EGSR 2008

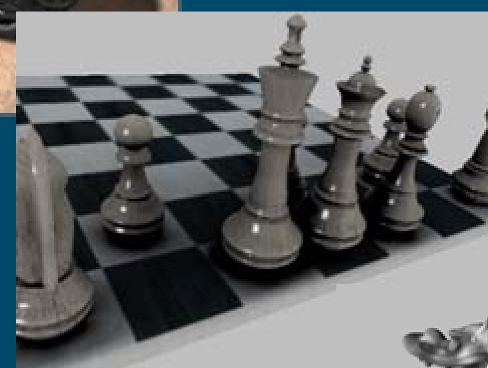
Geometry-Aware Framebuffer Level of Detail

Lei Yang   Pedro V. Sander
Hong Kong University of Science and Technology

Jason Lawrence
University of Virginia

Motivation

- Expensive procedural shading effects
  - Heavy pixel shader workload
  - Examples
    - Soft shadows
      27fps
    - Ambient Occlusion
      3.2fps
    - Procedural noise texture
      120fps
    - …



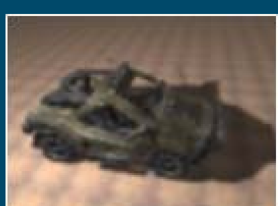
Motivation

- A method for reducing pixel workload
  - General
  - Lightweight
  - No preprocessing
  - Smoothly adjustable tradeoff between speed/quality

Dynamic Resizing

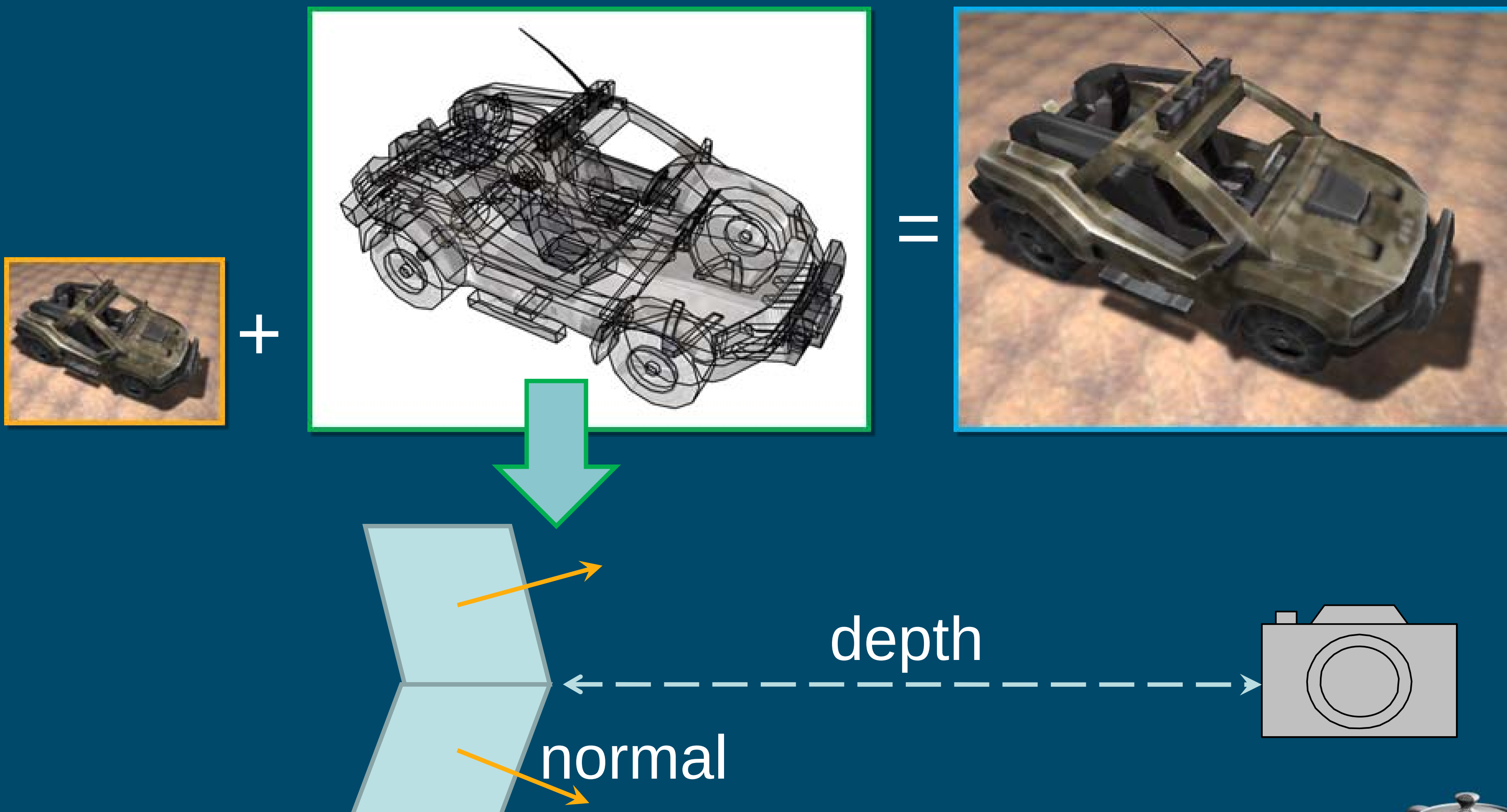
- Render scene to low-res buffer (1^{st} pass), then upsample to target resolution (2^{nd} pass). [Montrym97]
  - # of original pixel shader invocation is reduced ($\propto 1/r^2$)
  - Blurs geometric discontinuities

1^{st} pass
Original shader



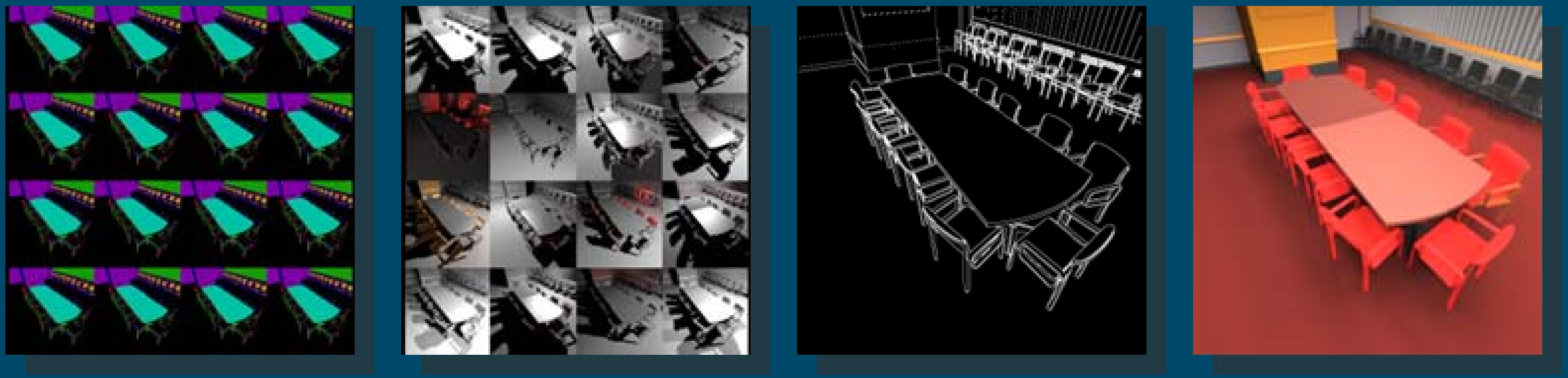
2^{nd} pass
Upsample

Geometry-Aware?



Related Work

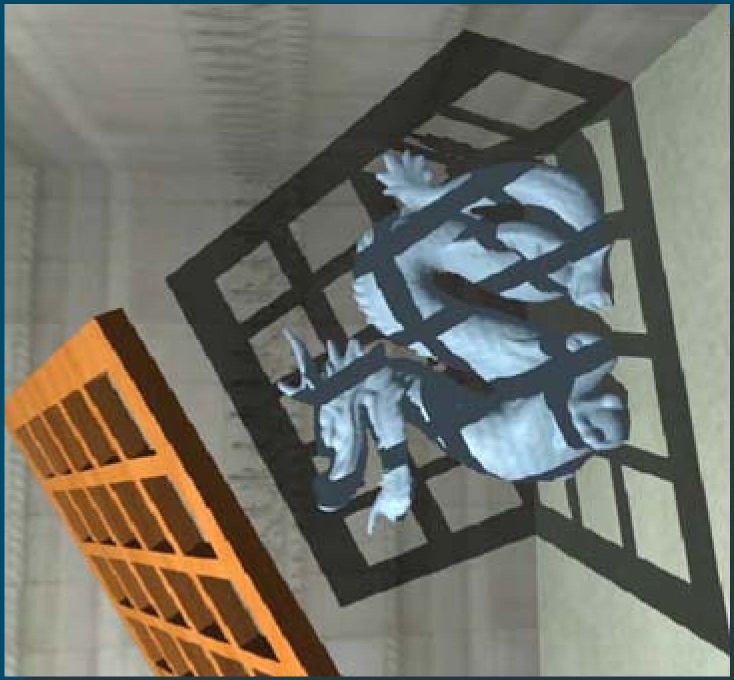
- **Interleaved sampling [Segovia06, Laine07]**



- **Image-based proxy accumulation [Sloan07]**

Related Work

- **Edge-and-Point render cache**
  [Bala03, Velázquez-Armendáriz06]



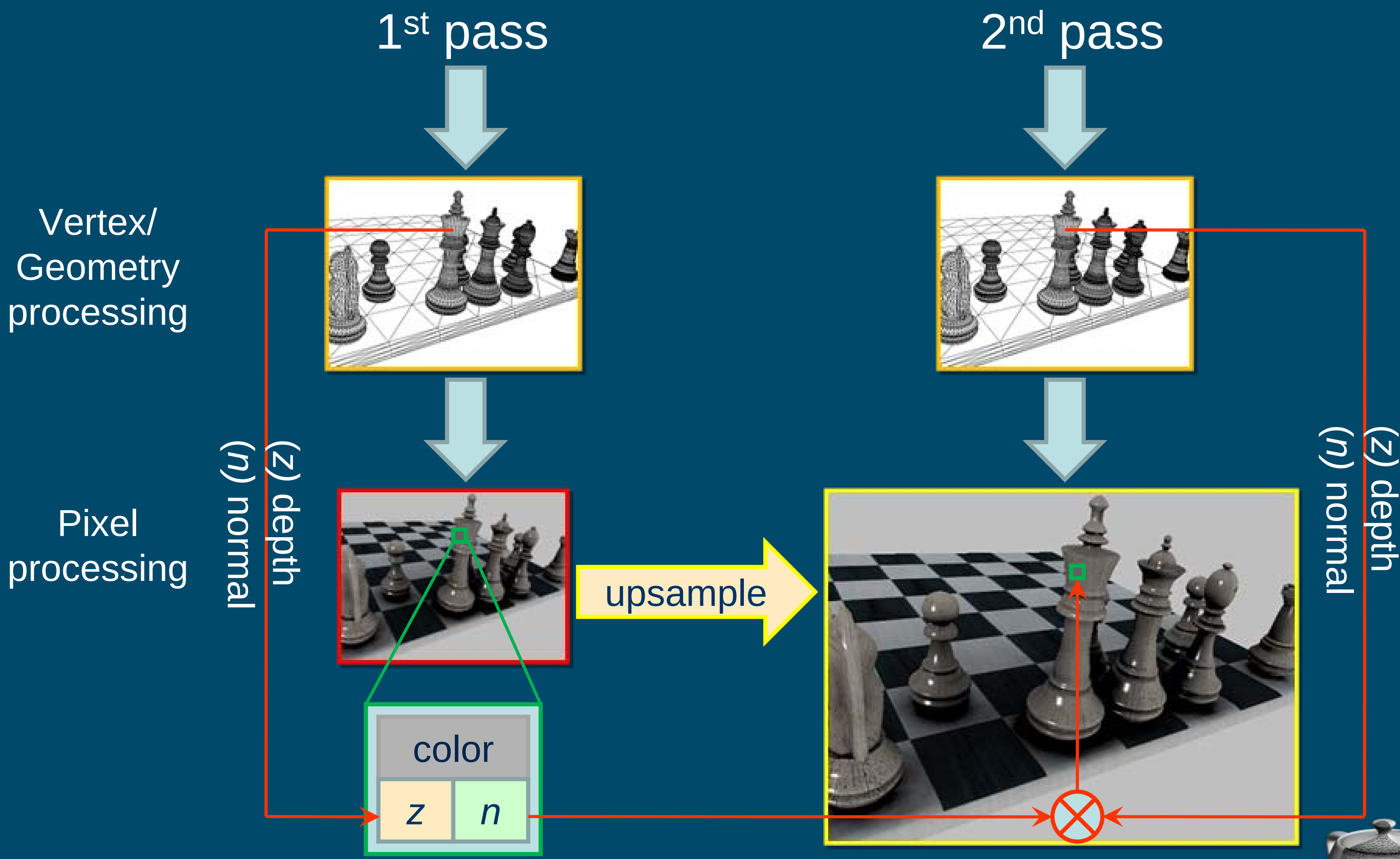
Overview

- Geometry-Aware Resizing
- Fine-Grained Resizing
- Automatic Framerate Control
- Results and Demo
- Discussions and Conclusion

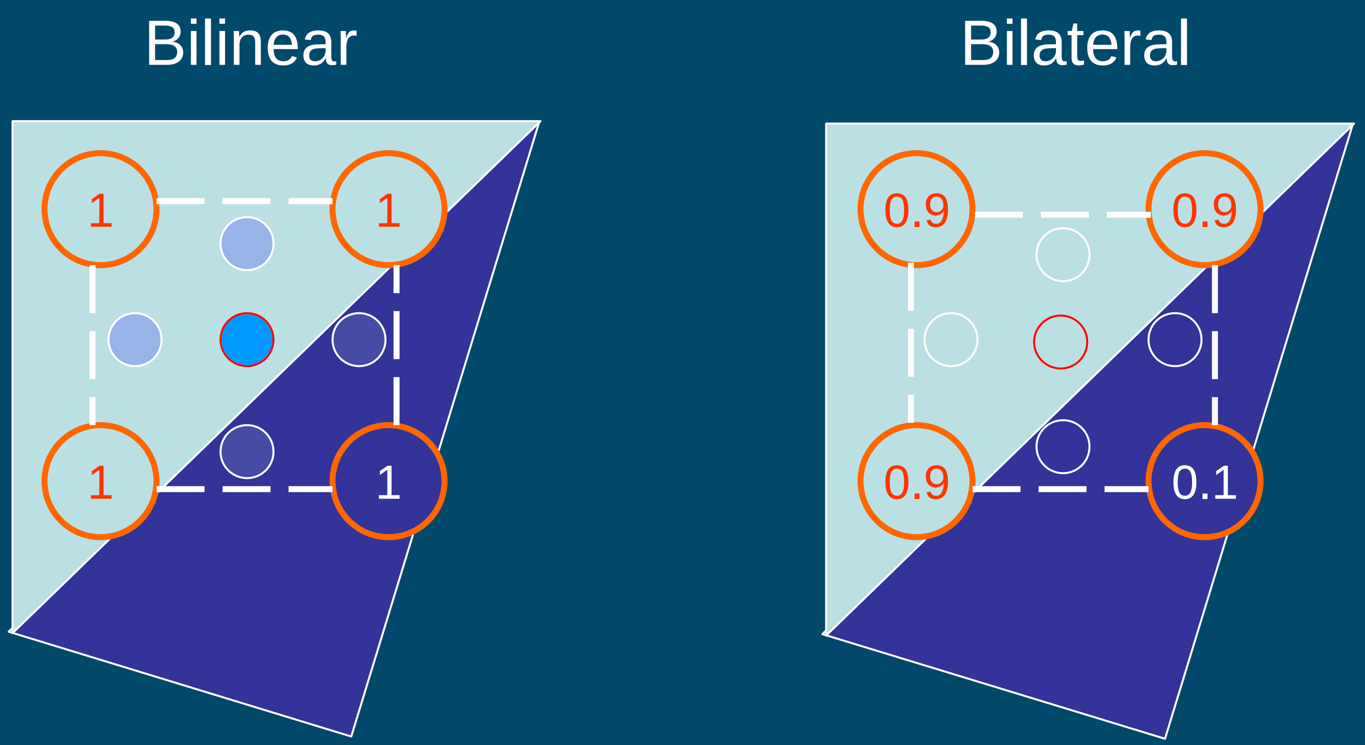
Our Approach

- **Geometry-Aware Resizing**
  - **Upsample according to geometric similarities between lo-res and hi-res buffers**
  - **Two-pass technique**
    - **1st pass: Render geometry with the original pixel shader on low-res buffer, store *geometric info* (normal & depth) + color**
    - **2nd pass: Render geometry at full resolution and use *geometry-aware kernel* to reconstruct the shading from the lo-res buffer**

Geometry-Aware Resizing



Geometry-Aware Reconstruction



Weight samples based on geometric similarity

Joint Bilateral Filter

$$c_i^H = \frac{\sum \boxed{c_j^L} \boxed{f(\hat{x}_i, x_j)\ g(|n_i^H - n_j^L|, \sigma_n)\ g(|z_i^H - z_j^L|, \sigma_z)}}{\sum \boxed{f(\hat{x}_i, x_j)\ g(|n_i^H - n_j^L|, \sigma_n)\ g(|z_i^H - z_j^L|, \sigma_z)}}$$

Color sample *j* from the low-res buffer

Filter weight of sample *j*

Joint Bilateral Filter

$$c_i^H = \frac{\sum \boxed{c_j^L}\ \boxed{f(\hat{x}_i, x_j)}\ g(|n_i^H - n_j^L|, \sigma_n)\ g(|z_i^H - z_j^L|, \sigma_z)}{\sum \boxed{f(\hat{x}_i, x_j)}\ g(|n_i^H - n_j^L|, \sigma_n)\ g(|z_i^H - z_j^L|, \sigma_z)}$$

Color sample *j* from the low-res buffer

Spatial filter: bilinear / biquadratic / bicubic / Gaussian

Joint Bilateral Filter

$$c_i^H = \frac{\sum \boxed{c_j^L}\, f(\hat{x}_i, x_j)\, \boxed{g(|n_i^H - n_j^L|, \sigma_n)}\, g(|z_i^H - z_j^L|, \sigma_z)}{\sum f(\hat{x}_i, x_j)\, \boxed{g(|n_i^H - n_j^L|, \sigma_n)}\, g(|z_i^H - z_j^L|, \sigma_z)}$$

Color sample *j* from the low-res buffer

Range filter 1: Gaussian of the ***normal*** distance

Joint Bilateral Filter

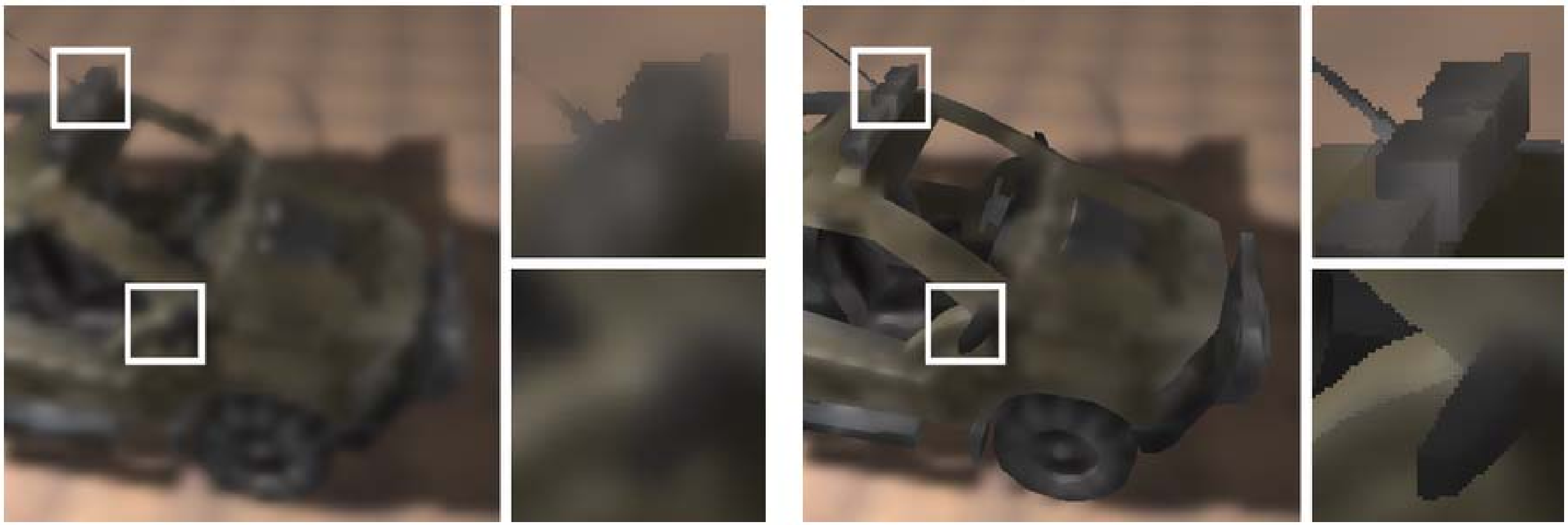
$$c_i^H = \frac{\sum \boxed{c_j^L} \, f(\hat{x}_i, x_j) \, g(|n_i^H - n_j^L|, \sigma_n) \boxed{g(|z_i^H - z_j^L|, \sigma_z)}}{\sum f(\hat{x}_i, x_j) \, g(|n_i^H - n_j^L|, \sigma_n) \boxed{g(|z_i^H - z_j^L|, \sigma_z)}}$$

Color sample *j* from the low-res buffer

Range filter 2: Gaussian of the ***depth*** distance

Joint Bilateral Filter

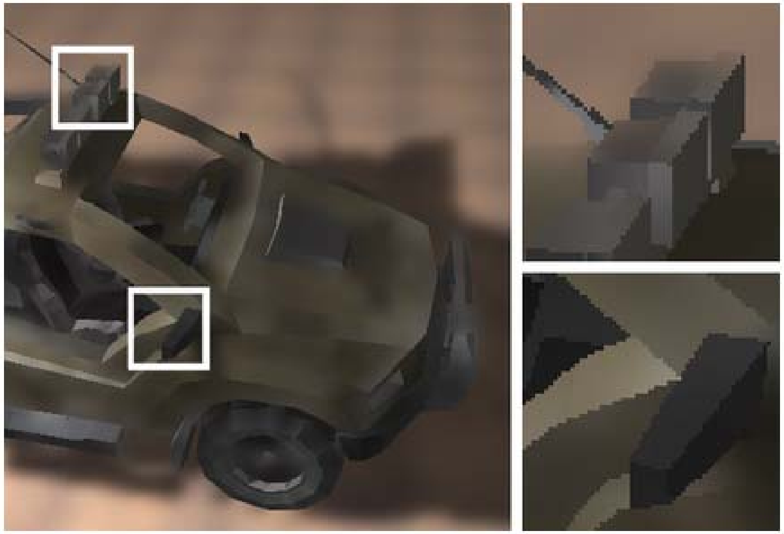
$$c_i^H = \frac{\sum c_j^L \, f(\hat{x}_i, x_j)\; g(|n_i^H - n_j^L|, \boxed{\sigma_n})\; g(|z_i^H - z_j^L|, \boxed{\sigma_z})}{\sum f(\hat{x}_i, x_j)\; g(|n_i^H - n_j^L|, \boxed{\sigma_n})\; g(|z_i^H - z_j^L|, \boxed{\sigma_z})}$$



Large σ_z, large σ_n Small σ_z, large σ_n

Joint Bilateral Filter

$$c_i^H = \frac{\sum c_j^L \, f(\hat{x}_i, x_j)\, g(|n_i^H - n_j^L|, \boxed{\sigma_n})\, g(|z_i^H - z_j^L|, \boxed{\sigma_z})}{\sum f(\hat{x}_i, x_j)\, g(|n_i^H - n_j^L|, \boxed{\sigma_n})\, g(|z_i^H - z_j^L|, \boxed{\sigma_z})}$$



Large σ_z, small σ_n

Small σ_z, small σ_n

Overview

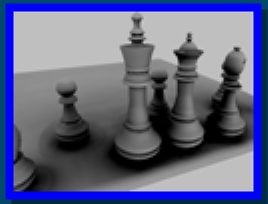
- Geometry-Aware Resizing
- Fine-Grained Resizing
- Automatic Framerate Control
- Results and Demo
- Discussions and Conclusion

Fine-Grained Resizing

- Resize only expensive & spatially smooth computations
- Break up the original shader
  - Expensive & spatially smooth computation: 1st pass (at low-res)
  - Inexpensive / spatially high-freq computation: 2nd pass (at full-res)

Fine-Grained Resizing

1st pass 2nd pass

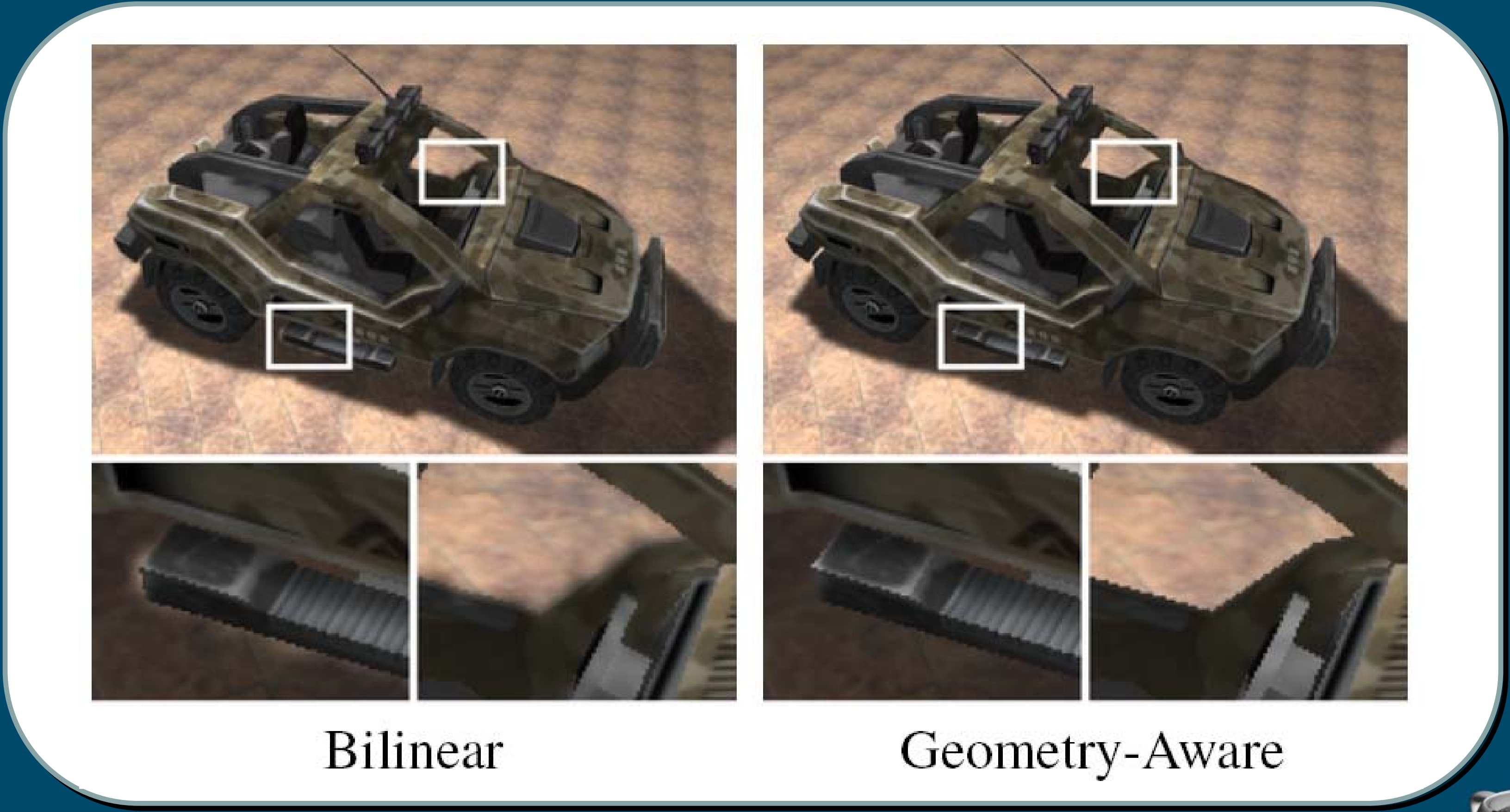


+

=

Comparison: Bilinear vs. Bilateral

- Fine-grained resizing + Bilinear upsample?

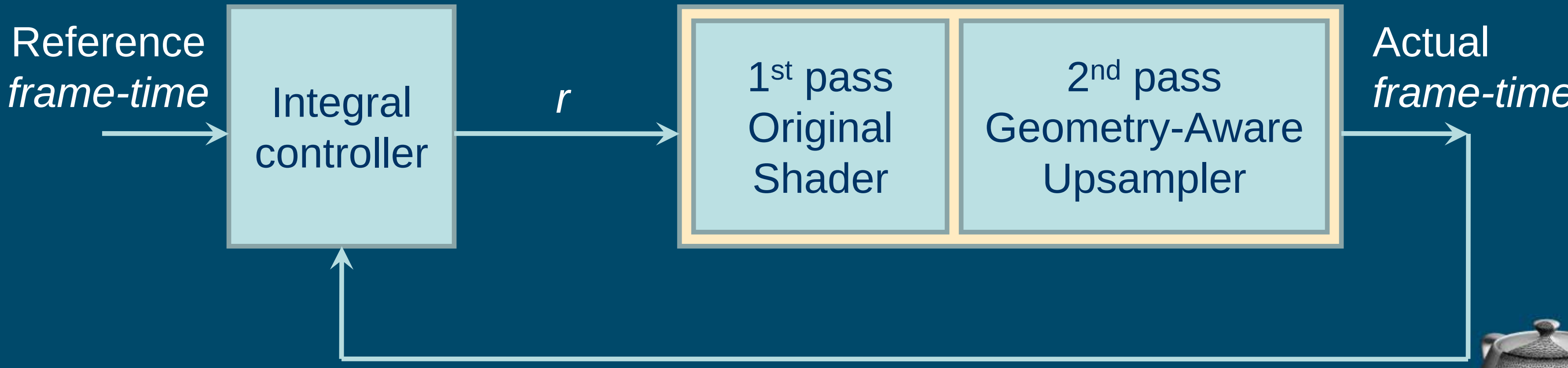


Overview

- Geometry-Aware Resizing
- Fine-Grained Resizing
- Automatic Framerate Control
- Results and Demo
- Discussions and Conclusion

Automatic Framerate Control

- **Dynamically select resizing factor *r* to maintain a *constant* framerate**
- **Use a feedback control mechanism**
  - **Input: previous *frame-time***
  - **Output: *r***
  - **Integral controller**



Controller Formulation

$$t \approx Kp + C$$

1. Pixel processing time $\propto$ # of pixels
2. Pixel-bound

$$p \propto wh/r^2$$

Constant screen coverage

$$t \approx K'(1/r^2) + C$$

$$\Delta t \approx K' \Delta(1/r^2)$$

AFC implementation

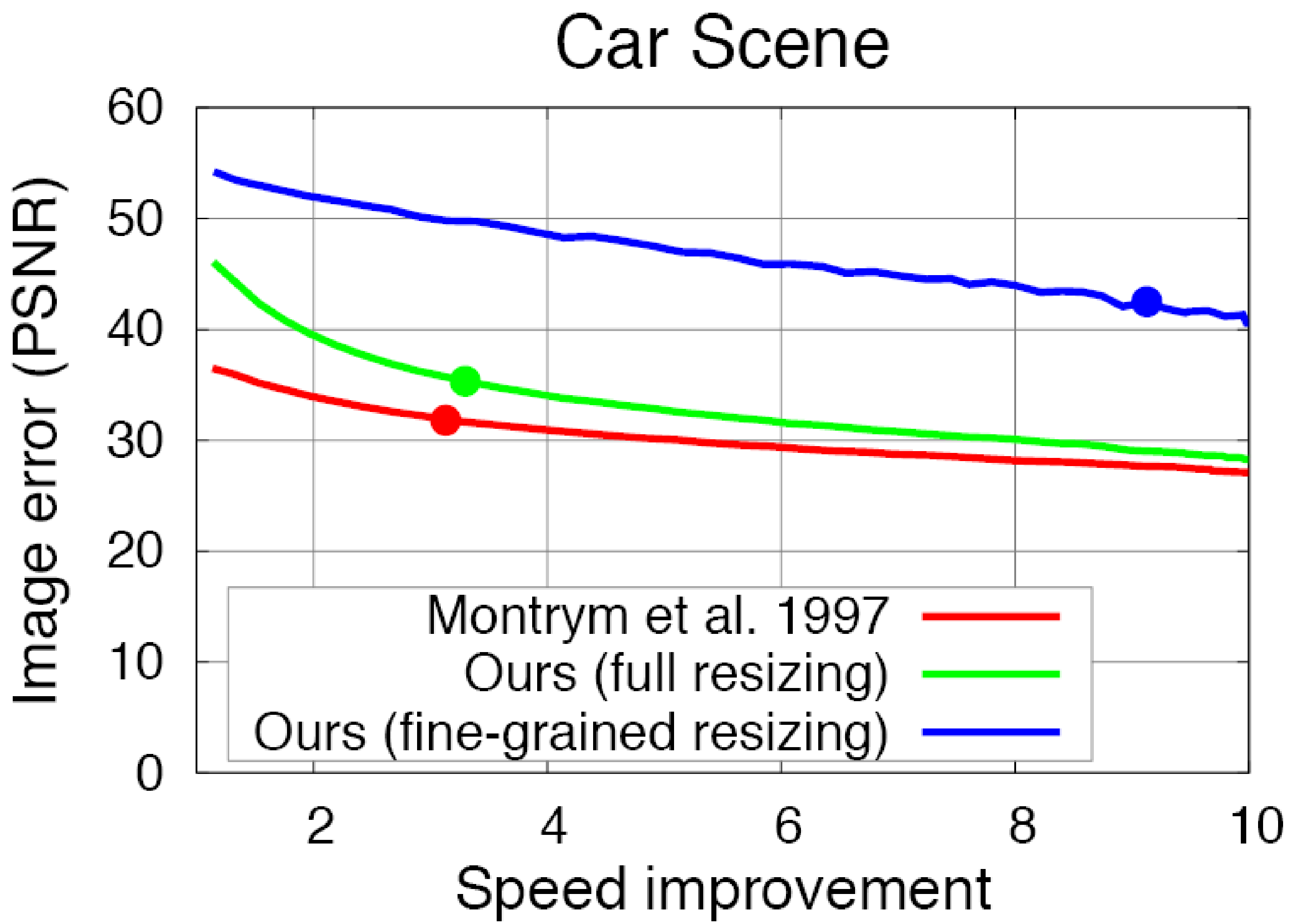
- **Limit the range of Δt, Δr and r**
- **Experimentally determine K' with the maximum screen coverage**

Overview

- Geometry-Aware Resizing
- Fine-Grained Resizing
- Automatic Framerate Control
- Results and Demos
- Discussions and Conclusion

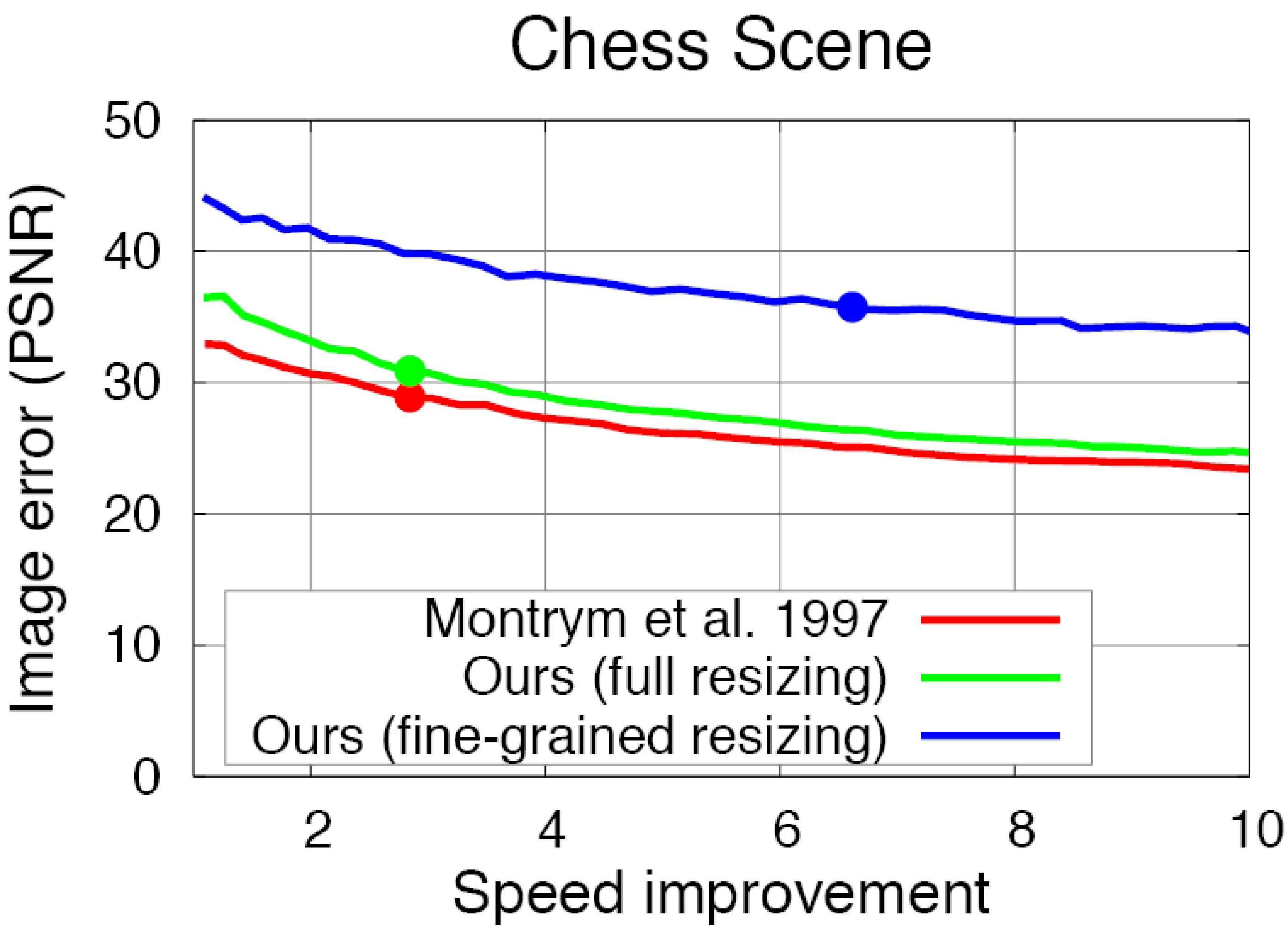
Results – Car

Results – Car (con't)

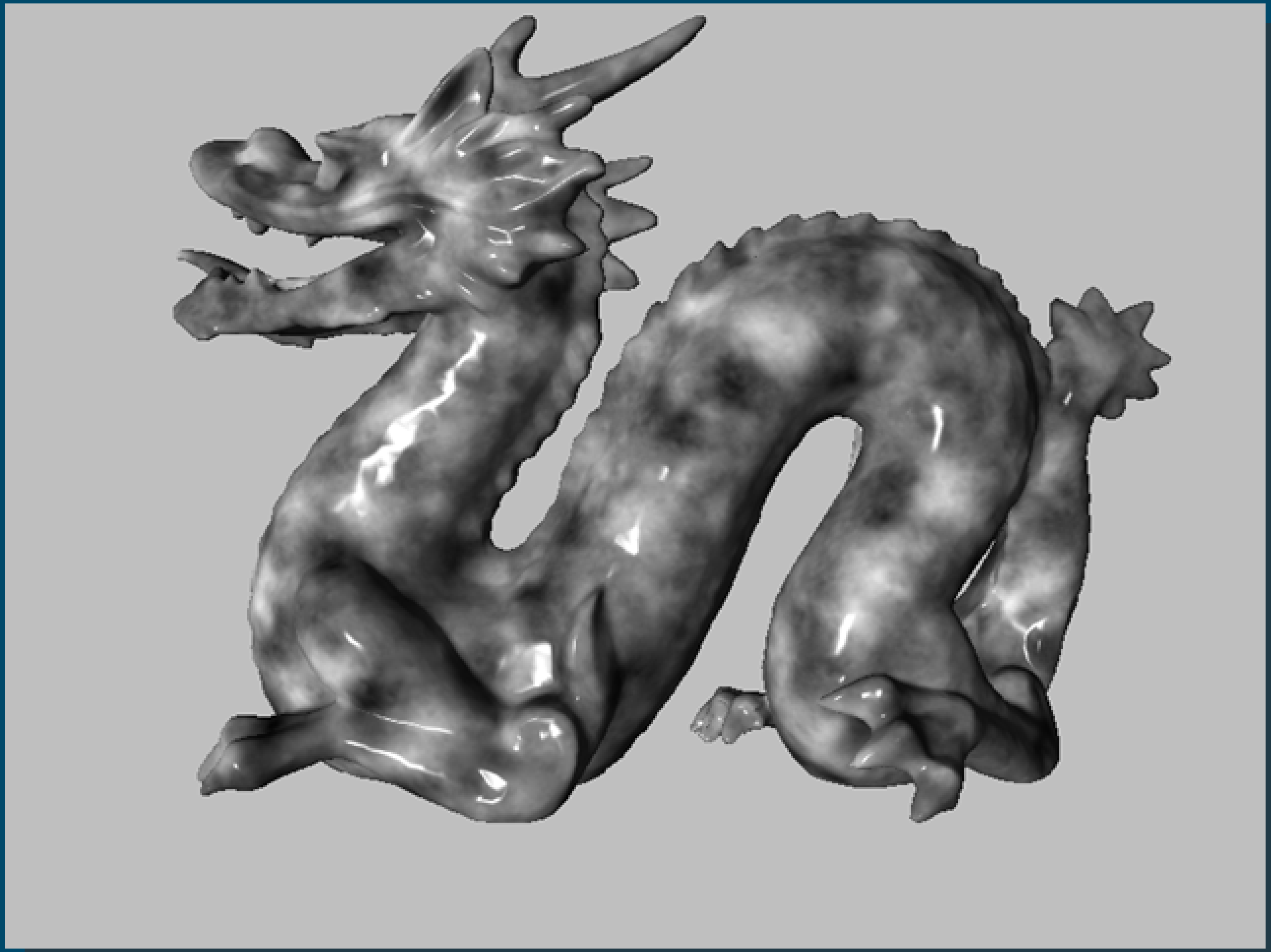


Results – Chess

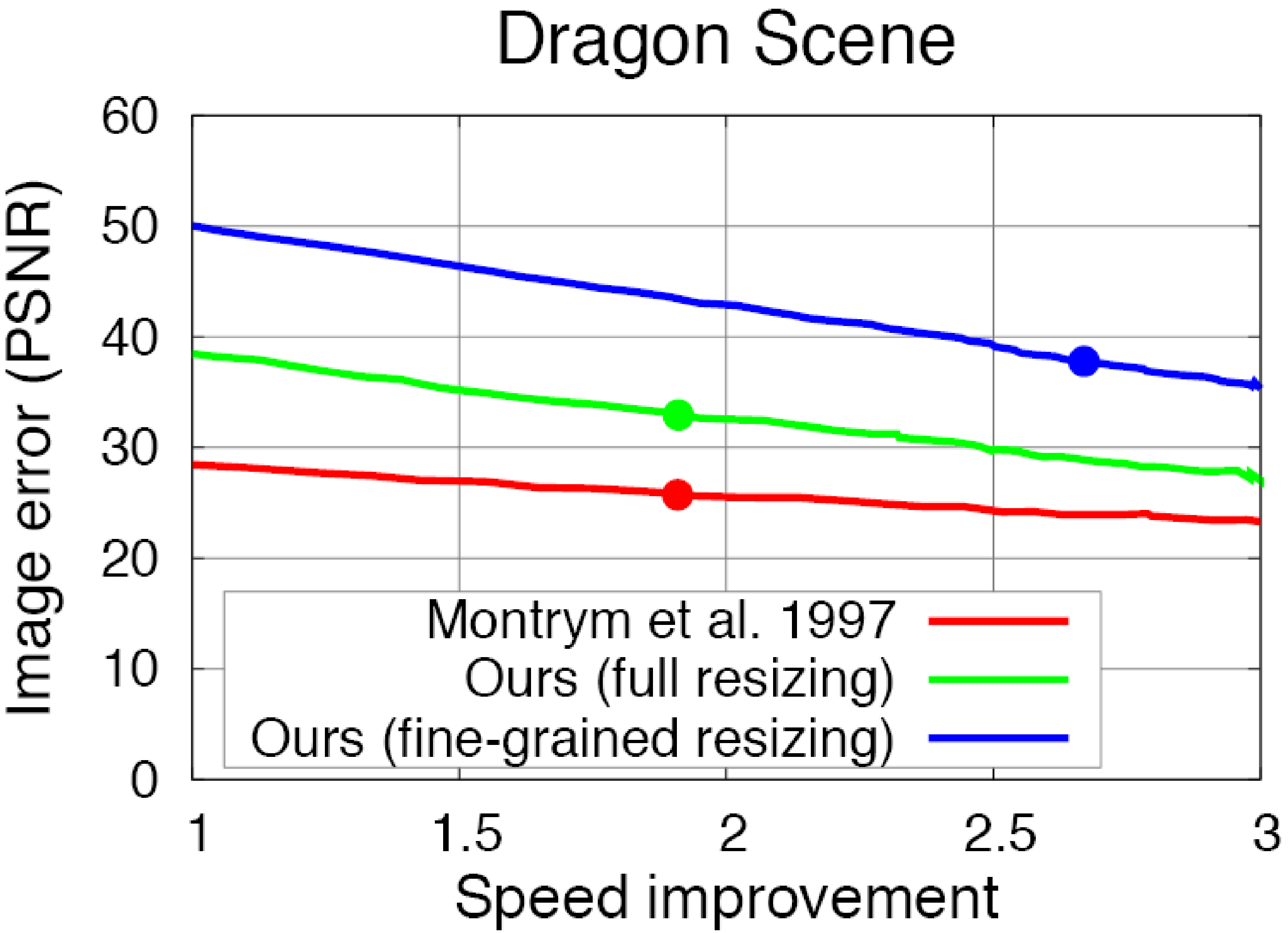
Results – Chess (con't)



Results – Dragon

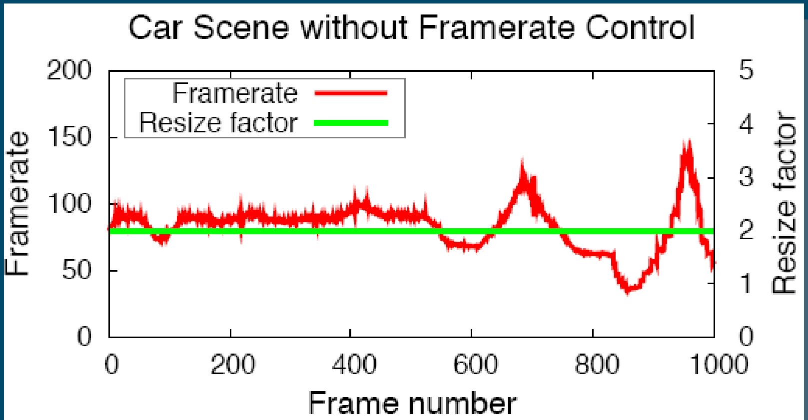


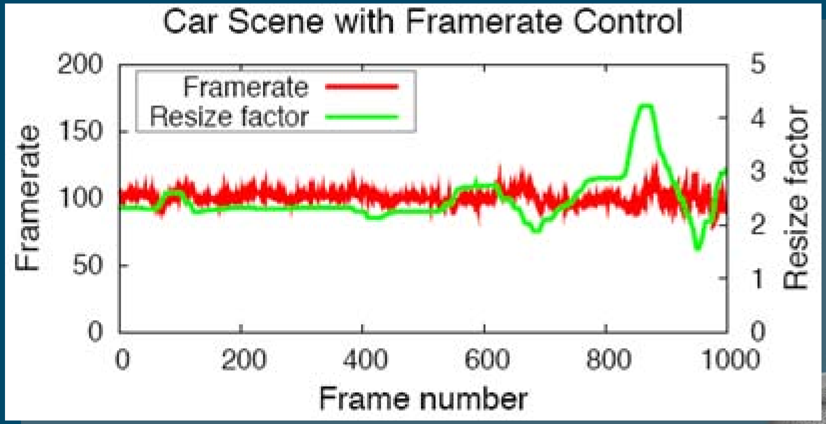
Results – Dragon (con't)



AFC results

- **Experimental data:**
  - Over 1000 frames
  - Various outside disturbances
    - View changes
    - Screen coverage changes
    - Shader workload changes





Overview

- Geometry-Aware Resizing
- Fine-Grained Resizing
- Automatic Framerate Control
- Results and Demo
- Discussions and Conclusion

Limitations

- Resizing high frequency signal
  - Popping and flickering artifacts (aliasing)
- Undersampled fine geometry
  - Missing details around regions with high depth/normal complexities
  - Recompute missing samples in a 3rd pass?
- Added geometry processing overhead

Practical Advantages

- **Multiple shader / objects**
  - **Sharing the same resized buffer**
  - **Sharing the reconstruction pass**
  - **Allow unified AFC**
- **Easy to apply**
  - **Mainly an added reconstruction pass**

Conclusion

- A general approach for reducing shading costs
- Respect geometric discontinuities better than conventional resizing
- Allow continuous adjustment of error/performance tradeoff
- Automatic framerate control
- Straightforward to incorporate into existing systems

Future Work

- Multi-resolution resizing
- Automated selection of resized elements
- Resize for super-sample anti-aliasing
- Obtain a Bosnia-Herzegovina visa ☺

Questions?