SIGGRAPHASIA2008

NEW HORIZONS

Real-Time Reyes

Programmable Pipelines and Research Challenges

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SIGGRAPHASIA2008

NEW HORIZONS

This talk

- Parallel Computing for Graphics: In Action
- What does it take to write a programmable pipeline?
  - Many questions
  - Some answers
- We will focus on the Reyes pipeline

Graphics on parallel devices

- Over the years
  - Increasing performance
  - Increasing programmability
- How is that useful for real-time graphics?
  - Improve existing pipeline
  - Redesign the pipeline

Redesign the pipeline

- An Exploration
  - May not be the answer for everyone
- My Goals
  - Interactive performance
  - High visual quality
- **How should I choose a pipeline?**

My real-time pipeline

- An improvement in real-time rendering
  - Build around shading
  - Remove existing rendering artifacts

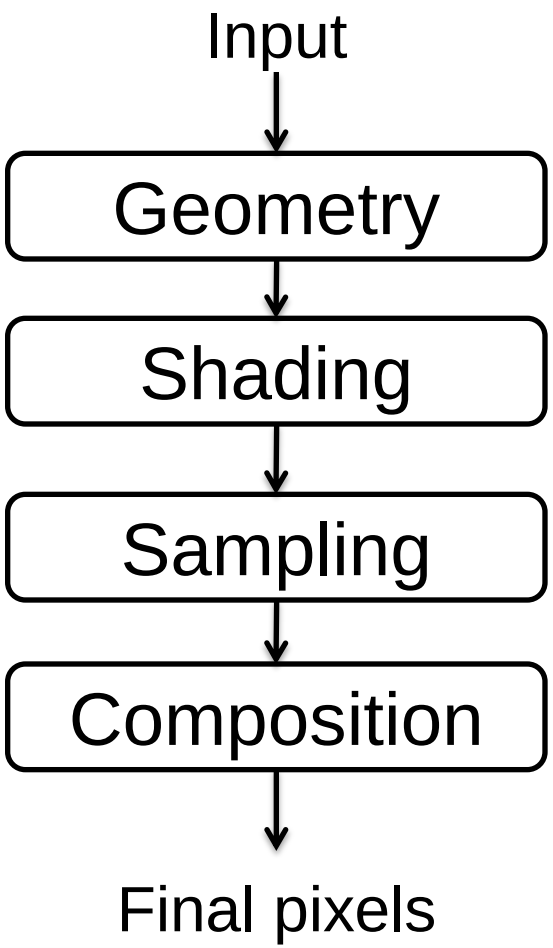
- Desired features
  - High-quality anti-aliasing
  - Realistic motion-blur, depth-of-field, volume effects
  - Global Illumination
  - Order-independent transparency

Reyes

- Introduced 1987
- Photorealistic rendering
  - Smooth surfaces
  - Complex shading, lighting
  - Depth of field, motion blur
  - Order-independent blending
- Designed for offline use
  - But favors SIMD

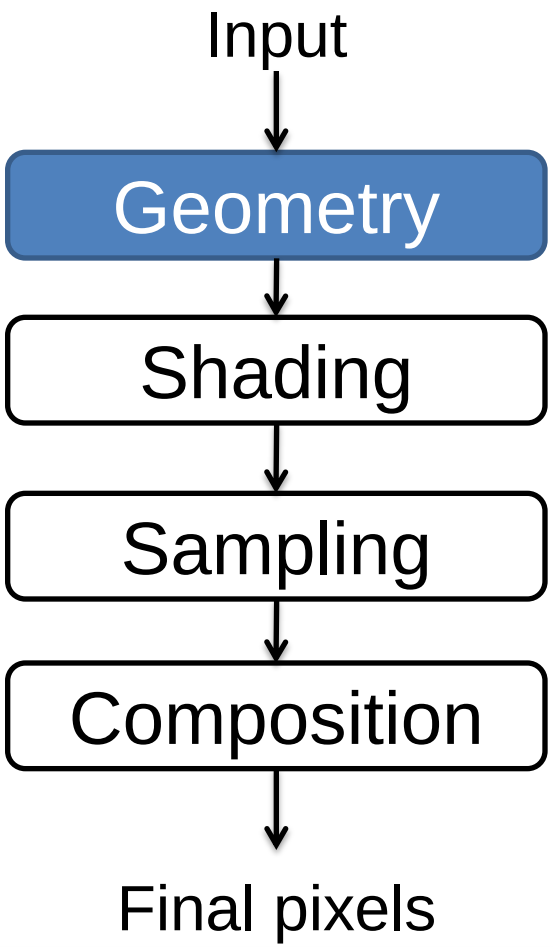
Image courtesy: Pixar

Real-Time Reyes



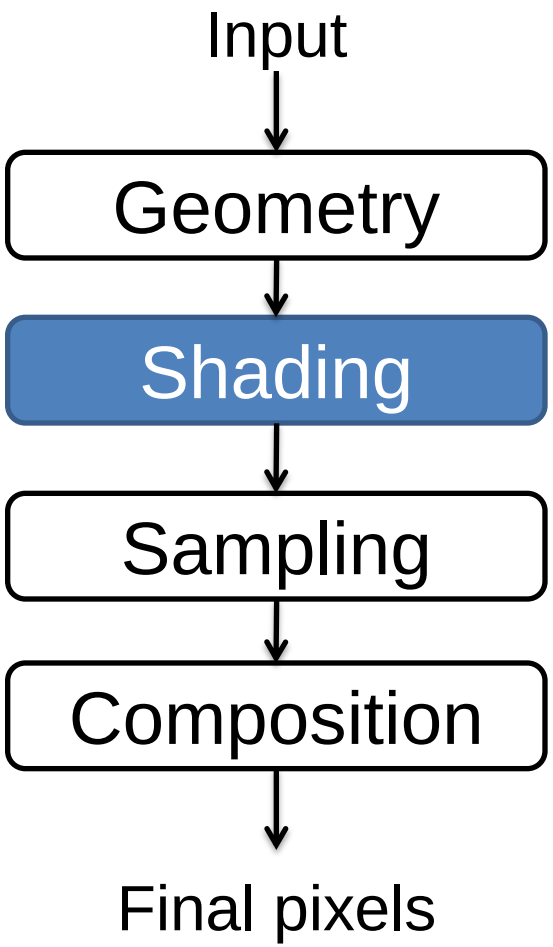
Step 1: Geometry

Convert input surfaces to micropolygons



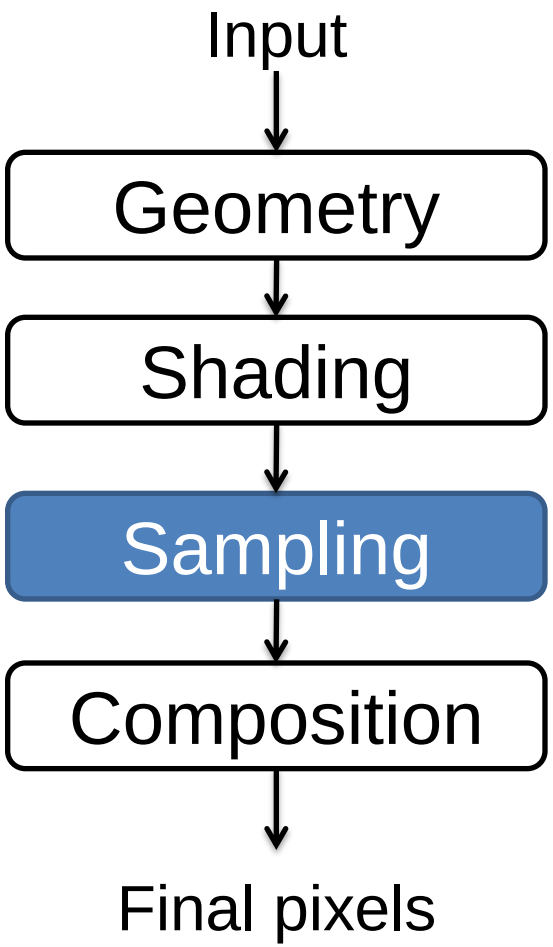
Step 2: Shading

Decide colors for grid micropolygons



Step 3: Sampling

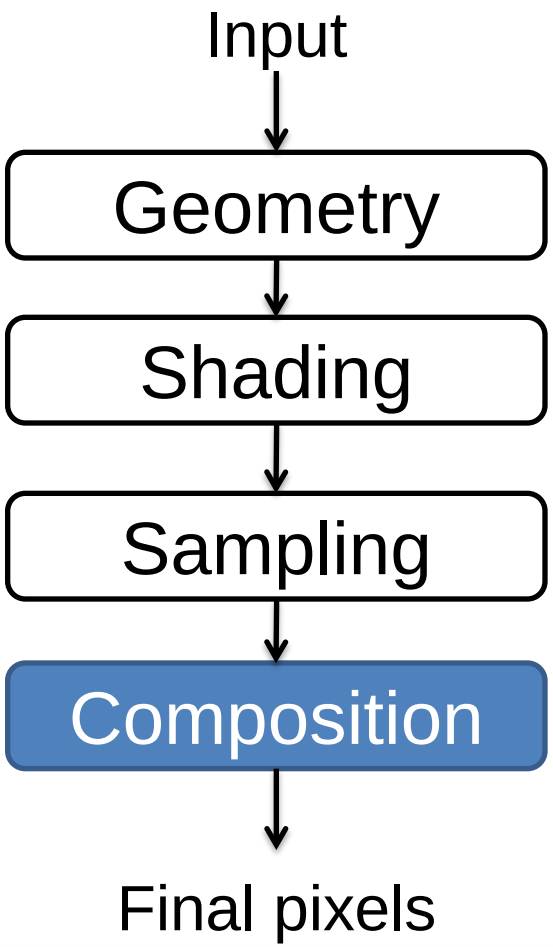
Collect stochastic samples of micropolygons



Step 4: Image Composition

Blend samples to get colors

Combine colors to get pixels



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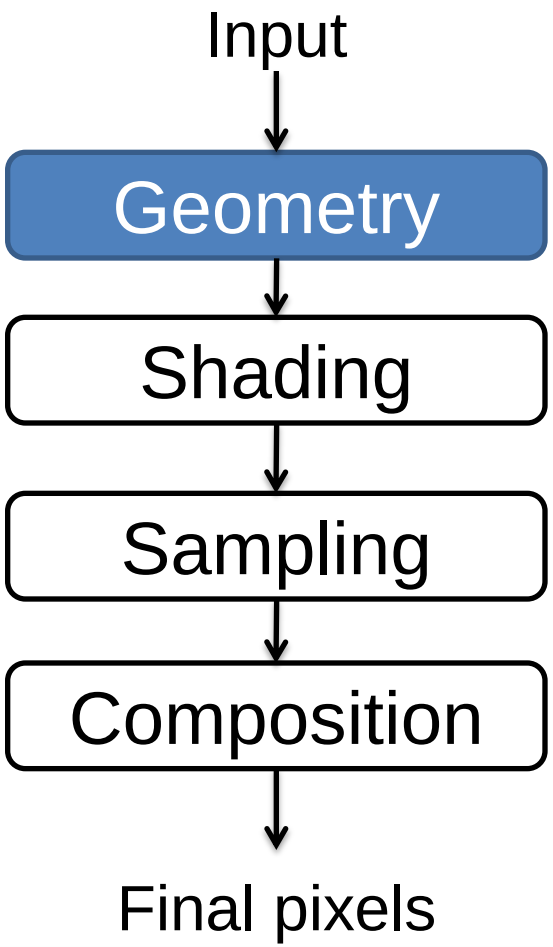
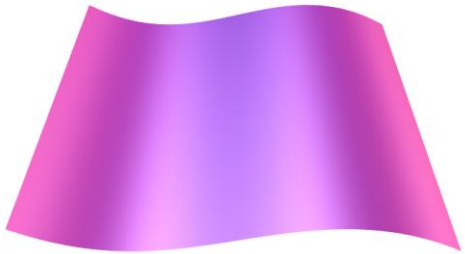


Input

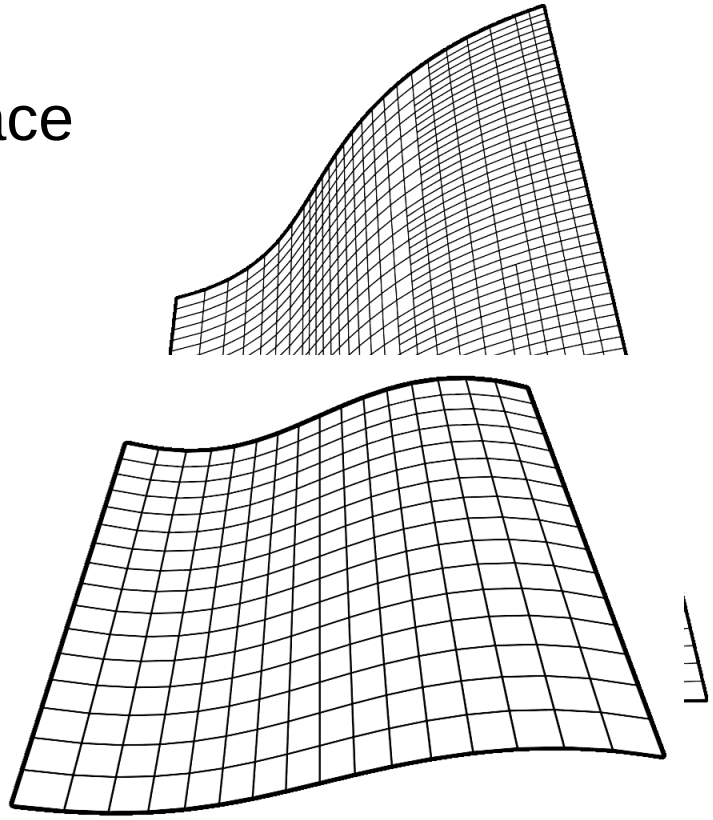
- Higher-order surfaces
  - Bézier surfaces
  - NURBS
  - Subdivision surfaces
- Displacement-mapped
- Animated



Hand image courtesy: Tamy Boubekeur, Christophe Schlick

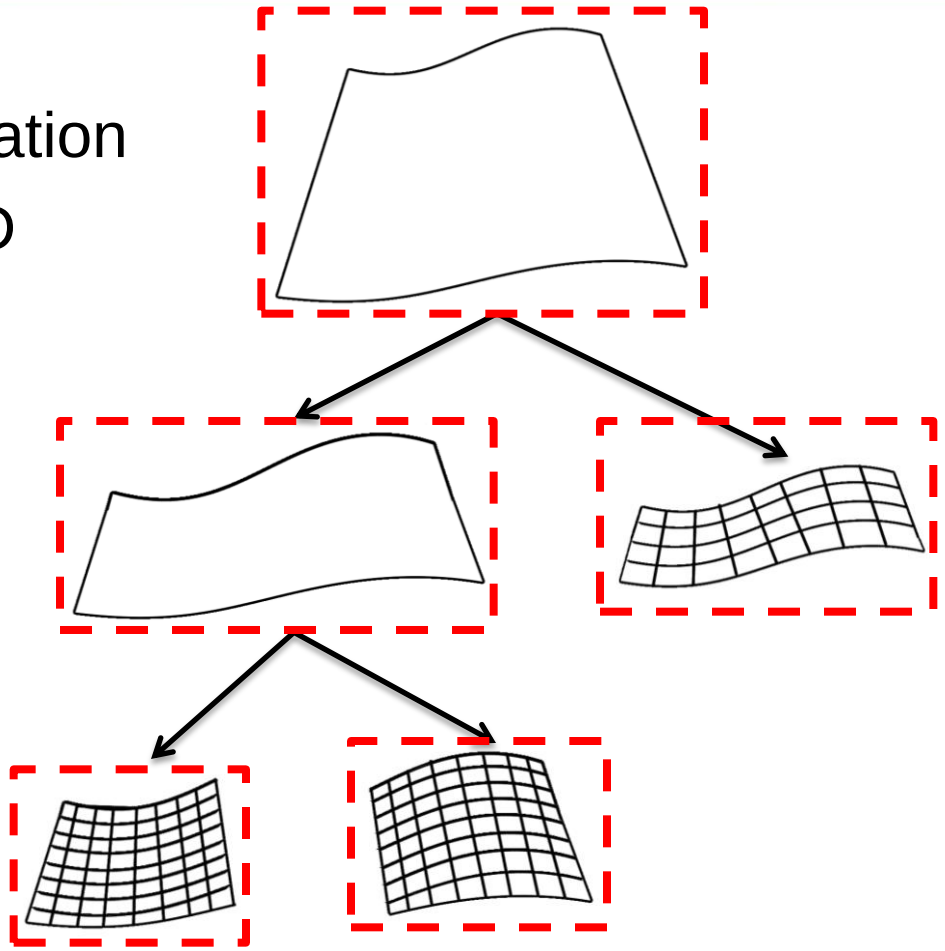
Task – Split and Dice

- Adaptively subdivide the input surface
- Tessellate when small enough
- Rinse and repeat



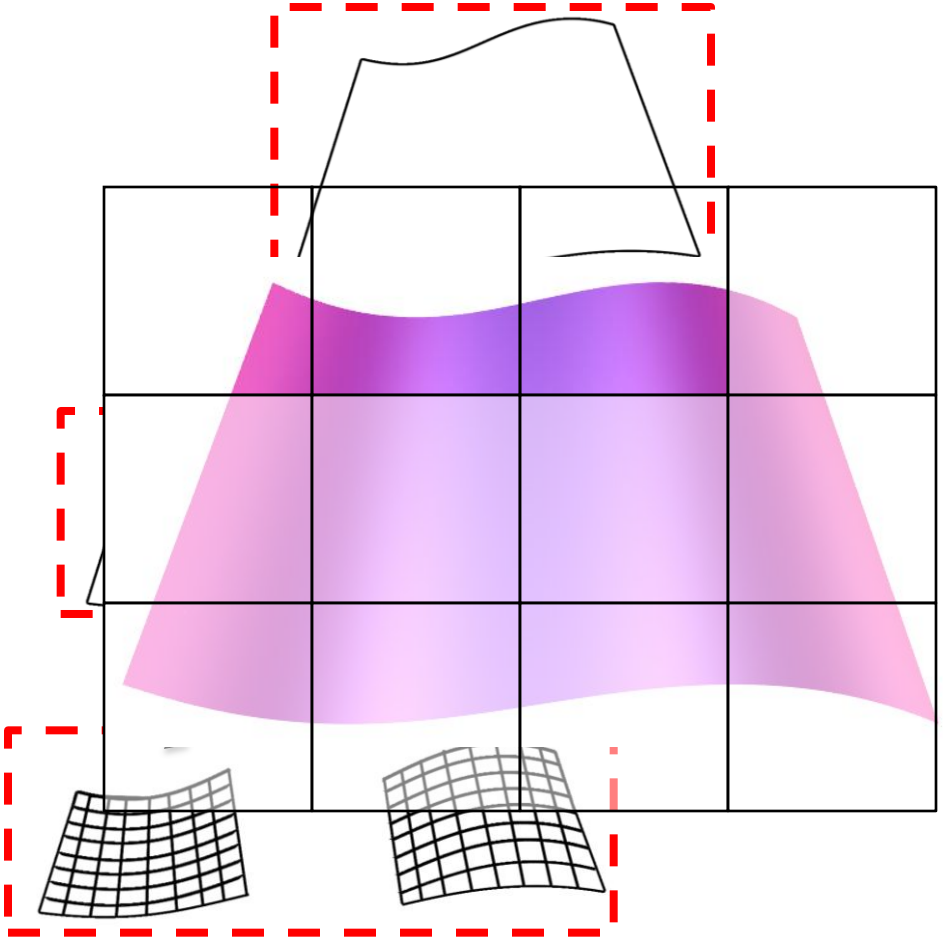
Challenges

- Recursive, irregular computation
  - Bad for parallelism, SIMD
- Too many micropolygons
  - Limited memory

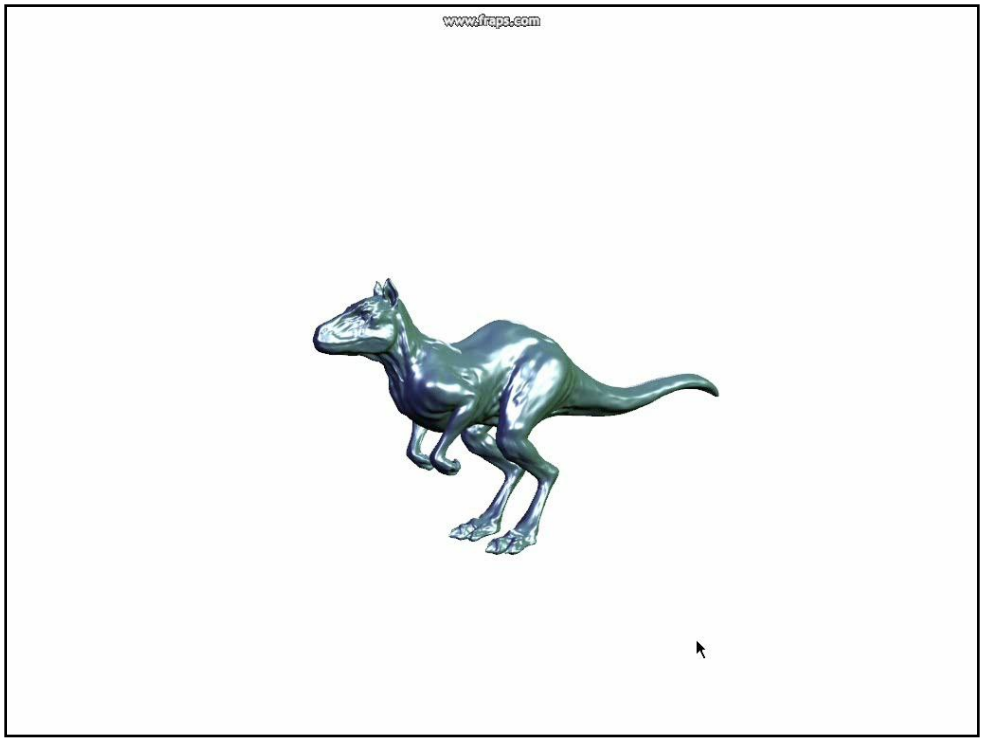


Ideas

- Breadth-first Traversal
- Bucket Rendering



Works in real-time!

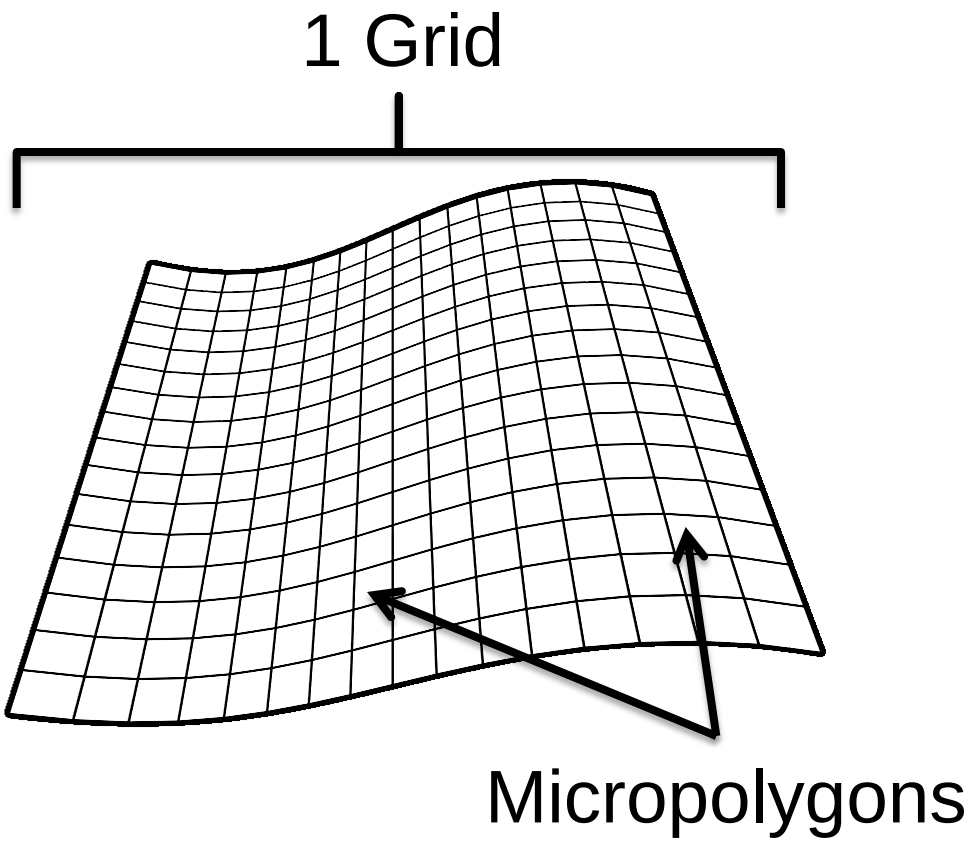


Patney and Owens, 2008

- Killeroo: 11532 Patches
- Split and dice in 9.8 ms
- 29.69 fps at 512 x 512
- Parametric surfaces only
- Subdivision cracks

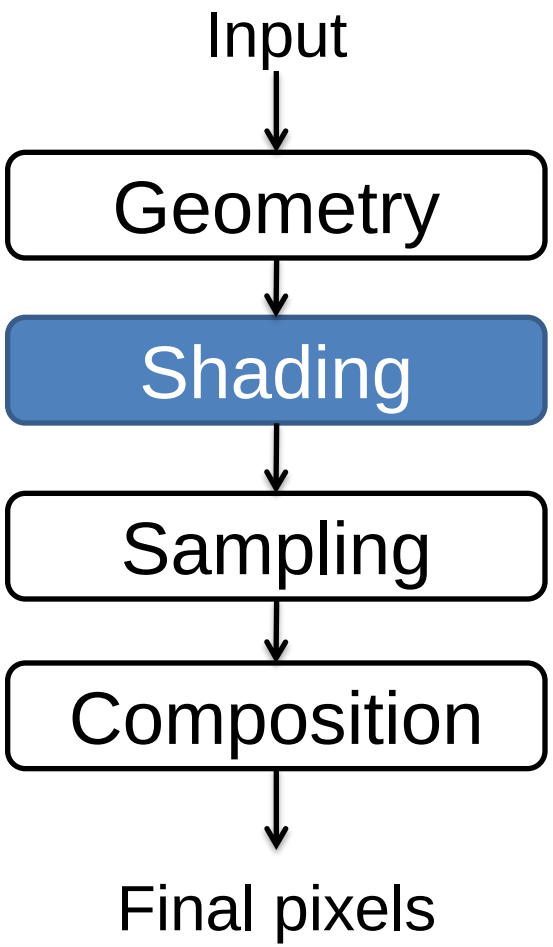
Killeroo Model Courtesy Headus Inc.

Geometry Output – Unshaded Grids



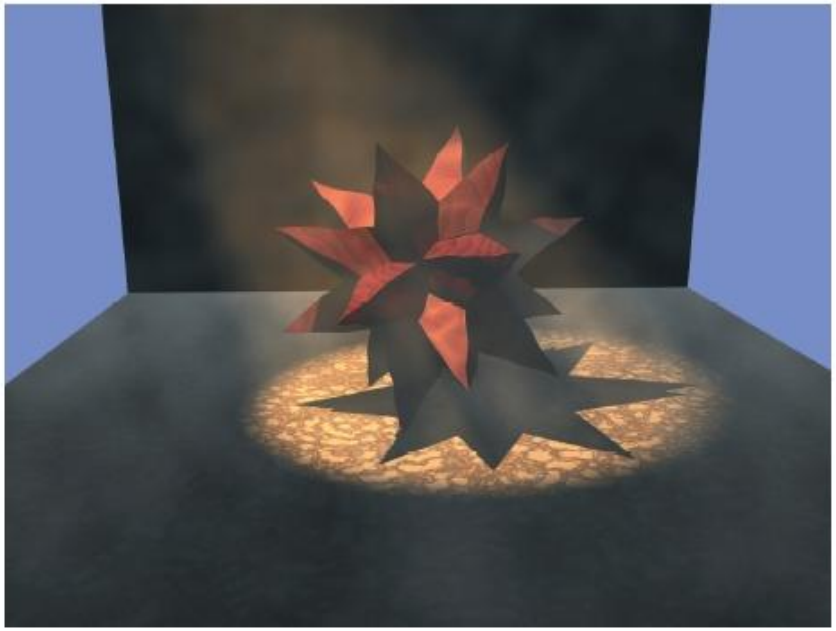
Step 2: Shading

Decide colors for grid micropolygons



Task

- Run shader(s) for each grid
  - Displacement
  - Surface
  - Light
  - Volume
  - Imager



- Good behavior
  - Highly parallel, SIMD friendly
  - Good locality behavior

Image courtesy: Saty Raghavachary

Challenges

- Massively parallel is great
  - But is it good enough?

- Shaders can be complex
  - Too many instructions, conditionals
  - Global illumination
  - File I/O
  - Arbitrary texture fetches

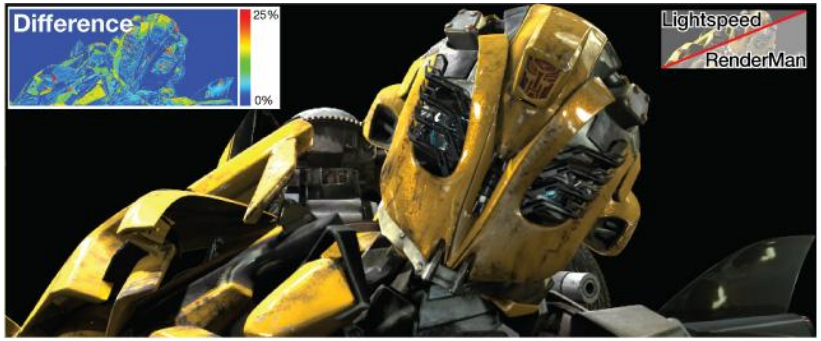
Ideas

- Cache redundant computation
  - Across a grid
  - Across frames
- Architectural support
  - Virtual memory

Interactive Relighting

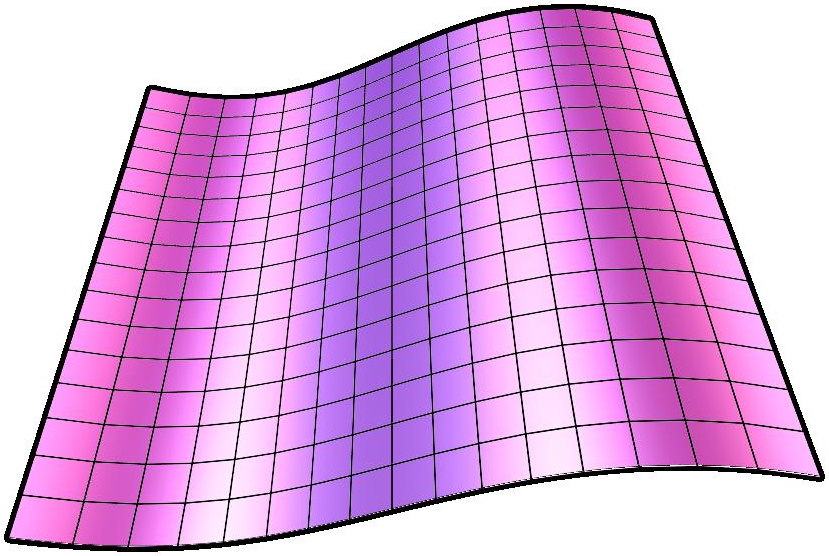
- Lpics [Pellacini 2005]
  - Cache image-space samples
  - Interactive feedback
  - Manual pre-processing

- Lightspeed [Ragan-Kelley 2007]
  - Shader caching
  - Interactive preview
  - Slow pre-processing

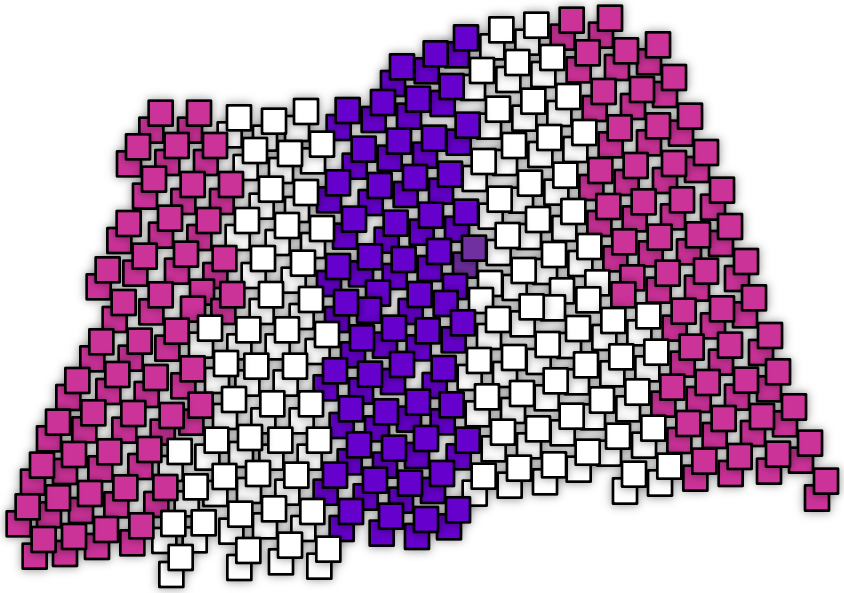


Images belong to respective paper authors

Output – Shaded Grids



Bust: Many micropolygons



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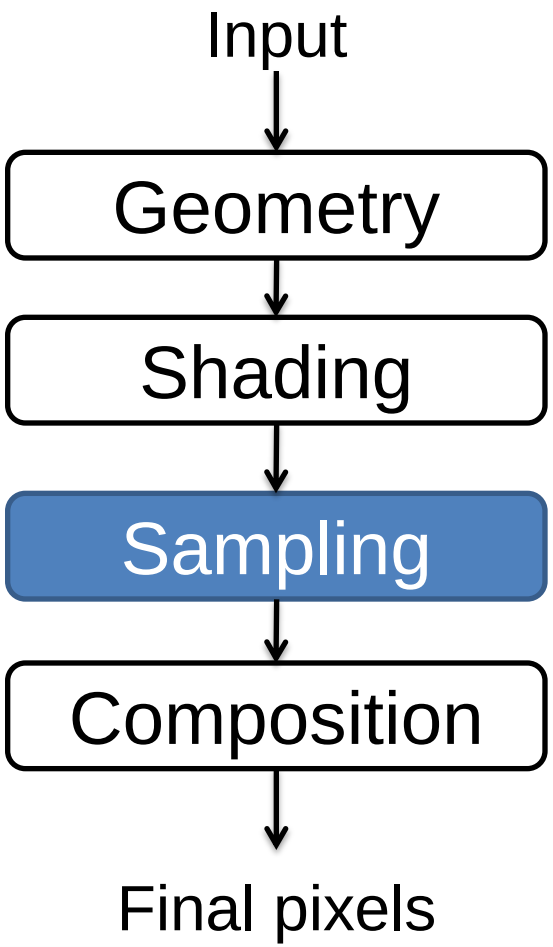
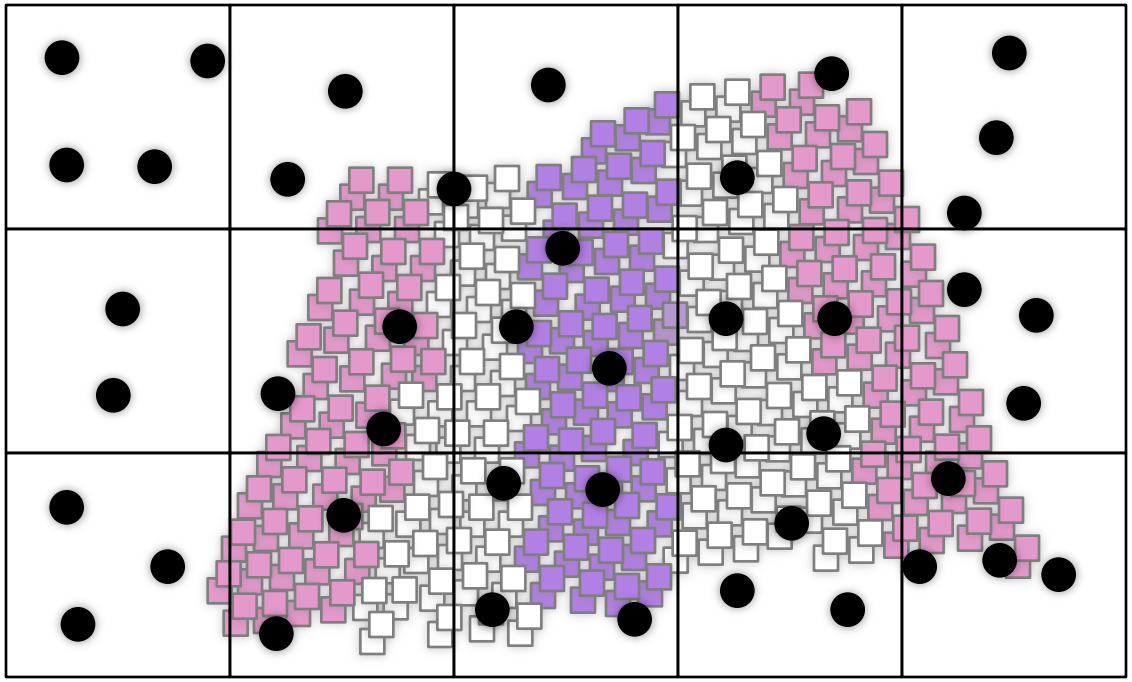
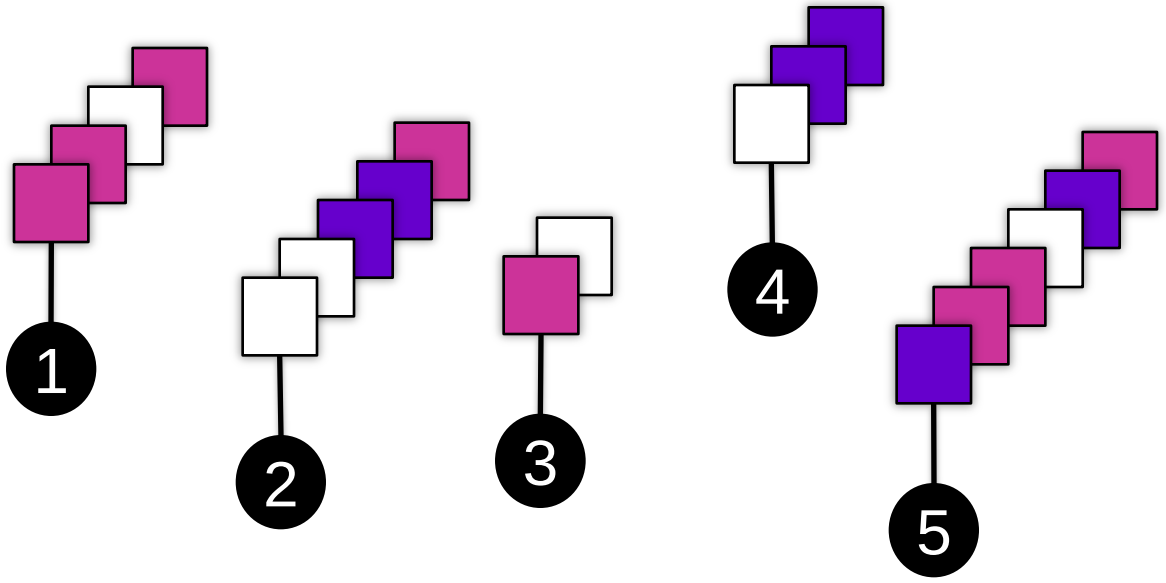


Task



Samples



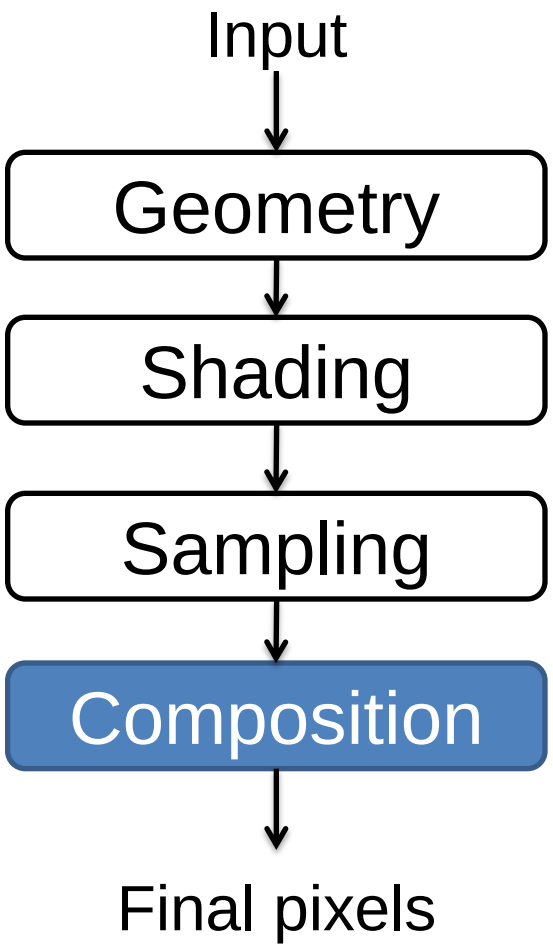
Challenges

- Generate samples
  - Jittered grid
  - Parallel Poisson sampling [Wei 2008]
- For each sample, find all intersecting micropolygons
  - Raycast or Rasterize?
- Output: A (depth-sorted?) list of samples

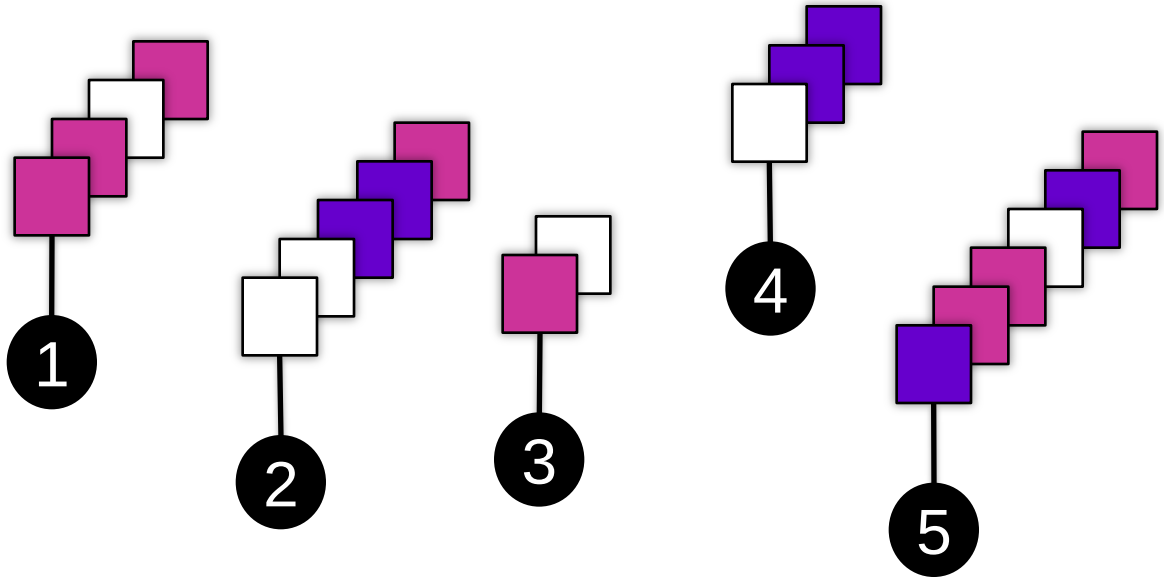
Step 4: Image Composition

Blend samples to get colors

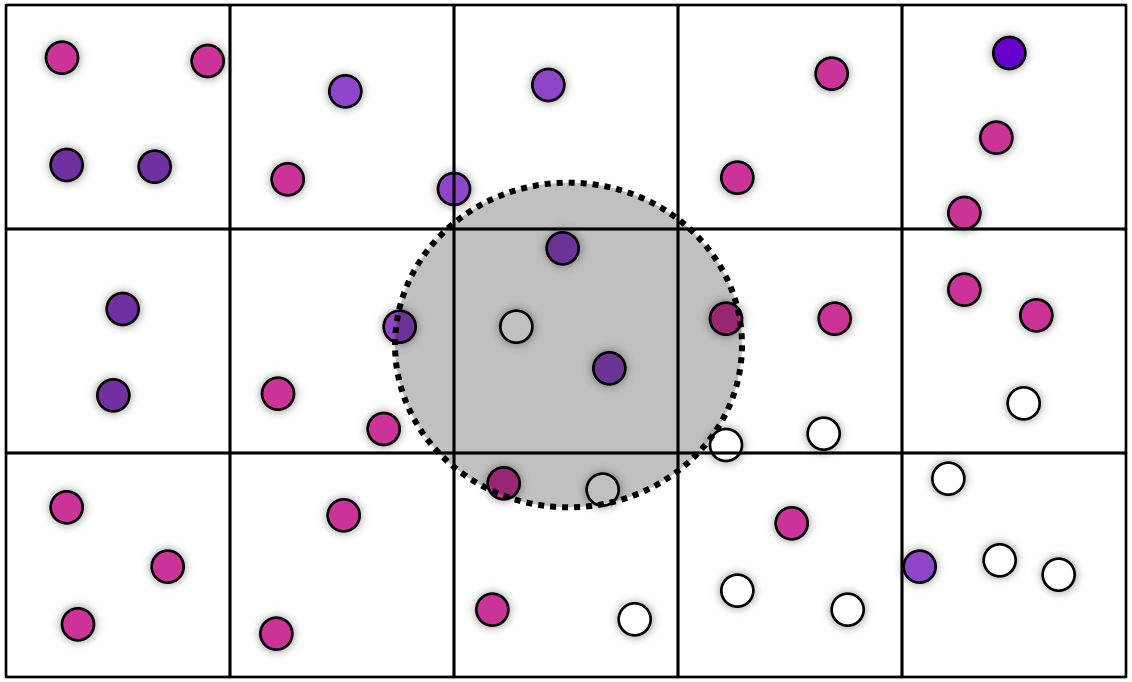
Combine colors to get pixels



Task 1: Blend

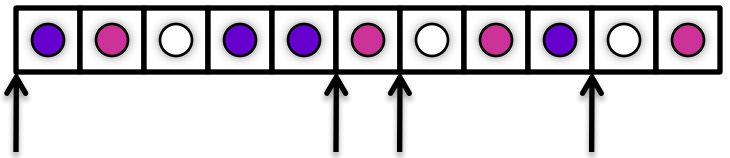


Task 2: Filter to get pixel colors



Challenges

- Represent the irregular work-list
  - Traditionally: linked-list per sample (arbitrary size)
- Sort and Reduce
  - Unequal work-items

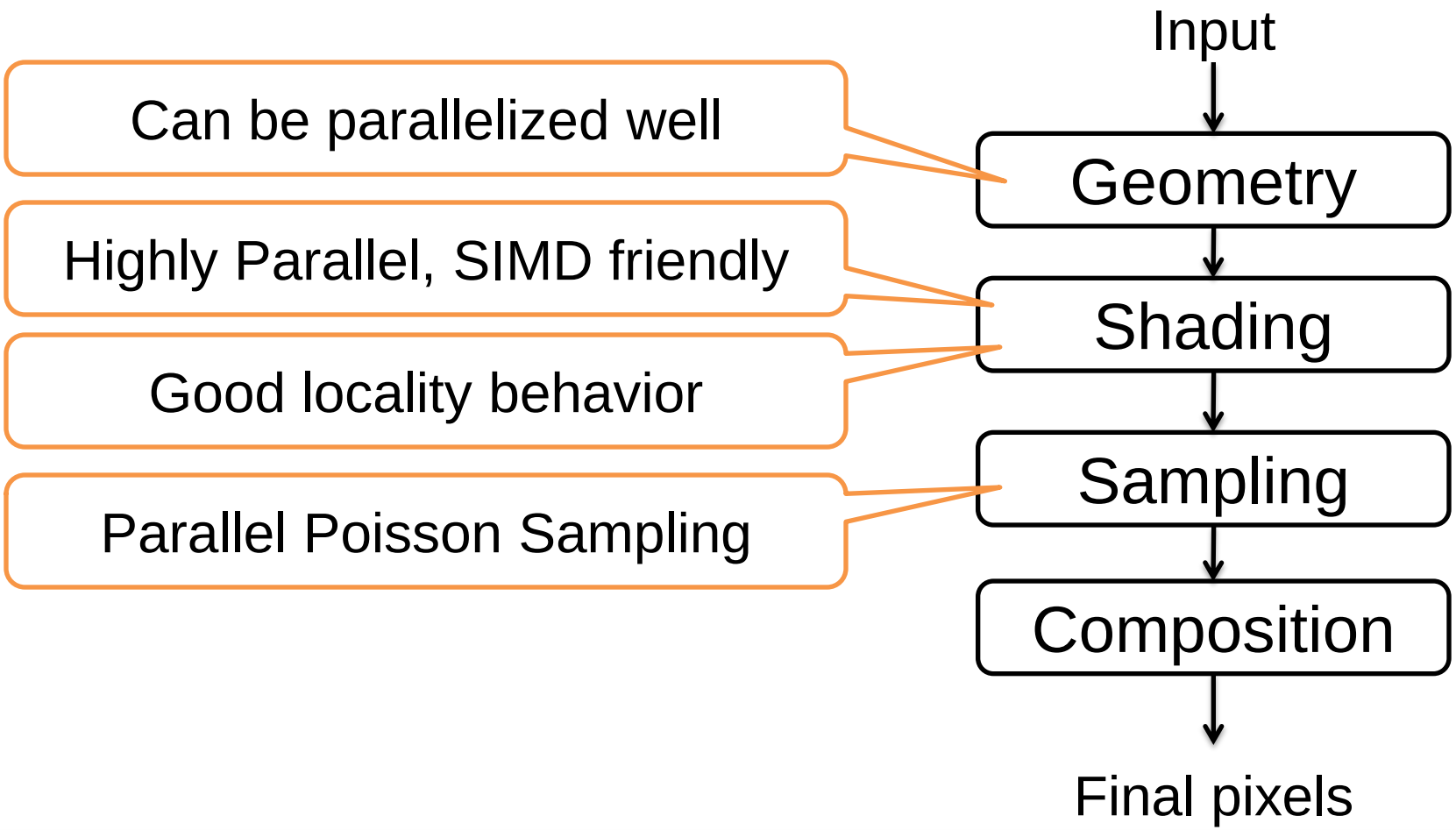


- Generate and apply filter kernels
  - Box
  - Gaussian

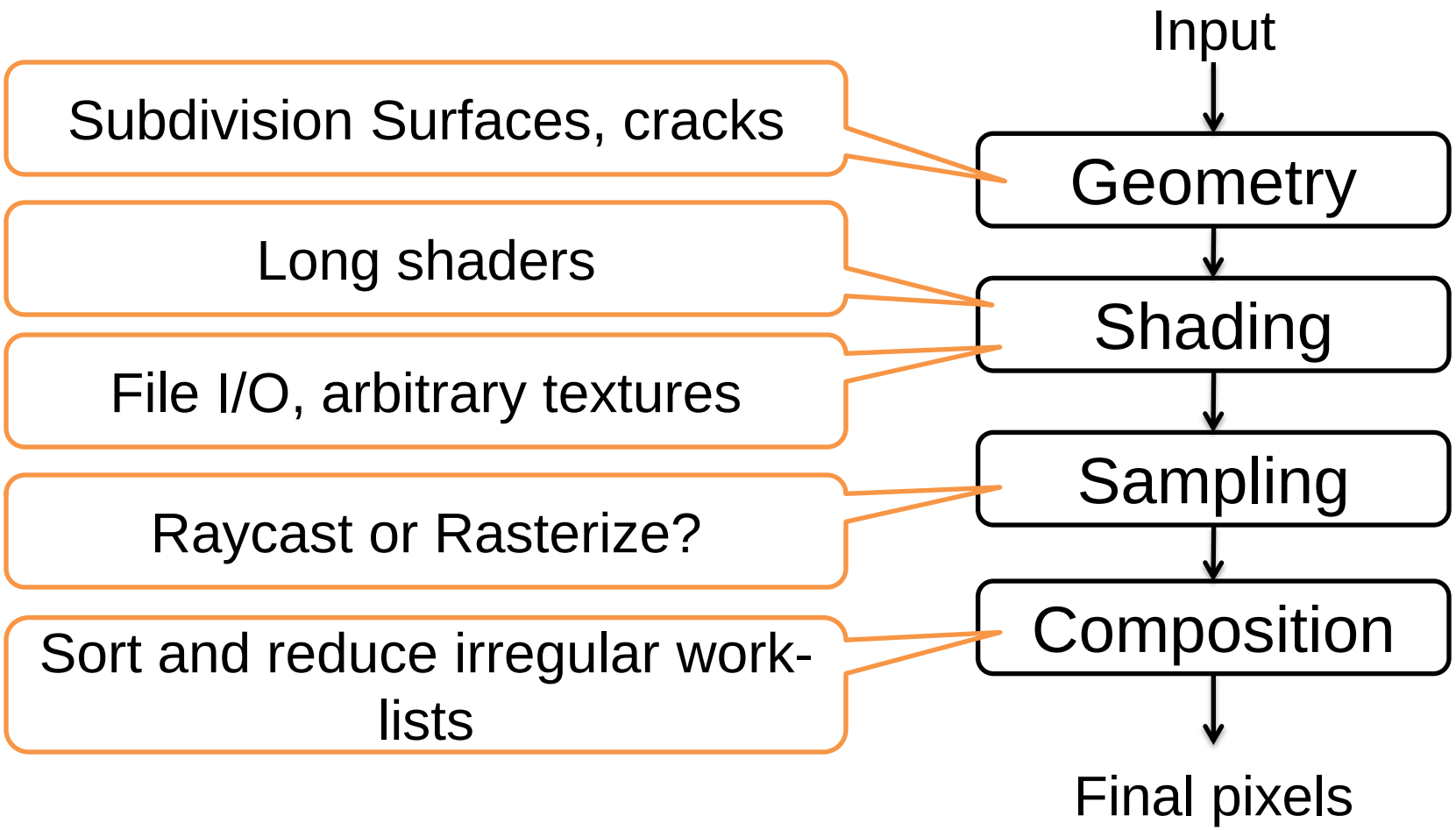
Stencil-Routed A-buffer

Myers and Bavoil, NVIDIA, 2007

Summary: What is easy?



Summary: What is hard?



Conclusion

- Reyes is promising for real-time
  - Enables natural high-quality rendering
  - Portions map well to current hardware
- But there are challenges
  - Everything isn't easy to implement
  - Architecture limitations
- Lots of interesting questions

Thanks to

- Course organizers
- Prof. John Owens, Shubho Sengupta
- Tim Foley
- Per Christensen
- Matt Pharr

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NEW HORIZONS

Realistic Effects using Reyes

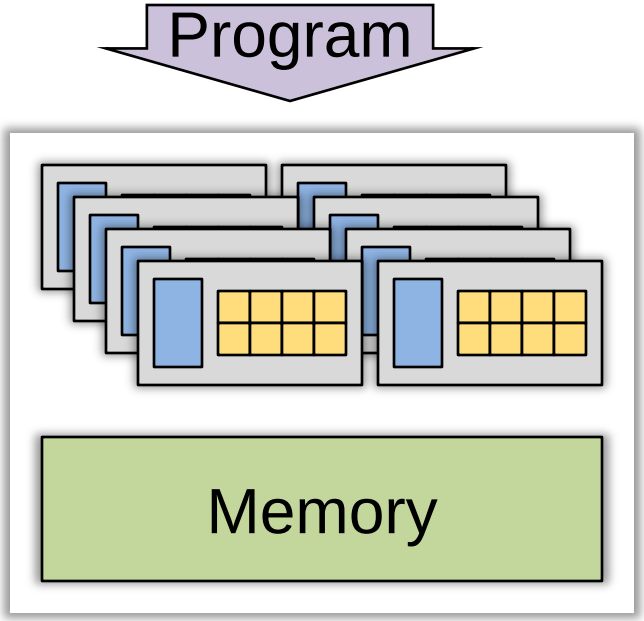
- Motion-blur
  - A stochastic time for each sample
  - Move micropolygons accordingly
- Depth-of-field
  - A stochastic lens position for each sample
  - Render micropolygons accordingly
- Take many samples to ensure quality
- Adjust screen bound during subdivision

Global Illumination with Reyes

- Traditional: shadow maps, environment maps
- Raytracing [Christensen et al. 2006]
  - Multi-level geometry cache
  - Ray-differentials to select appropriate resolution
- Effects taken care of
  - Shadows and reflections
  - Ambient Occlusion

My version of the world - today

- Many SIMD Cores (16-32)
- Precious memory bandwidth
- Data-parallel (SPMD)



My version of the world - tomorrow

- More cores, still SIMD (8-16)
- Memory bandwidth still precious
  - But flexible access behavior
- Data-Parallel and Task-Parallel