On Realism of Architectural Procedural Models

Jan Beneš, Tom Kelly, Filip Děchtěrenko, Jaroslav Křivánek, Pascal Müller
Quick Quiz
Quick Quiz

Computer Generated

Photograph
Overview

Procedural Modeling & Realism

Questions

Experiment & Data Acquisition

Previous Work

Answers

Jan Beneš - On Realism of Architectural Procedural Models
• Procedural modeling
  – Tool for artists
  – Or fully automatic
  – Wide range of outputs

[Palubicki09]
Procedural Modeling

• Procedural modeling
  – Tool for artists
  – Or fully automatic
  – Wide range of outputs
• Wide use
Realism

Realism ⇔ Plausibility ⇔ Immersion

[Velocipedia, Gianluca Gimini]
Realism

Realism ↔ Plausibility ↔ Immersion

• Model & material & display
• Should be studied
• For procedural modelling

[Velocipedia, Gianluca Gimini]
What we did

Procedural architecture
What we did

User Study
(1) Can people tell procedurally generated buildings from real ones?
(2) Is realism carried in the detail or in the larger structure?
(2) Is realism carried in the detail or in the larger structure?
(2) Is realism carried in the detail or in the larger structure?
(3) What factors do the users think influence the perception of realism?
Questions

(1) Can people tell procedurally generated buildings from real ones?

(2) Is realism carried in the detail or in the larger structure?

(3) What factors do the users think influence the perception of realism?
Previous Work
“There is no dirt, no dust, no fingerprints on the glass table...simply too beautiful, too clean and polished...”
[Reinhard13]
Previous Work - Realism

CG2Real [Johnson11]
Previous Work - Realism

[Rademacher01]
Previous Work - Buildings

- Building generation
  - Grammar [Stiny80, Wonka03, Muller06, Schwarz15]
  - Data [Fan16]
  - Sketch [Nishida16]
  - Predefined parts [Kalogerakis12, Talton12]
Previous Work - Miscellaneous

• Machine Learning
  – What makes Paris look like Paris [Doersch12]
  – Architectural Style Recognition [Mathias11]

• Image Quality & Similarity
  – Visible Differences Predictor [Daly92]
  – Visual Equivalence and Aggregates [Ramanarayanan07,08]
  – Structural Similarity - SSIM [Wang04]
Experimental Setup
Datasets

Favela

Medieval

Paris

Venice
Datasets

Computer Generated

Photos

Favela  Medieval  Paris  Venice
Classification Screen

Classify images as Photographs or Computer Generated (not blurry)

You need to classify 12 more images.
Blurs

1px – no blur

7px blur

13px blur

25px blur

32px blur

55px blur
Summary
Summary

TRAINING

Venice-55px

Medieval-55px

Paris-55px

Favela-55px
Summary

TRAINING

Venice-55px

Medieval-55px

Paris-55px

Favela-55px

Venice-37px

Medieval-37px

Paris-37px

Favela-37px
Summary

TRAINING

Venice-55px

Medieval-55px

Paris-55px

Favela-55px

Venice-37px

Medieval-37px

Paris-37px

Favela-37px

Venice-1px

Medieval-1px

Paris-1px

Favela-1px
On Realism of Architectural Procedural Models

- Venice
- Medieval
- Paris
- Favela
Renders

render to HDR

expose

crop
Data Characteristics
Data Characteristics

Choose subset
Quick Peek at Results
Quick Results

random choice = 0.5

Accuracy

Blur size

Computer Generated
Photographs
random choice = 0.5
Quick Results

Medieval
Worst Dataset

random choice

Accuracy

Blur size

Favela
Medieval
Paris
Venice

1px 7px 13px 25px 37px 55px
Q1: CG vs Real
Q1: CG vs Real

- $H_{DIFF}$: participants can tell photographs and generated buildings apart.
  - Random choice = 0.5 accuracy
  - No blur, overall – $p<.001$
  - Can accept $H_{DIFF}$
  - Also true for each dataset
Q1: CG vs Real

• $H_{DIFF}$: participants can tell photographs and generated buildings apart.
  – Random choice = 0.5 accuracy
  – No blur, overall – $p < .001$
  – Can accept $H_{DIFF}$
  – Also true for each dataset

• Also true @ 55px
Q2: Details vs Structure
Q2: Details vs Structure

• $H_{\text{SCALE}}$: the detail that allows participants to tell photographs and generated images apart is present at various scales.

• ANOVA
What’s ANOVA?

Black box

Independent variable

Independent variable

Independent variable

Dependent variable
What’s ANOVA?

Blurr Size

Original image class

Dataset

Accuracy
What’s ANOVA?

• ANOVA
  – Linear model
  – Effects of independent variables
Significant Effects

- **Significant effects**
  - Blur, $p<.001$
  - Dataset, $p<.001$
• Significant effects
  – Blur, $p < .001$
  – Dataset, $p < .001$

$H_{\text{SCALE}}$ accepted
More on Blur

- Significant effects
  - Blur, $p<.001$
  - Dataset, $p<.001$
- Blur, $p<.001$
  $\Rightarrow H_{\text{SCALE}}$ accepted
Post-Hoc - Blur

Significant

Not significant

Computer Generated

Photographs

Accuracy

Blur size

1px 7px 13px 25px 37px 55px

Jan Beneš - On Realism of Architectural Procedural Models
**Blurs**

1px – no blur  
7px blur  
13px blur  
25px blur  
32px blur  
55px blur

$H_{\text{SCALE}}$: the detail that allows participants to tell photographs and generated images apart is present at various scales.
Two- & Three-Way Interactions

- Three factors
- Interactions
- More in paper
Q2: Summary

• Blur
  – $p < .001$, significant factor
  – $=> H_{SCALE}$ accepted
  – Realism at different scales
Q3: What users thought
Participants

- 52 total
  - 11 female
  - 24.3 years old
What users thought

• Manually tallied debriefings
  1. Imperfections & small detail (30/52 ~ 58%)
  2. Texture (19/52 ~ 37%)
  3. Reflections in windows (18/52 ~ 35%)
  4. “Weird” or uniform color (17/52 ~ 33%)
  5. Things in & around windows (16/52 ~ 31%)
  6. Model Structure (14/52 ~ 27%)
  7. Lighting (12/52 ~ 23%)
  8. Shadow (12/52 ~ 23%)
  9. Regularity (11/52 ~ 21%)
1. Imperfections & Small Detail

- Imperfections & small detail (30/52 ~ 58%)

Computer Generated  Computer Generated  Photograph
2. Texture

• Texture (19/52 ~ 37%)

Computer Generated

Computer Generated
5. Windows

- Things in & around windows (16/52 ~ 31%)
6. Model Structure

- Model Structure (14/52 ~ 27%)
9. Regularity

- Regularity (11/52 ~ 21%)

Computer Generated

Computer Generated
• **Cut-Out Edges**
  - 21/52 ~ 40% – “played role”

• **Camera Angles**
  - 18/52 ~ 35% – Influenced for at least one

• **Background**
  - 8/52 ~ 15% – Made me choose computer generated more often
Opinions Summary

• Multi-faceted
  – Guidelines, guesses
  – Not hard facts

• Biases
More Exploration
Confounding Buildings @ 55px

Photographs

Computer Generated
Summary and Future Work
• Realism in
  – Procedural Modelling
  – Buildings

• Methodology for experiment
  – Procedural content

• Verified
  – People can tell CG and Photos apart
  – Realism is carried at different scales

• “Soft results”
  – What people consider
  – Exploration of results
Future Work & Limitations

• Future Work
  – Understand asset reuse better
  – Understand importance of structure better
  – Study buildings in context
  – Neural networks to automate testing & drive rule generation

• Limitations
  – Design limitations & Biases
  – Generalization
Acknowledgements

- ESRI
- Charles University Grant SVV-2016-260332
- Czech Science Foundation grant 16-18964S.
- Filip Děchtěrenko was supported by Czech Academy of Sciences Strategy AV21 – RVO 68081740
- vrbn.io
- Corona Renderer
Thank You!

http://JanBenes.net
Supplemental Material
Biases

• Cut-Out Edges
  – 21/52 ~ 40% – “played role”

• Camera Angles
  – 18/52 ~ 35% – Influenced for at least one

• Background
  – 8/52 ~ 15% – Made me choose computer generated more often
What users thought

• Manually tallied debriefings
  1. Imperfections & small detail (30/52 ~ 58%)
  2. Texture (19/52 ~ 37%)
  3. Reflections in windows (18/52 ~ 35%)
  4. “Weird” or uniform color (17/52 ~ 33%)
  5. Things in & around windows (16/52 ~ 31%)
  6. Model Structure (14/52 ~ 27%)
  7. Lighting (12/52 ~ 23%)
  8. Shadow (12/52 ~ 23%)
  9. Regularity (11/52 ~ 21%)