High Quality Surface Splatting on Today's GPUs

Mario Botsch, Alexander Hornung, Matthias Zwicker, Leif Kobbelt





# Introduction

- Point-based representations suitable for massive data sets
- Rendering is important for interactive applications
  - High performance
  - High visual quality









## **Current PBR methods**

- High quality
  - Projectively correct rasterization
  - Phong shading
  - EWA anti-aliasing
- ... or high performance





## **Current PBR methods**

- Trade-off performance against quality
  Limited by available GPU features
- Exploit latest GPUs' features to get both







## • Related Work

Deferred Shading

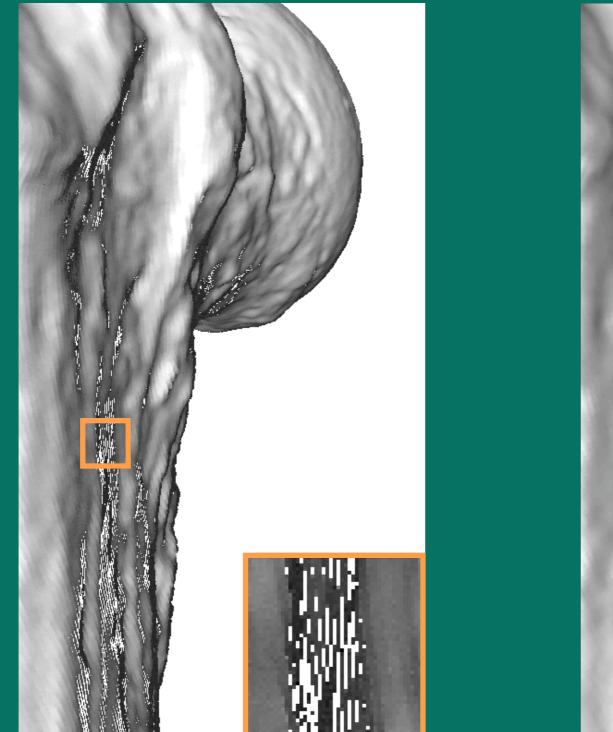
- EWA Filter Approximation
- Results







# **Perspectively Correct Rendering**





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# Per-Pixel Phong Shading







Gouraud Shading



Phong Shading





## Anti-Aliasing

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## No filtering

### **EWA** filtering

### INTERACTING WITH OUR OTHER SENSES

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# Comparison

	Persp. Correct	Phong Shading	Anti- Aliasing	Splats/ sec
EWA Splatting	X	$\checkmark$	$\checkmark$	1M
NV30 Splatting PG '03	X	X	X	27M
Persp. Accurate GI '04	(√)	X	$\checkmark$	5M
Phong Splatting PBG '04	$\checkmark$	$\checkmark$	X	6M
NV40 Splatting PBG '05	$\checkmark$			







Related Work

• Deferred Shading

• EWA Filter Approximation

Results







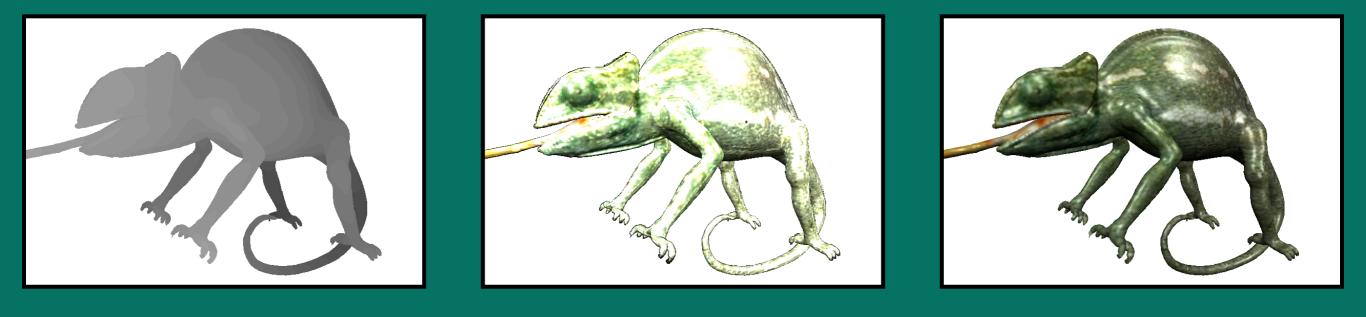
# Phong Shading for PBR

- Interpolate normal vectors
   No connectivity like for meshes
- Assign linear normal field
  Limited to static geometries
- Splat normals into framebuffer
  Deferred shading





## **3-Pass Shading**



Visibility Splatting Shading Blending

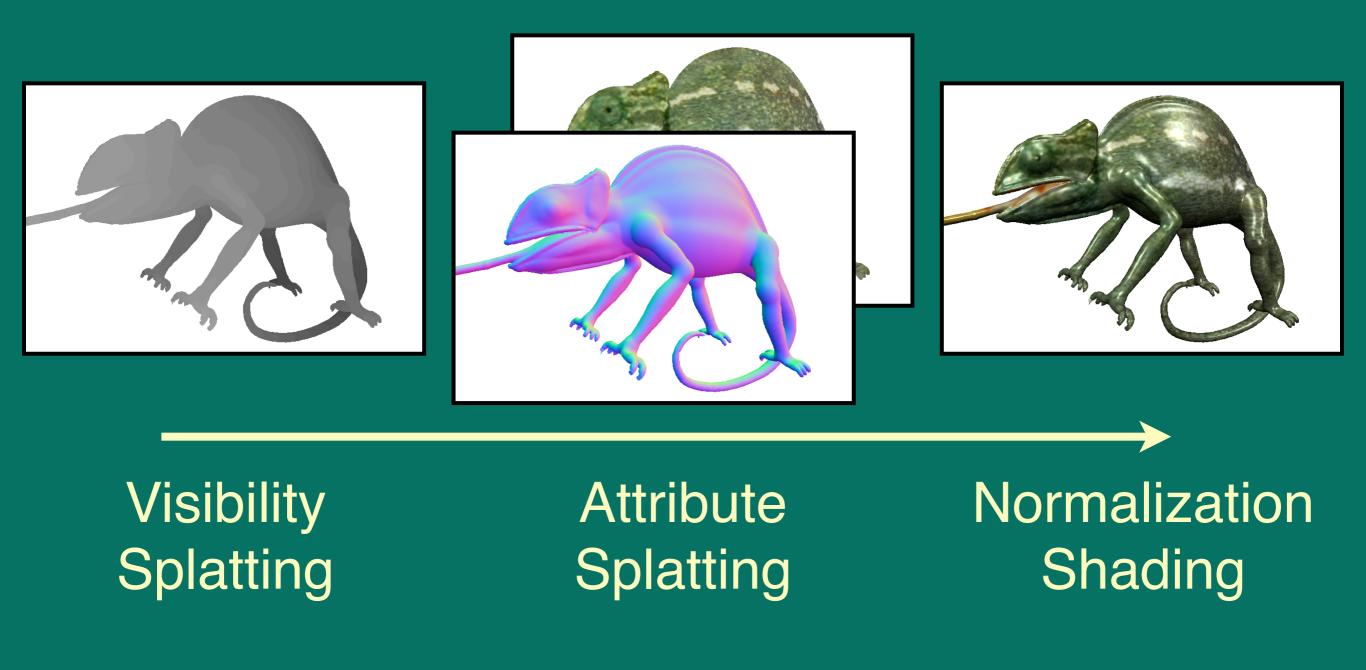
Normalization







## **3-Pass Deferred Shading**







# **Deferred Shading**

- Compute lighting for each <u>image pixel</u>, not for each <u>generated fragment</u>
- Splats mutually overlap
   #fragments ≈ 7 · #pixel
- Rasterization shader is bottleneck
  Keep it small by deferring shading

Performance does hardly depend on surface shader complexity

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# **Deferred Shading**

- Clear separation between rasterization and surface lighting / shading
- Simplifies shader development
   Same shader as for meshes





## **Required GPU Features**

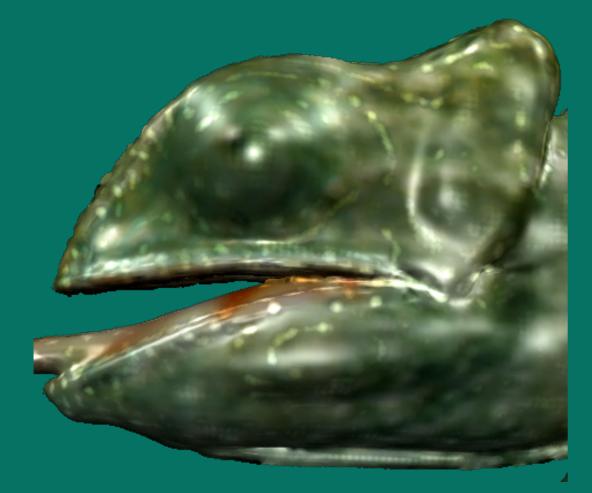
- Render attributes to several buffers
  Multiple render targets (MRT)
- Accumulate at high precision
  Floating point arithmetic
  Floating point buffers
  Floating point textures
  Floating point blending





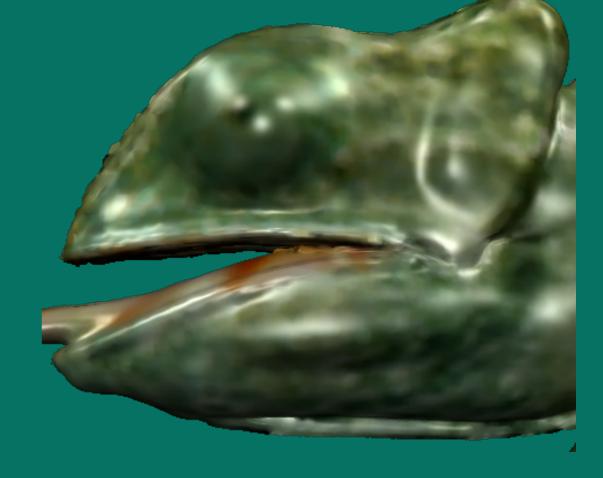


# Floating Point Precision



## 8 bit ubyte clamped to [0,1]

## 16 bit float un-clamped









## Related Work

Deferred Shading

- EWA Filter Approximation
- Results





## **EWA Anti-Aliasing**

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## Screen-space low-pass filter

**Object-space** reconstruction filter





# **EWA Filtering**

Combine both filters into one Choose both as Gaussians Affine approximation to projection GPU implementation in GI '04 Complex computations About 5M splats/sec

Screen-space filter often omitted

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## **Object-Space Filter Only**

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### INTERACTING WITH OUR OTHER SENSES

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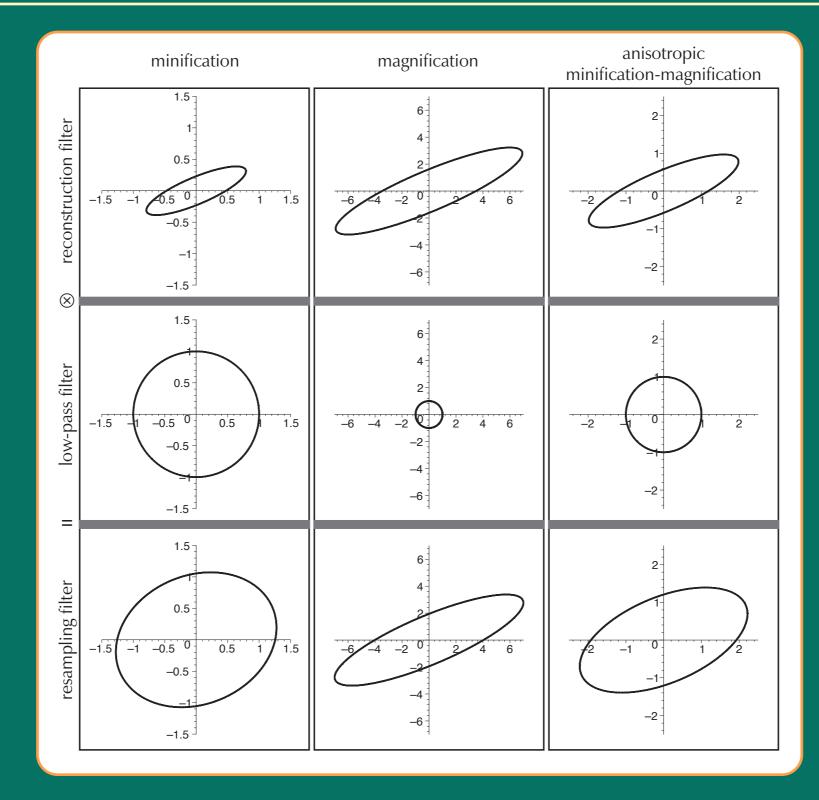
### No filtering

### **Object-Space**



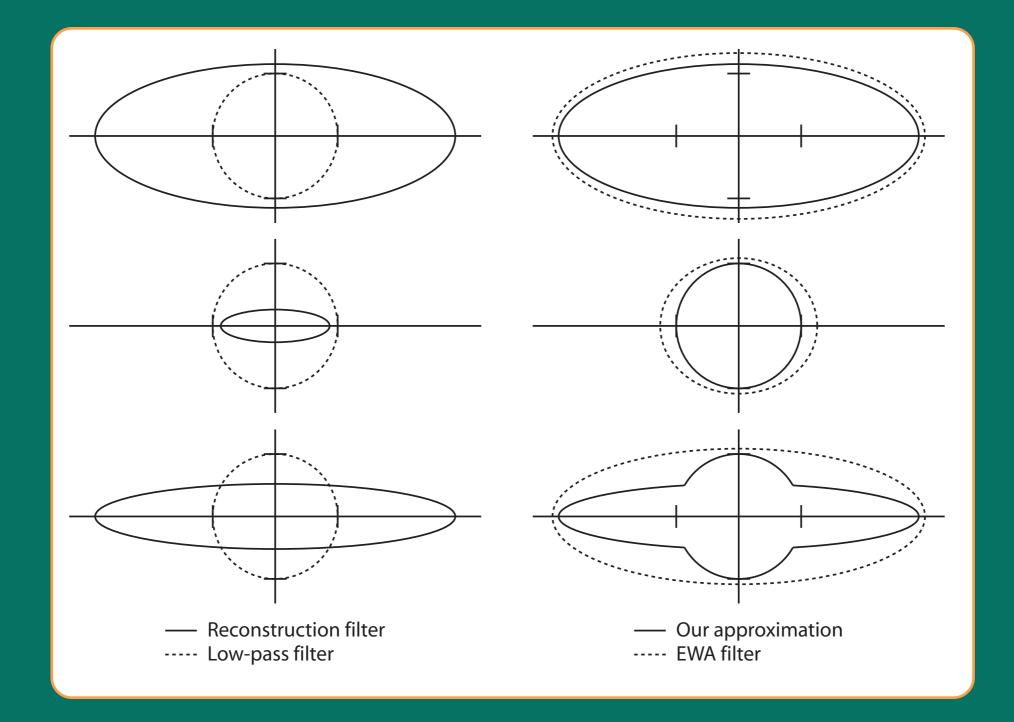


# **EWA Filtering**







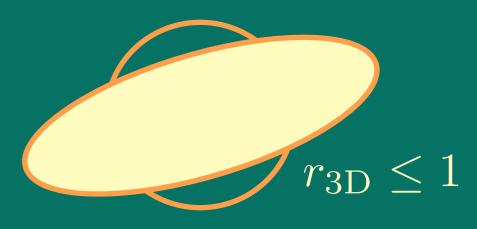




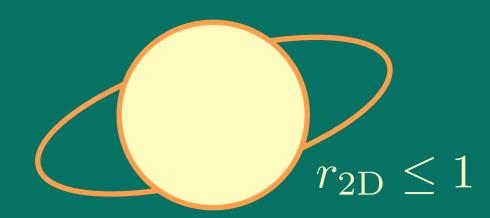




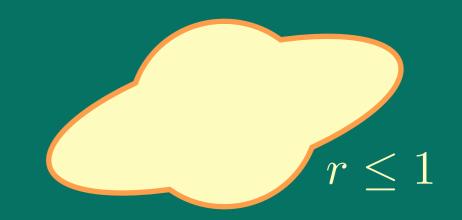
• Reconstruction filter radius  $r_{3D} := \sqrt{u^2 + v^2}$ 



• Screen-space filter radius  $r_{2\mathrm{D}} := d(x, y) / \sigma$ 



• Combined filter  $r := \min \{r_{3D}, r_{2D}\}$ w := Gauss(r)





- Restrict minimum projected splat size to  $2\sigma \times 2\sigma$  pixels
  - Ensure enough fragments for AA
  - Done in vertex shader
- Combine minimum of radii
  - Done in fragment shader
  - 3 additional instructions only





Simple approximation to exact EWA
Efficient implementation
Removes (most) aliasing

Generates much more fragments
 #fragments ≈ 30 · #pixel
 Deferred shading!







## Related Work

Deferred Shading

- EWA Filter Approximation
- Results





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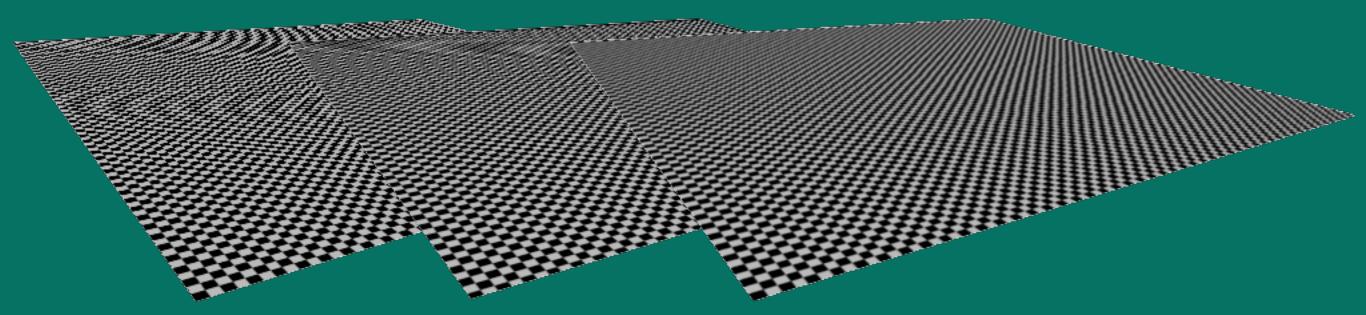
### No filtering

### **Object-Space**

## **Object-Space Screen-Space**

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**Object-Space** 

## Object-Space FSAA

## Object-Space Screen-Space





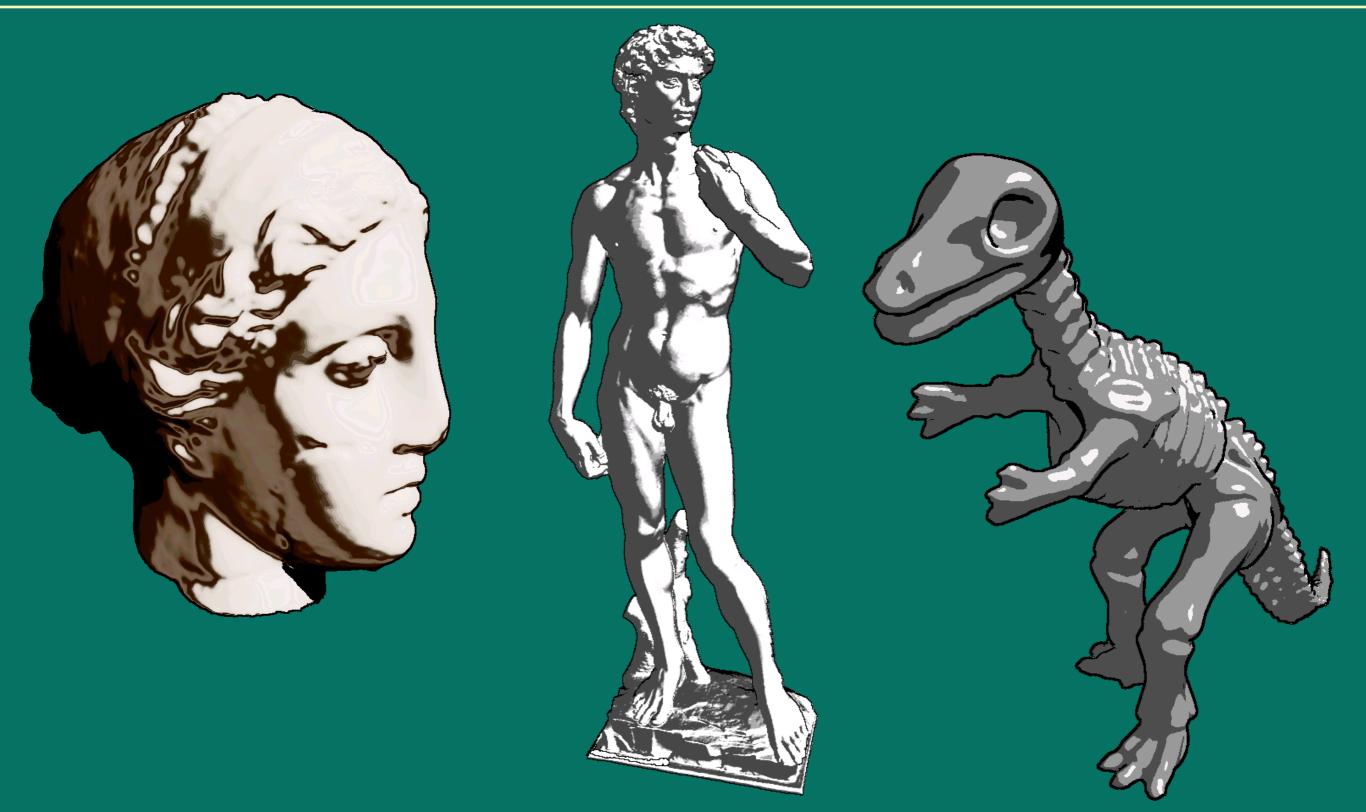
# Phong Shading







# NPR Shading







# Timings & Comparison

- Models from 100k to 14M splats
- Different surface shaders (GeForce 6800 Ultra)

	#instructions	Msplats/sec
Phong	8	22.8
NPR	48	21.3
Phong+Shadow	23	15.7
NPR+Shadow	61	15.0
PG '03		25.0
PBG '04		5.2





# Comparison

	Persp. Correct	Phong Shading	Anti- Aliasing	Splats/ sec
EWA Splatting	X	$\checkmark$	$\checkmark$	1M
NV30 Splatting PG '03	X	X	X	27M
Persp. Accurate GI '04	(√)	X	$\checkmark$	5M
Phong Splatting PBG '04	$\checkmark$	$\checkmark$	X	6M
NV40 Splatting PBG '05	$\checkmark$	$\checkmark$	(√)	23M





## Conclusion

Latest GPUs offer important new features
Multiple render targets
Floating point pipeline

Allows for fast & high quality splatting
Deferred shading

EWA approximation



