



Real-Time Programmable Shading

(<http://www.cs.unc.edu/~olano/papers/rtshading/>)

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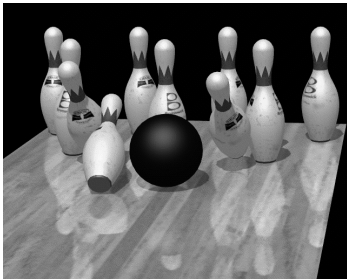
Real-Time Programmable Shading

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Introduction



Organization

Requirements
PixelFlow
Example

- ◆ Requirements of programmable shading
- ◆ PixelFlow shading architecture
- ◆ An example



Programmable what?

Requirements
PixelFlow
Example

- ◆ Simple functions
- ◆ Run at each pixel/sample
- ◆ Compute surface shading, lighting, displacement maps, atmospheric effects, ...
 - Whitted 82, Cook 84, Perlin 85, Hanrahan 90
 - Rhoades 92



Surface shader

Requirements
PixelFlow
Example

- ◆ For one sample
- ◆ Inputs:
 - Intrinsic color, normal, texture coordinates, width, length, bumpiness, swirliness, ...
- ◆ Outputs:
 - Color, (opacity)

Resource requirements

Requirements
PixelFlow
Example

- ◆ Programmability
- ◆ Memory
- ◆ Computational power

Programmability

Requirements
PixelFlow
Example

- ◆ Programmable processors at sample level
- ◆ High level language (i.e. RenderMan)
 - Hanrahan 90, Upstill 90

Resource requirements

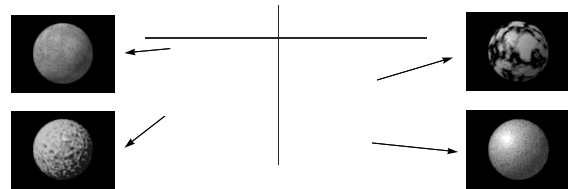
Requirements
PixelFlow
Example

- ◆ Programmability
- ◆ Memory
- ◆ Computational power

Memory

Requirements
PixelFlow
Example

- ◆ Table memory
- ◆ Local memory



Resource requirements

Requirements
PixelFlow
Example

- ◆ Programmability
- ◆ Memory
- ◆ Computational power
 - Parallelism
 - Deferred shading
 - Uniform/varying
 - Fixed point/floating point

Parallelism

Requirements
PixelFlow
Example

- ◆ Pixel-Planes 5 (Fuchs 89)
 - 2–50 Graphics processors (i860)
 - 1–20 Renderers (custom)
 - 16k Pixel processors / renderer (custom)
- ◆ Reality Engine (Akeley 93)
 - 8–12 Geometry engines (i860XP)
 - 5–20 Fragment generators (custom)
 - 80–320 Image engines (custom)

Resource requirements

Requirements
PixelFlow
Example

- ◆ Programmability
- ◆ Memory
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Deferred shading

Requirements
PixelFlow
Example

- ◆ Keep shading parameters at each pixel
- ◆ Shade after visibility is determined
- ◆ Pros:
 - Doesn't shade hidden pixels
 - Shading independent of geometric complexity!
 - Better utilization on SIMD
- ◆ Cons:
 - Can't affect visibility (No transparency, no displacement maps!)

Resource requirements

Requirements
PixelFlow
Example

- ◆ Programmability
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 - Deferred shading
 - Uniform/varying
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Uniform/varying

Requirements
PixelFlow
Example

- ◆ Uniform = constant across pixels/samples
 - Wood grain, marble vein frequency, ...
- ◆ Varying = different in each pixel/sample
 - Normal, texture coordinates, ...
- ◆ Don't compute uniform values at every pixel — compute once and broadcast

Resource requirements

Requirements
PixelFlow
Example

- ◆ Programmability
- ◆ Memory
- ◆ Computational power
 - Parallelism
 - Deferred shading
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Fixed point/floating point

Requirements
PixelFlow
Example

- ◆ Pixel processors
 - Many processors
 - Simple instruction set
 - Floating point acceleration is unlikely
- ◆ Fixed point
 - When required precision is known
 - More efficient in time and memory

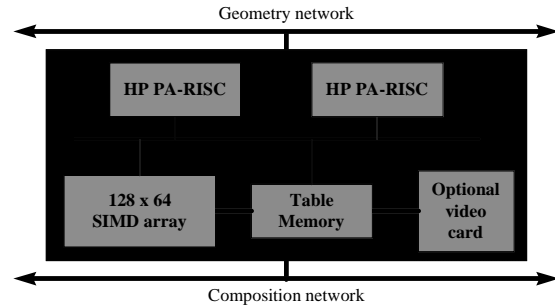
PixelFlow

Requirements
PixelFlow
Example

- ◆ Node description
- ◆ Memory
- ◆ Timings
- ◆ System

PixelFlow node

Requirements
PixelFlow
Example



PixelFlow

Requirements
PixelFlow
Example

- ◆ Node description
- ◆ Memory
- ◆ Timings
- ◆ System

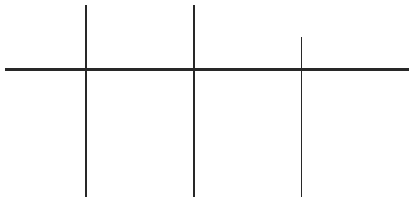
Memory

Requirements
PixelFlow
Example

- ◆ 16MB table memory
- ◆ 256 bytes local memory
- ◆ 128 bytes local memory/communication

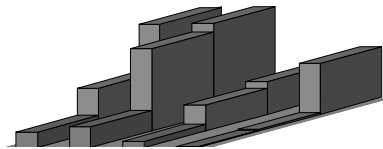
Timings (μ s)

Requirements
PixelFlow
Example



Timings (μ s)

Requirements
PixelFlow
Example



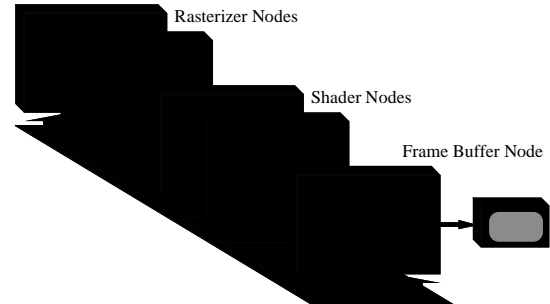
PixelFlow

Requirements
PixelFlow
Example

- ◆ Node description
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- ◆ Timings
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PixelFlow system

Requirements
PixelFlow
Example



An example

Requirements
PixelFlow
Example

- ◆ Video
- ◆ Shading functions
- ◆ Time

An example

Requirements
PixelFlow
Example

Show video

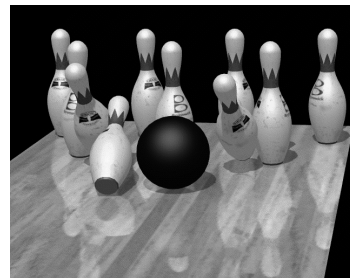
Shading functions

Requirements
PixelFlow
Example

- ◆ Pins
 - Crown, label, scuffs, dirt, Phong
- ◆ Alley
 - Wood, reflection map
- ◆ Ball
 - Phong
- ◆ Light
 - Shadow map

Shading functions

Requirements
PixelFlow
Example



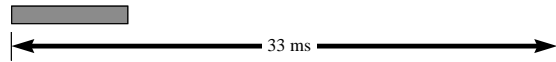
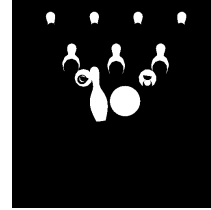
An example

Requirements
PixelFlow
Example

- ◆ Video
- ◆ Shading functions
- ◆ Time
 - Breakdown of 33ms frame time
 - Breakdown of 150μs to run all shaders (excluding table lookups)
 - Time for table lookups
 - Use of multiple processors

Time: 7 ms - shadow map

Requirements
PixelFlow
Example



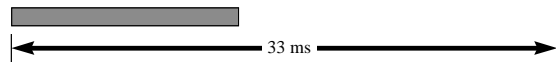
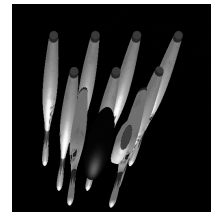
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Time: 7 ms - reflection map

Requirements
PixelFlow
Example



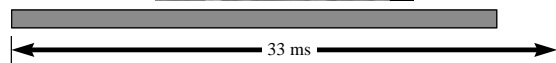
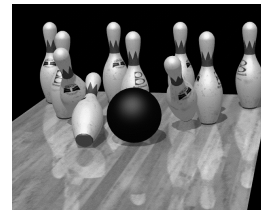
An example

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PixelFlow
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Time: 15.7 ms - final image

Requirements
PixelFlow
Example



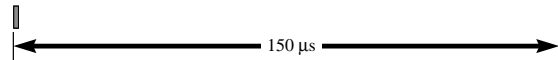
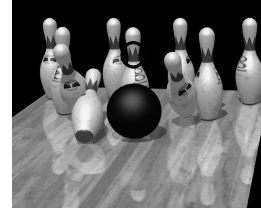
An example

Requirements
PixelFlow
Example

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Shading: 2 μ s - crown

Requirements
PixelFlow
Example



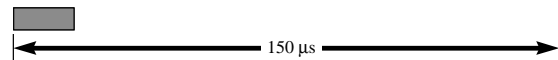
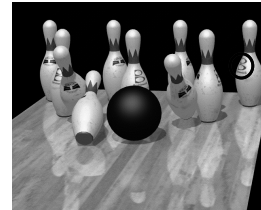
An example

Requirements
PixelFlow
Example

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Shading: 15 μ s - label

Requirements
PixelFlow
Example



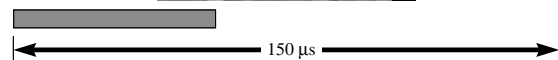
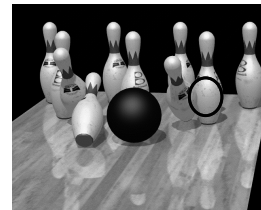
An example

Requirements
PixelFlow
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Shading: 39 μ s - scuffs & dirt

Requirements
PixelFlow
Example



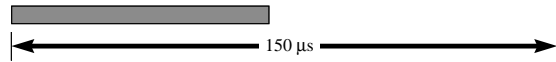
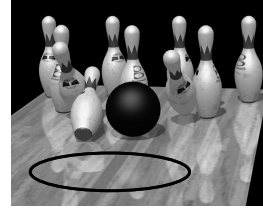
An example

Requirements
PixelFlow
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Shading: 15 μ s - wood

Requirements
PixelFlow
Example



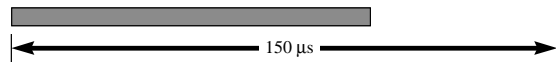
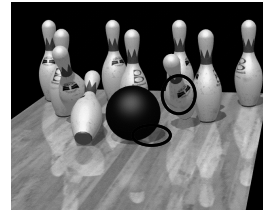
An example

Requirements
PixelFlow
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Shading: 28 μ s - light/shadows

Requirements
PixelFlow
Example



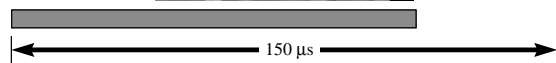
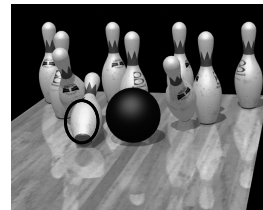
An example

Requirements
PixelFlow
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Shading: 12 μ s - Phong (pins)

Requirements
PixelFlow
Example



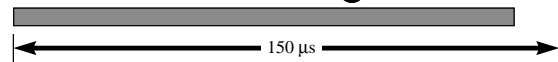
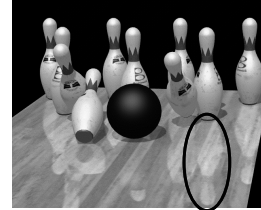
An example

Requirements
PixelFlow
Example

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Shading: 27 μ s - reflection

Requirements
PixelFlow
Example



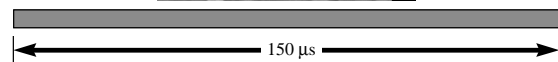
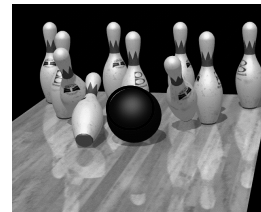
An example

Requirements
PixelFlow
Example

- ◆ Video
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 - Using multiple processors

Shading: 12 μ s - Phong (ball)

Requirements
PixelFlow
Example



An example

Requirements
PixelFlow
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- ◆ Video
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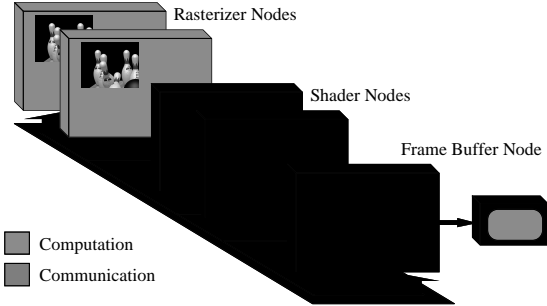
Time for table lookups

Requirements
PixelFlow
Example

- ◆ About 23ns per pixel
- ◆ Worst case
 - Bowling pin (4 lookups) in all pixels
 - » Label image
 - » Scuff bump map
 - » Dirt image
 - » Shadow map
 - Total 760 μ s per region

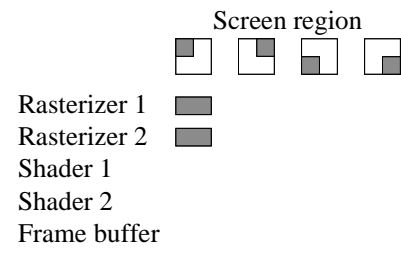
Using multiple processors

Requirements
PixelFlow
Example



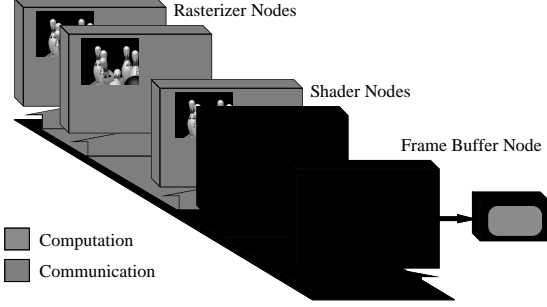
Using multiple processors

Requirements
PixelFlow
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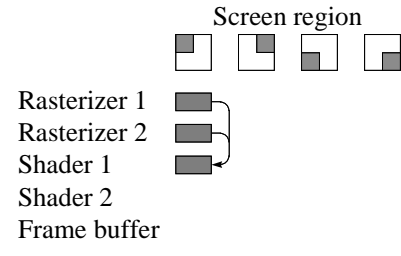
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Requirements
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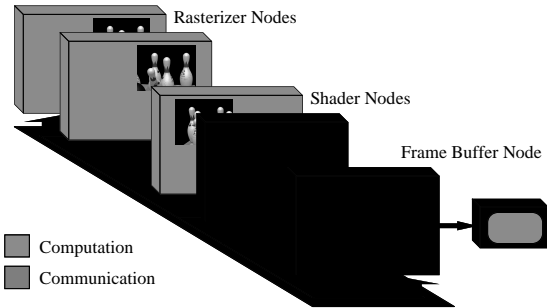
Using multiple processors

Requirements
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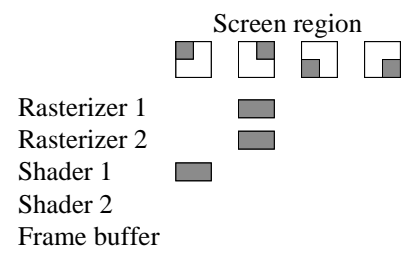
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Requirements
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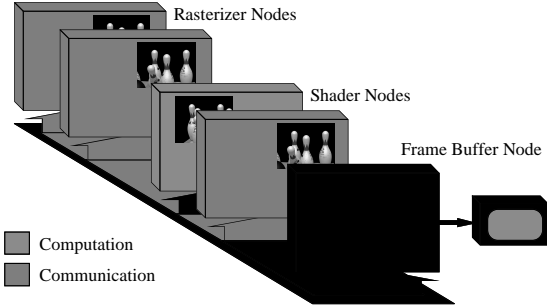
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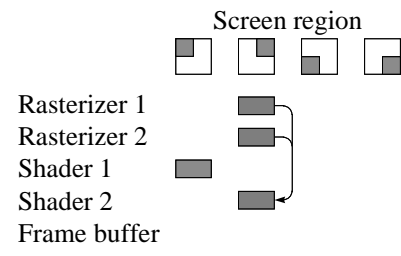
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Requirements
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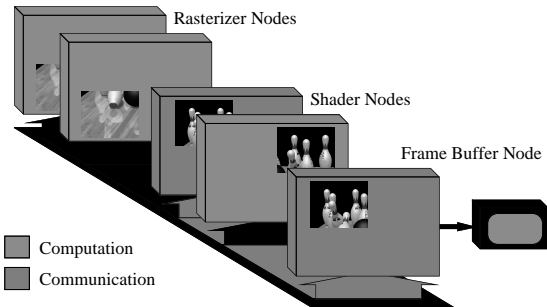
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Requirements
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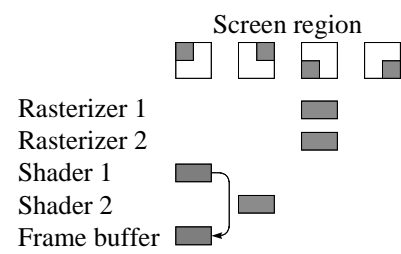
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Requirements
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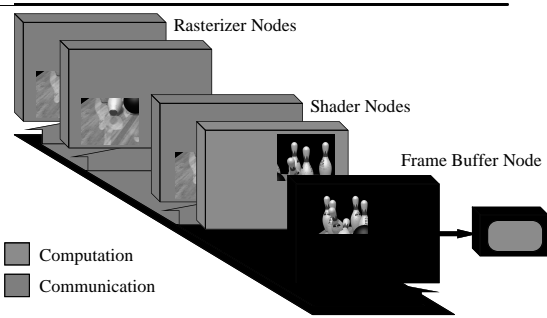
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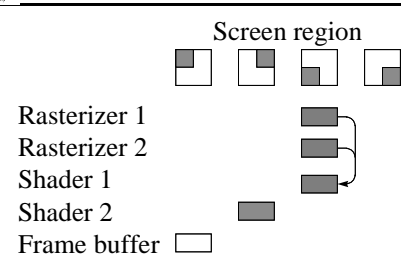
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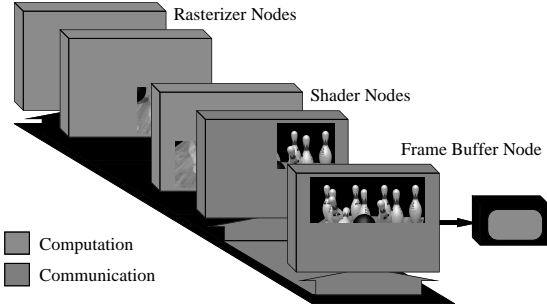
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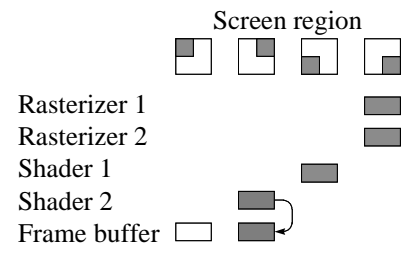
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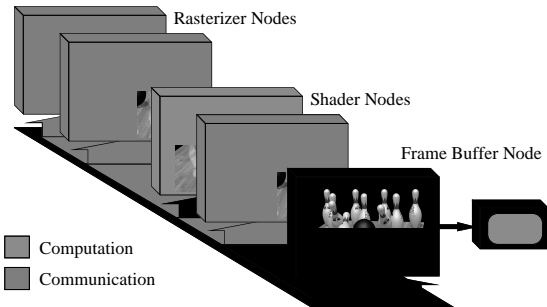
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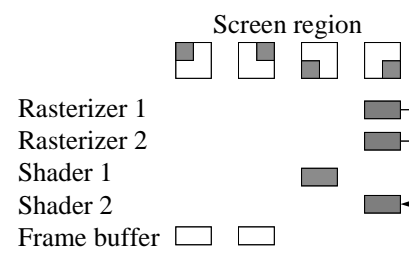
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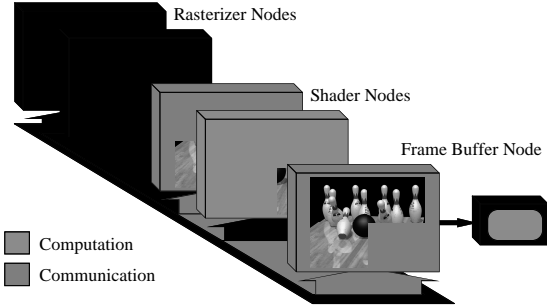
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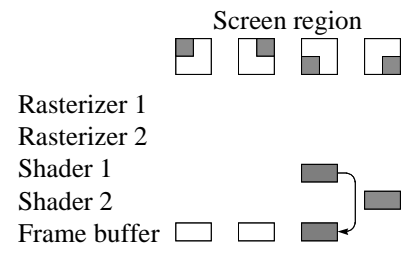
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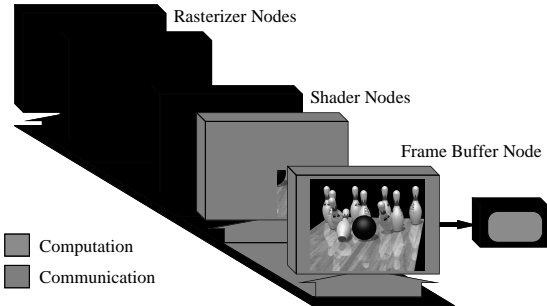
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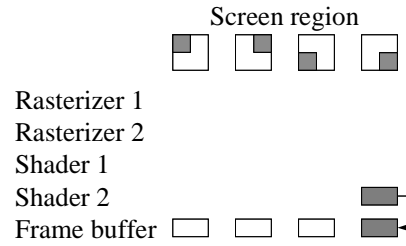
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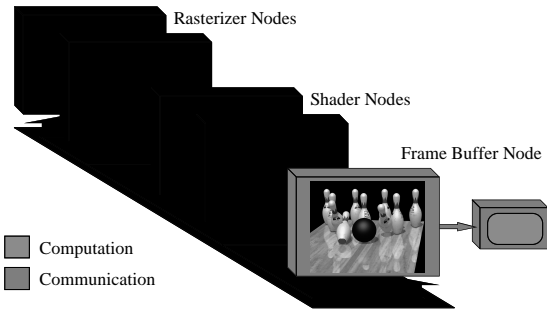
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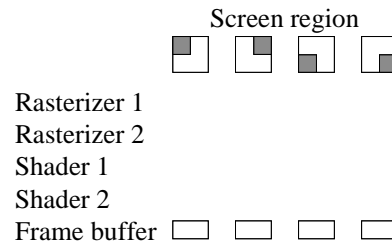
Using multiple processors

Requirements
PixelFlow
Example



Using multiple processors

Requirements
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Example



Future work

- ◆ RenderMan-like shading compiler
- ◆ Allow programming other places
- ◆ Convince commercial vendors that they can and should do programmable shading too

Acknowledgements

- ◆ Lawrence Kesteloot, Fredrik Fatemi
- ◆ UNC PixelFlow Group
- ◆ Tony Apodaca, Pixar
- ◆ Hewlett-Packard
- ◆ ARPA ISTO Order No. A410
- ◆ NSF Grant No. MIP-9306208