A shader unit
Architecture, OpenGL-specific aspects, simulator implemented using SystemC, adaptations for embedded systems

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Gliederung

1. Introduction
2. Architecture
3. Implementing OpenGL
4. Adaptions for use in embedded systems
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4 Adaptions for use in embedded systems
Shaders

- Replace parts of the graphics pipeline to gain flexibility
- Written in special-purpose languages like GLSL
- Executed on special-purpose, programmable processors called shader units
- Unified shaders: Shader units can be dynamically assigned to different shader types
- Different architectures in use
Goals

- Architecture of a shader unit (for OpenGL shaders)
- Selected aspects of hardware implementation
- Adaptions for embedded systems
- Cycle-accurate simulator written in SystemC
- Assembler
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Processor and parts of its environment
Execution environment

- (Up to) 240 general-purpose registers
- (Up to) 14 texture units
- 2 index registers
- Single address space for general-purpose registers, texture units, indirect addressing
- 64K program address space
- Program counter
General-purpose registers

- 128 bit wide, treated as 4-component vectors by most instructions
- Data is passed from and to the rest of the graphics pipeline through these
Typical instructions:
- One or two source operands
- One destination operand
- Destination write mask to selectively write components of destination operand

Example: Double the first and third component of register 1

add 1.xz, 1, 1
Dot products

- Common in shaders
- Can be used for other tasks: Matrix multiplication, Taylor series
- Map well to a pipeline that has three execution stages
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- Drivers generate shaders for fixed-function pipeline
- Legacy pseudo-assembly languages’ functionality is a subset of GLSL functionality
- GLSL has many built-in functions
Example - cosinus

\[
\cos(c) = \sum_{i=0}^{\infty} (-1)^n \frac{x^{2i}}{(2i)!} \quad (1)
\]

\[
\cos(x) = t \left( g \left( \frac{x}{2\pi} + \frac{1}{2} \right) - \frac{1}{2} \right) \quad (2)
\]

\[
g(x) = x - \lfloor x \rfloor \quad (3)
\]

\[
t(x) = \sum_{i=0}^{\infty} (-1)^n \frac{(2\pi x)^{2i}}{(2i)!} \approx \sum_{i=0}^{4} (-1)^n \frac{(2\pi x)^{2i}}{(2i)!} = s(x) \quad (4)
\]

\[
\cos(x) \approx a(x) := s \left( g \left( \frac{x}{2\pi} + \frac{1}{2} \right) - \frac{1}{2} \right) \quad (5)
\]
Cosinus approximation error
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OpenGL ES

- OpenGL for embedded systems
- Removes legacy functionality
- Removes highend features
Architecture

- Often no hardware-accelerated vertex processing
- Reduced (half) precision is sufficient for fragment shaders
- 64 bit wide general-purpose registers
- Indirect addressing and integer support not mandatory
Moving functionality to shaders results in simpler texture units

- Texture filtering (texture units support bilinear filtering, shader does trilinear filtering)
- Calculation of level-of-detail parameter from texture coordinates derivative’s