Shader Programming: What's Next?

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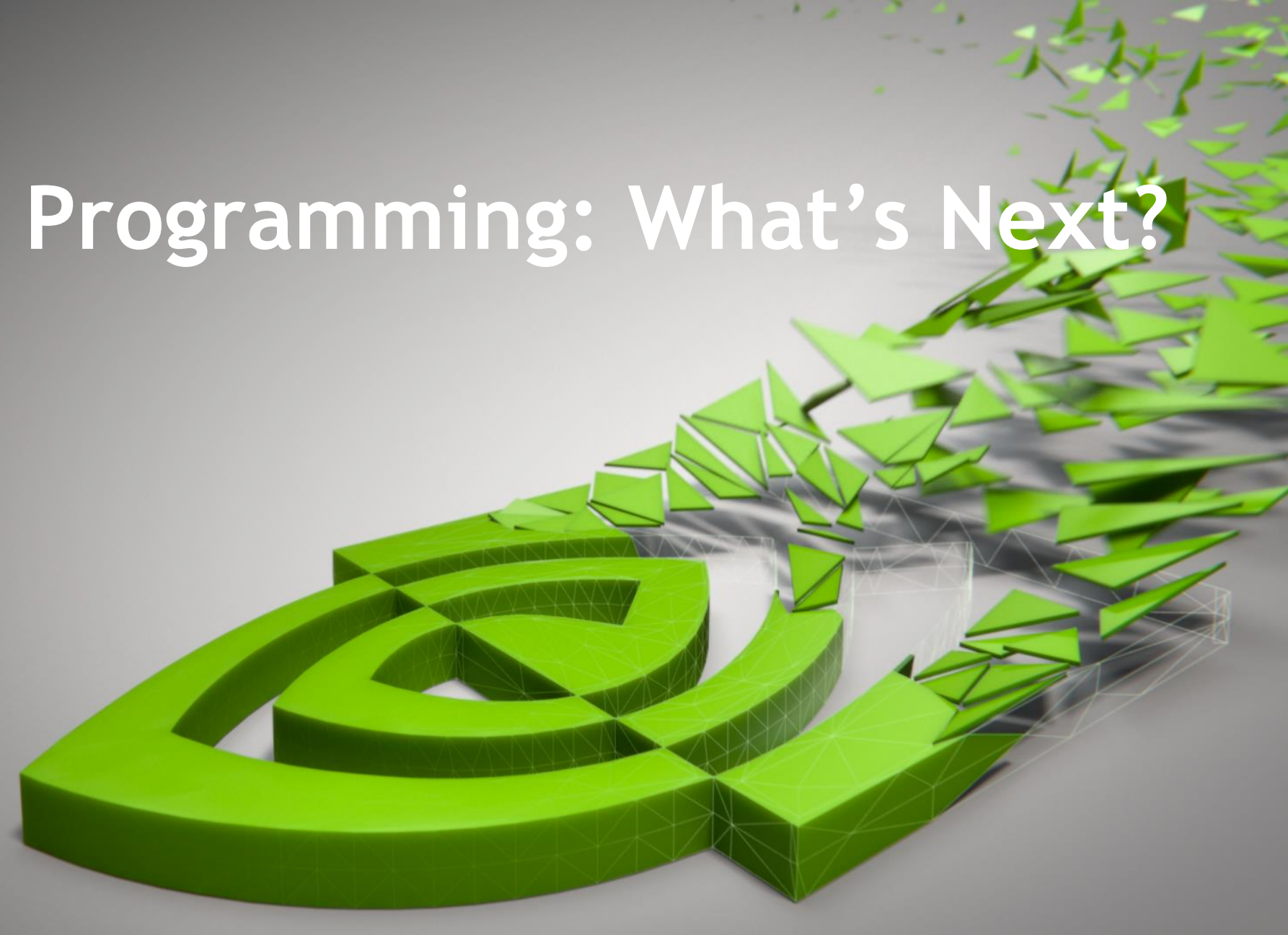
NVIDIA



An interesting time in graphics programming

Many platforms, and even more APIs

- Vulkan 1.0 released just weeks ago

Still programming shaders like it's 2002

- Author shaders in D3D9-era HLSL
- Translate to GLSL, Metal, etc.

Isn’t SPIR-V going to solve all of this?

Vulkan’s intermediate language (IL) for shaders

- Documented binary format, consumed by drivers
- Intended to support alternative front-ends

May encourage other APIs to follow suit

Not a panacea today

- Somebody still has to write all the new front- and back-ends

Benefits of building your own tools

A shader compiler tailored to your engine

Not a language designed for somebody else's API

Target a wide range of platforms

Including future rendering pipelines for, e.g., VR

Transform and manipulate shaders

Example: Mechanically generate shader LODs

This Talk

Two in-progress research projects

Exploring possible approaches to building shader tools

Rapid exploration of scheduling choices

In context of future/extended pipelines

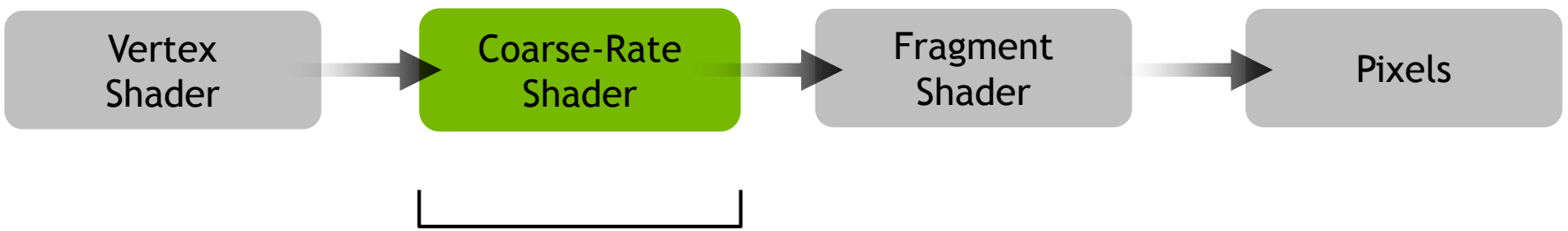
Framework for rapidly building custom shader language/tools

Shaders as a performance-oriented domain-specific language (DSL)

Rapid Exploration of Shader Scheduling Choices

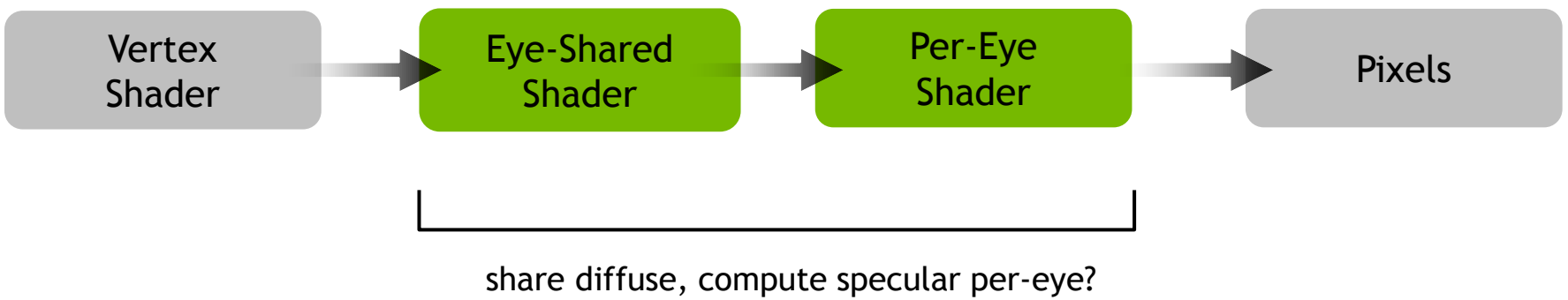
Collaborators: Yong He, Kayvon Fatahalian (CMU)

Pipelines with new shading rates

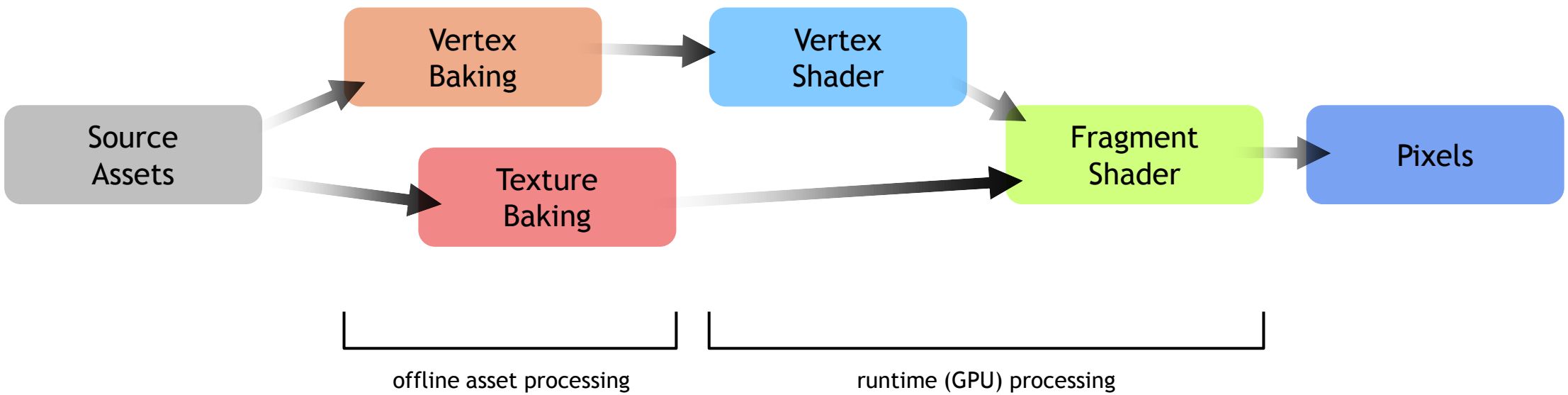


texture space?
quarter-resolution screen space?
“foveated” rendering?

Shading reuse for stereo (VR)



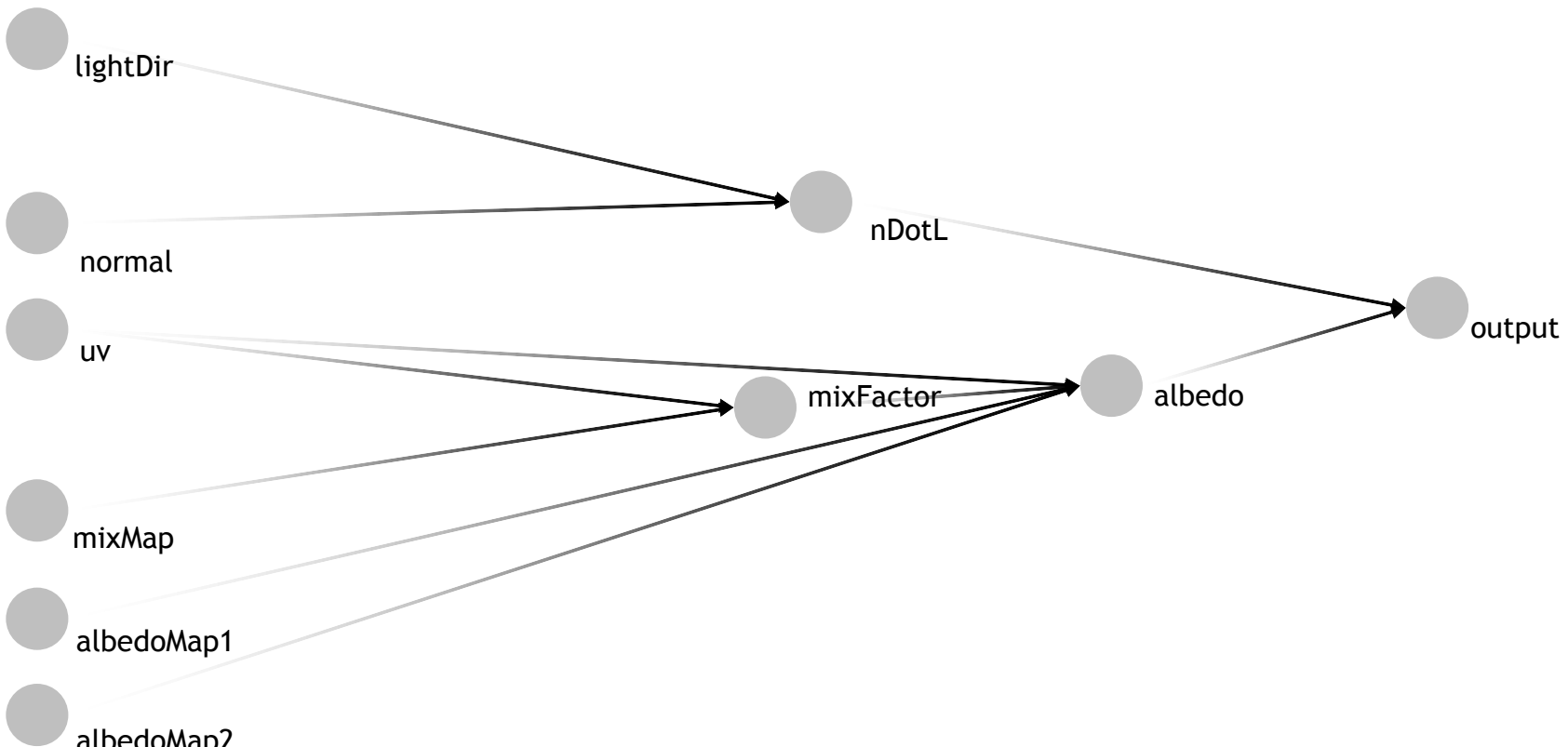
Define engine-specific pipeline



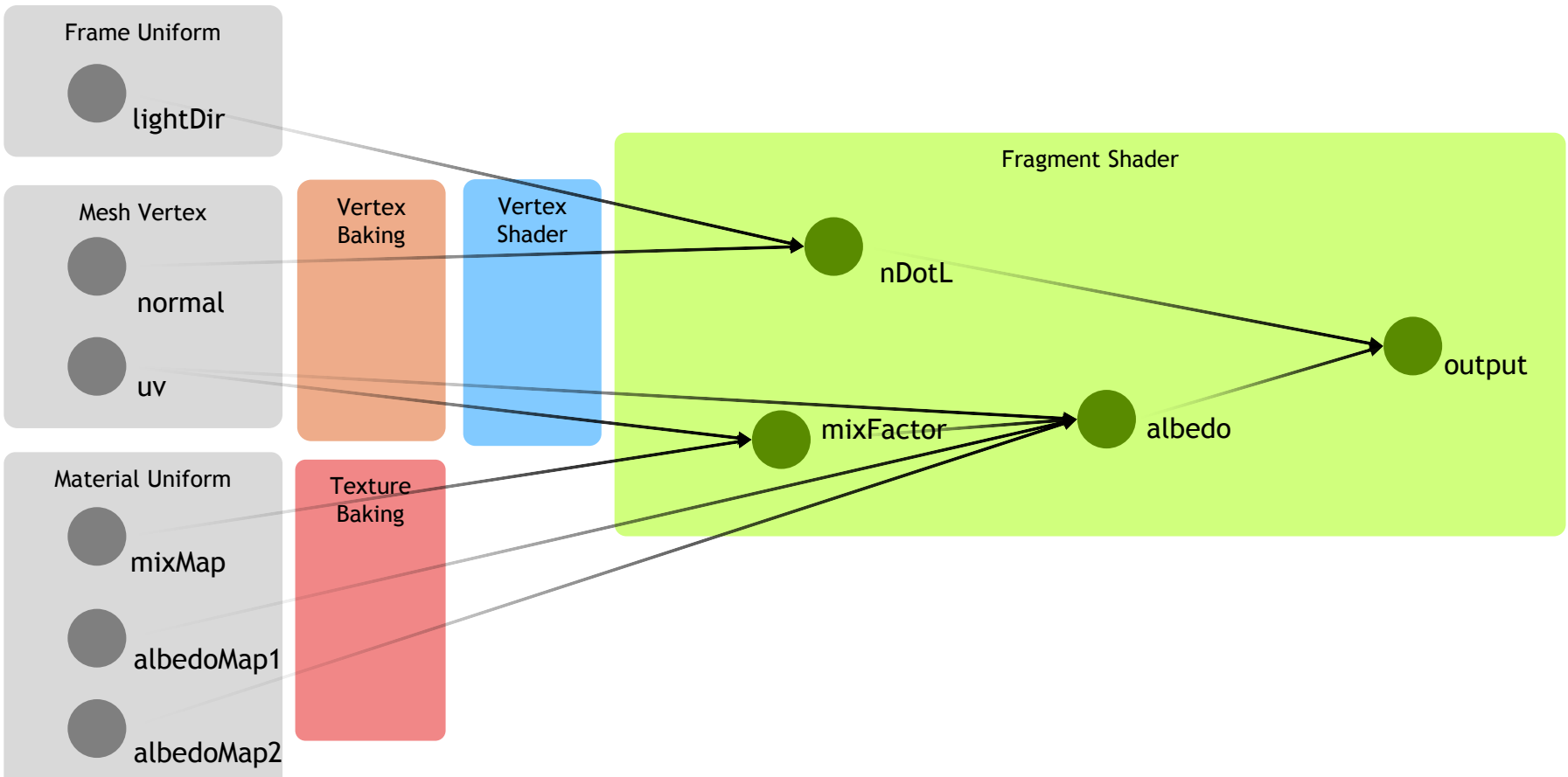
Write shaders against that pipeline

```
shader Terrain using MyEnginePipeline
{
    @MeshVertex      vec2      uv;
    @MaterialUniform sampler2D albedoMap1, albedoMap2;
    @MaterialUniform sampler2D mixMap;

    float mixFactor = texture(mixMap, uv);

    vec4 albedo
    {
        vec4 c1 = texture(albedoMap1, uv);
        vec4 c2 = texture(albedoMap2, uv);
        return mix(c1, c2, mixFactor);
    }

    // ...
}
```

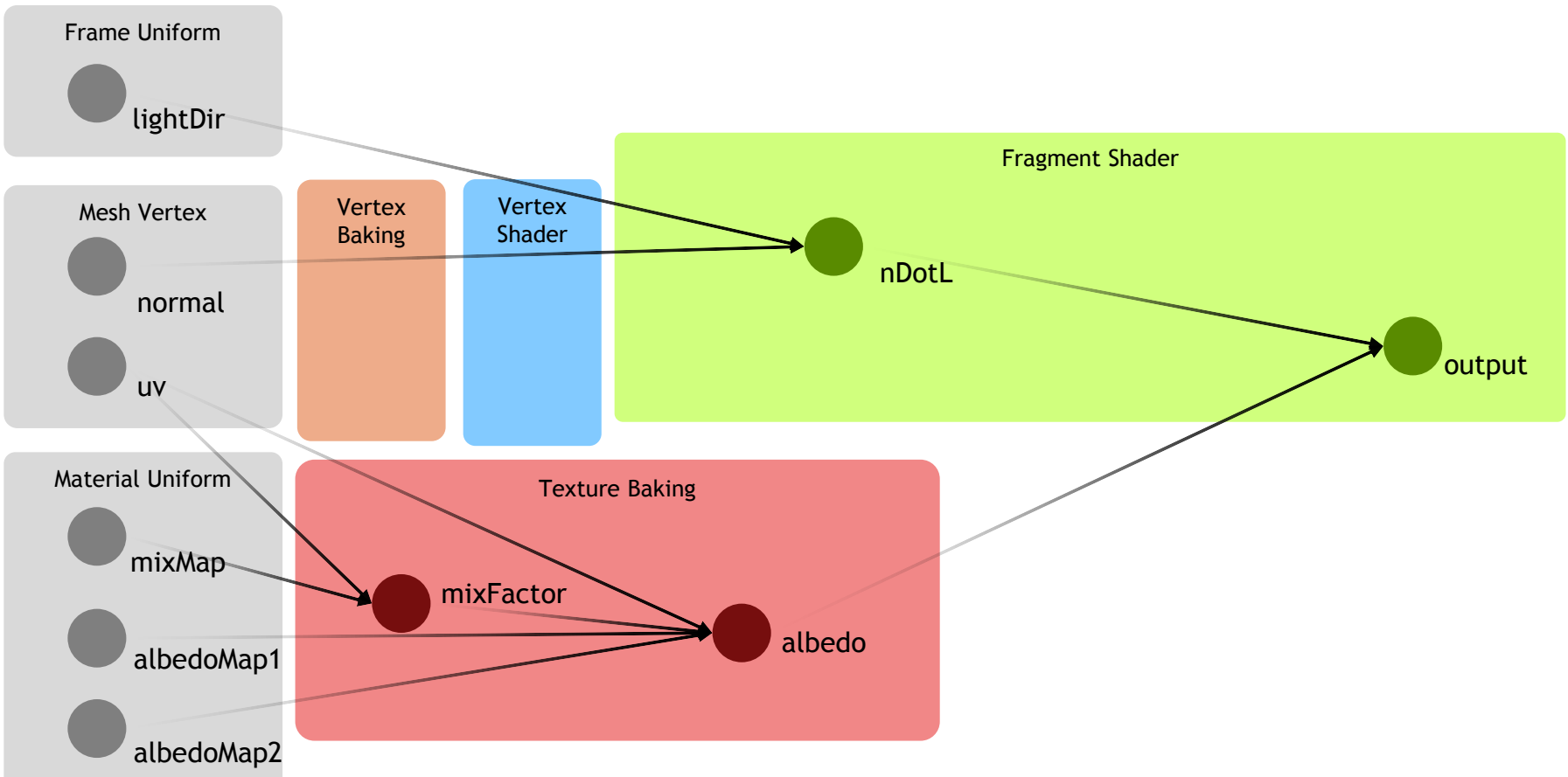
Shader = Dataflow Graph



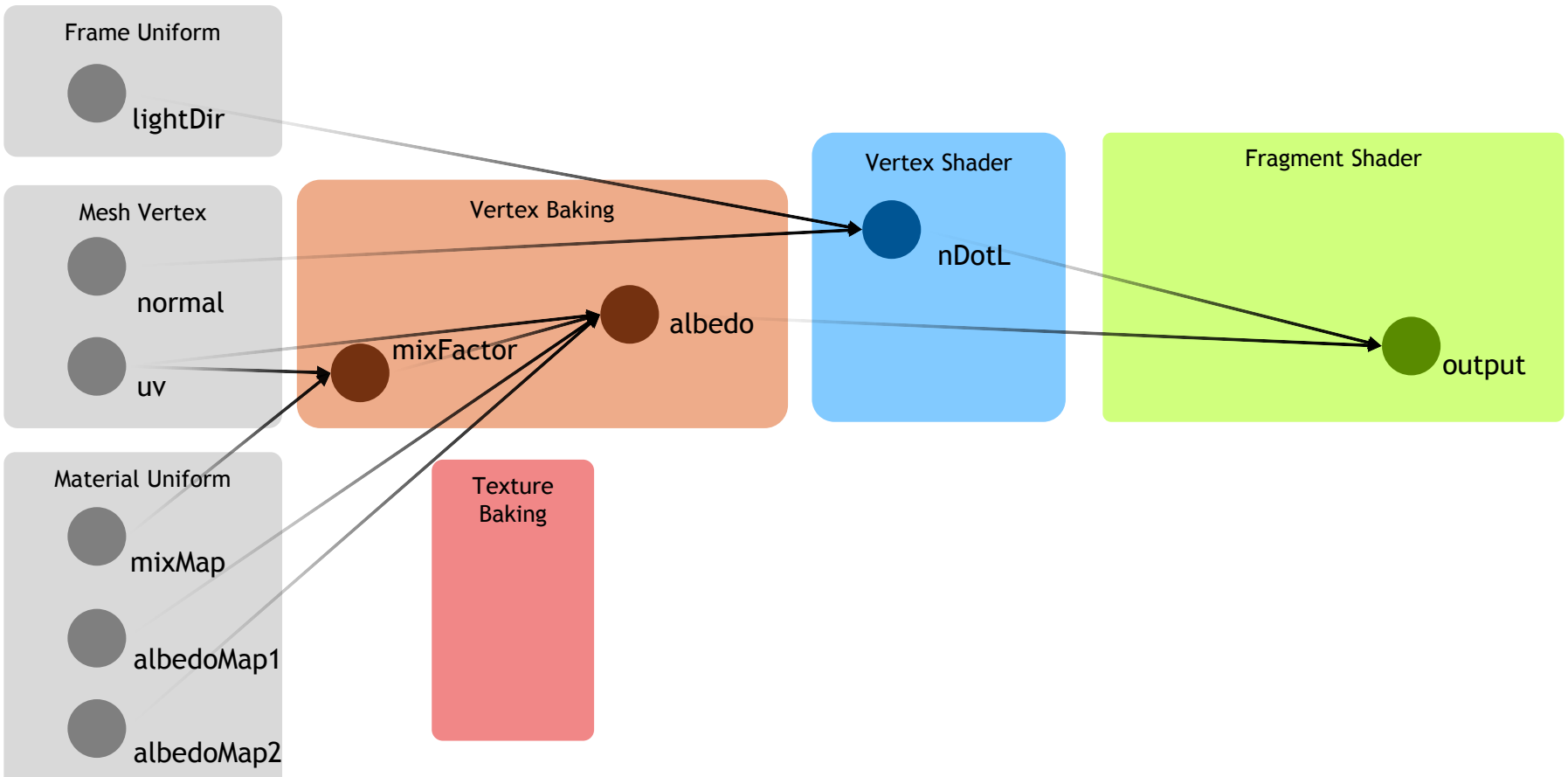
Scheduling = Placing Computation in Stages



Low LOD? Older GPU? Bake texture offline.



Even lower LOD? Do lighting per-vertex.



What can you do with a representation like this?

Rapidly explore performance/quality trade-offs

Use a UI tool to explore different shader variants

Auto-tune scheduling choices

Meet performance constraints on a particular target

Mechanically apply LOD choices to many shaders

Guarantee that low LODs share same vertex/fragment code

Exploring Choices

(Multi-Rate / Object Space Pipeline)

Rapid Development of Engine-Specific Shading Tools

Collaborators: Kerry Seitz, John Owens (UC Davis)

Building engine-specific shader infrastructure

Front-end language

Integration with other systems

Back-end code generation

Shaders as domain-specific languages (DSLs)

Performance-oriented DSLs

- Halide (for image processing) is poster child

Terra: framework for easily constructing DSLs

- Low-level C-like language
- Use Lua scripts to extend language/compiler, generate code
- Supports LLVM code generation out of the box

Building Shader Tools in Terra

Write shader code directly in the Terra language

Can re-use types, functions between app (CPU) and shaders (GPU)

Shader-specific features implemented as syntax extensions

Lua scripts that run inside the compiler

Building Shader Tools in Terra

Built-in support for HLSL/GLSL code generation

Additional tools can parse/inspect/manipulate shaders

- Using a Lua library API
- Artist UI
- Statically-typed engine interface
- Asset processing tools

Wrapping Up

What is the right shader infrastructure for you?

Looking ahead: opportunities and challenges

- Don’t expect Khronos, Microsoft, etc. to build all the pieces
- Opportunity to build what you really want

Researchers can help accelerate and guide your efforts

- Programming models that are ready for new HW and SW pipelines
- Frameworks to rapidly build engine-specific compilers and tools

Thank You

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