Crowd Light: Evaluating the Perceived Fidelity of Illuminated Dynamic Scenes

Adrian Jarabo[1] Tom Van Eyck[2] Veronica Sundstedt[3]
Kavita Bala[4] Diego Gutierrez[1] Carol O'Sullivan[2]

[1]Universidad de Zaragoza [2]Trinity College Dublin
[3]Blekinge Institute of Technology [4]Cornell University

Why Crowd Lighting?

LOTR: The Two Towers (2002) © 2002 New Line Productions, Inc

Why Crowd Lighting?

Assassins Creed (2007) © 2007 Ubisoft

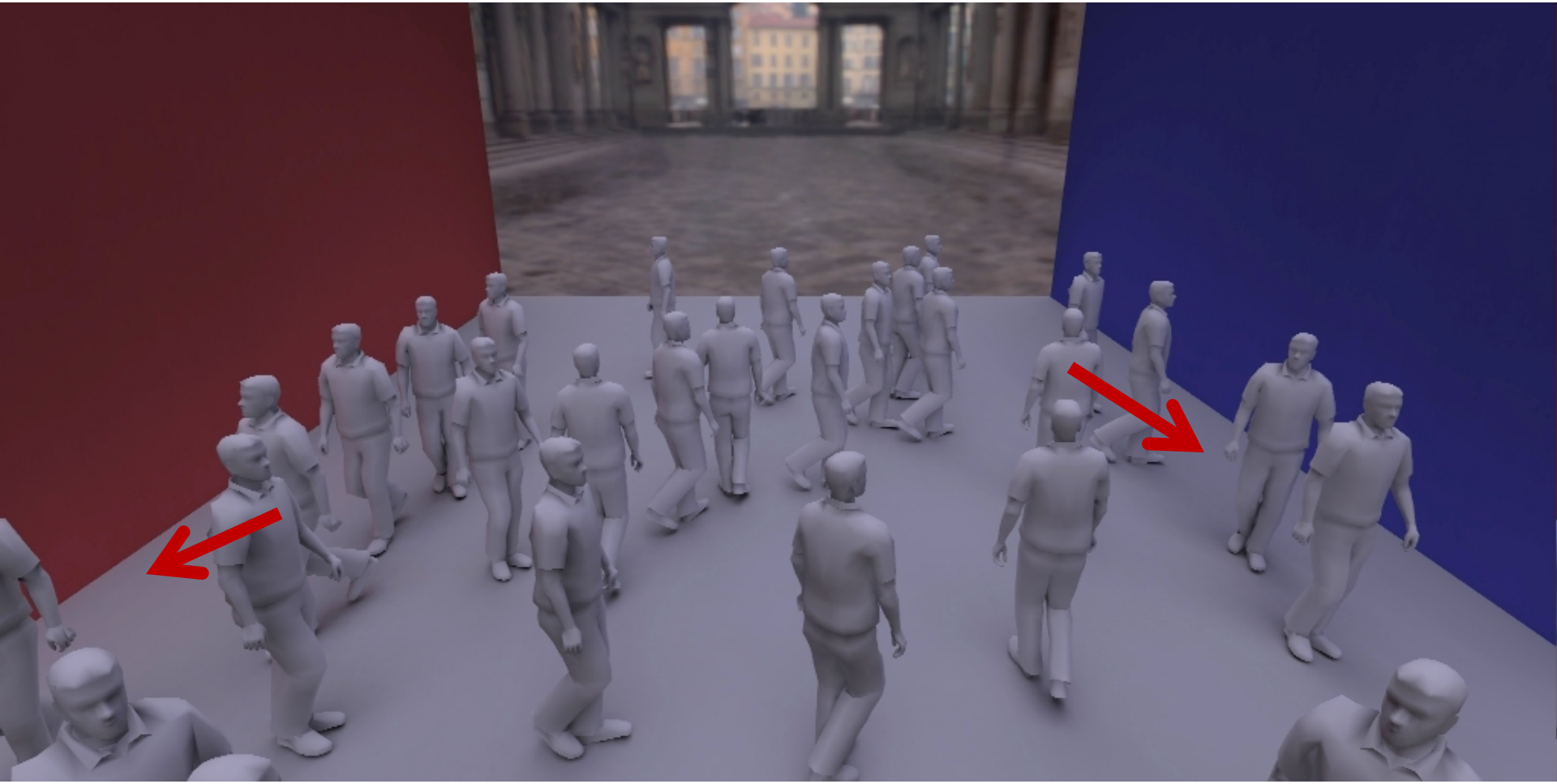
Why Crowd Lighting?

LOTR: The Return of the King (2003) © 2003 New Line Productions, Inc

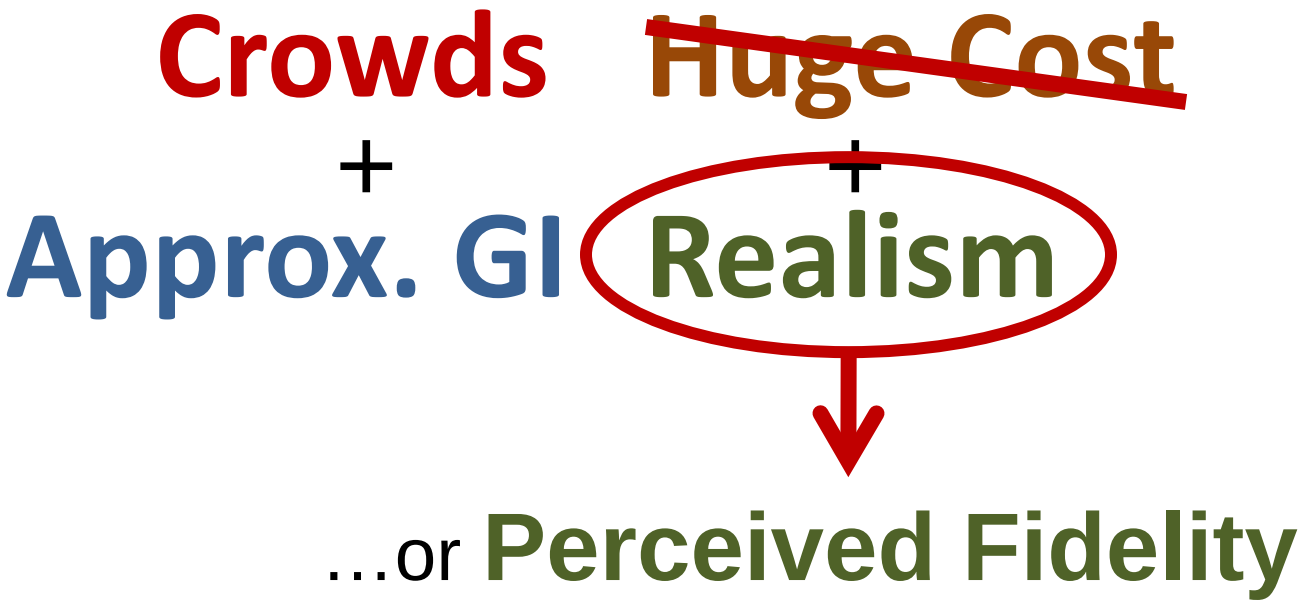
Why Crowd Lighting?

Metropolis - Supercrowds for Multisensory Urban Simulations

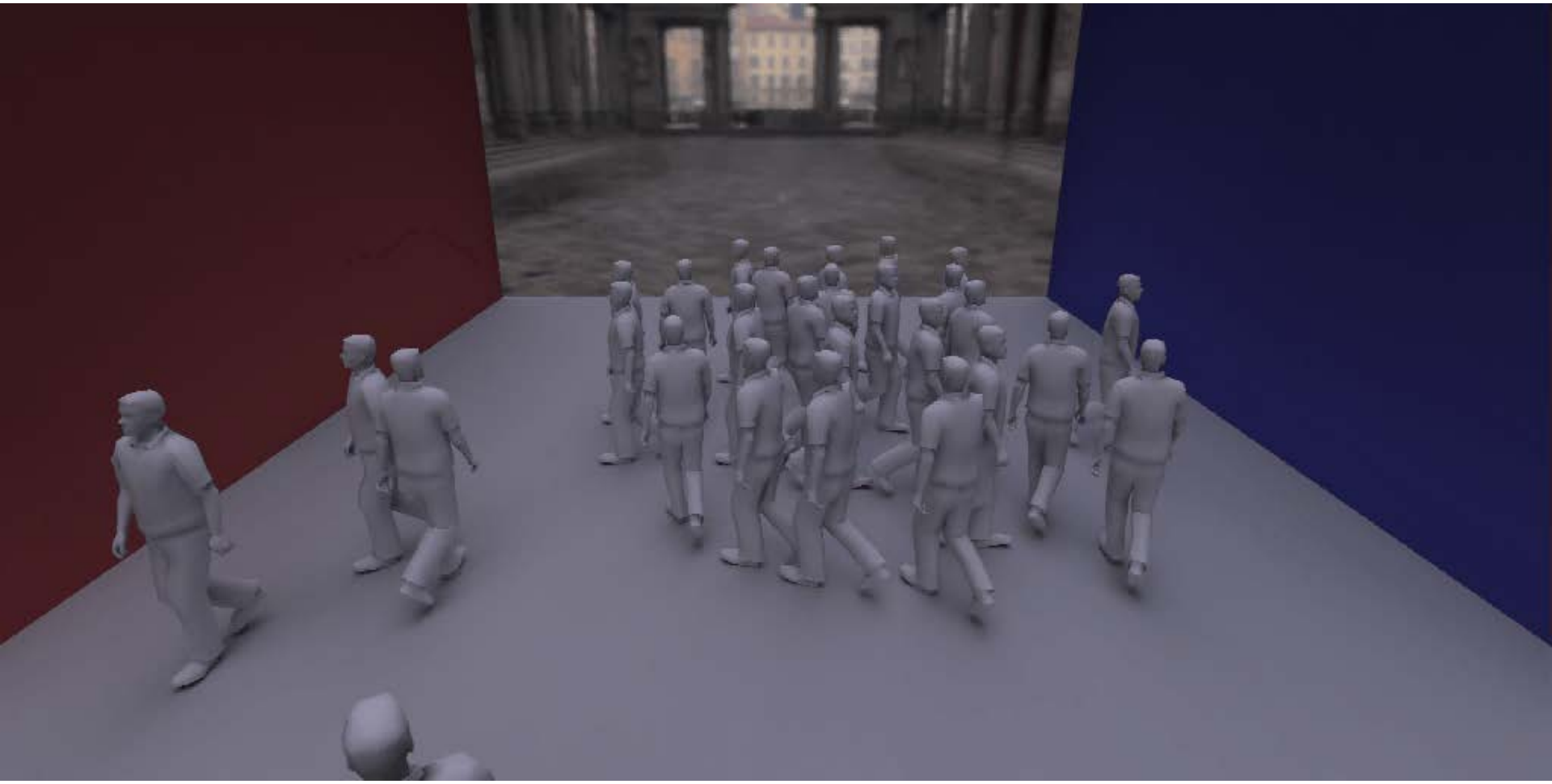
Why Crowd Lighting?



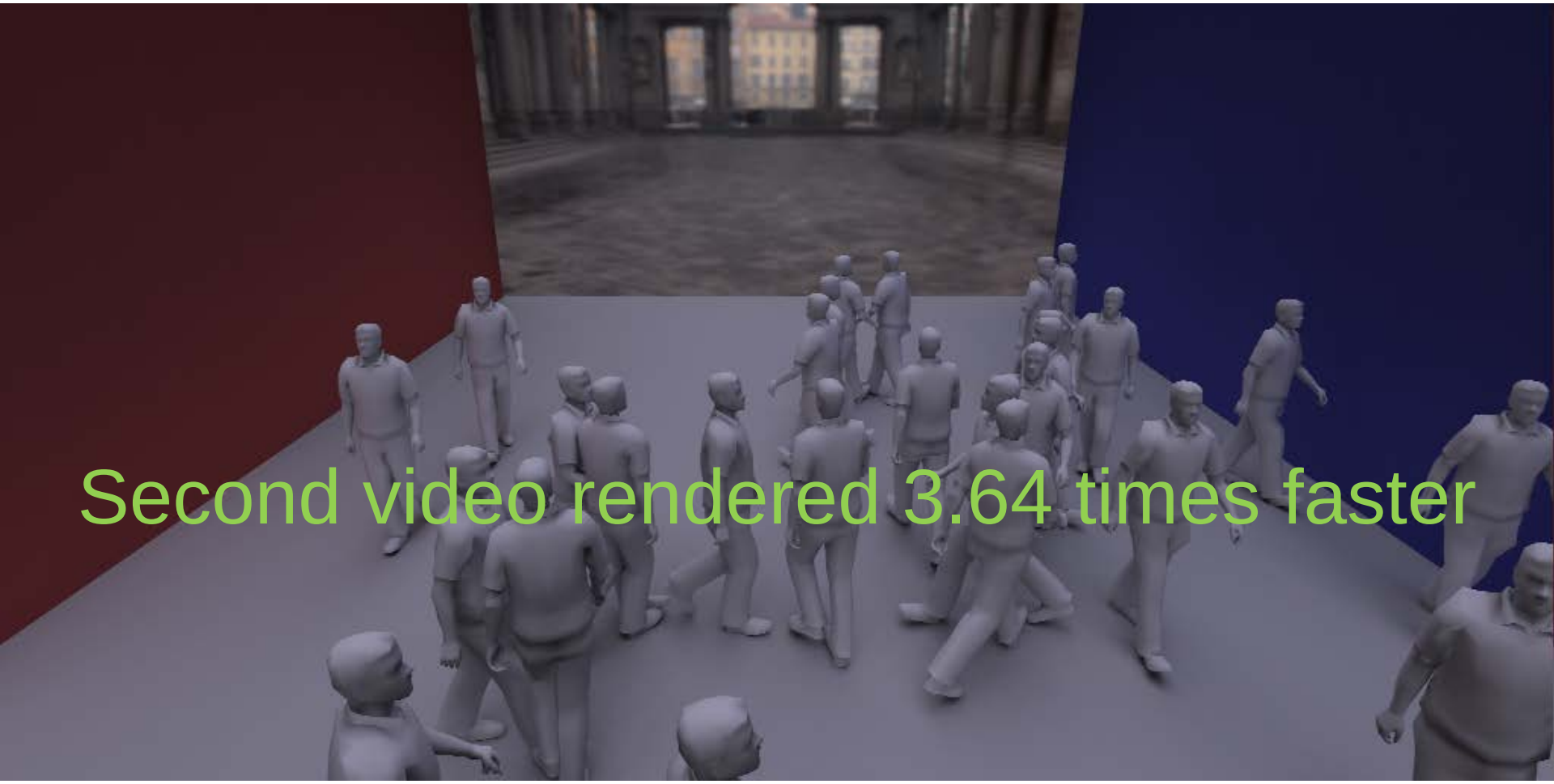
Why Crowd Lighting?



An example…



An example…



Related Work

- Perceptual rendering:
  - Visible Difference Predictor

    [Bolin and Meyer 95/98, Myszkowski et al. 01, …]
  - Illumination components

    [Stokes et al. 04; Debattista et al. 05]
  - Approximated Visibility

    [Kozlowski and Kautz 07, Yu et al. 09, Ritschel et al. 08]
  - Visual attention

    [Yee et al. 01, Ferwerda and Pellacini 03, Sundstedt et al. 07, Hasic and Chalmers 09]

Related Work

- Perception in crowds:
  - Perception of general aggregates

    [Ramanarayanan et al. 08]
  - Perception of crowd variety

    [McDonnell et al. 08]
- Visual Equivalence:

  [Ramanarayanan et al. 07, Ramanarayanan et al. 08, Vangorp et al. 09, Krivanek et al. 10]

Our goal

Evaluate and understand the perceived fidelity of illumination in scenes with complex dynamic crowds.

Our goal – Questions to answer

Q1. Does the complexity of the crowd affect perceived quality of illumination?

Q2. Are errors in direct or indirect lighting more salient?

Q3. What effect does colour have on the perceived fidelity of illuminated crowd scenes?

- Illumination
- Experiments
- Comparison with Video Quality Metric

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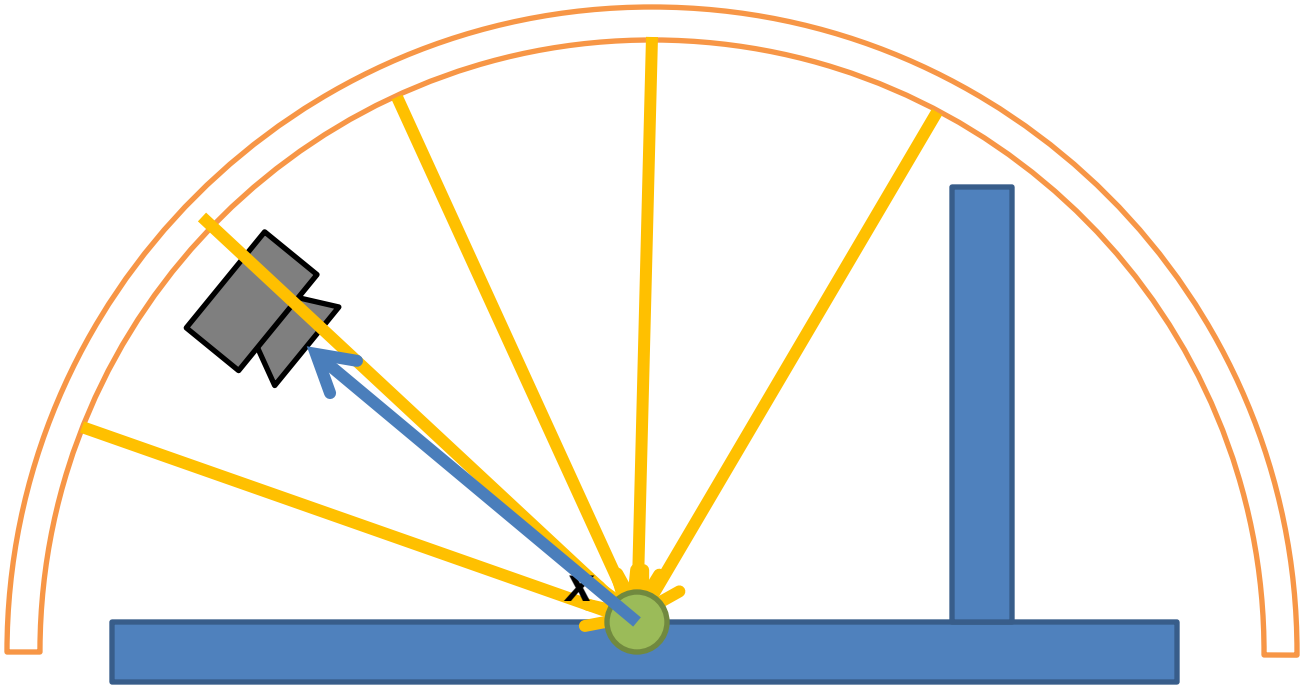
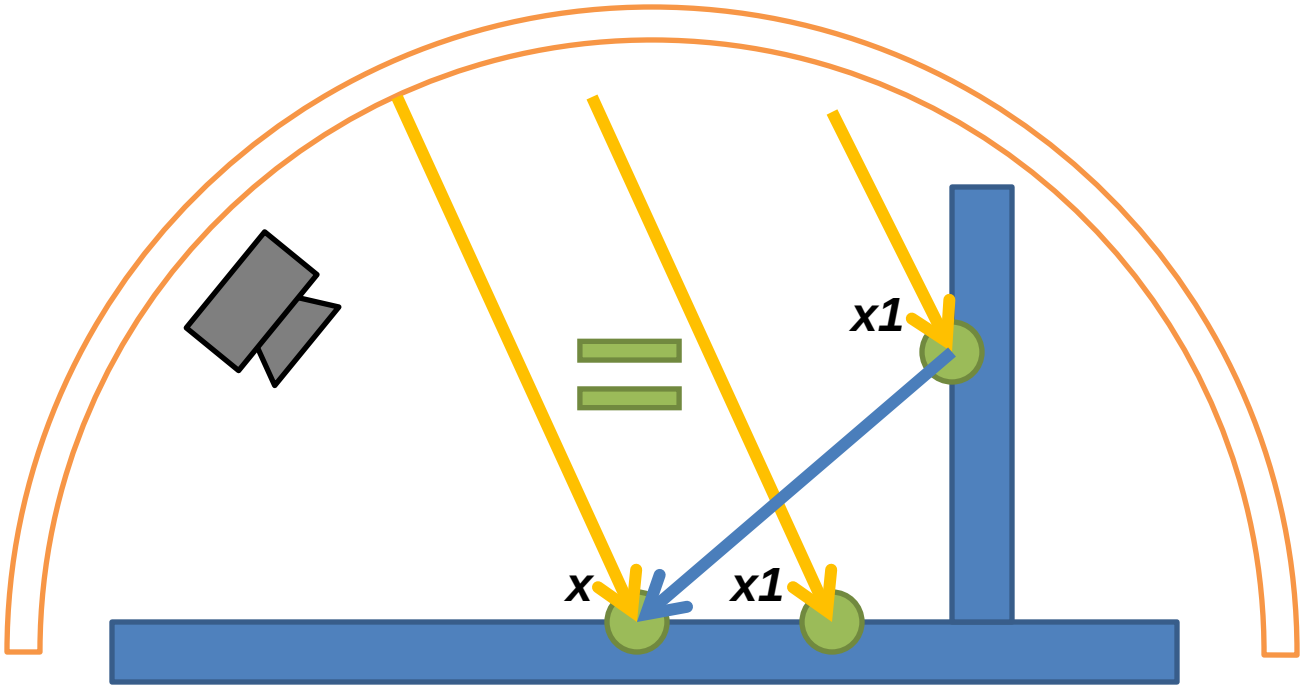
Illumination



$$L_o(x,\omega_o) = \int_{\Omega^+} L_i(x,\omega)\rho(x,\omega,\omega_o)V(x,\omega)(\omega\cdot n)d\omega$$

Illumination



light transport in the scene: direct + GI + SSS

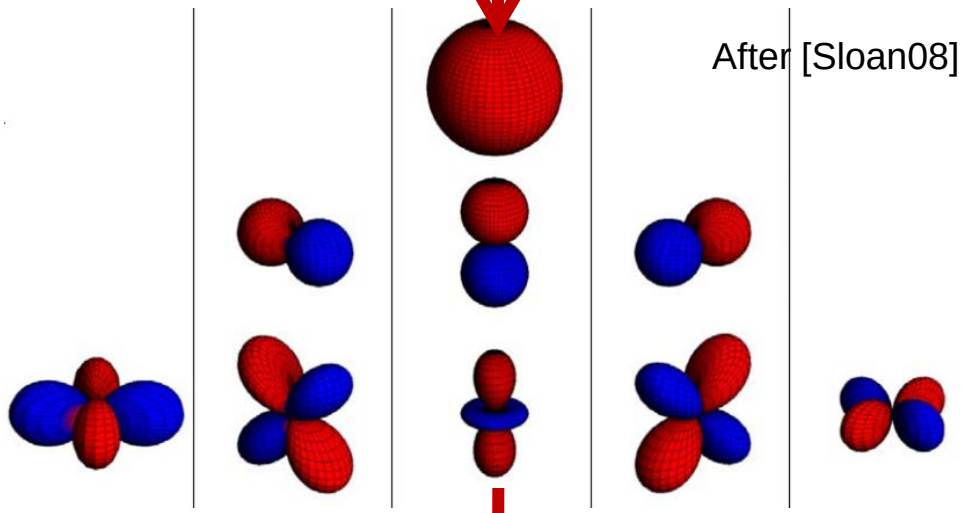
$$L_o(x, \omega_o) = \int_{\Omega^+} L_i(\omega) T(x, \omega, \omega_o) d\omega$$

Illumination – SH

$$T(x, \omega, \omega_o)$$

$$\omega, \omega_o$$

Huge vector modeling $T(x, \omega, \omega_o)$



After [Sloan08]

$$L_o(x, \omega_o) = \int_{\Omega} \ldots \omega_o) d\omega$$

SH Coefficients [Sloan02]

Illumination – SH

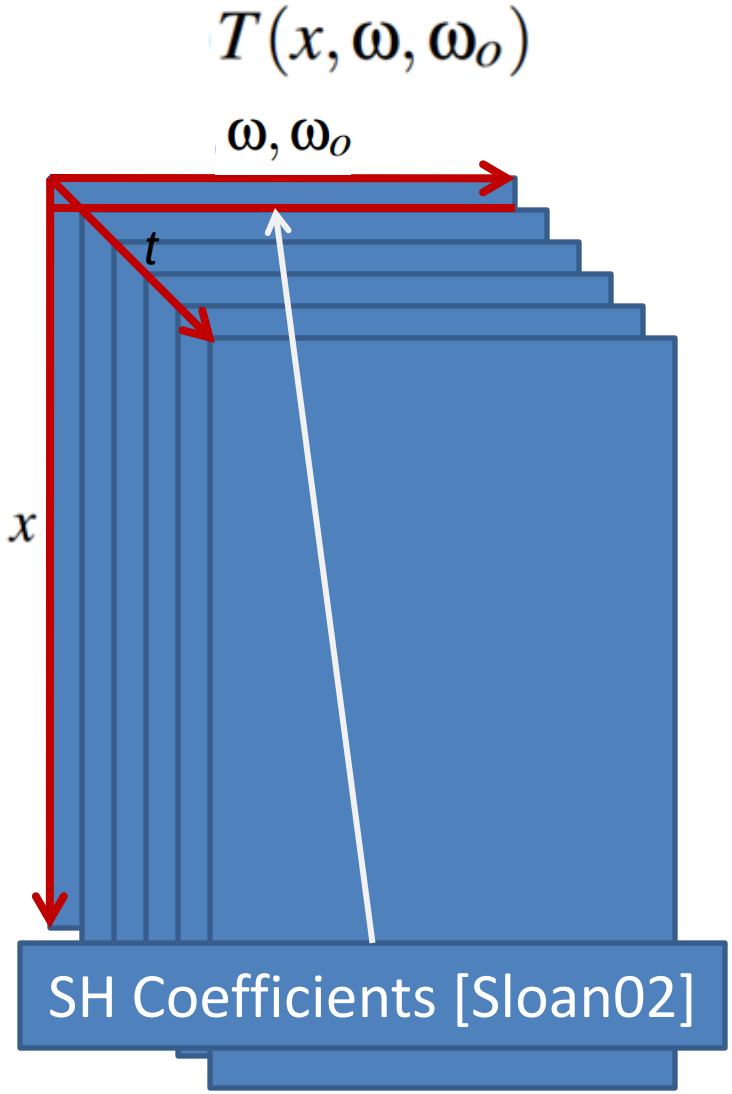
- Used in Film Production [Pantaleoni11]:

PantaRay: Fast Ray-traced Occlusion Caching of Massive Scenes

Jacopo Pantaleoni* NVIDIA Research
Luca Fascione† Weta Digital
Martin Hill† Weta Digital
Timo Aila* NVIDIA Research

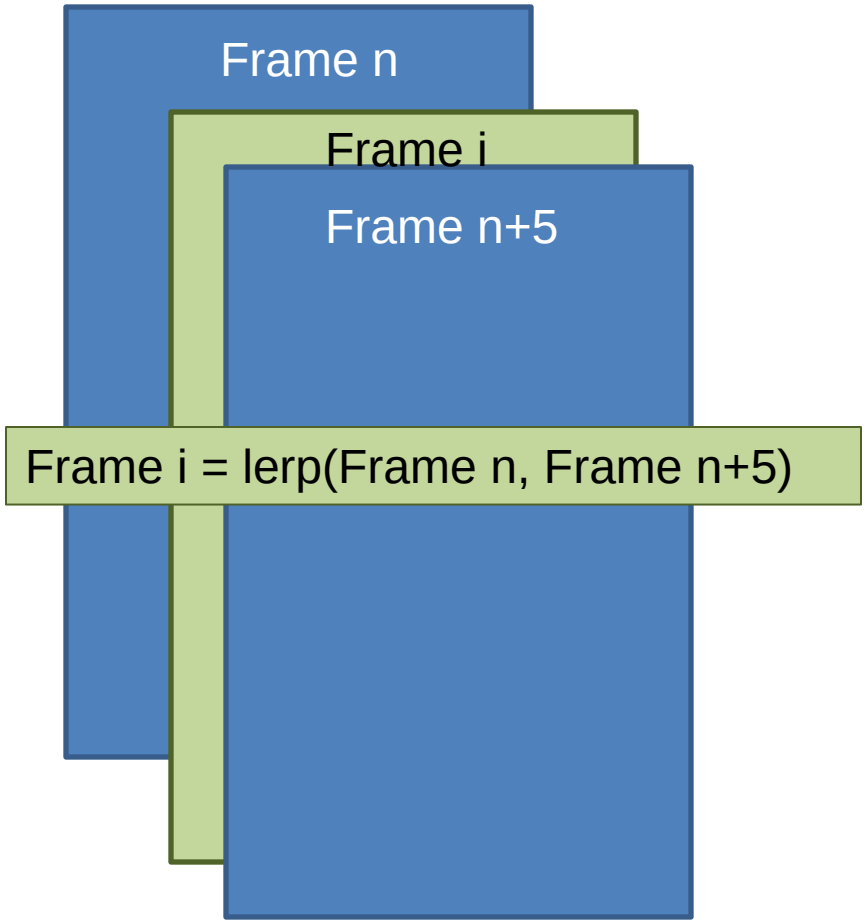
Figure 1: *The geometric complexity of scenes rendered in the movie Avatar often exceeds a billion polygons and varies widely: distant rocks and vegetation are tessellated to a level of meters and centimeters, while the faces of even distant characters are modeled to over 40,000 polygons from forehead to chin. The spatial resolution of occlusion caches precomputed by our system also spans several orders of magnitude.*

Illumination – Interpolation



Illumination – Interpolation

$$T(x, \omega, \omega_o)$$



- Illumination
- Experiments
- Comparison with Video Quality Metric

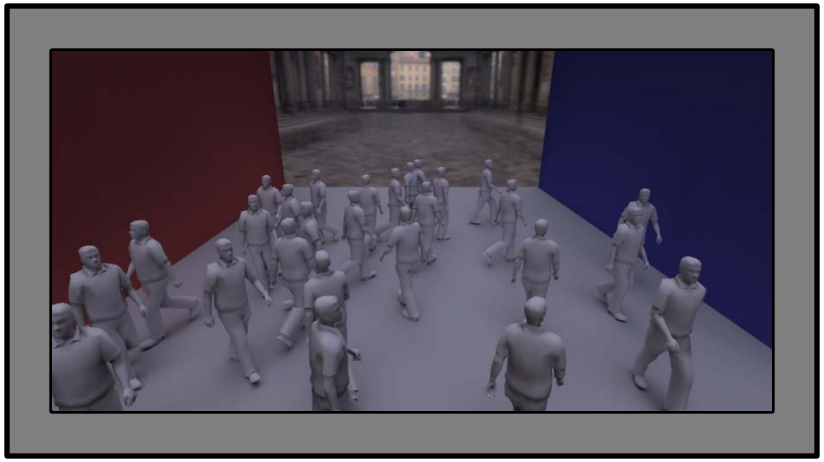
Experiments

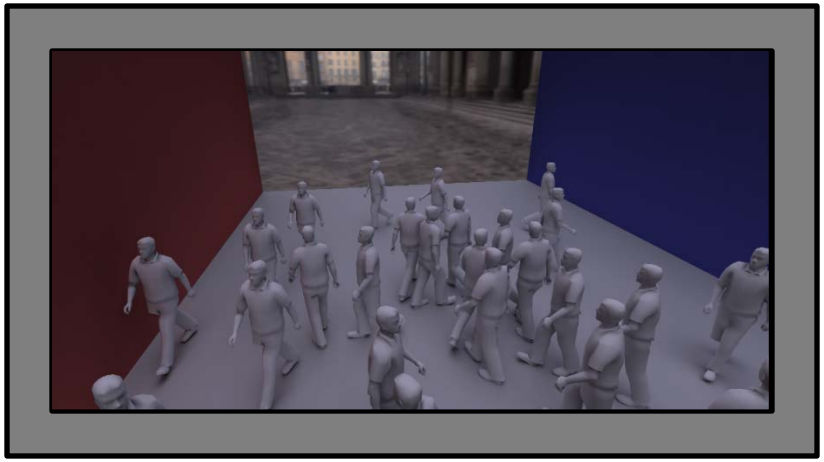
- Question:

"Is the illumination in the scene being evaluated the same quality as in the gold standard?"

Experiments – Methods

- Two screens
  - One shows test video.
  - Other shows reference from different PoV and desynchronized. ➔ Avoid side-by-side comparison





Experiment 1

Q1. Does the complexity of the crowd affect perceived quality?

Q2. Are errors in direct or indirect lighting more salient?

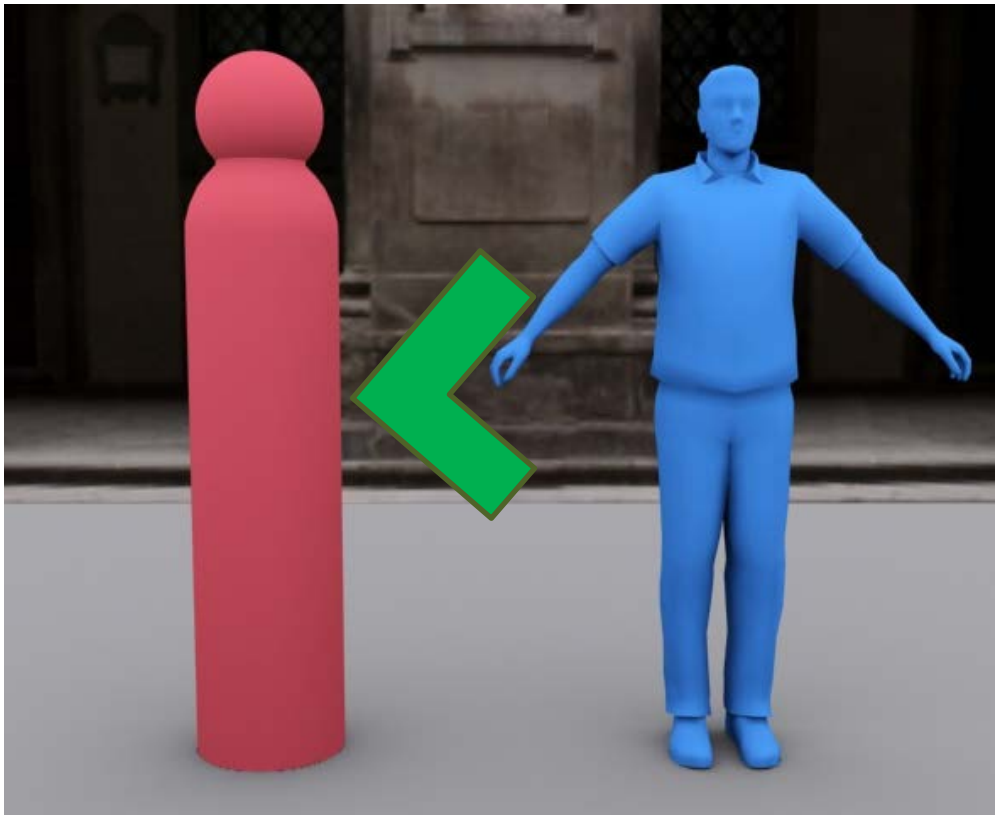
Q3. What effect does colour have on the perceived fidelity of illuminated crowd scenes?

Experiment 1 – Variables

- Character Object (OBJ): *Pawn* & *Human*

Variables – Character Object

- *Pawn*
  - Static
  - Smooth
- *Human*
  - Animated
  - Sharp gradients
  - Self-occlusions



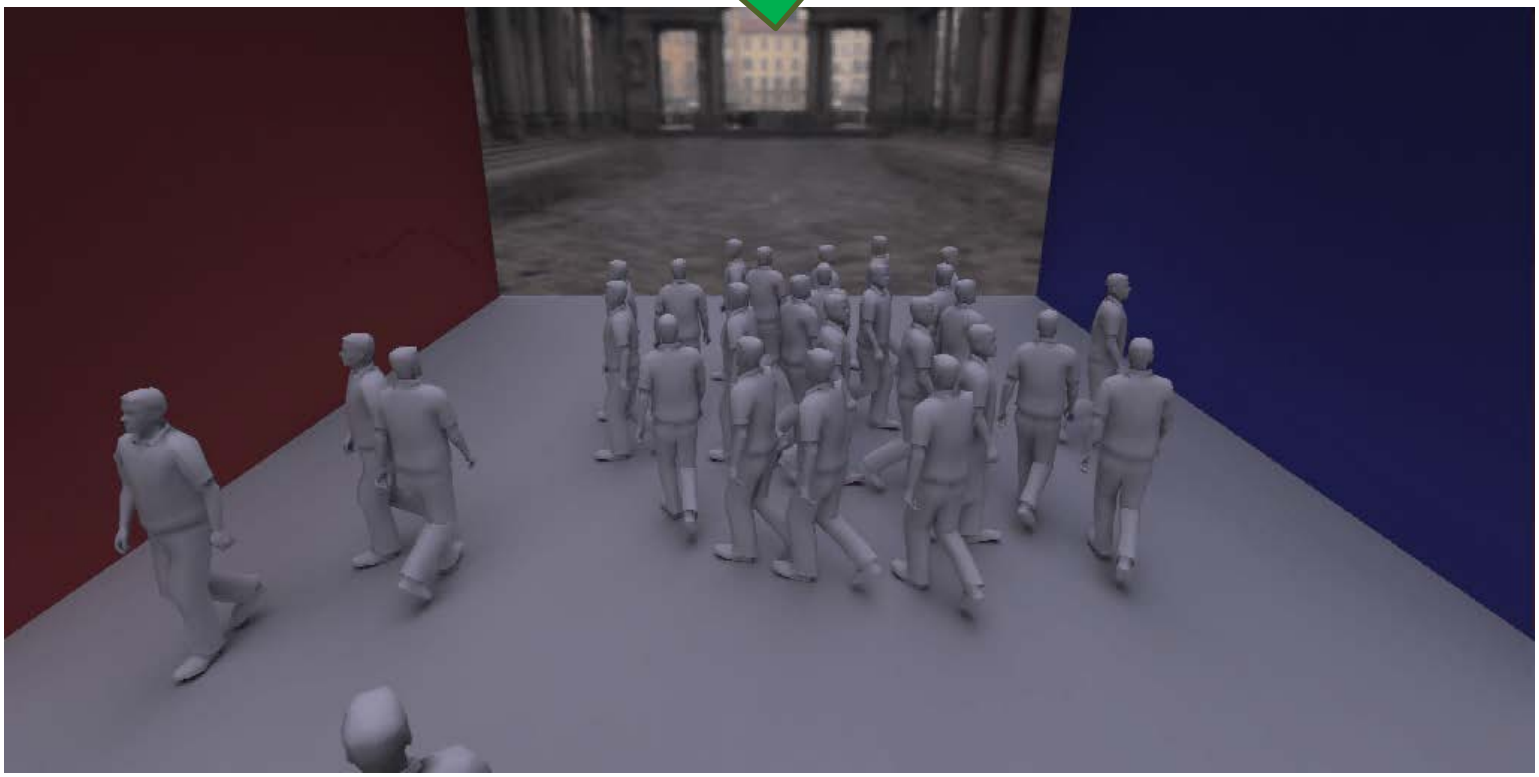
Experiment 1 – Variables

- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*

Variables – Crowd Movement

- *Army*

- *Random*



Experiment 1 – Variables

- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*
- Illumination Setup (ILL): *Visibility only* & *Full GI*

Variables – Illumination Setup

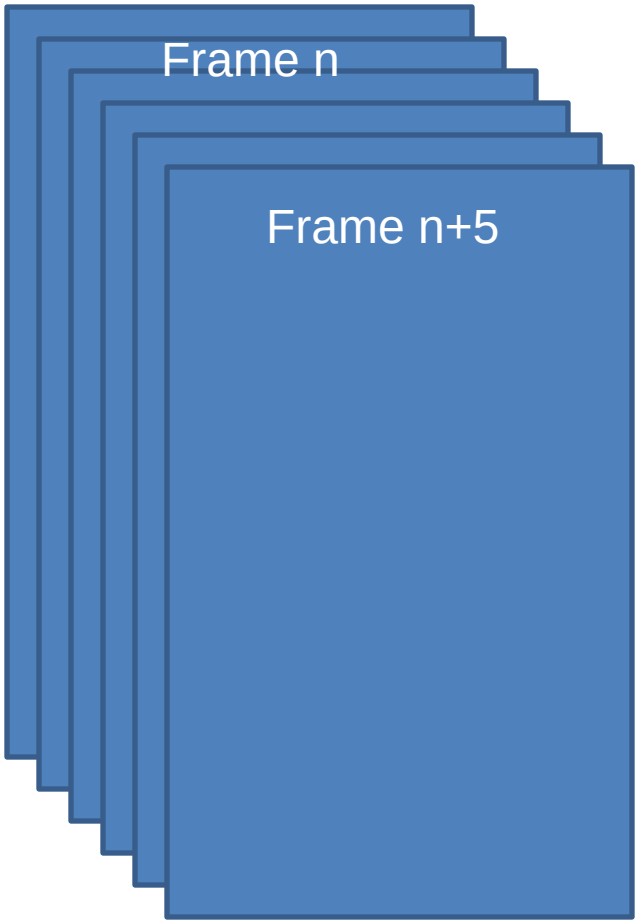
- *Visibility only*
- *Full GI*

Experiment 1 – Variables

- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*
- Illumination Setup (ILL): *Visibility only* & *Full GI*
- Interpolation Intervals (INT) : [GS, 2, 3, 4]

Illumination – Interpolation

$$T(x, \omega, \omega_o)$$



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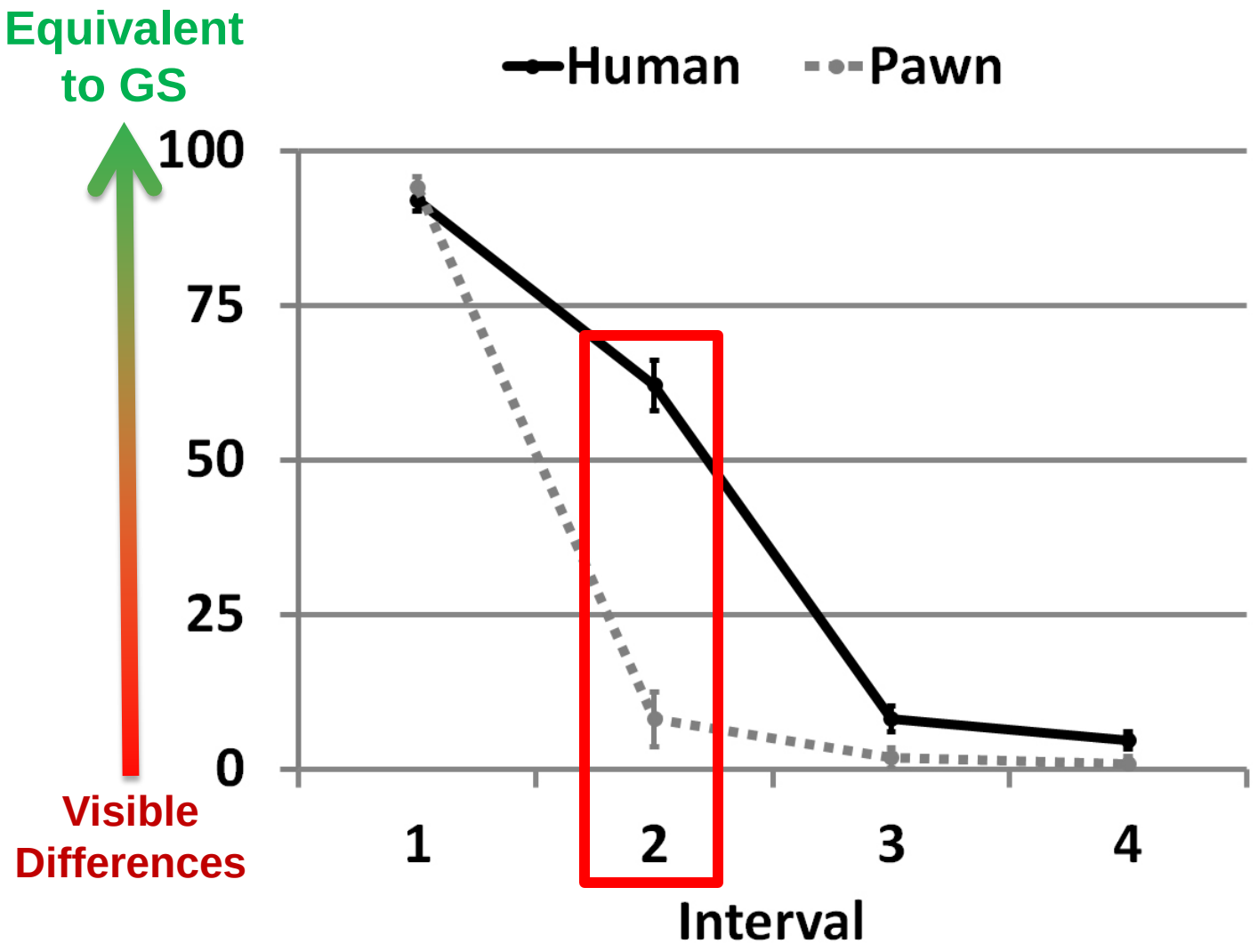
- Crowd Movement (MOV): *Army* & *Random*
- Illumination Setup (ILL): *Visibility only* & *Full GI*
- Interpolation Intervals (INT) : [GS, 2, 3, 4]

32 combinations

Experiment 1 – Results



Experiment 1 – Discussion

- Local artifacts are not masked by global complexity.
- Interpolating direct lighting coefficients creates unacceptable artifacts in most cases.

Experiment 1

Q1. Does the complexity of the crowd affect perceived quality?

Q2. Are errors in direct or indirect lighting more salient?

Experiment 2

Q1. Does the complexity of the crowd affect perceived quality?

Q3. What effect does colour have on the perceived fidelity of illuminated crowd scenes?

Experiment 2 – Variables

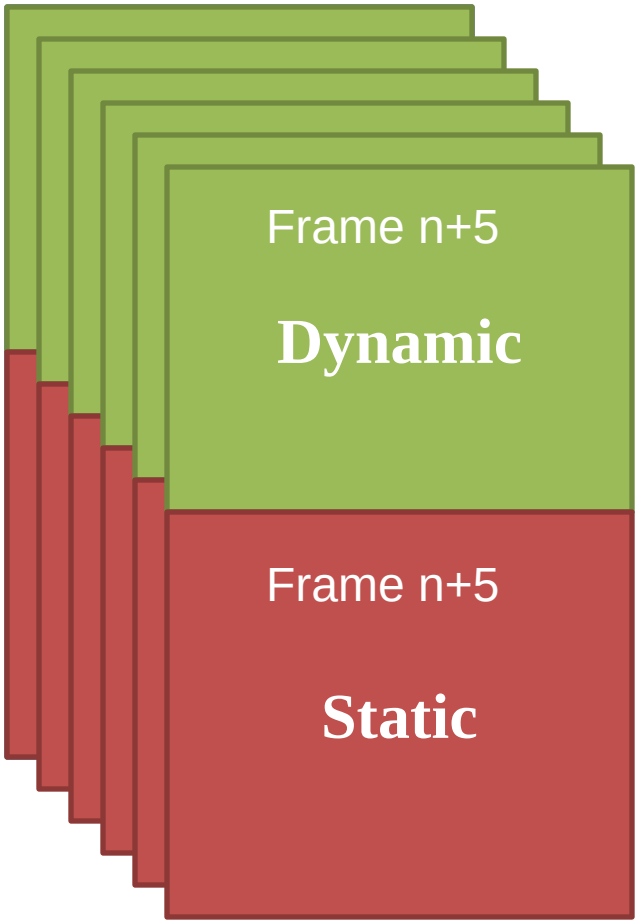
- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*
- Illumination Setup (ILL): *Visibility only* & *Full GI*

Experiment 2 – Variables

- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*
- Color (COL): *Color* & *No Color*
- Interpolation Type (TYP): *Motion-based & GI-based*

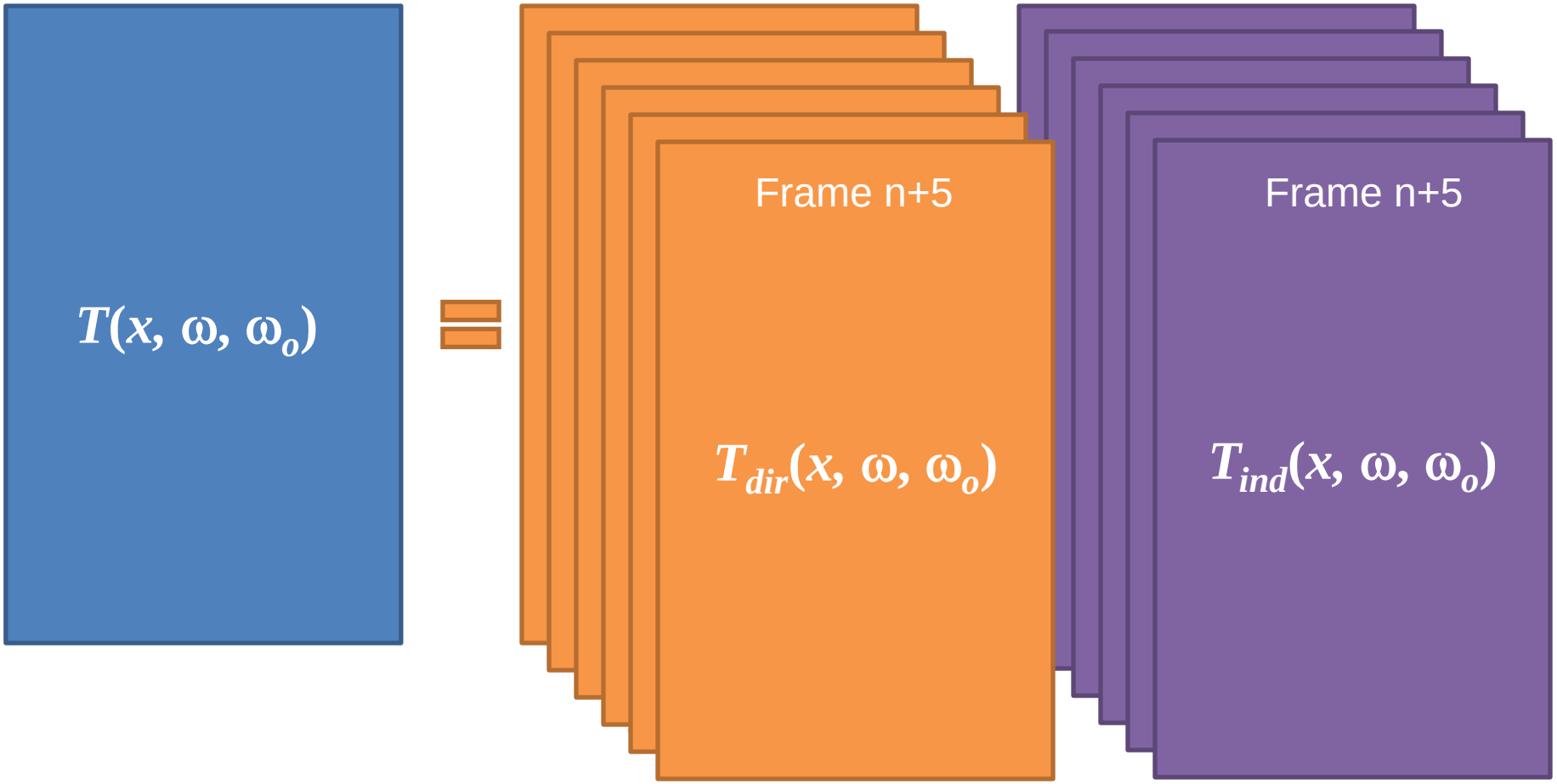
Variables – Interpolation Type

- *Motion-based*



Variables – Interpolation Type

- *Motion-based*
- *GI-based*

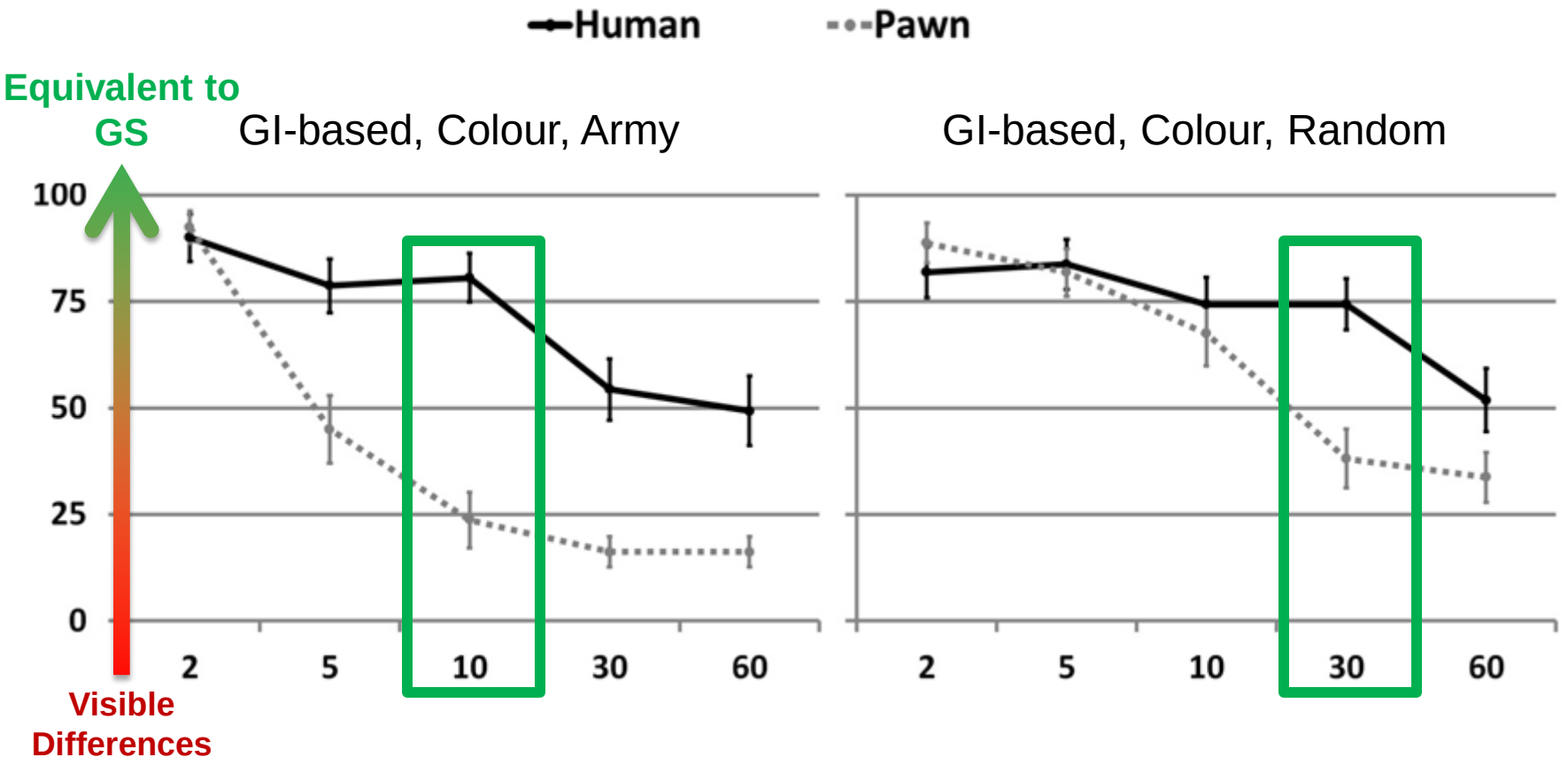


Experiment 2 – Variables

- Character Object (OBJ): *Pawn* & *Human*
- Crowd Movement (MOV): *Army* & *Random*
- Color (COL): *Color* & *No Color*
- Interpolation Type (TYP): *Motion-based & GI-based*
- Interpolation Intervals (INT) : [GS, 2, 5, 10, 30, 60]

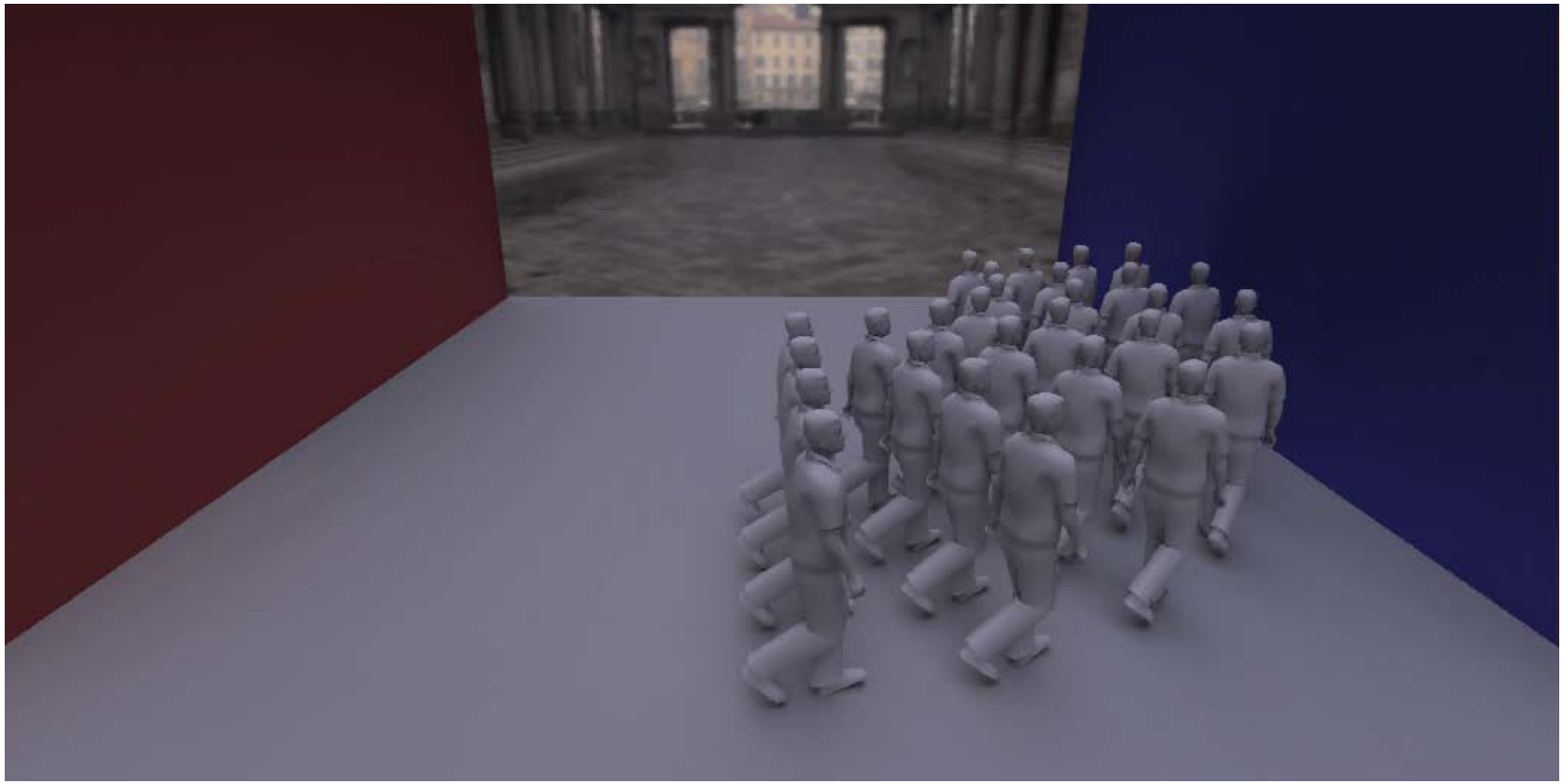
48 combinations

Experiment 2 – Results



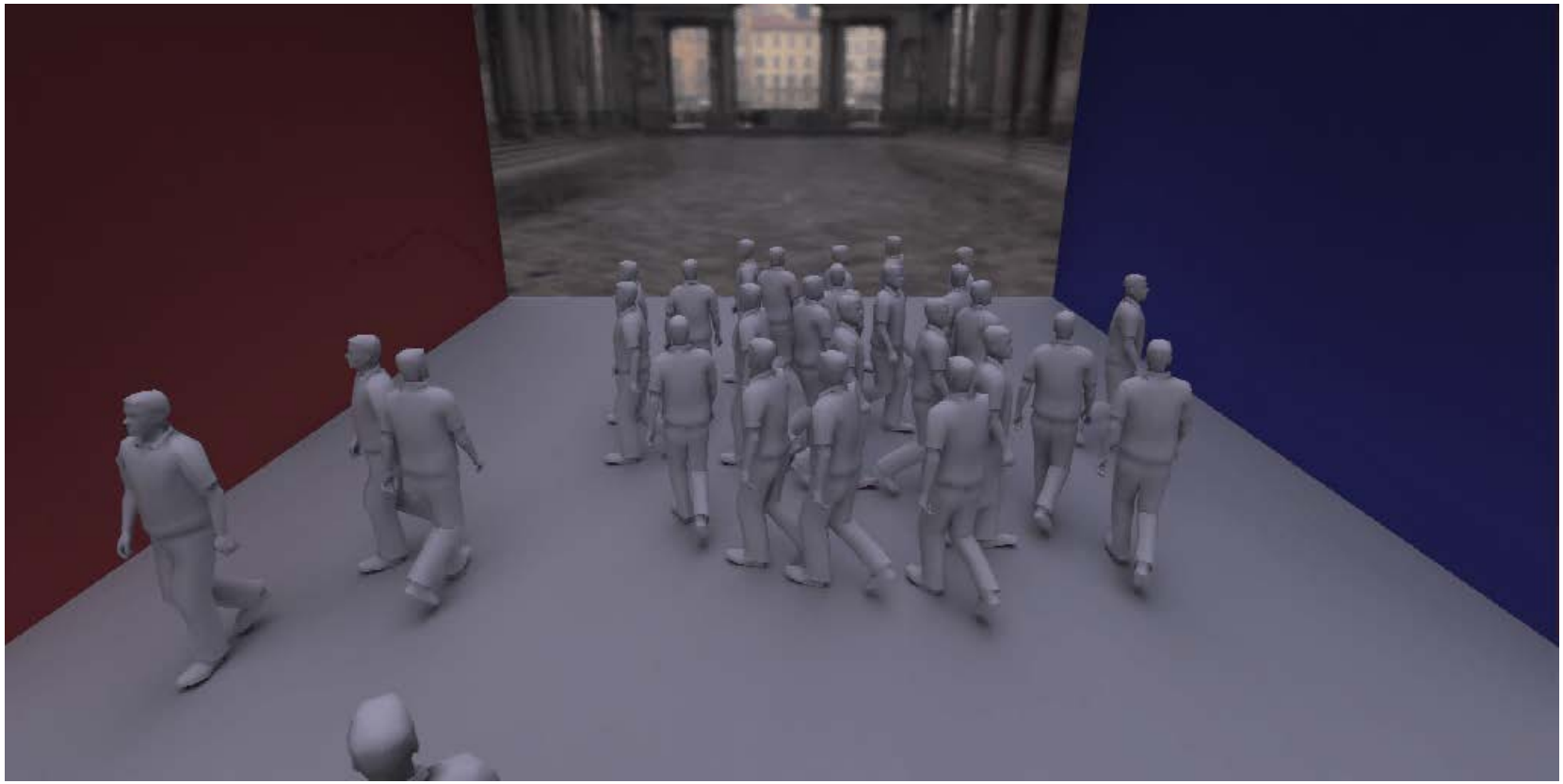
Experiment 2 – Results

Video GI-based, Army, Human, INT = 10



Experiment 2 – Results

Video GI-based, Random, Human, INT = 30



Experiment 2 – Discussion

- Complexity masks artifacts produced by approximating GI:
  - *Human* allows more approximation than *Pawn.*
  - *Random* allows more approximation than *Army.*

- We can interpolate up to 10 frames for human crowds with structured motion, and 30 for the un-structured random motion.

Performance

Timings and Speed Up for *Human* crowds:

Motion	Intp. Type	N	Time/frame	Speed-Up
Army	Motion-based	5	4’18’’	1.15x
Crowd	Motion-based	5	4’18’’	1.15x
Army	GI-based	10	1’36’’	3.08x
Crowd	GI-based	30	1’21’’	3.64x

Speed-Ups are bounded by 1.19x and 4x for Intp.Type *Motion-based* and *GI-based* respectively.

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Comparison with Video Quality Metric

- State of the art VQM [Aydin et al. 10]

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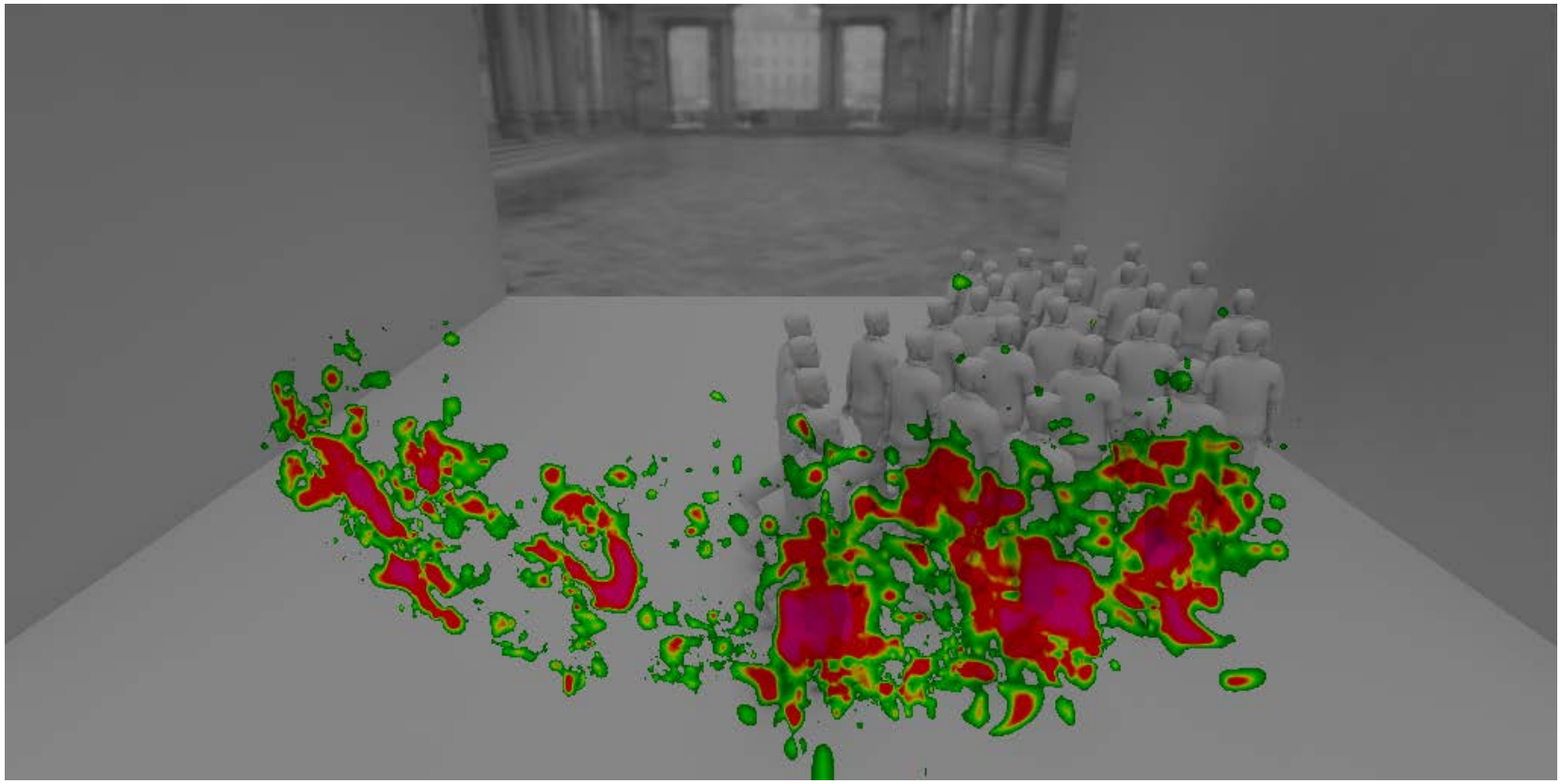
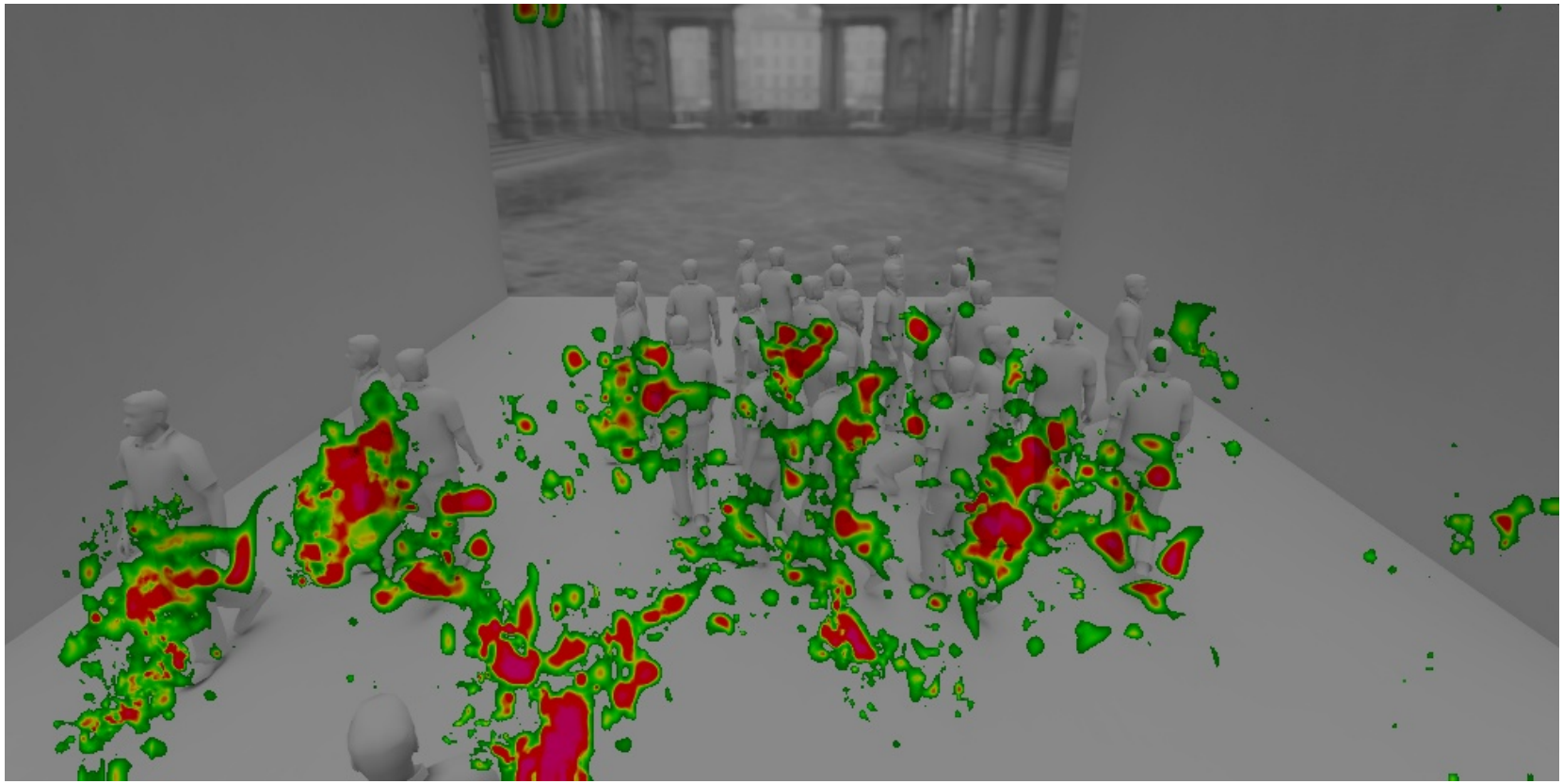


Comparison with Video Quality Metric

- State of the art VQM [Aydin et al. 10]



Comparison with Video Quality Metric

- State of the art VQM [Aydin et al. 10]

- VQM focus on low-level vision (pixels):
  - Too conservative
- Introducing high-level vision knowledge allows more aggressive approximations.

Conclusion

- Presented a framework to evaluate the perceived fidelity of approximated illumination solutions in dynamic crowds.

- Errors in illumination can be masked by the aggregate characteristics.

  Faster rendering even with naïve approximations.

- Compared against VQM. Show that using scene properties would improve these metrics.

Conclusion – Questions to answer

Q1. Does the complexity of the crowd affect perceived quality of illumination?

More complex crowds allows approximating more the illumination when approximating GI.

Q2. Are errors in direct or indirect lighting more salient?

Errors in direct lighting are more salient.

Q3. What effect does colour have on the perceived fidelity of illuminated crowd scenes?

The most acceptable approximation for human crowds is to interpolate indirect illumination in colour scenes.

Future Work

- Explore other aggregate properties.

  E.g. numerosity, variety, LoD…

- Explore new approximation algorithms for rendering.
- Account for scene properties in objective video quality metrics.

Thank you!

Acknowledgments

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- National Science Foundation
- CAI Programa Europa

- Experiment participants

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