Adaptive
Real-Time Rendering

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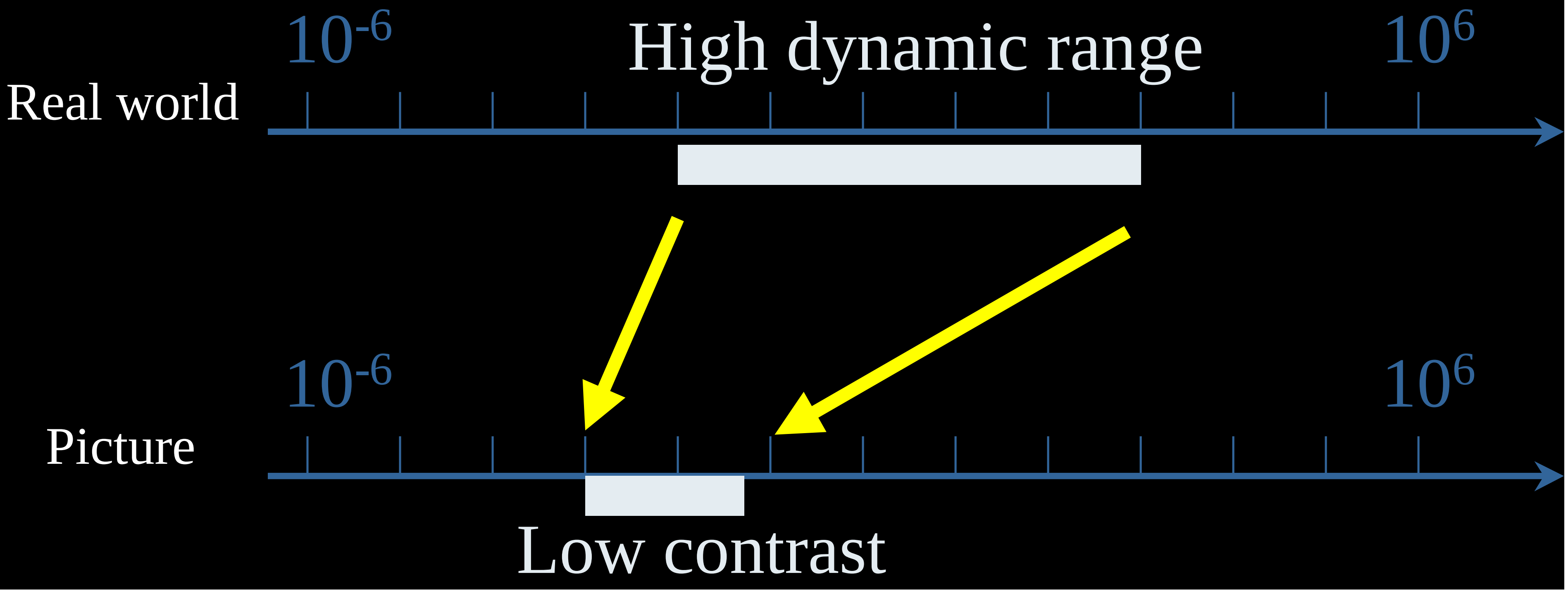
Digression: Photography & Video

- Enhancement
  - Contrast management
  - Flash photography
  - Capture style & skills from professionals
- Tools
  - Non-linear filtering
  - Gradient domain
  - Statistical analysis
- High Computational cost
- The Image is a stream

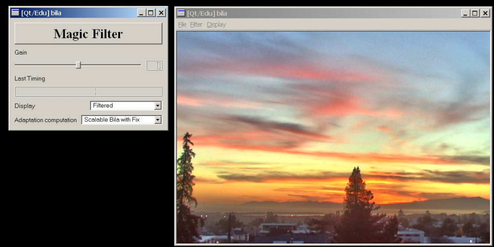
e.g. Contrast management

- Real world: high range of intensity (often 1: 100,000)
- Display or print have a limited contrast (1:50)



Live demo

- 1.6 GHz Pentium 4



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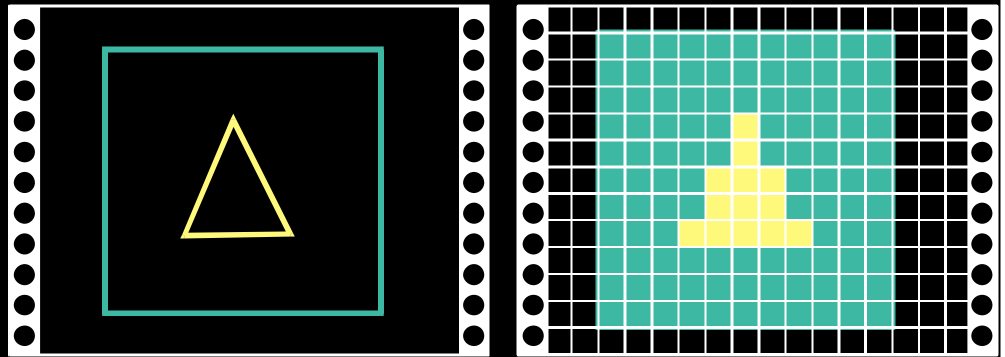
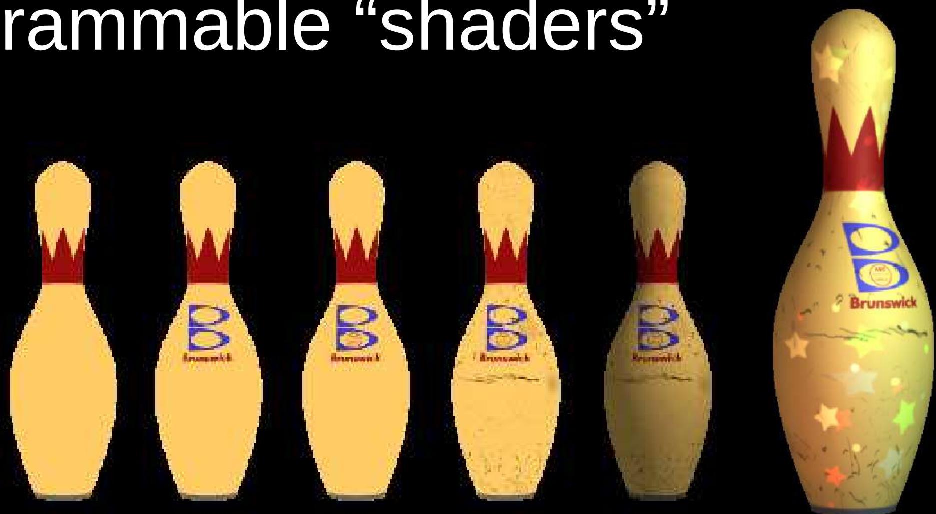
Real Time Rendering: Context

- Send geometry: mostly polygons
- Rasterization
- Visibility (z buffer)



- Appearance
  - Programmable “shaders”



Quality: amazing

Rules of the game

- Real time is Important
- Highly parallelizable
- We can degrade quality
- Multiple platforms/architectures
  - PC, PlayStation, GameCube, Xbox
- Various levels of parallelism
- Before an application (e.g. game) is shipped, a lot of optimization is affordable

Goals in Real-time graphics

- Better
  - Nicer appearance, better lighting
- Faster
  - Culling (do not draw what is hidden)
  - Simplification (for distant objects)
  - Optimizations (hardware specific)
- Easier
  - For the programmer
  - For the artists

Better: e.g Fake soft shadows

With Eric Chan

shadow map

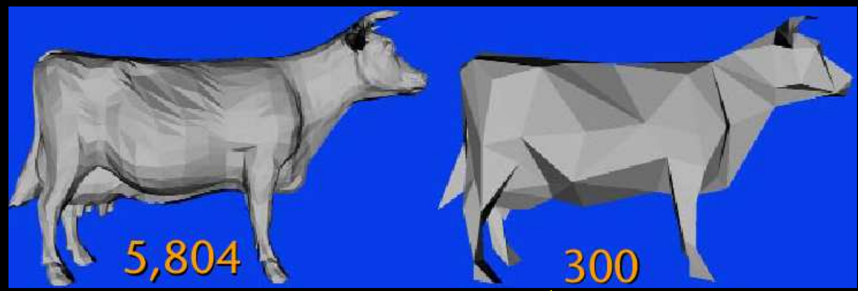
bicubic filter

Our method (t = 0.02)

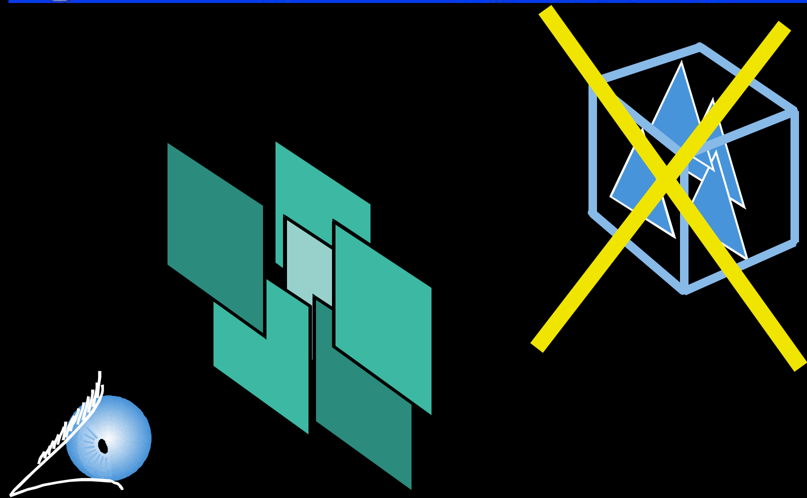
Our method (t = 0.08)

Faster

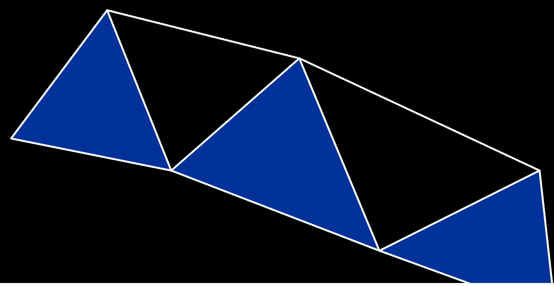
- Simplification: cheaper model for distant objects



- Culling
  - Do not waste resources on hidden objects

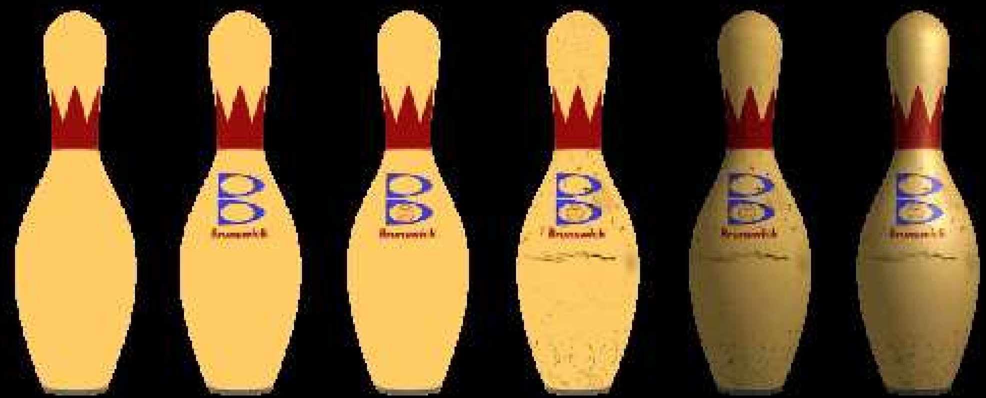


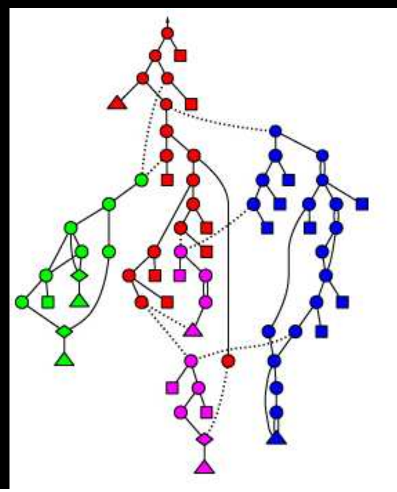
- Optimization
  - hardware specific



Hot Topic: Shader Simplification

- Adapt shader to hardware:
- Manipulation of expression tree
- Lossless: Hardware virtualization
  – [Chan et al. 02]
- Lossy: Degrade shader quality
  – Find simplification operations (peephole)
  – Predict impact of simplification





Simplification metric

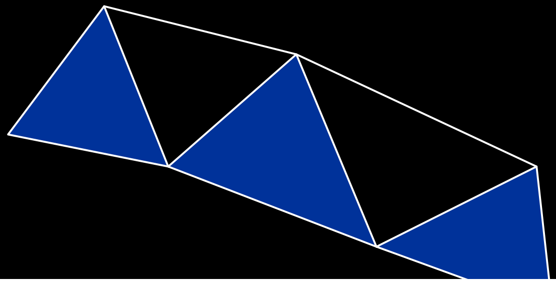
- Objective: Geometric, L2
- Subjective: perceptual
  - Use psychophysics
  - Just Noticeable difference
  - Masking (frequency content)
  - Saliency
  - Ad hoc developer judgment

Faster

- Simplification: cheaper model for distant objects

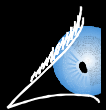
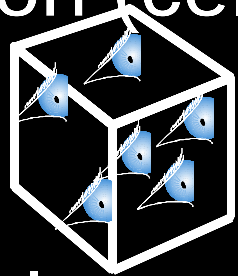
- Culling
  - Do not waste resources on hidden objects

- Optimization
  - hardware specific

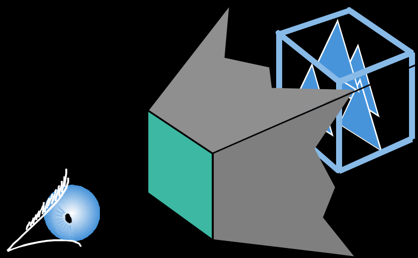
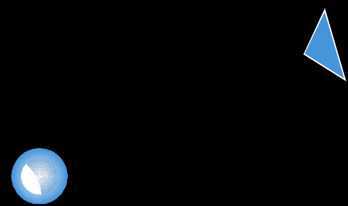


Visibility culling – many choices

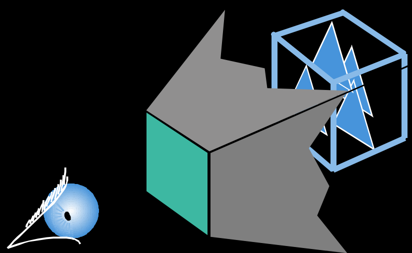
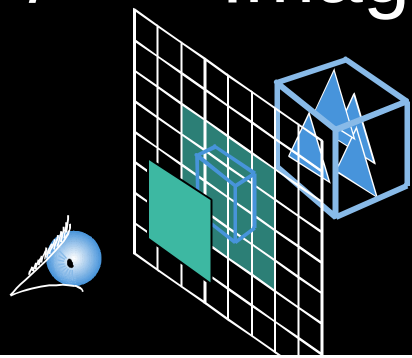
- point-based / From region (cells)

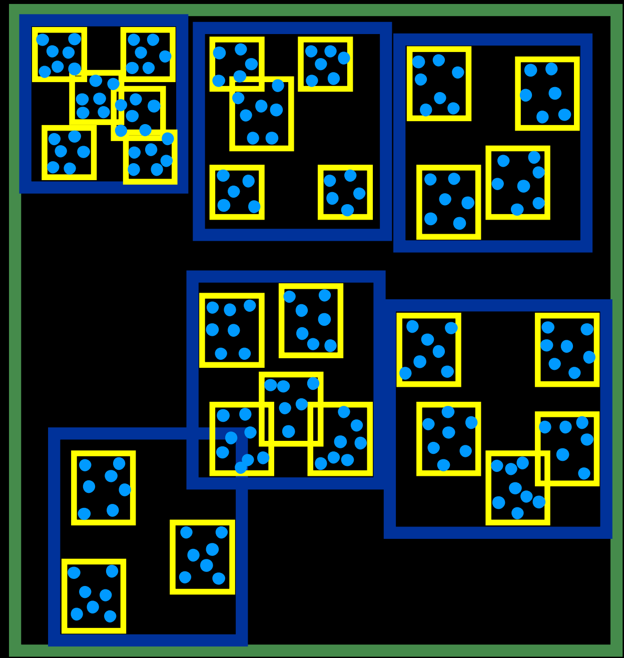
- Occluders / Portals

- Object space / Image space

Additional degrees of freedom

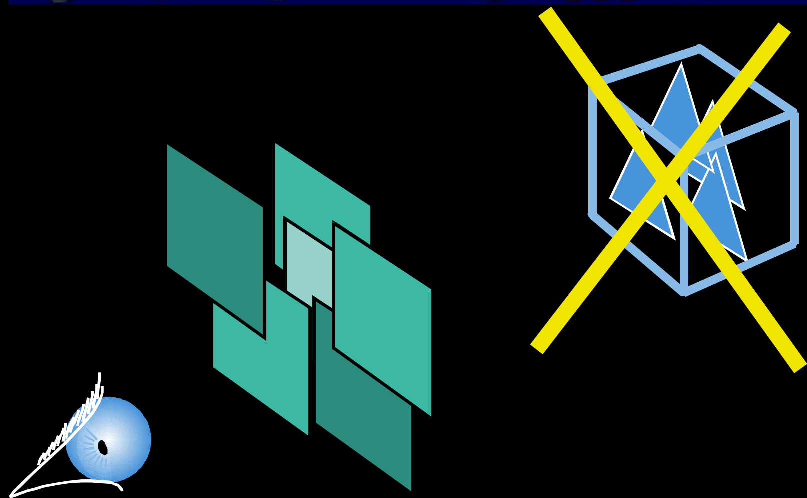


- Spatial hierarchy
  – Which hierarchy?
  – Which depth?
- Latency issues
  – E.g. occlusion queries:
    - Ask graphics hardware if object is visible
    - Large delay
  – Importance of scheduling

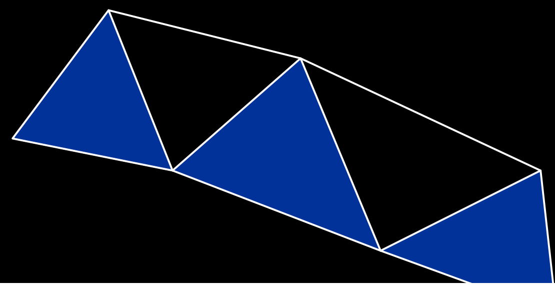
Faster

- Simplification: cheaper model for distant objects

- Culling
  - Do not waste resources on hidden objects

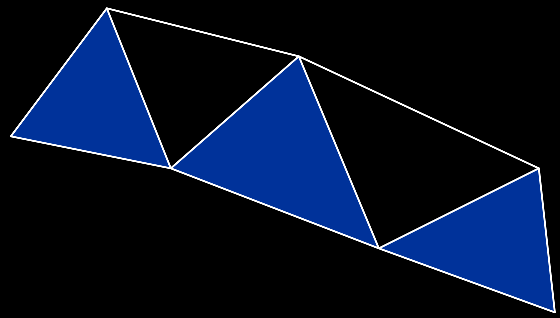


- Optimization
  - hardware specific



Faster: Low-level optimization

- Improve bandwidth/caching
  - Triangle strips
  - Vertex cache
  - Vertex arrays
- Avoid context switch
  - Sort by material
  - But conflicts with spatial hierarchy



Dealing with complexity

- Better and faster conflict with easier

=>Put more intelligence in the system

- – Inspiration from compilation, optimization, linear algebra packages

Adaptive real-time rendering

- Problem
  - Writing a fast rendering engine is a black art

  - Performances depend on
    - The hardware configuration (CPU, GPU bandwidth, memory)
    - The scene properties
  - It is impossible to optimize for all configurations
- Solution: automatic optimization
  and self-adaptive systems

Adaptive real-time rendering

- High-level
  - Choose acceleration strategies
  - Optimize parameters
  - Scheduling, latency (e.g. culling queries)
- Low level
  - Optimize how geometry is sent
  - Sort by material, find a smart order of triangles for better caching
- Hardware level
  - Reconfigure hardware
  - E.g. shadows in Doom 3 make most of the programmable transistors idle

Rules of the game

- Real time is Important
- Very repetitive computation
- We can degrade quality
- Multiple platforms/architectures
  - PC, PlayStation, GameCube, Xbox
- Various levels of parallelism
- Before an application (e.g. game) is shipped, a lot of optimization is affordable

Thanks

Invitation

- Opportunities for much architecture and compiler research
- One big difference: quality can be degraded

Real-time shaders

- Capabilities vary tremendously
  - Some hardware is not programmable
  - Different set of instructions
  - Different control structures
  - Different speed
- Hard to develop for all platforms
- Developers target for 1 or 2 platforms

Goal

- Systems that can adapt
  - To the hardware resources
  - To the scene
- Real-time
  - Set the minimal frame rate
- Adaptation
  - Tune the parameters
  - Choose the algorithms
  - Static and dynamic
- Longer-term: distributed context

Degrade the image to reach real time

- Frame rate is more important than image quality
- Generalize the notion of levels of details
- Study precisely how framerate varies
- Prediction of rendering time
- Control problem
- Perceptual metric to estimate image degradation

Pervasive computing makes it harder!

- Very different resources
  - PDA, laptop, desktop
- Distributed
  - Maybe the framebuffer is on one machine, the display on the other machine, etc.
  - Bandwidth and latency must be taken into account
- Load varies
  - Dynamically adapt to load variation

Challenges

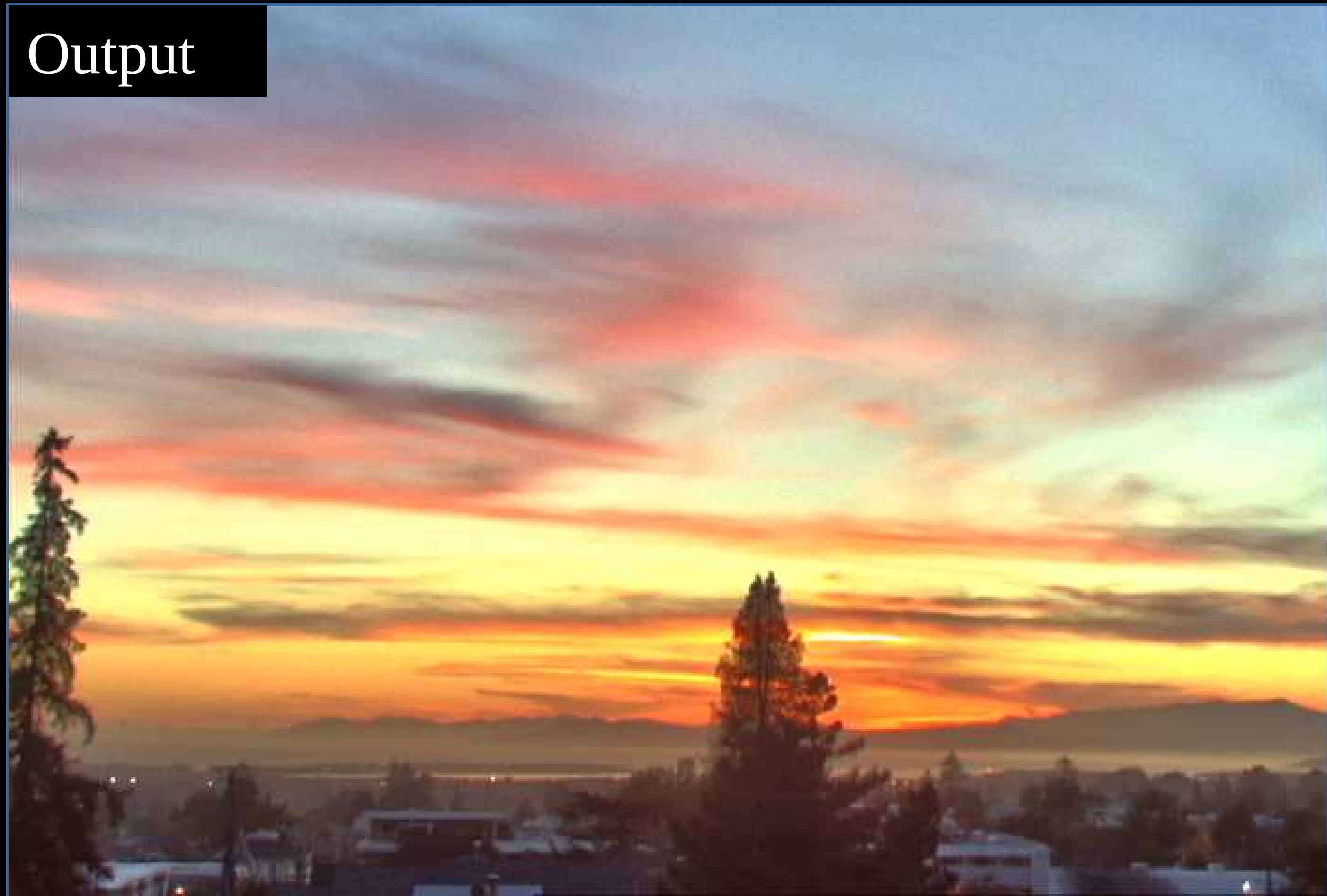
- Flexible architecture
- More flexible acceleration techniques
- Shader simplification and levels of detail
- Transitions between levels of details
- Speed prediction (statistics, law)
- Optimize the algorithms and parameters

High-performance compilation

- Better than scientific computing ;-)
- Industry demand
- Performance matters
- Programs are smaller
- Analysis and profiling
- Result can be changed

Our approach

- 2-scale decomposition of intensity



Feedback & optimization

- If we know the final image, we can optimize for it
- Reduction operators
- Delay streams and others
  - It is easier to optimize when you know the results
- Adaptive, perception, masking
  - Masking
  - Gaze

What is the situation?

- Everything needs to be precisely targeted
- Usually choose one or two target platform and optimize manually
- Each programmer have their favorite algorithms

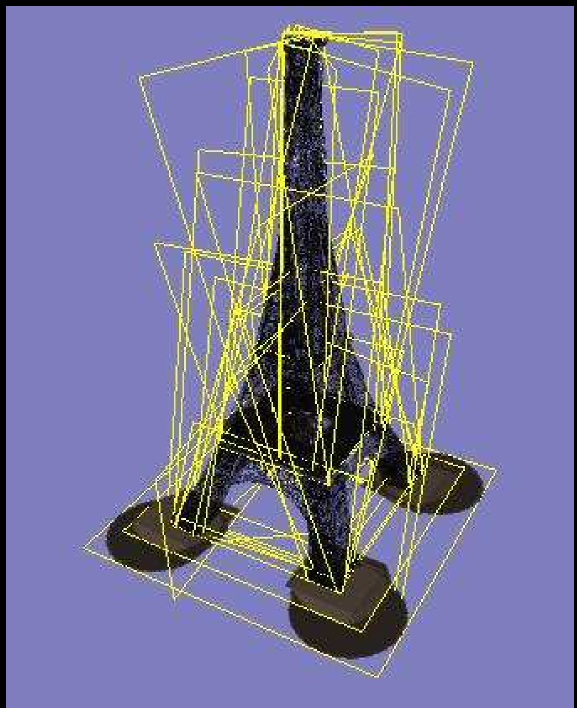
- Tedious
- Sub-optimal for most platforms

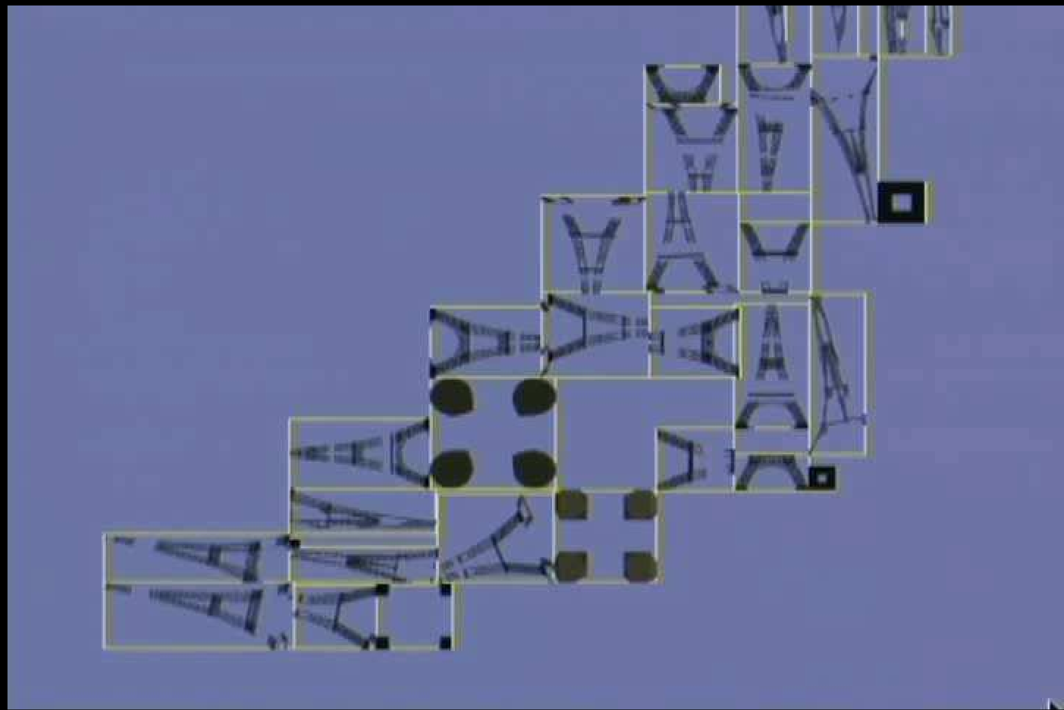
- Real-time is not ensured

Simplification: Billboard clouds

(Decoret, Durand, Sillion and Dorsey)

- Approximate shape by a set of plane
- Project model on these planes => textures





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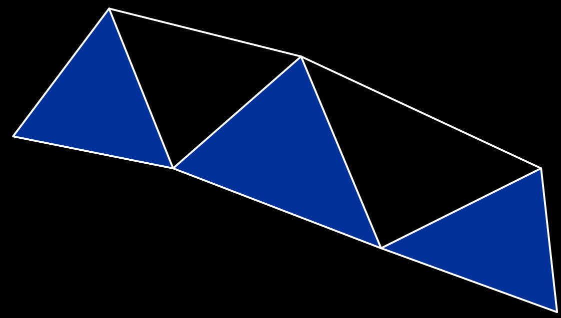

- Avoid context switch
  - Sort by material

- Electronic Art uses an art-asset compiler