Voicu Popescu, Chunhui Mei, Jordan Dauble, and Elisha Sacks
Purdue University

Reflected-Scene Impostors for Realistic Reflections at Interactive Rates

Reflections—a difficult problem

- Every reflector is a portal onto a world which is as rich as the directly observed scene and which has complex image formation laws

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Prior work—vast

Ray tracing	Image-Based Rendering
Feed-forward reflection rendering	Approximation of reflected scene

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Problem of rendering reflections

- Compute
  - Intersection with reflector
  - Reflected ray
  - Intersection with reflected scene
  - antialiasing

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Problem of rendering reflections

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"OpenGL"

???

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Reflected-scene approximation

- Reflected scene replaced with approx. that provides
  - Fast intersection with ray
  - Antialiasing

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Reflected-scene approximation

- Example: environment mapped reflections
  - Reflected scene infinitely far away
  - Straight forward intersection with ray
  - Antialiasing computed in 2D (mipmapping)

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Reflected-scene approximation

- Example: environment mapped reflections
  - Reflected scene infinitely far away
  - Straight forward intersection with ray
  - Antialiasing computed in 2D (mipmapping)
  - Drastic approximation, incorrect results close to the reflector

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Our approach

- Approximate reflected scene with impostors
  - Considerable prior work on impostors
  - Reflector surface prevents desired viewpoint from getting too close to the impostor
  - Reflection distortion hides impostor artifacts

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Impostor requirements

- Impostor has to provide
  - Fast construction
  - Fast intersection with ray
  - Antialiasing

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Results: billboard impostors

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Results: depth image impostors

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Billboard impostors

- Replace reflected object with billboard
- Higher order reflections
  - Reflective billboards (normal mapped quads)

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Billboard impostors

- Impostor has to provide
  - Fast construction YES
  - Fast intersection with ray YES
  - Antialiasing YES

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Pixel algorithm

- For *D* diffuse, *R* reflective billboards, and maximum reflection order *K*
  - Compute reflected ray *r*
  - For reflection order 1 to *K*
    - Intersect with (*D*+*R*-1) billboards
    - If no intersection
      - return *EM(r)*
    - Else if intersection with diffuse billboard DB_i
      - return $DB_i(r)$
    - Else if intersection with reflective billboard DB_i
      - $r = DB_i(r)$

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Pixel algorithm

- For *D* diffuse, *R* reflective billboards, and maximum reflection order *K*
  - Compute reflected ray *r*
  - For reflection order 1 to *K*
    - Intersect with (*D*+*R*-1) billboards
    - If no intersect
      - return *EM(r)*
    - Else if interse
      - return $DB_i(r)$
    - Else if intersection with reflective billboard DB_i
      - $r = DB_i(r)$

$O(K*(D+R))$

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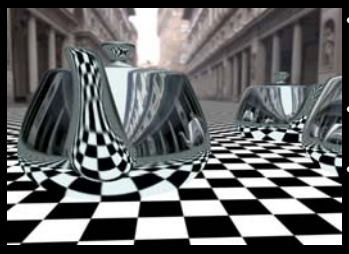
Example: 4 teapots



- *D* = 1, *R* = 4, *D*+(*R*-1)+*D* = 5 intersections / pix
- 12 second order reflections
- 40fps

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Example: table scene

- *D* = 2, *R* = 2, *D*+(*R*-1)+*D* = 5 intersections / pix
- 2 second order reflections
- 33 fps

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Example: table scene

- *D* = 2, *R* = 2, *D+(R-1)+D* = 5 intersections / pix
- 2 second order reflections
- 33 fps

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Example: table scene

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Example: pushing-it scene

- *D* = 2, *R* = 9, *D+(R-1)+D* = 11 intersections / pix
- 72 second order reflections
- 11 fps

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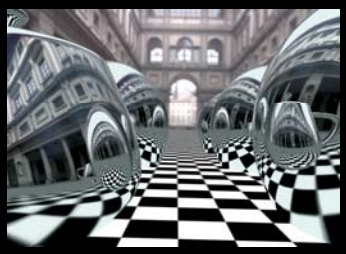
Example: pushing-it scene



- *D* = 2, *R* = 9, *D+(R-1)+D* = 11 intersections / pix
- 72 second order reflections
- 6 fps

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Example: pushing-it scene

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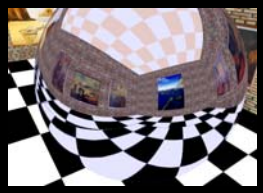
Problem



Transition from impostor to environment map (*red* in left image) is discontinuous.

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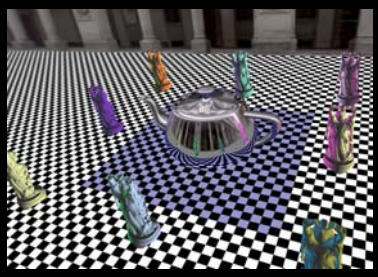
Solution: ray morphing



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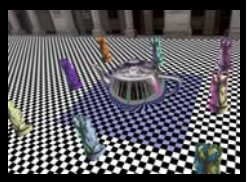
Solution: ray morphing



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Solution

Left—continuous transition. *Right*—morph region (*green*), environment map (*red*).

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Ray morphing

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Attenuation w/ distance

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Fresnel

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Combined effects

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Animation and materials

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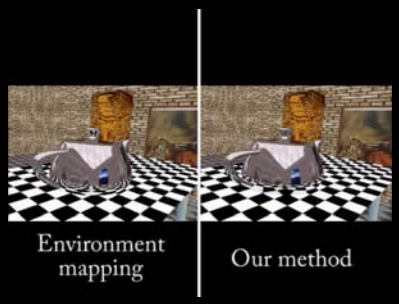
Comparison to env. mapping



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Billboard limitations

- No support for objects very close to the reflector
- Limited accuracy
  - Flat reflection
  - Lack of motion parallax

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Depth image impostors

- Impostor has to provide
  - Fast construction YES
  - Fast intersection with ray ???
  - Antialiasing YES

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Depth image—ray intersection

Epipolar-like constraints: intersection computed as 1D search
Still too many steps along epipolar segment

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Simplified Rotated Depth Maps

Pre-rotate depth map.
All rays ever needed project to rows.
Pre-simplify rows.

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Simplified Rotated Depth Maps

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SRDM construction cost

Number of segments	8	16	32	64
Construction time [ms]	210	300	480	980

Rigid body transformations, color updates, and reflector updates do not require reconstruction.

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Depth image impostor results

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Depth image impostor results

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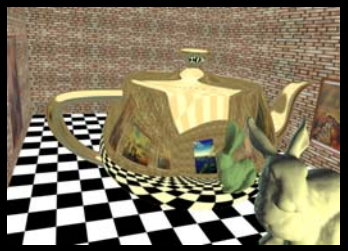
Depth image impostor results



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Depth image impostor results

Depth image impostor results

Depth image impostor results

SRDM under-sampling

One rotated depth map every 20^{o}, 10^{o}, 3^{o}, and 2^{o}, respectively.

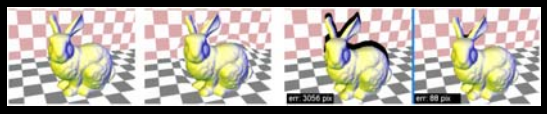
Depth image impostor results

Conclusions

- The reflected-impostor approach works
  - Fast, realistic
  - Increased modeling effort
- Rendering reflections reduced to the lesser problem of rendering w/ impostors

Future work

- Other types of impostors
  - occlusion-resistant



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Future work

- Other types of impostors
- Other BRDFs
- Self-reflections
- Constructing the SRDMs on the GPU

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- Funding & equipment
  - NSF, Intel, Microsoft, Computer Science Purdue, Visualization Laboratory Purdue
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