SOLUTION TO SHADER RECOMPILES IN RADEONSI

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PROBLEM

- Shaders are compiled in draw calls
  - Emulating certain features in shaders
- Drivers keep shaders in some intermediate representation
- And insert additional code based on the states
- While compiling, everything stops
- Number of state combinations is exponential
EMULATED STATES

Fragment shader:
- Conversion to colorbuffer formats (RGBA32, RGBA FP16, ...)
- Alpha-test
- Selecting between front and back colors
- gl_FragColor
- GL_ALPHA_TO_ONE
- Polygon stippling
- Line & polygon smoothing
- Point smoothing
- Fragment color clamping
EMULATED STATES, CONT.

Vertex shader:
- Loading inputs from vertex buffers manually
- Vertex color clamping
Observation:
- All states can be applied at the beginning or end of shaders
- At link time, compile application shaders
- At draw time, append any shader bytecode needed

3 shader sections:
- Prolog section
- Main section (application shader)
- Epilog section

Concatenate them
FRAGMENT SHADER EPILOG

Color outputs are expected in r0, r1, ...

\[
\begin{align*}
\text{out0} &= r0; \\
\text{out1} &= r1;
\end{align*}
\]
If we need alpha-test:

```glsl
if (!alphafunc(r0.w, alpharef)) discard;

out0 = r0;
out1 = r1;
```
FRAGMENT SHADER EPILOG

If we need color clamping:

```c
r0 = clamp(r0, 0, 1);
r1 = clamp(r1, 0, 1);
if (!alphafunc(r0.w, alpharef)) discard;

out0 = r0;
out1 = r1;
```
If we need polygon stippling:

```glsl
r0 = clamp(r0, 0, 1);
r1 = clamp(r1, 0, 1);
if (!alphafunc(r0.w, alpharef)) discard;
if (texture2D(stipple, gl_FragCoord.xy / 32).x < 0.5) discard;
out0 = r0;
out1 = r1;
```
If we need smoothing:

```glsl
r0 = clamp(r0, 0, 1);
r1 = clamp(r1, 0, 1);
if (!alphafunc(r0.w, alpharef)) discard;
if (texture2D(stipple, gl_FragCoord.xy / 32).x < 0.5) discard;
r0.w *= coverageMask; // popcount(gl_SampleMaskIn) / gl_NumSamples
r1.w *= coverageMask;
out0 = r0;
out1 = r1;
```
If color conversion is required:

\[
\begin{align*}
    r0 &= \text{clamp}(r0, 0, 1); \\
    r1 &= \text{clamp}(r1, 0, 1); \\
    \text{if} \ (\text{!alphafunc}(r0.w, \text{alpharef})) \ \text{discard}; \\
    \text{if} \ (\text{texture2D(stipple, \text{gl\_FragCoord}.xy / 32).x} < 0.5) \ \text{discard}; \\
    r0.w &= \times \text{coverageMask}; \ // \ \text{popcount(gl\_SampleMaskIn) / gl\_NumSamples} \\
    r1.w &= \times \text{coverageMask}; \\
    r0.xy &= \text{vec2(packHalf2x16(r0.xy), packHalf2x16(r0.zw))}; \\
    r1.xy &= \text{vec2(packHalf2x16(r1.xy), packHalf2x16(r1.zw))}; \\
    \text{out0} &= r0; \\
    \text{out1} &= r1;
\end{align*}
\]
If GL_ALPHA_TO_ONE is enabled:

```glsl
r0 = clamp(r0, 0, 1);
r1 = clamp(r1, 0, 1);
if (!alphafunc(r0.w, alpharef)) discard;
if (texture2D(stipple, gl_FragCoord.xy / 32).x < 0.5) discard;
r0.w *= coverageMask; // popcount(gl_SampleMaskIn) / gl_NumSamples
r1.w *= coverageMask;

r0.w = 1;

r0.xy = vec2(packHalf2x16(r0.xy), packHalf2x16(r0.zw));
r1.xy = vec2(packHalf2x16(r1.xy), packHalf2x16(r1.zw));
```

out0 = r0;
out1 = r1;
FRAGMENT SHADER PROLOG

- Only contains two-side color selection
- Decreases performance if done always

3 scenarios:

- Two-side colors are enabled:
  - Select colors based on `gl_FrontFacing`
  - Store them into registers `r0, r1`
- Two-side colors are disabled:
  - Just copy front colors into `r0, r1`
- No color inputs => prolog is empty

Application shader should read colors from `r0, r1`
COMPILING PROLOGS/EPILOGS

- Still have to be compiled in draw calls
  - Can be slow

- Use an assembler instead of the compiler
  - Our LLVM backend has an assembler too
VERTEX SHADER INPUTS

- R600 had fetch shader
- Removed since GCN

Current implementation:
- One buffer per input
- Instance divisor == 0: Fetch BaseVertex + VertexID
- Instance divisor != 0: Fetch StartInstance + (InstanceId / instance divisor)
Emulate fetch shader with prolog section
- Drawback: can’t move loads to hide latencies, register usage

Instead, only calculate load addresses:
- Prolog writes the addresses to r0, r1, ...
- Main shader section executes the loads
VERTEX SHADER EPILOG?

- Radeon has 3 ways to write VS outputs:
  - For rasterizer
  - For geometry shader
  - For tessellation control shader

- Don’t use an epilog
- OpenGL sometimes knows which shader follows
- If not, compile all 3 variants with 3 threads in parallel
- Piglit only: Compile on demand in draw calls

- Vertex color clamping: use conditional assignment
Middle-end, translates shaders from GLSL IR into TGSI

Does that in draw calls

State dependencies for draw calls:
- Center vs sample interpolation
  - Instead, select coordinates with conditional assignment
- Vertex and fragment color clamping
- GL rendering context

Any dependencies should be dealt with in drivers

Other drivers will benefit too
- GLSL->TGSI always done at link time
IF GAMES COMPILE TOO LATE

- Compiling at link time doesn’t help
- Use shader cache
- 1 shader variant => shader cache in core Mesa
- If games compile early => don’t need it
SKIP MESA OPTIMIZATIONS?

⚠️ Our LLVM backend can do most optimizations
- No need to do them in Mesa

⚠️ Mesa/GLSL passes we do need:
- Demoting inputs/outputs to local variables (dead code elimination?)
- Function inlining
- Breaking built-in input/output arrays into variables
Questions?
THANK YOU
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