
- Variants
- References
- Payloads

USD Composition Arcs

- L ayers
- I nheritance
- V ariants
- R eferences
- P ayloads

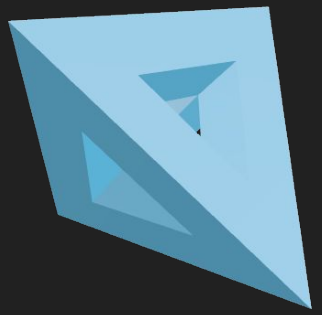
(demo)


PIXAR
USD
Overview
Documentation
Forum
Workflows
Universal Scene Description (USD) is an efficient, scalable system for authoring, reading, and streaming time-sampled scene description for interchange between graphics applications.
DOWNLOAD USD PREVIEW
DOWNLOAD SKETCHUP PLUGIN
©Disney/Pixar
Universal Scene Description
Open Source
Announcement
SIGGRAPH 2013 Presentation
USD Presentation Slides
Download, 10 MB
Demonstration Videos
Integration:
Part 1: Scripting API
Part 2: ASCII File Format
Part 3: Asset Structure
USD in Action:
Pipeline Workflows
Alembic Integration
Katana Integration

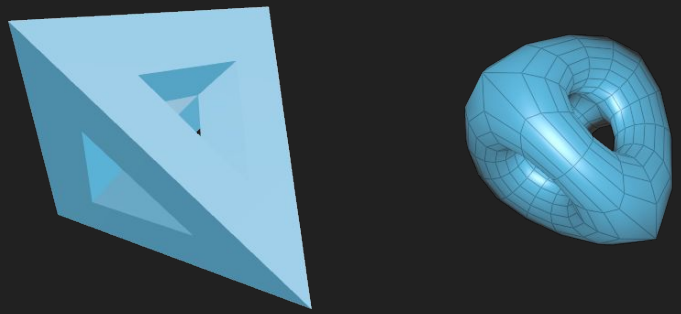
Subdivision Surfaces

What is a subdivision surface?

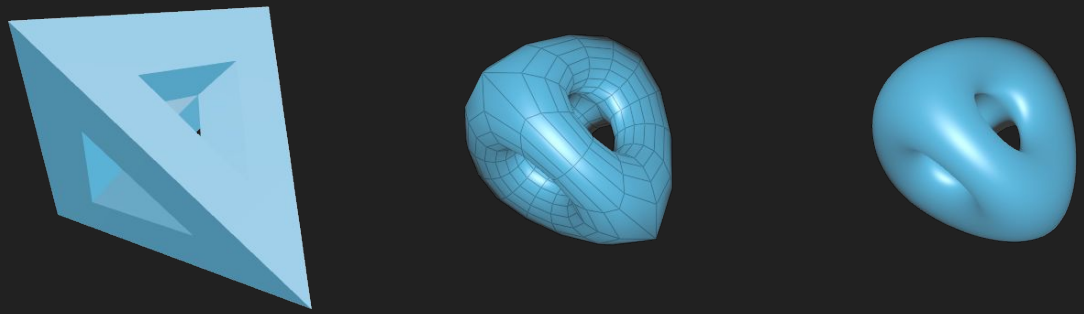
What is a subdivision surface?



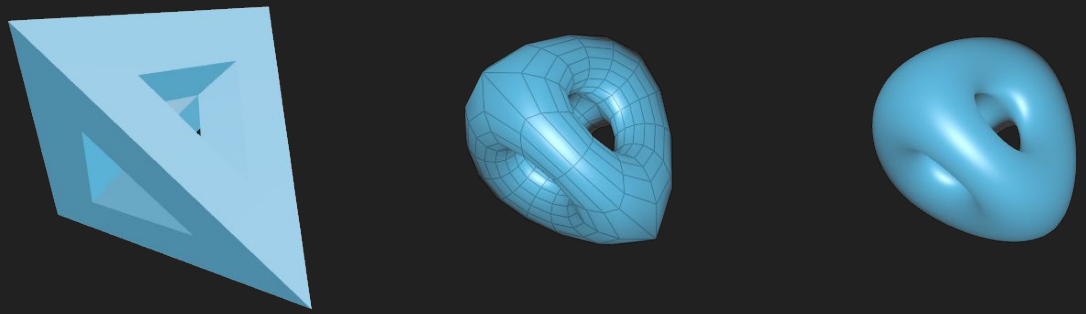
What is a subdivision surface?



What is a subdivision surface?

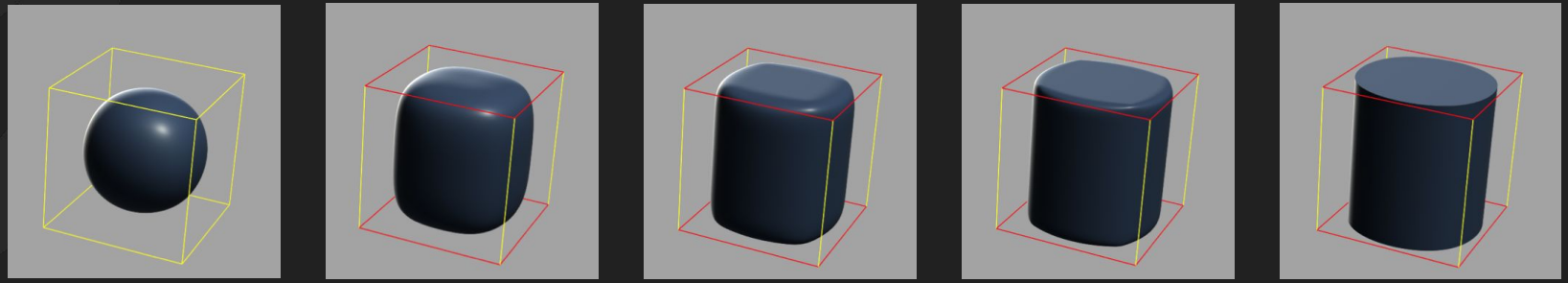


What is a subdivision surface?



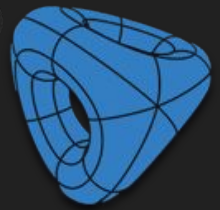
Poly Count:	48	384	1,572,864

What is a subdivision surface?



Creased edges with varying sharpness and more!

www.pixar.com/about/Pixar-In-A-Box



OpenSubdiv

PIXAR

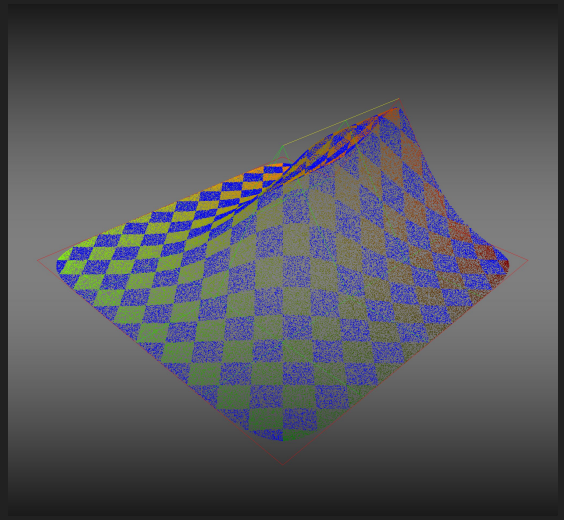
OpenSubdiv

- RenderMan's subdivision algorithm
- Fast evaluation for rigging
- Fast rendering for preview
- Broad API for many clients

OpenSubdiv

OpenSubdiv

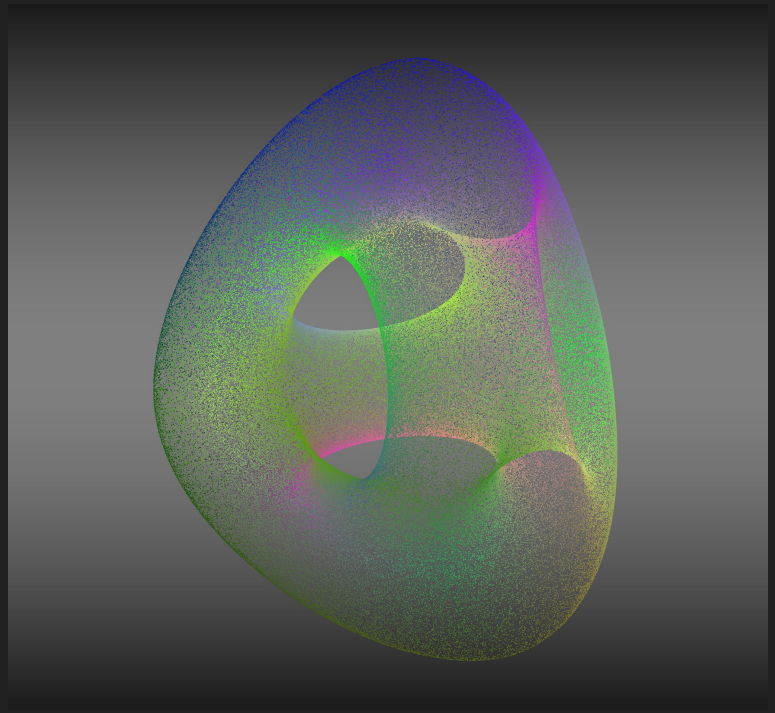
- Suitable for off-line rendering
- Suitable for real-time applications
- Major improvements in version 3.0
  - Simpler GPU shader configuration
  - Faster CPU refinement
  - Evaluation API
  - Simpler API
- Coming this Summer version 3.1
  - Smooth UV evaluation on patches
  - Separate refinement levels
  - 2nd derivative evaluation



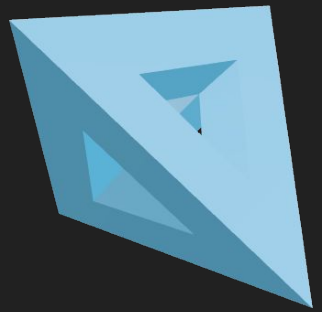
OpenSubdiv

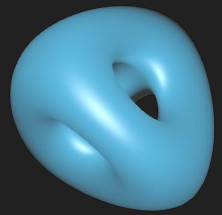
OpenSubdiv Evaluators

- Osd: parallel evaluation
  - OpenGL Compute
  - OpenGL Transform Feedback
  - CUDA
  - TBB
  - OpenCL
  - ISPC
- Far: single-threaded evaluation
  - Ideal for off-line rendering



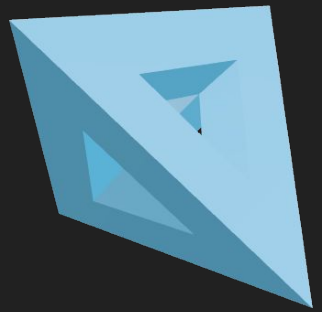
Feature Adaptive Subdivision

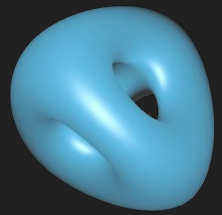




Uniform:	48	1,572,864

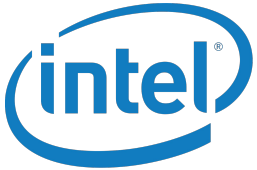
Feature Adaptive Subdivision





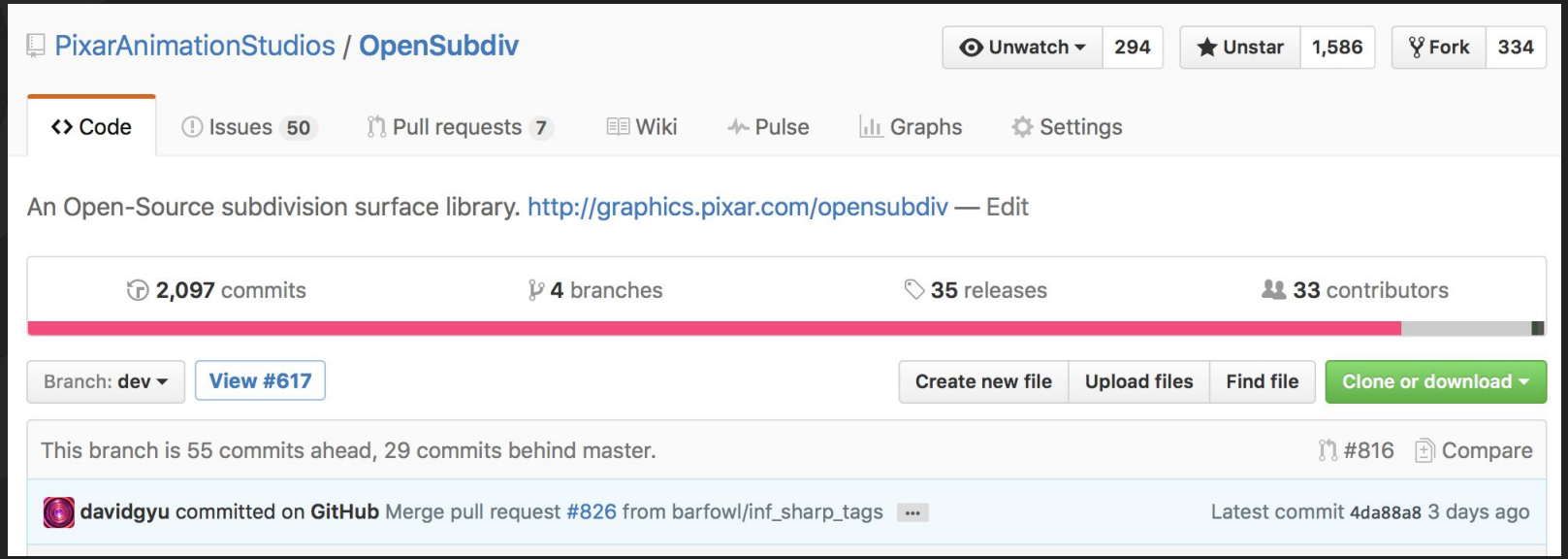
Uniform:	48	1,572,864
Adaptive:	48	1,100

OpenSubdiv Contributors



Integrated Tools & Render Engines

Available on Github



github.com/PixarAnimationStudios/OpenSubdiv

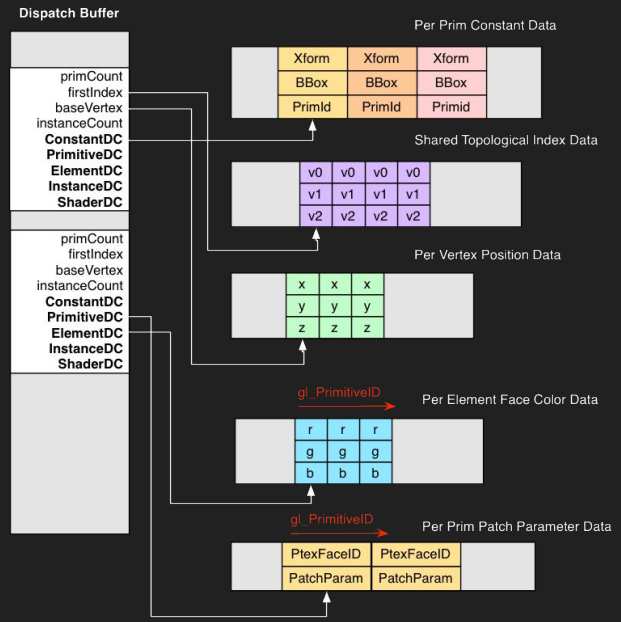
HYDRA

Real-Time Render Engine

PIXAR

Hydra: Real-Time Render Engine

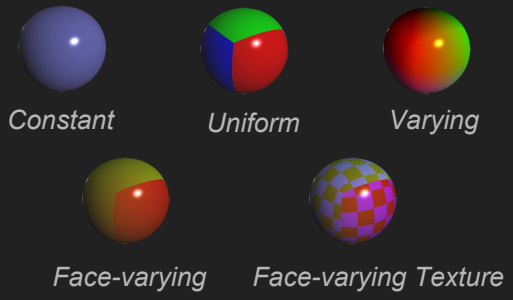
- Render engine for content creation
- Built for modern graphics APIs
  - Fastest w/ OpenGL 4.5 + Bindless Textures + Bindless Buffers + Direct State Access
  - Graceful fallback to OpenGL 4.0
- Designed for scalability



See the GTC 2015 talk for technical details

Hydra Engine Features

- Highlighting for faces, points, etc
- Just-in-time data consumption
- Consumes RenderMan inputs
- Hardware tessellated curves
- Configurable representations
- Render-based object picking
- Heavily multi-threaded
- Wireframe on surface
- OpenSubdiv tessellation



RenderMan Primvar Interpolation Modes

See the GTC 2015 talk for technical details

Hydra Engine Features

- Highlighting for faces, points, etc
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- Consumes RenderMan inputs
- Hardware tessellated curves
- Configurable representations
- Render-based object picking
- Heavily multi-threaded
- Wireframe on surface
- OpenSubdiv 3.0

▸ Designed for feature film production

See the GTC 2015 talk for technical details

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```
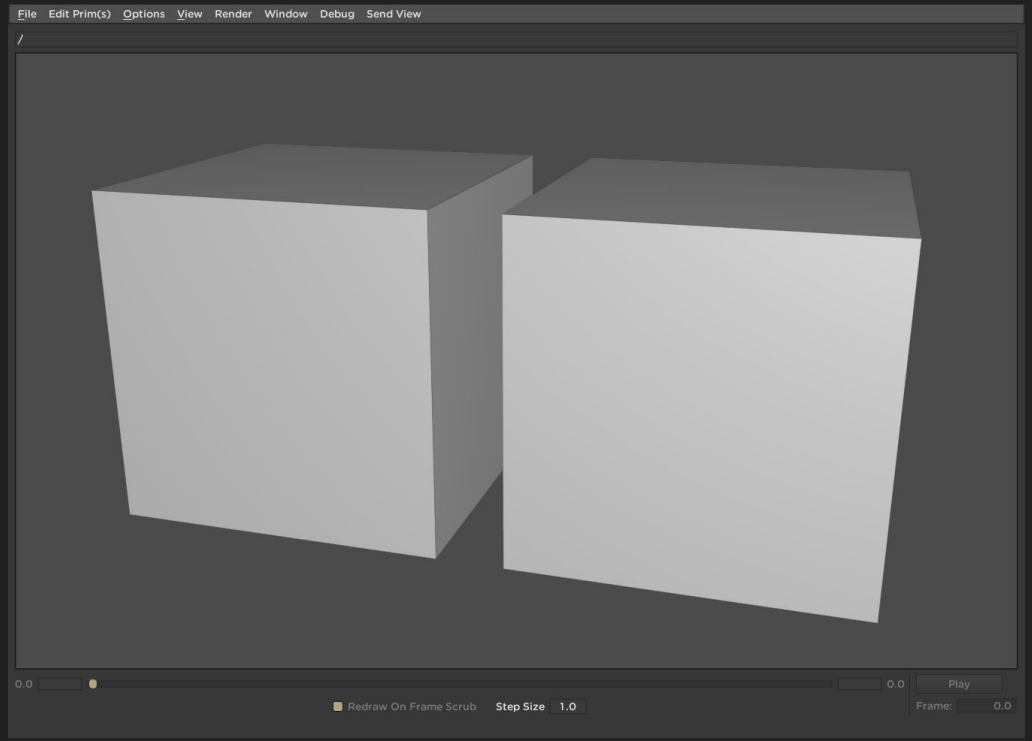
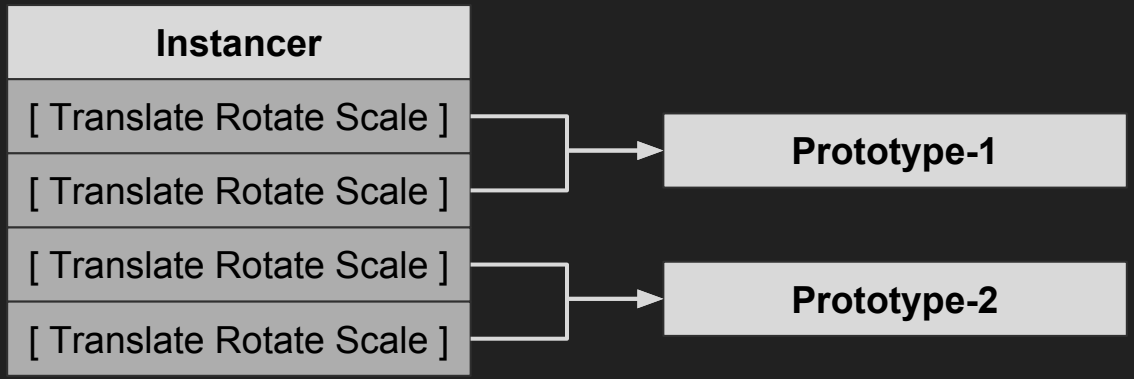
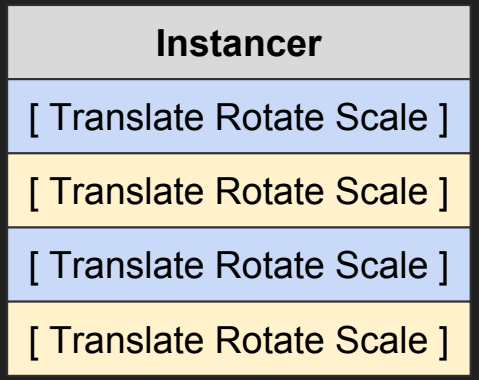



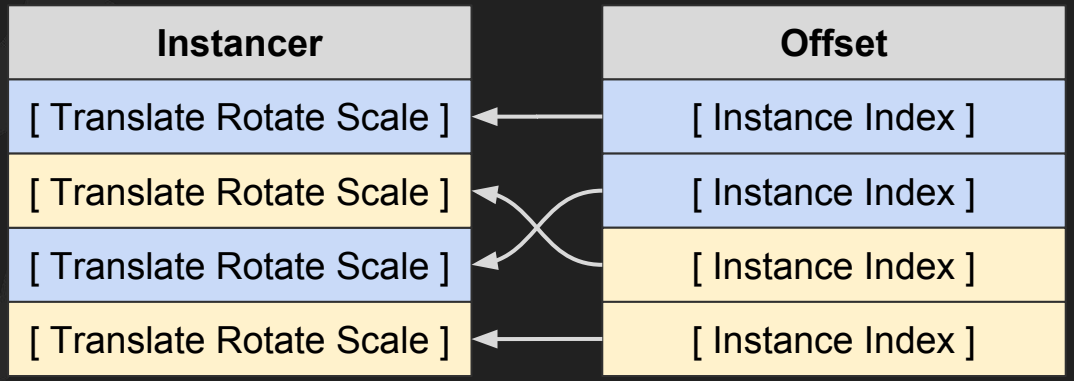
Hardware Instancing



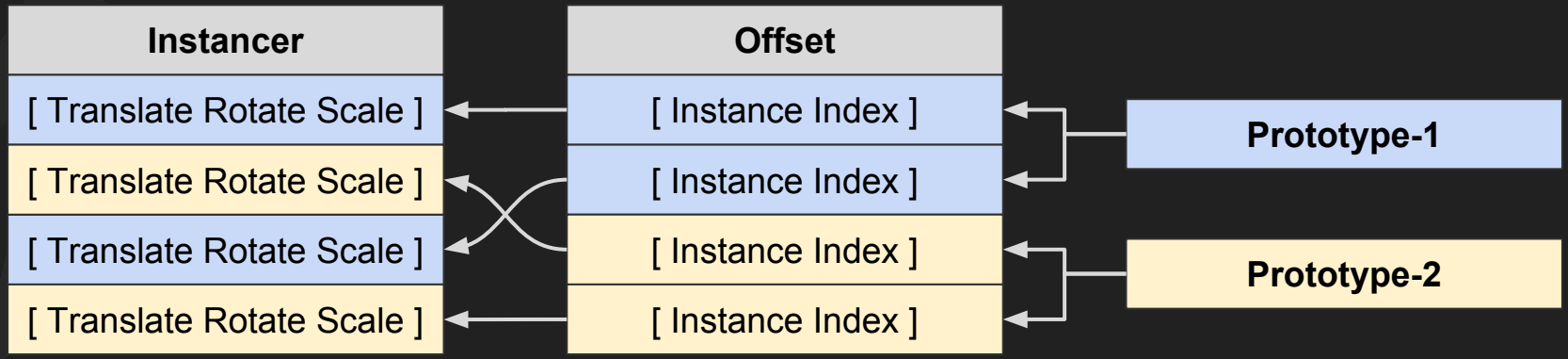
Hardware Instancing



Hardware Instancing



Hardware Instancing



PIXAR

But what about instancers

But what about instancers that instance

But what about instancers
that instance
more instancers?

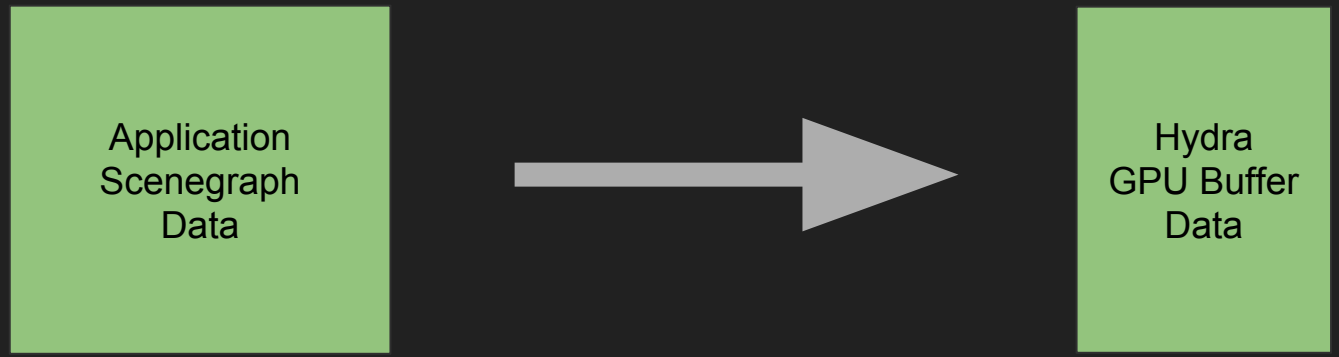
But what about instancers
that instance
more instancers?!

Recursive Instancing

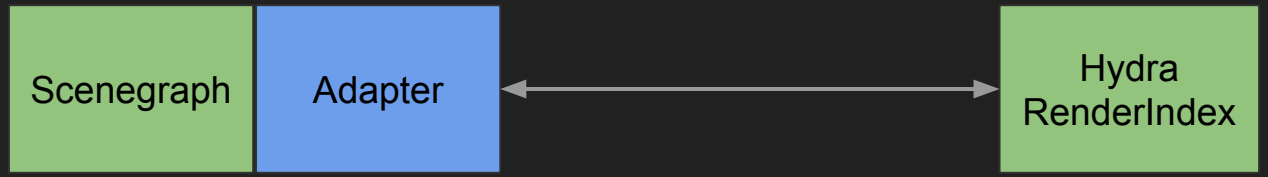
(demo)

Hydra Integration

- Push-Pull Data Model
  - Push: Scenegraph declare primitives
  - Pull: Hydra requests data from primitives on demand
  - Avoids pulling all data up front

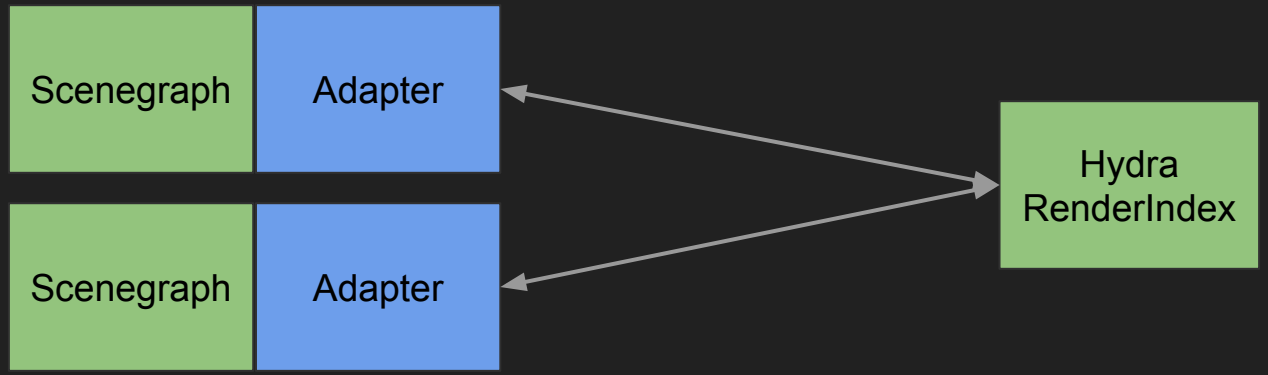


Hydra Integration

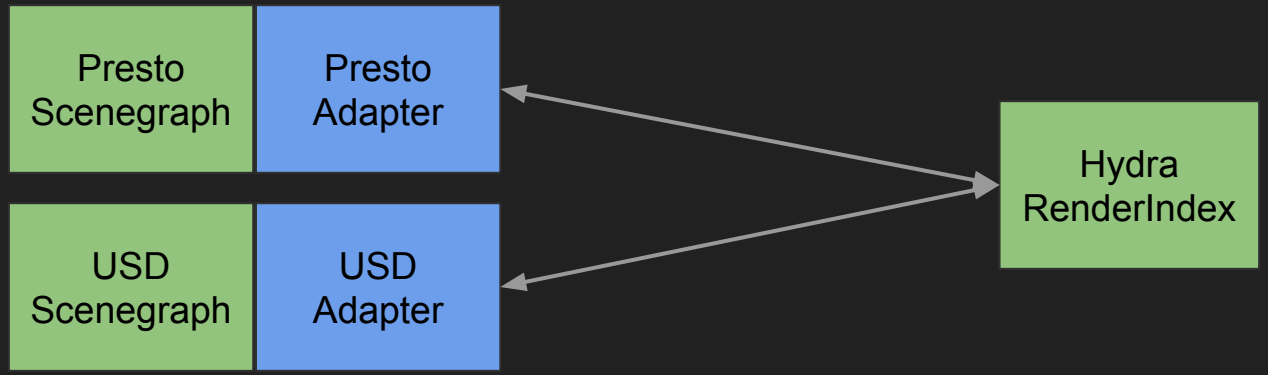


PIXAR

Hydra Integration

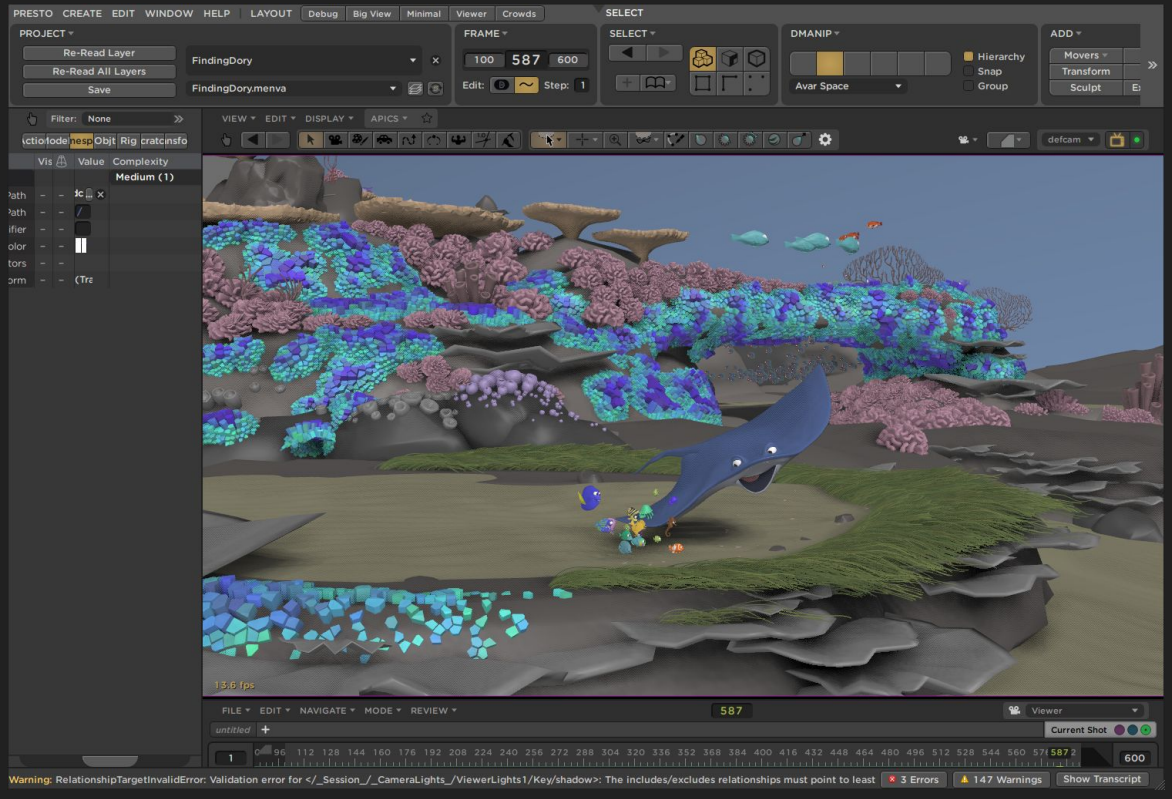


Hydra Integration



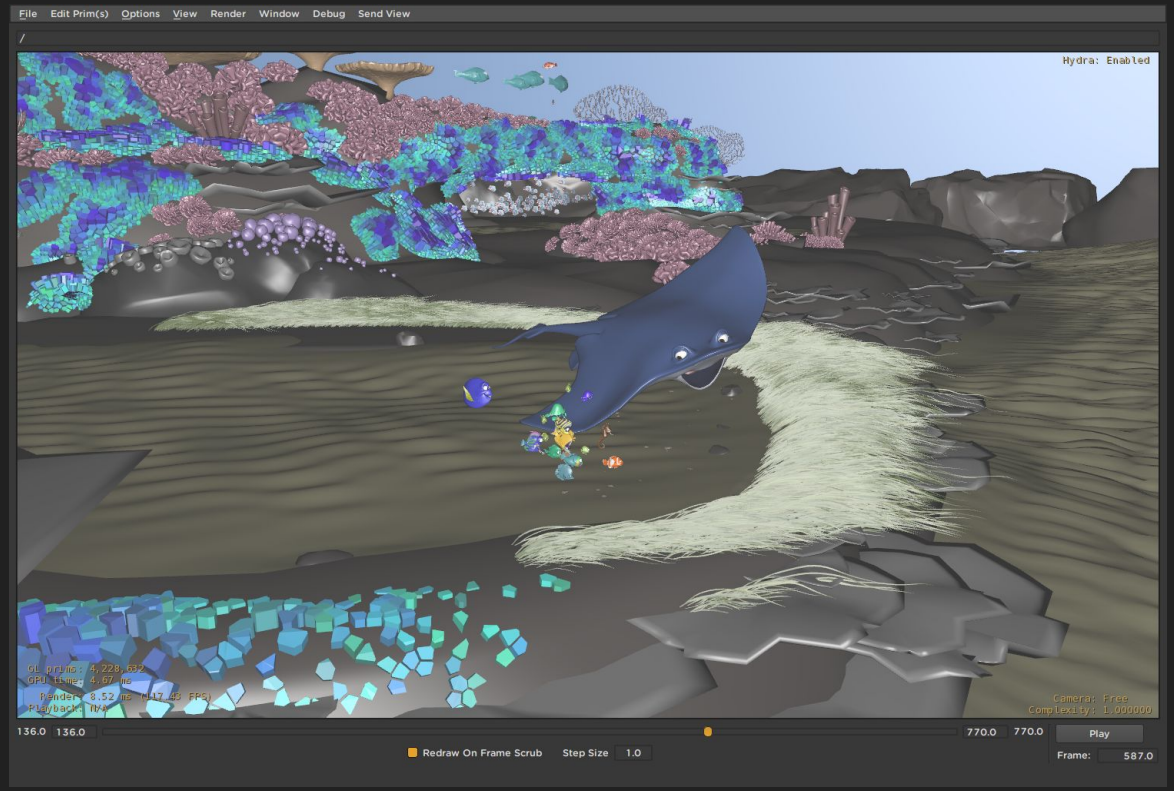
Integrated with ...

Presto



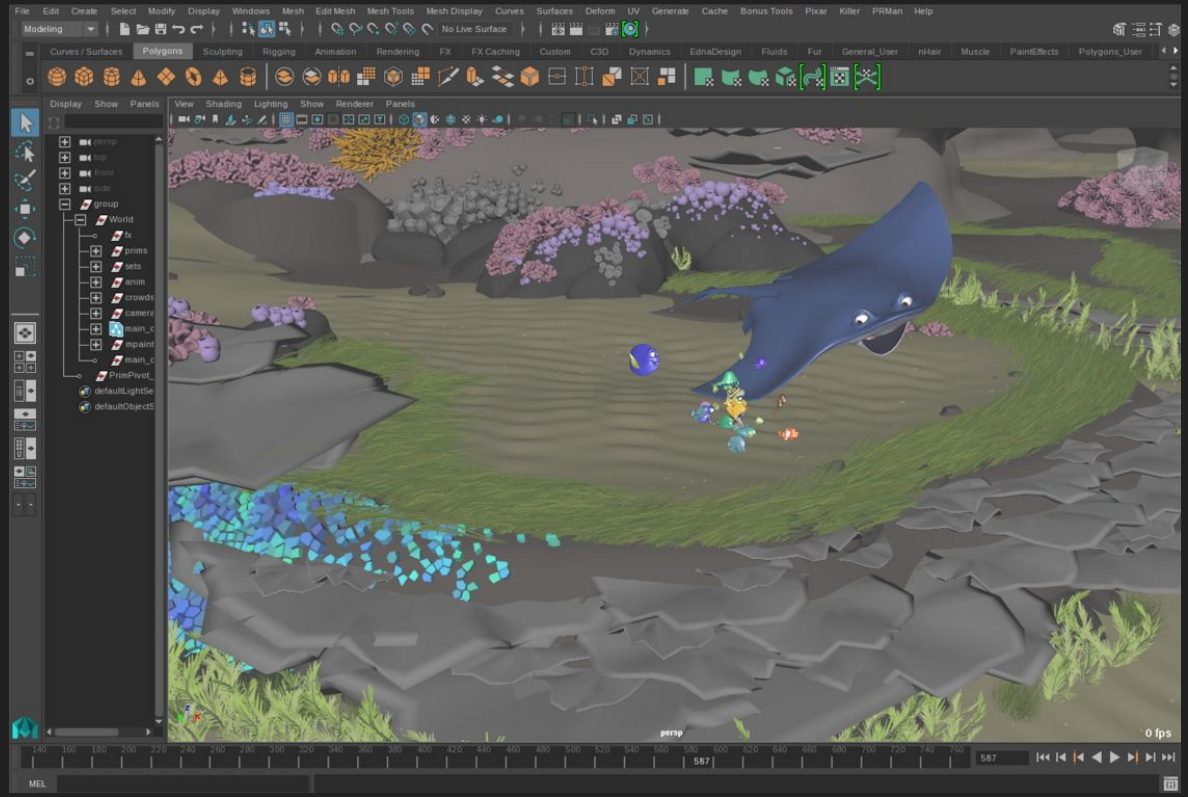
PIXAR

usdview



PIXAR

Maya


File Edit Create Select Modify Display Windows Mesh Edit Mesh Mesh Tools Mesh Display Curves Surfaces Deform UV Generate Cache Bonus Tools Pixar Killer PRMan Help
Modeling
No Live Surface
Curves / Surfaces Polygons Sculpting Rigging Animation Rendering FX FX Caching Custom C3D Dynamics EdnaDesign Fluids Fur General_User nHair Muscle PaintEffects Polygons_User
Display Show Panels
View Shading Lighting Show Renderer Panels
persp
top
front
side
group
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fx
prims
sets
anim
crowds
camera
main_c
mpaint
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defaultObjectS
persp
0 fps
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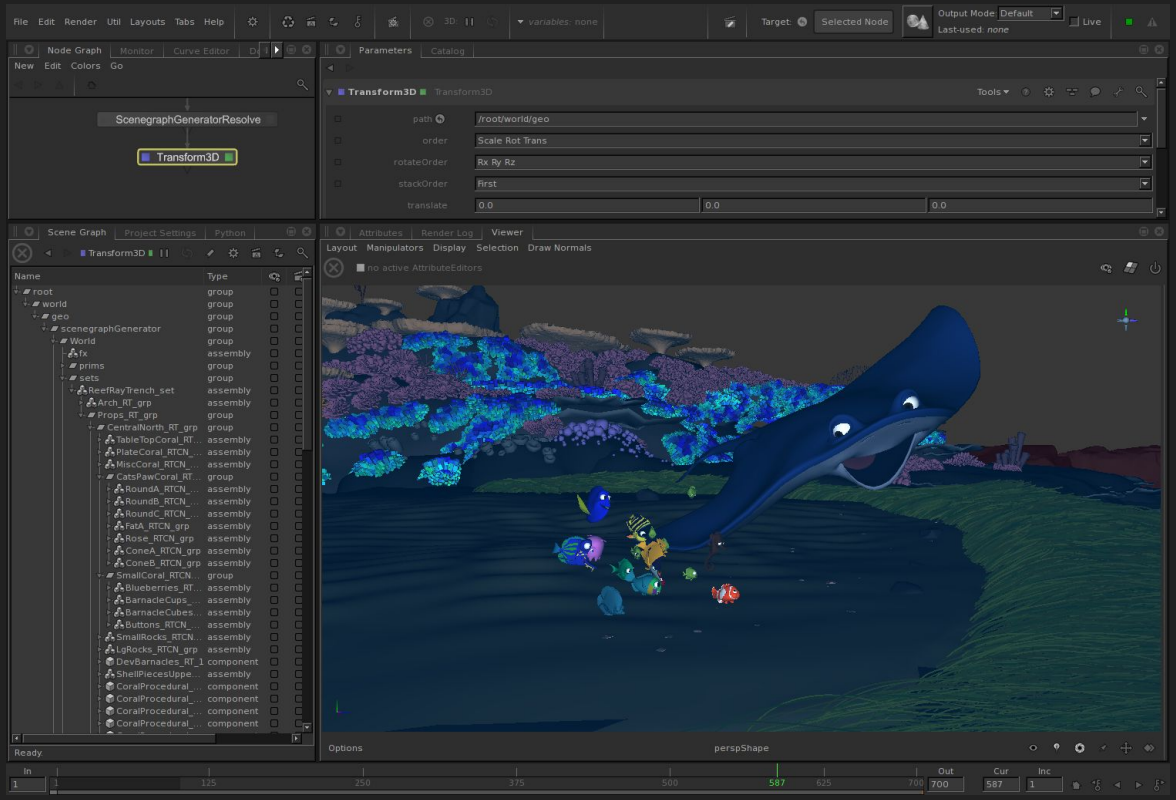
587
MEL

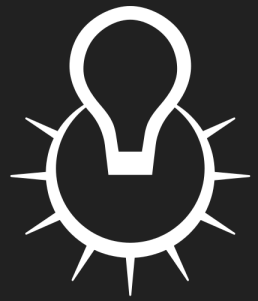
PIXAR

Katana



PIXAR

Hydra for Virtual Production



INDUSTRIAL
LIGHT & MAGIC

PIXAR

Millennium Falcon

- 14,500 meshes
- 140 textures @ 8k each
- Hybrid renderer:
  - Native ILM scenegraph
  - Hydra populates g-buffer
  - ILM’s engine does deferred shading & lighting

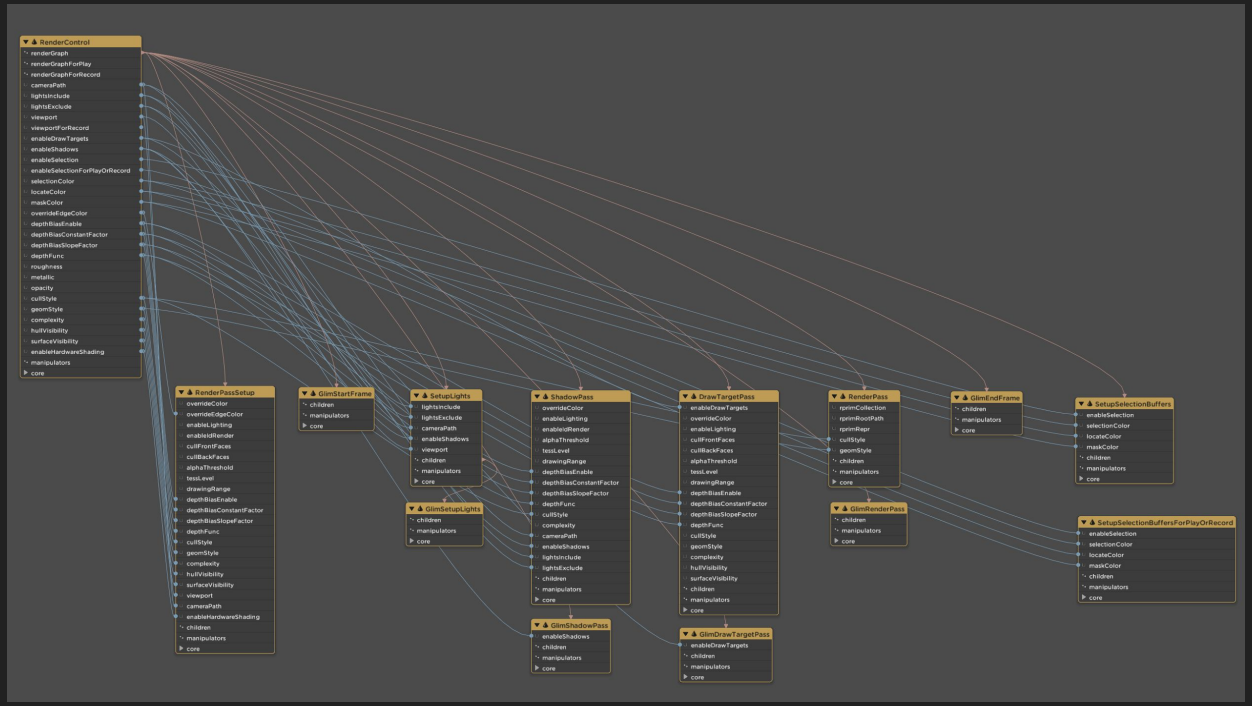
Hydra **open sourced** with USD!

Effects

Requirements

- Easy to setup and maintain
- Reliable approximation of the final render
  - Don’t mislead the artist
- Keep the common case fast
- Minimal asset build requirements

Building Effects: The Render Graph



Real-Time Effects in Presto

- Depth of Field
- Soft Shadows
- Ambient Occlusion
- Portal Reflections
- Reflection & Refraction
- Motion Blur
- Barrel Distortion
- Scene & Camera Lights
- Murk Light
- Post-Effect Lights
- Camera Masking
- Curvature
- Fur / Hair / Feathers
- Refractive Eyes

(demo)

Physically-Based Shading

- RenderMan
- Real-time OGL approximation

More info :

blog.selfshadow.com/publications/[s2012,s2013,s2014,s2015]-shading-course

Physically-Based Shading

- RenderMan
- Real-time OGL approximation

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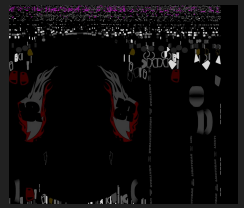
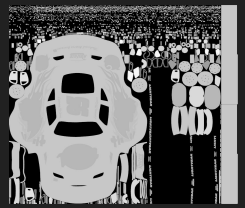
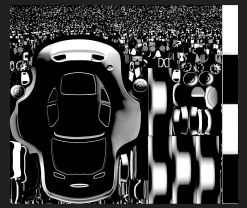
Physically-Based Shading

- Complex material networks
  - Baked signals from RenderMan

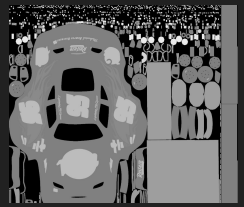
diffuse color


specular color

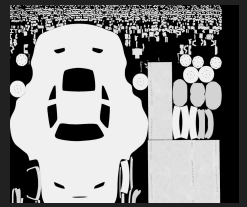

specular roughness


displacement

clearcoat color


clearcoat roughness

roughspecular color


roughspecular roughness

Physically-Based Shading

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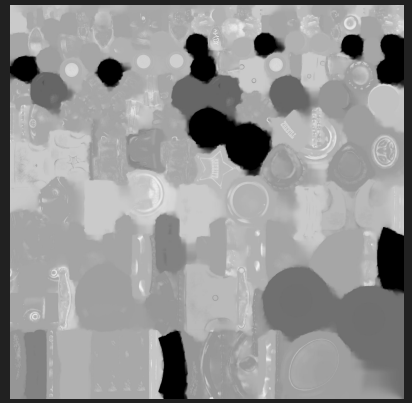
  - Baked signals from RenderMan

diffuse color

specular color



specular roughness

displacement

Physically-Based Shading

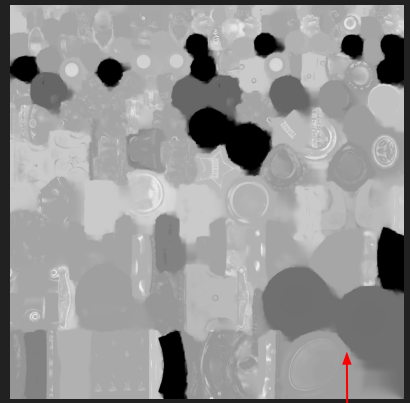
- Complex material networks
  - Baked signals from RenderMan

diffuse color

4K

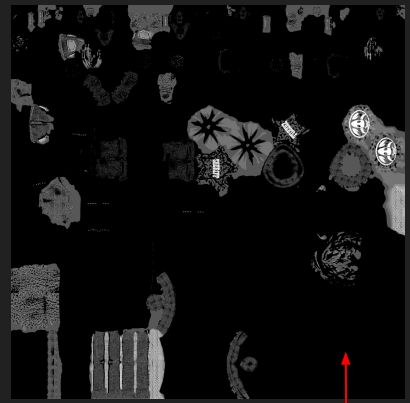
specular color

4K



specular roughness

4K



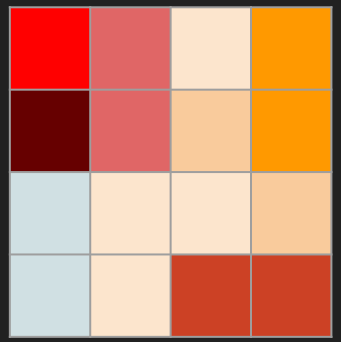
displacement

4K

Lots of Textures

- We need compression, lots of compression!
  - Hello **BPTC**!

16 pixels
* 3 channels
* 1 byte
=
48 bytes



16 bytes

  - BC7 & BC6H

Lots of Textures

Uncompressed

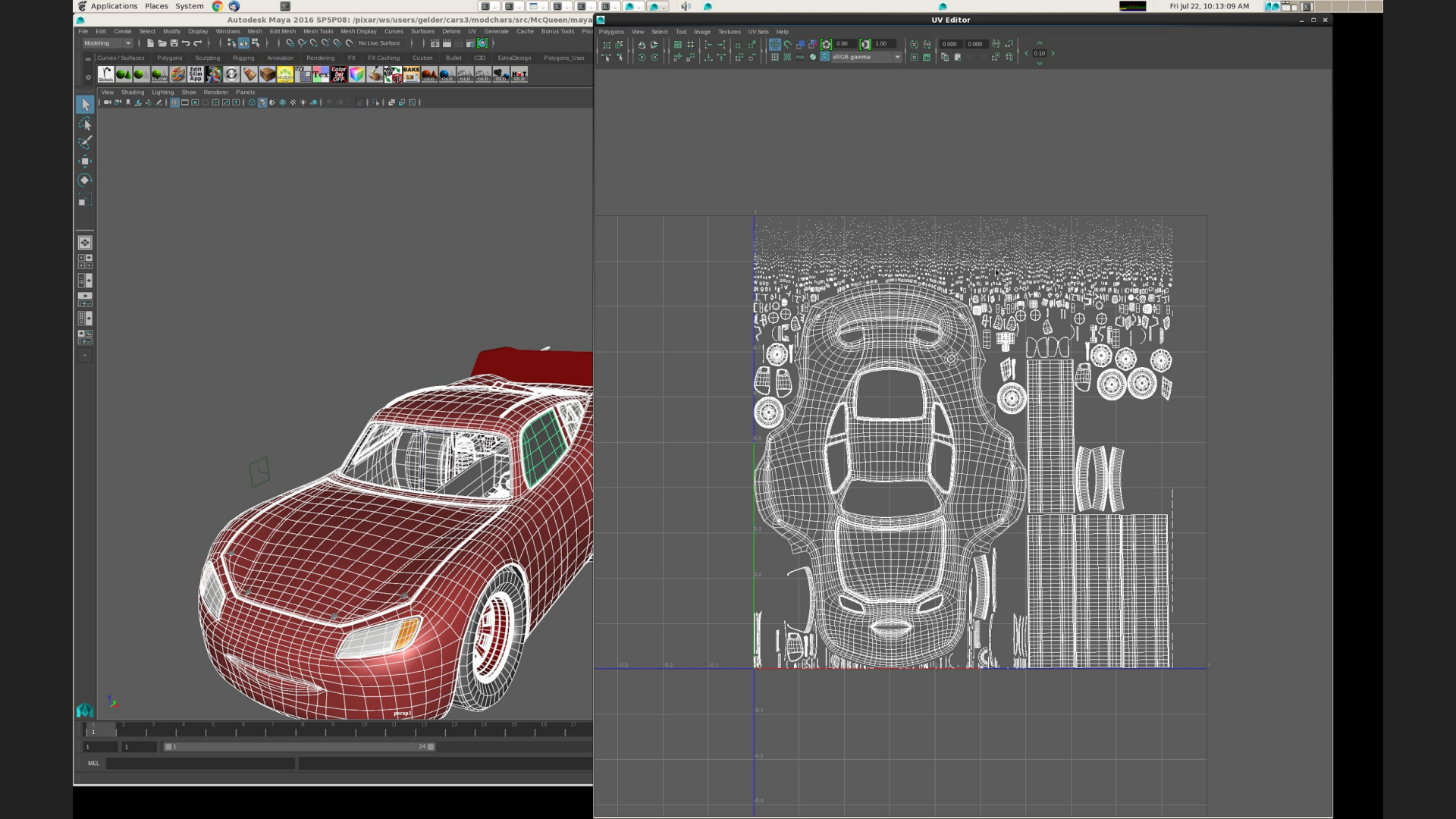
Compressed

UV and Ptex

- Support for both!
- UV
  - Characters
- Ptex
  - Sets
  - Backlot

Shader Baking

- Sample RenderMan shaders used for final image into OpenGL textures
- Us Bxdf inputs, combined when necessary due to real time constraints
- Use Katana livegroups wired through command line python scripts
- Built-in support new in RenderMan 21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Autodesk Maya 2016 SP5P08: /pixar/ws/users/gelder/cars3/modchars/src/McQueen/maya
UV Editor
persp

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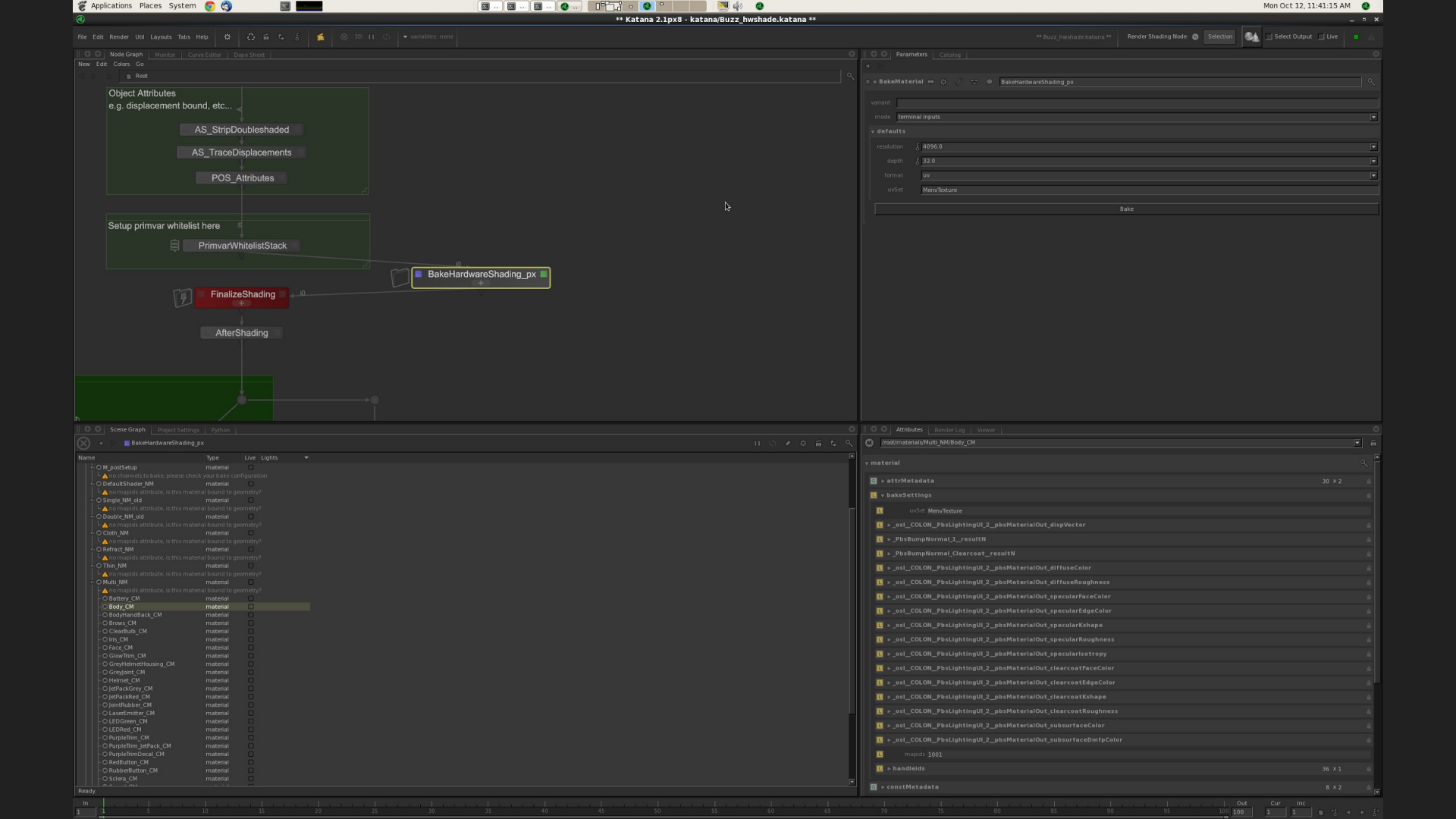
Rust-eze
Bumper Ointment
Lightning McQueen
LIGHTYEAR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** Katana 2.1px8 - katana/Buzz_hwshade.katana **
File Edit Render Util Layouts Tabs Help
Node Graph
Monitor
Curve Editor
Dope Sheet
New Edit Colors Go
Root
Object Attributes
e.g. displacement bound, etc...
AS_StripDoubleshaded
AS_TraceDisplacements
POS_Attributes
Setup primvar whitelist here
PrimvarWhitelistStack
BakeHardwareShading_px
FinalizeShading
AfterShading
Parameters
Catalog
BakeMaterial
BakeHardwareShading_px
variant
mode
terminal inputs
defaults
resolution
4096.0
depth
32.0
format
uv
uvSet
MenvTexture
Bake
Scene Graph
Project Settings
Python
BakeHardwareShading_px
Name
Type
Live
Lights
M_postSetup
DefaultShader_NM
Single_NM_old
Double_NM_old
Cloth_NM
Refract_NM
Thin_NM
Multi_NM
Battery_CM
Body_CM
BodyPlandBack_CM
Brows_CM
ClearBulb_CM
Iris_CM
Face_CM
GlowTrim_CM
GreyHelmetHousing_CM
GreyJoint_CM
Helmet_CM
JetPackGrey_CM
JetPackRed_CM
JointRubber_CM
LaserEmitter_CM
LEDGreen_CM
LEDRed_CM
PurpleTrim_CM
PurpleTrim_JetPack_CM
PurpleTrimDecal_CM
RedButton_CM
RubberButton_CM
Sclera_CM
Ready
Attributes
Render Log
Viewer
/root/materials/Multi_NM/Body_CM
material
attrMetadata
bakeSettings
uvSet MenvTexture
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_PbsBumpNormal_1__resultN
_PbsBumpNormal_Clearcoat__resultN
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_osl__COLON__PbsLightingUI_2__pbsMaterialOut_subsurfaceDmfpColor
mapids 1001
handleids
constMetadata

(demo)

Future Work

- Ground truth effects (accumulation buffer, motion blur, etc)
- Volumetric effects
- Subsurface Scattering
- Hydra & OpenSubdiv support for Vulkan/DX12/Metal

Thank You!

USD Team

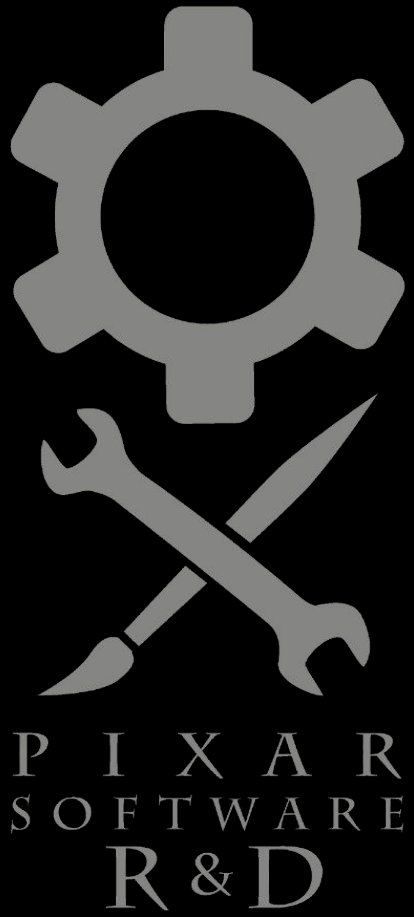
Pixar R&D Department

All Pixar Artists and TDs

Special Thanks

Contributors

- Hydra and USD : Jeremy Cowles
- OpenSubdiv : Barry Fowler



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