On Realism of Architectural Procedural Models

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

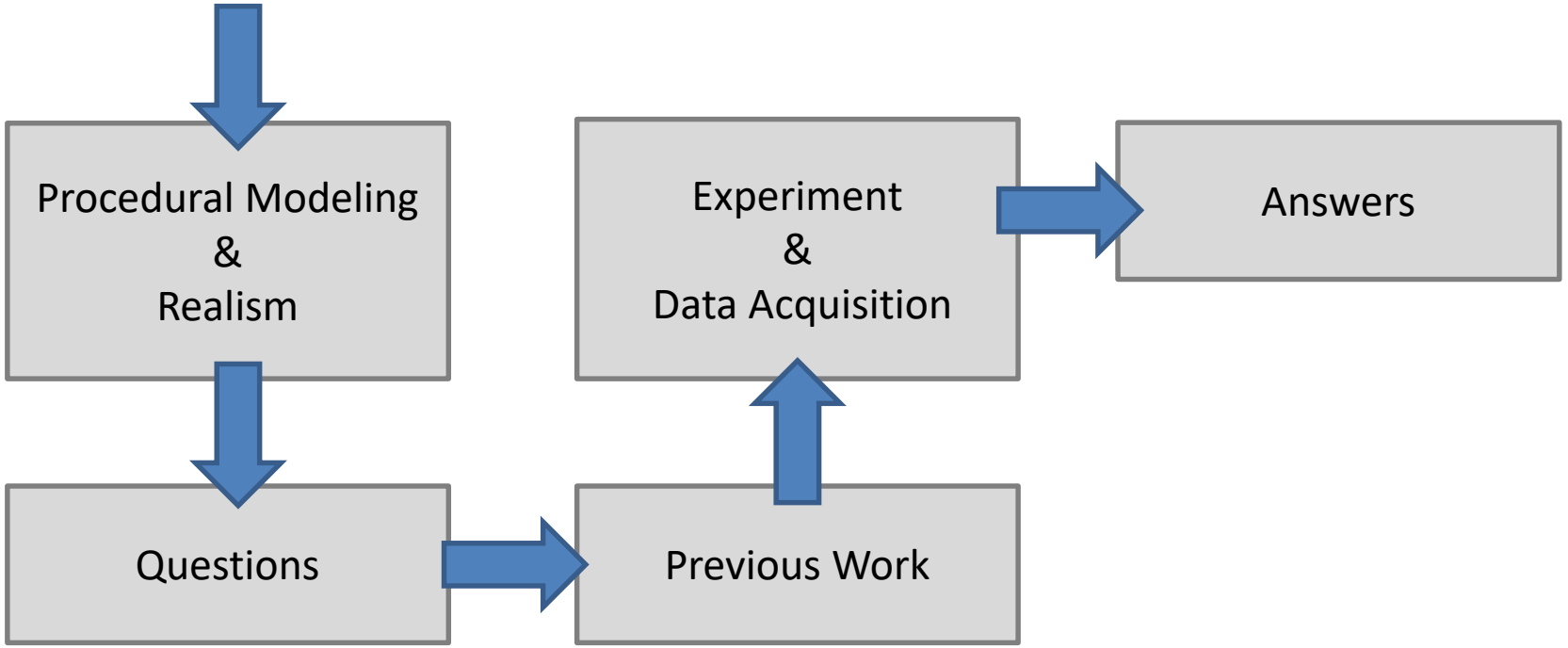
Quick Quiz

Quick Quiz

Computer Generated

Photograph

Overview


Procedural Modeling
&
Realism
Questions
Previous Work
Experiment
&
Data Acquisition
Answers

Procedural Modeling

- **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**

[Palubicki09]

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

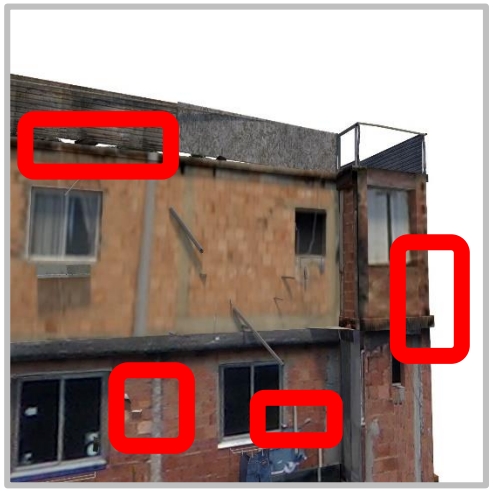
Question #1

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

Question #2

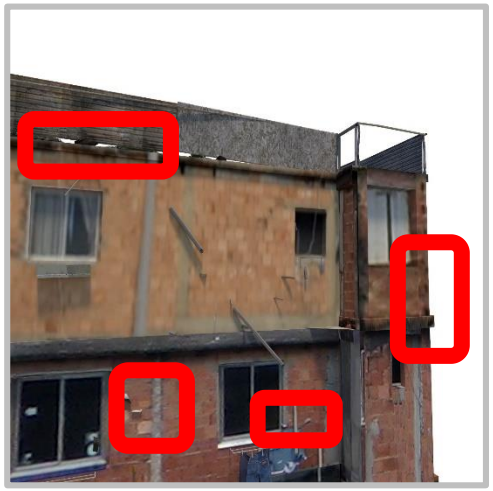
(2) Is realism carried in the detail or in the larger structure?

Question #2



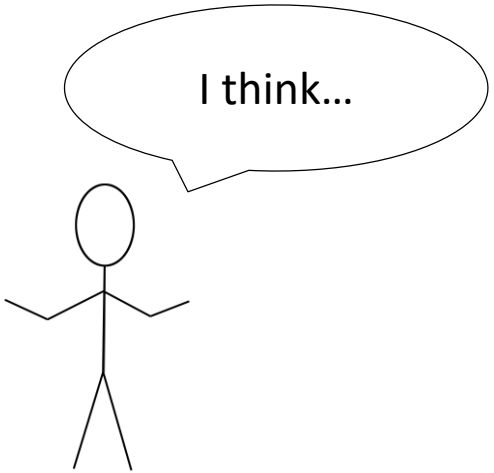
(2) Is realism carried in the detail or in the larger structure?

Question #2



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

Question #3



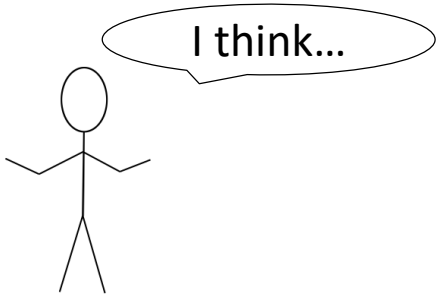
(3) What factors do the users think influence the perception of realism?

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

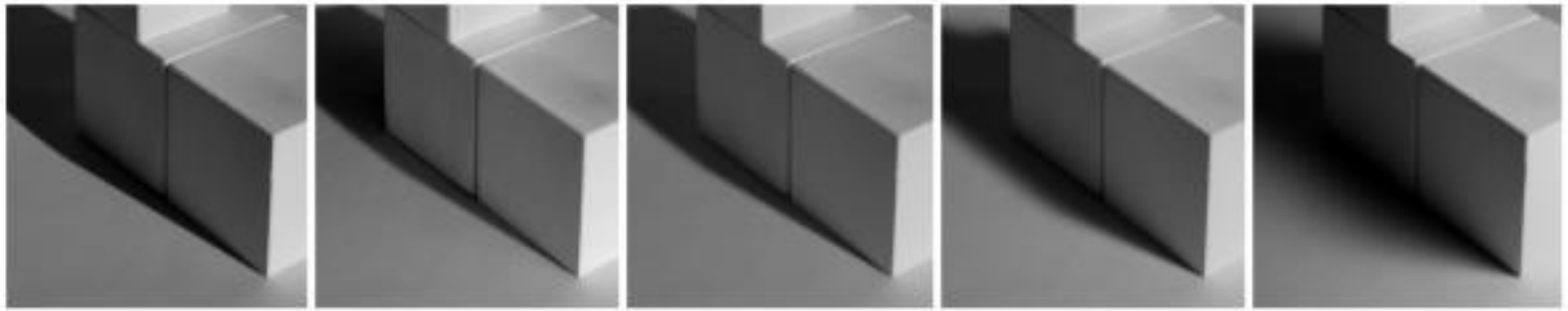
Previous Work - Realism

"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

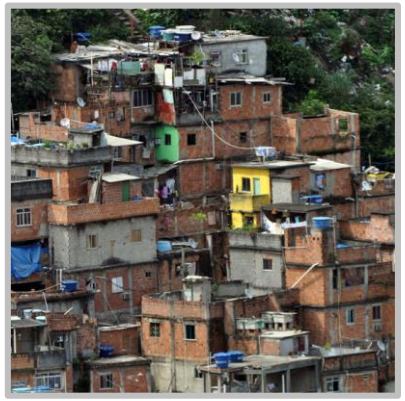
- Building generation
  - Grammar [Stiny80, Wonka03, Muller06, Schwarz15]
  - Data [Fan16]
  - Sketch [Nishida16]
  - Predefined parts [Kalogerakis12, Talton12]

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

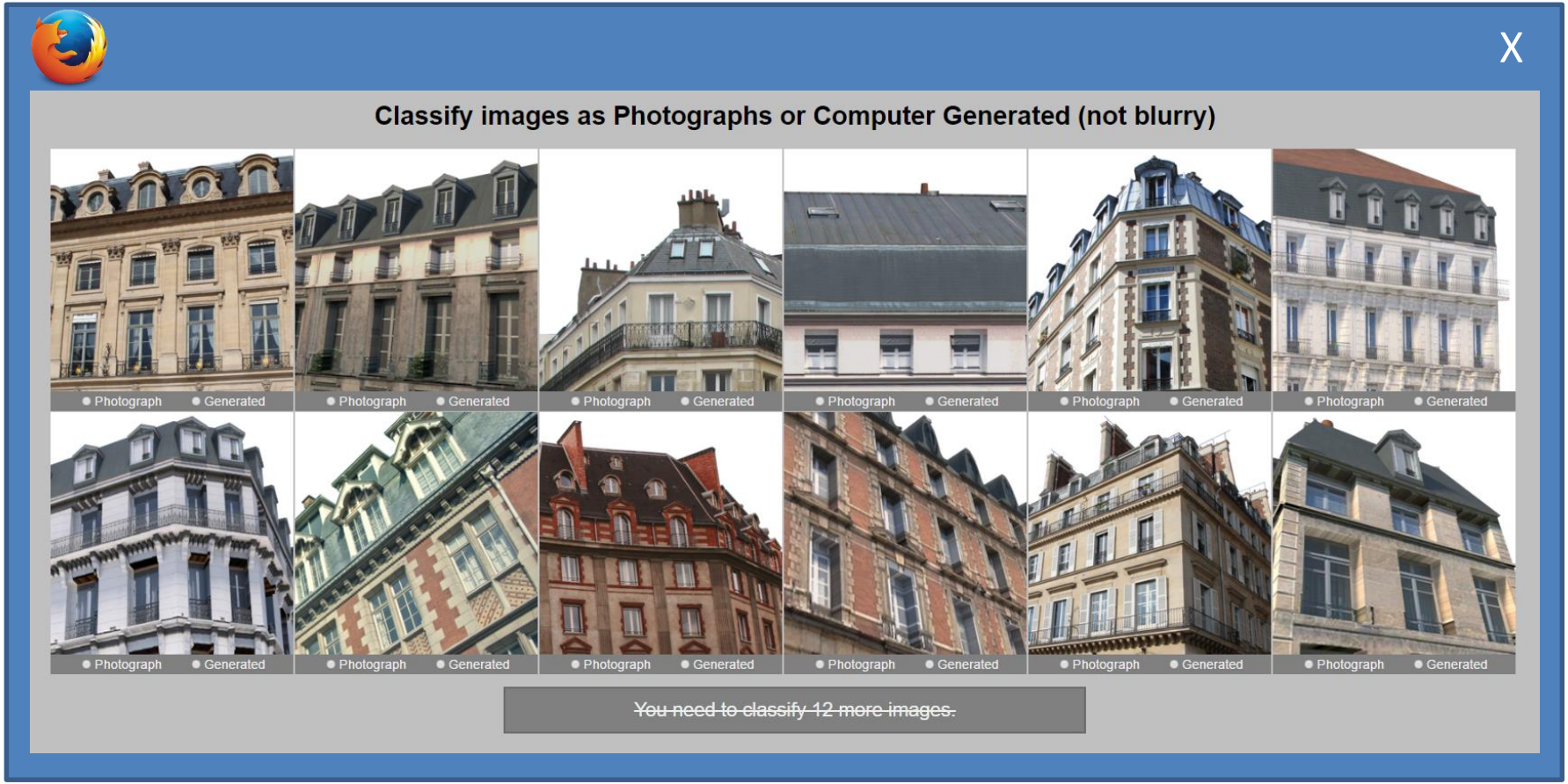
Datasets

Computer Generated

Photos

Favela | Medieval | Paris | Venice

Classification Screen



Blurs

1px – no blur

7px blur

13px blur

25px blur

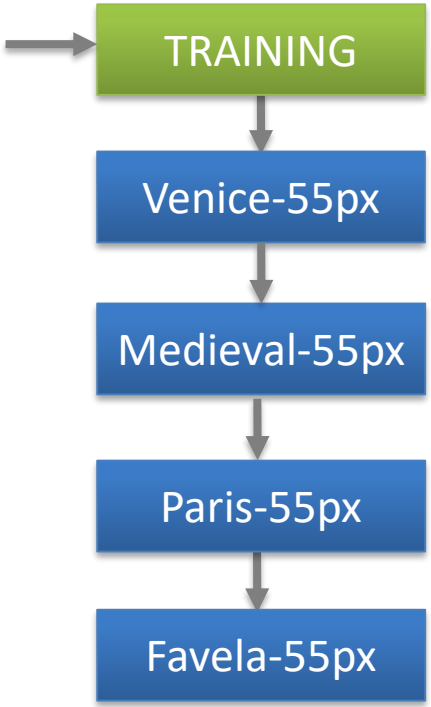
32px blur

55px blur

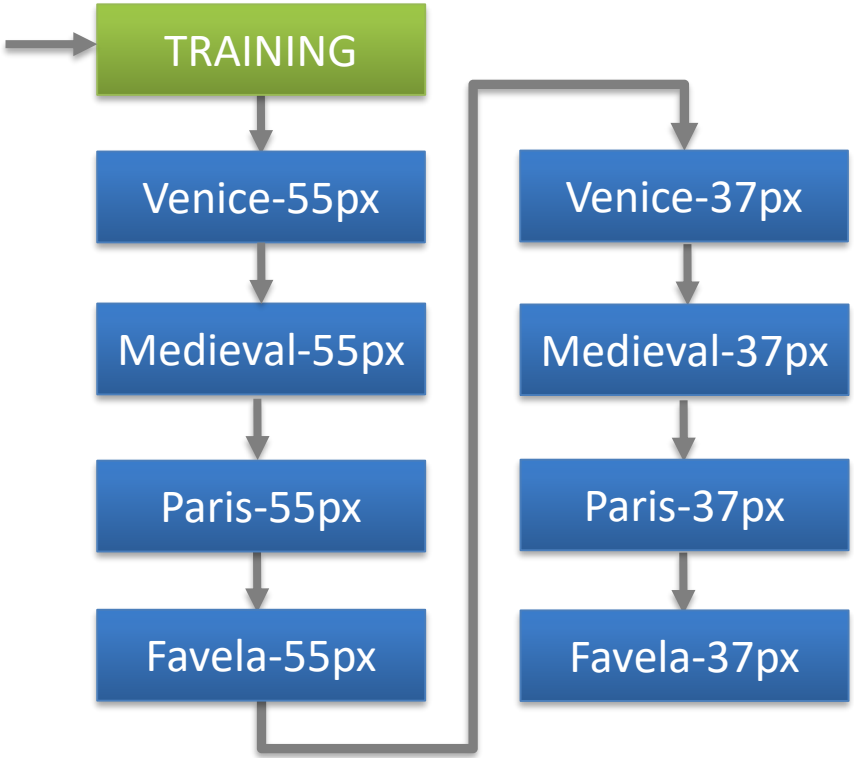
Summary

TRAINING

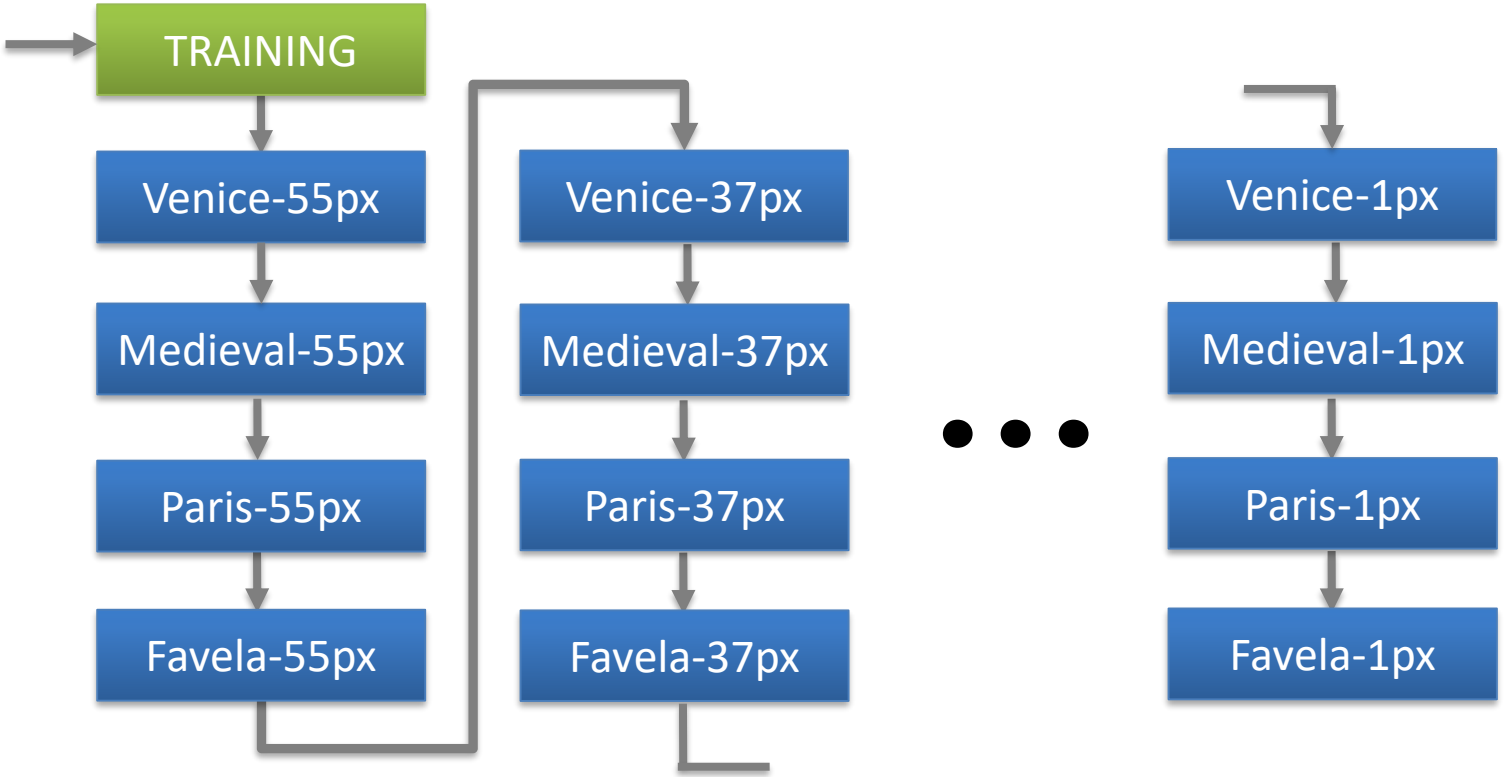
Summary



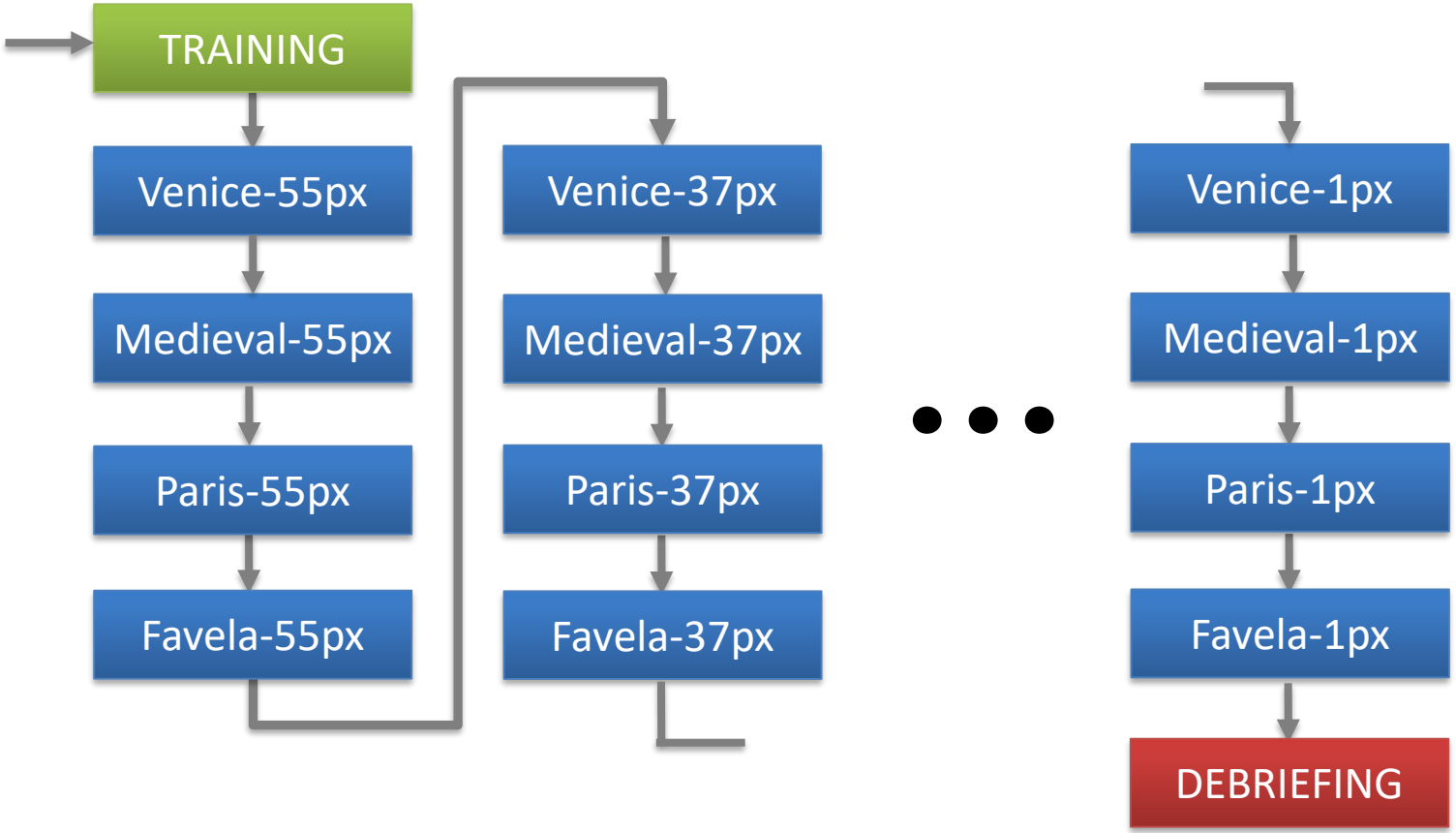
Summary


TRAINING
Venice-55px
Medieval-55px
Paris-55px
Favela-55px
Venice-37px
Medieval-37px
Paris-37px
Favela-37px

Summary

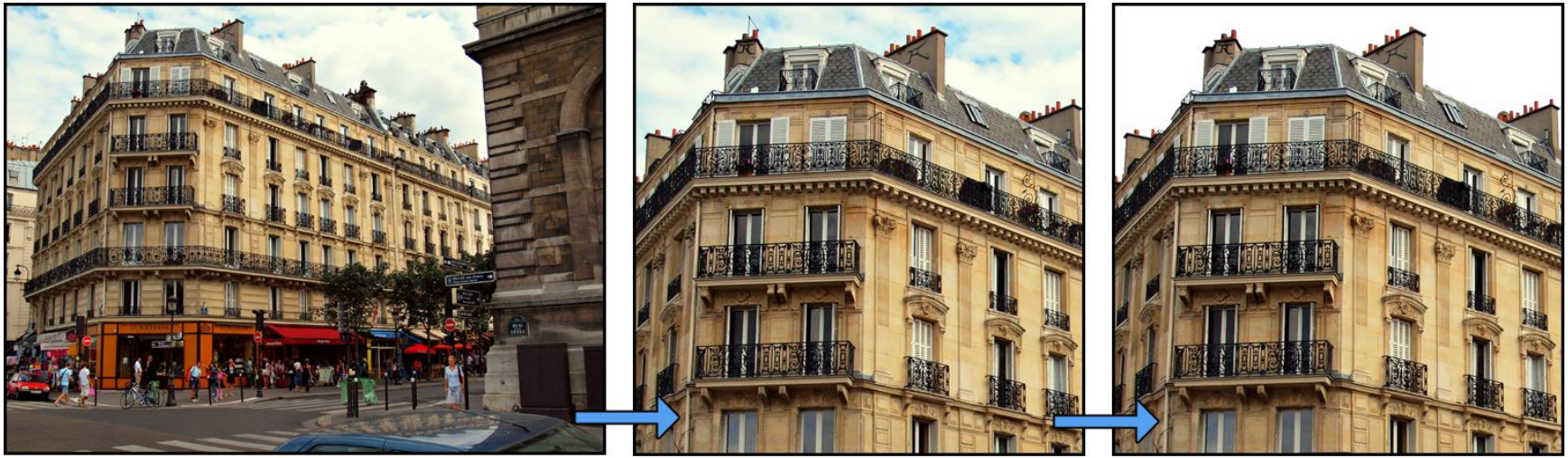

TRAINING
Venice-55px
Medieval-55px
Paris-55px
Favela-55px
Venice-37px
Medieval-37px
Paris-37px
Favela-37px
Venice-1px
Medieval-1px
Paris-1px
Favela-1px

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
DEBRIEFING

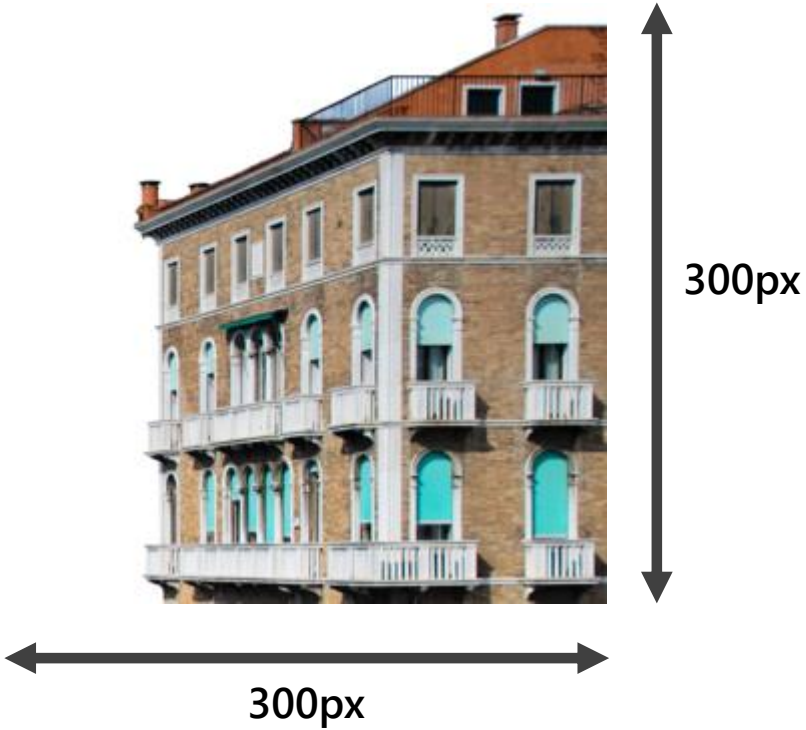
Data preparation

Photographs



Renders

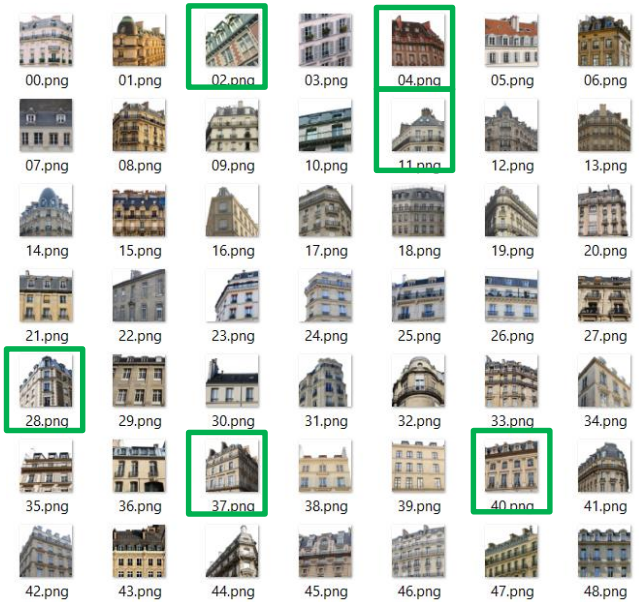
Data Characteristics



Data Characteristics

300px

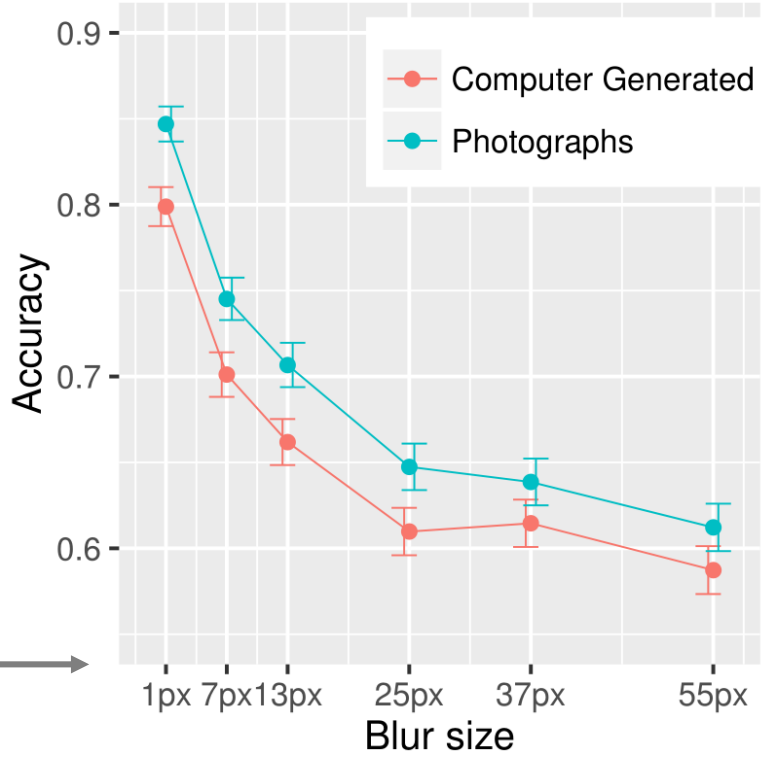
300px



Choose subset

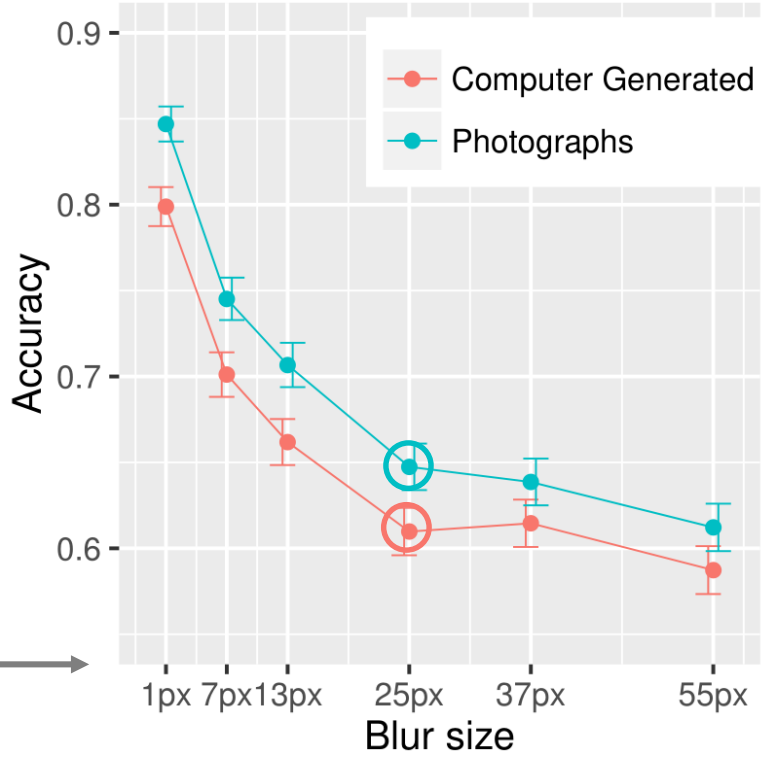
Quick Peek at Results

Quick Results



random choice = 0.5

Quick Results

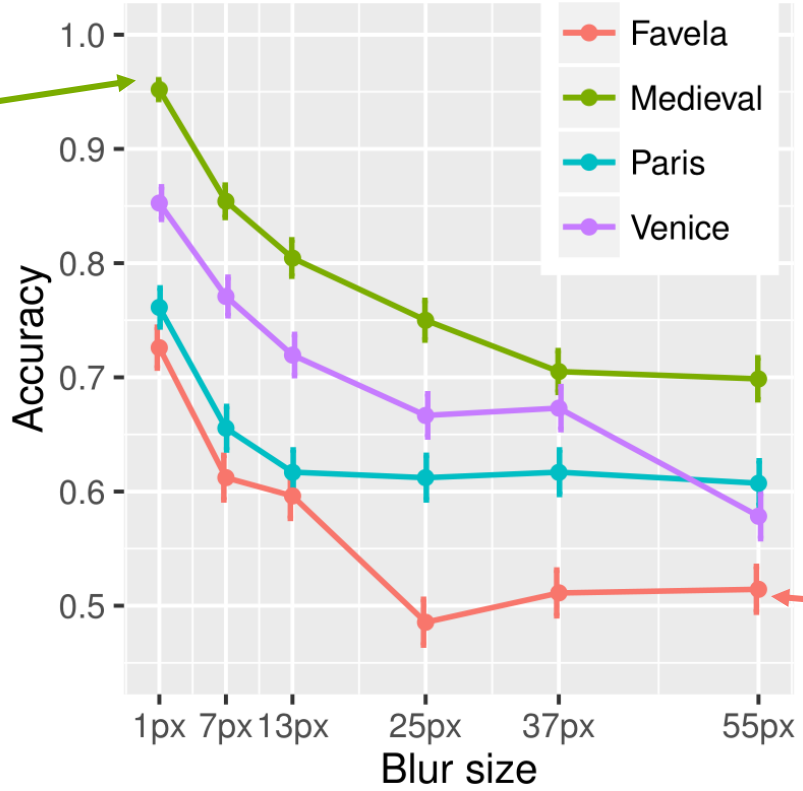


random choice = 0.5

Quick Results

Medieval
Worst Dataset

random choice →



Favela
Best Dataset

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

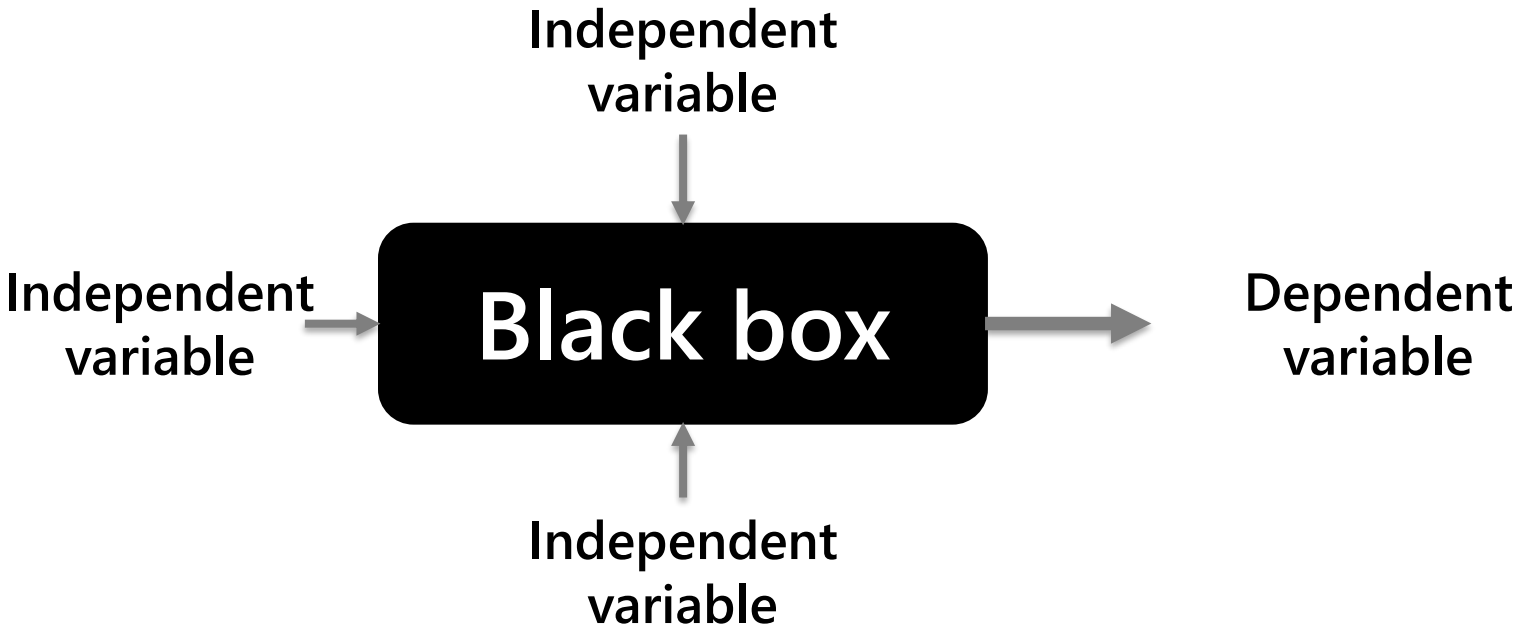
- H_{DIFF}: participants can tell photographs and generated buildings apart.
  - Random choice = 0.5 accuracy
  - No blur, overall – $p<.001$
  - Can accept H_{DIFF}
  - Also true for each dataset
- Also true @ 55px

Q2: Details vs Structure

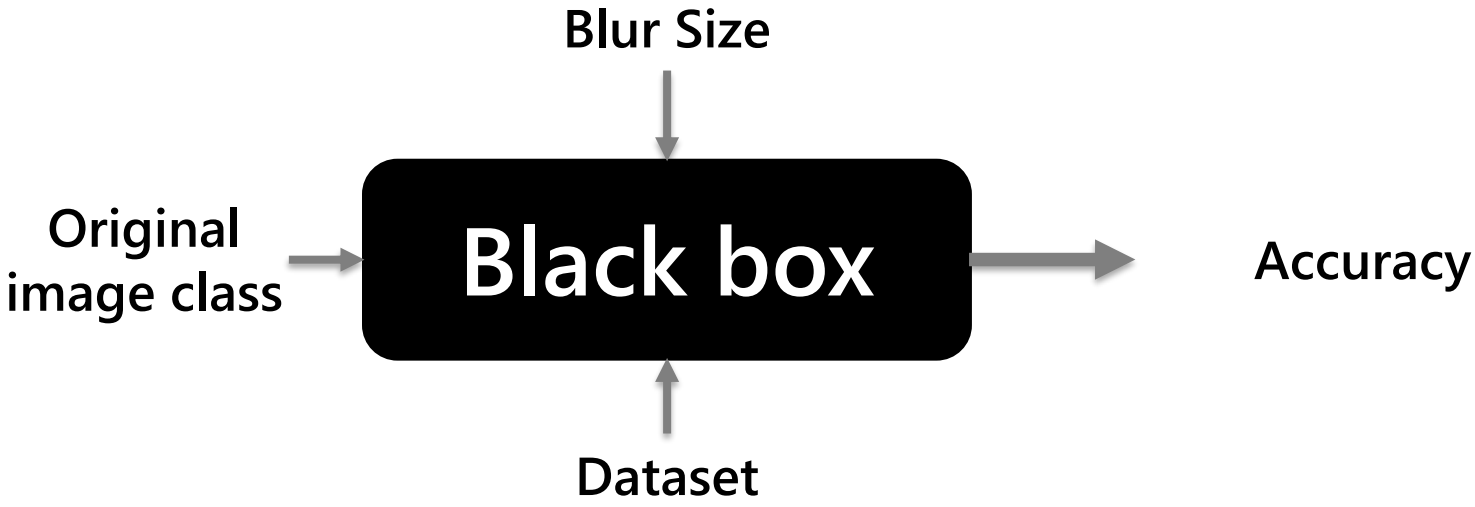
Q2: Details vs Structure

- H_{SCALE}: the detail that allows participants to tell photographs and generated images apart is present at various scales.
- ANOVA

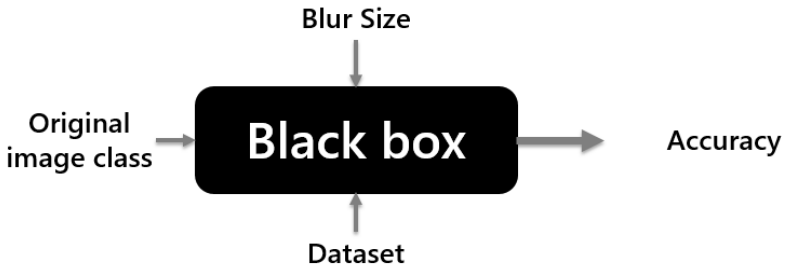
What's ANOVA?


Independent variable
Independent variable
Black box
Dependent variable
Independent variable

What's ANOVA?

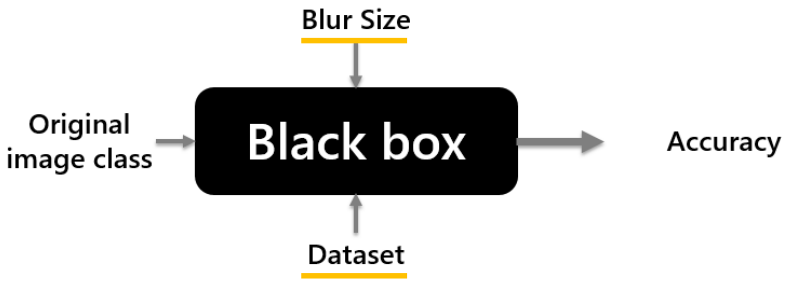


What's ANOVA?



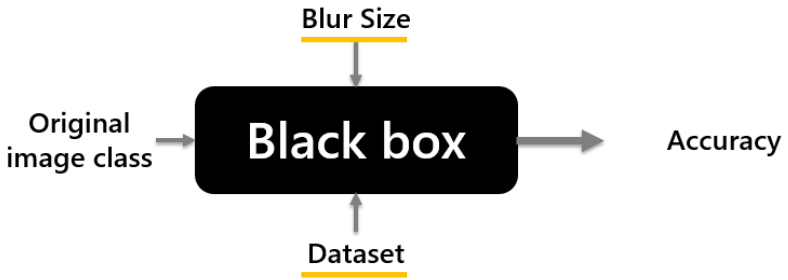
- ANOVA
  - Linear model
  - Effects of independent variables

Significant Effects



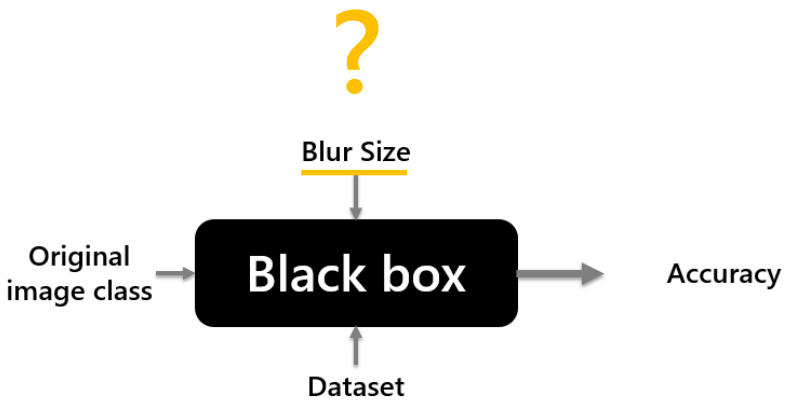
- **Significant effects**
  - Blur, $p<.001$
  - Dataset, $p<.001$

H_{SCALE}



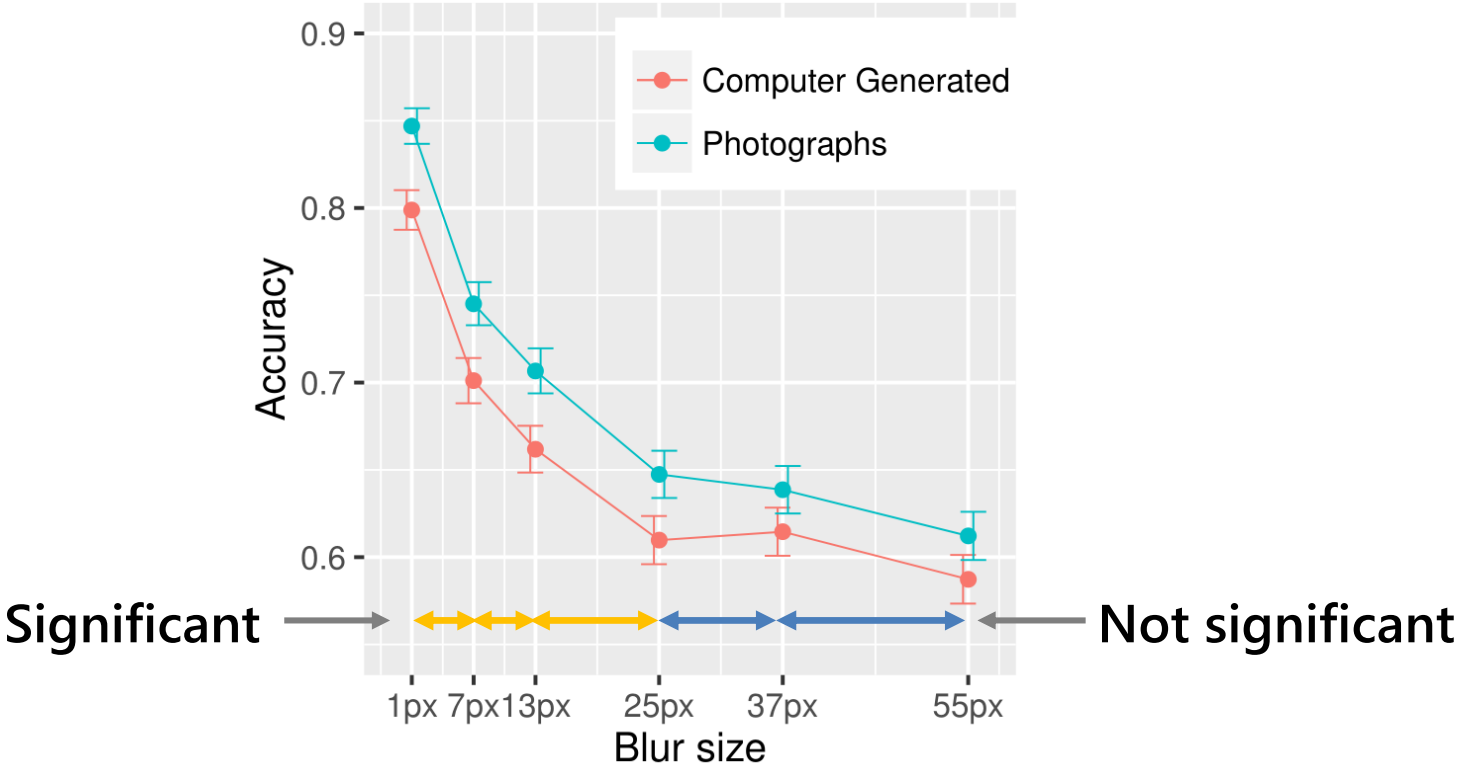
- Significant effects
  - Blur, $p<.001$
  - Dataset, $p<.001$
- Blur, $p<.001$
  $=>H_{SCALE}$ accepted

More on Blur

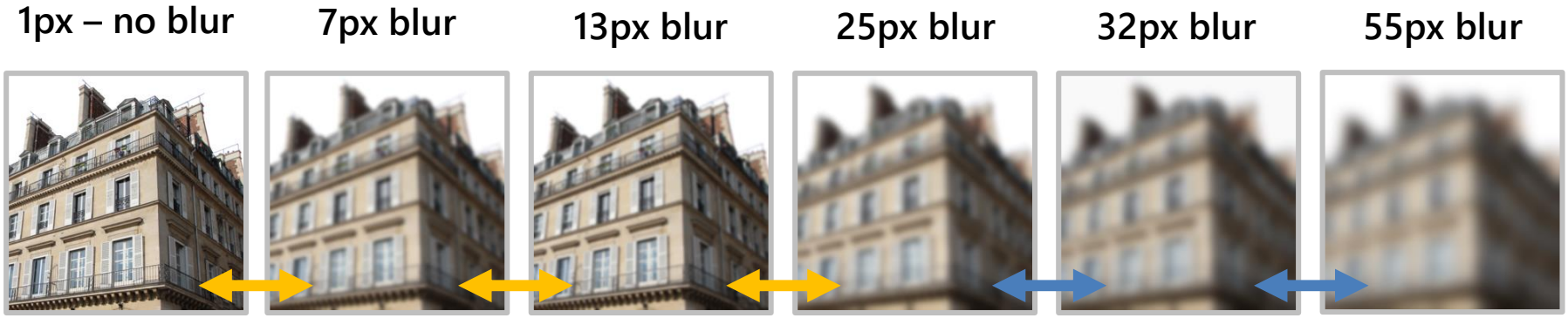


- Significant effects
  - Blur, $p<.001$
  - Dataset, $p<.001$
- Blur, $p<.001$
  $=> H_{SCALE}$ accepted

Post-Hoc - Blur



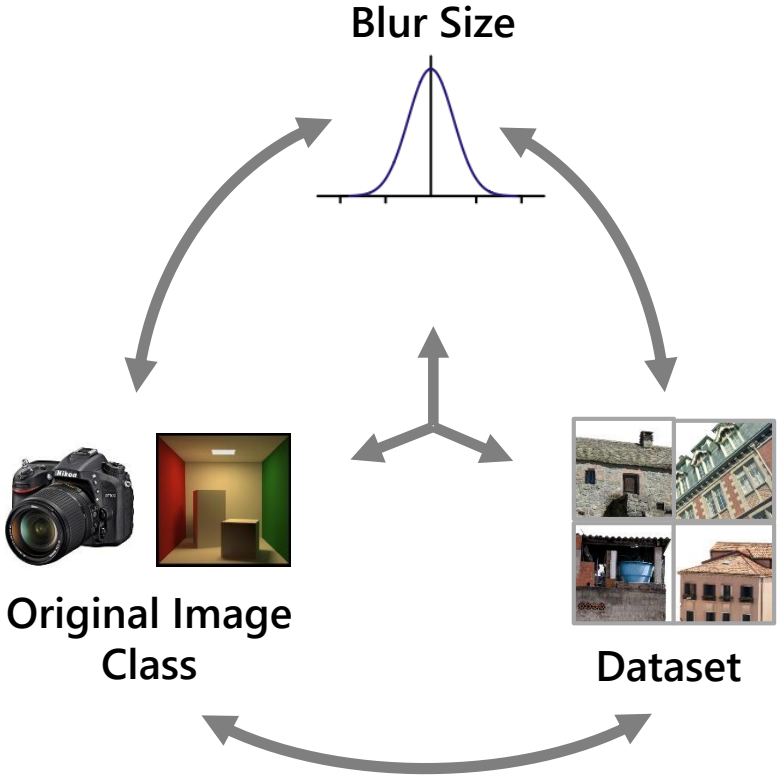
Blurs



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

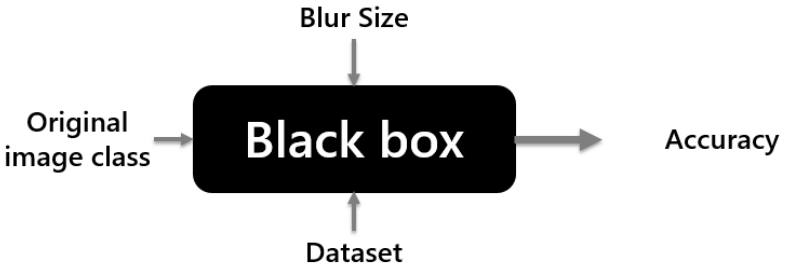
Two- & Three-Way Interactions

- 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%)

Computer Generated

Photograph

Photograph

6. Model Structure

- **Model Structure (14/52 ~ 27%)**

Computer Generated

Computer Generated

9. Regularity

- **Regularity (11/52 ~ 21%)**

Computer Generated

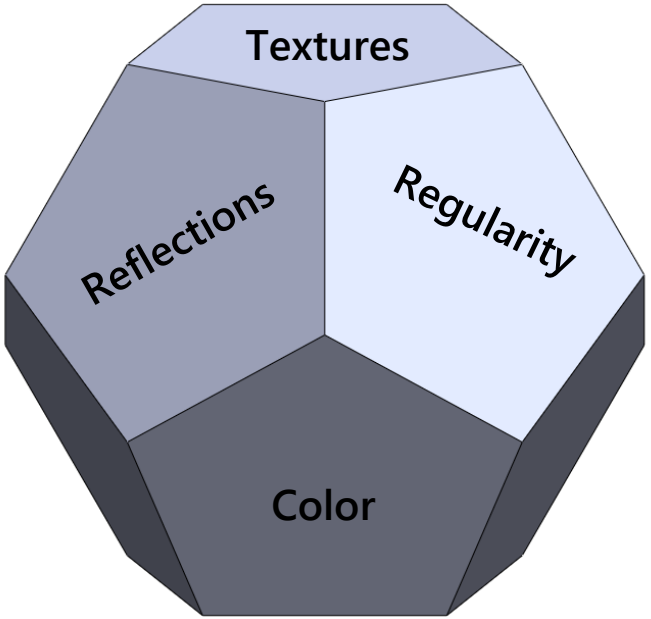
Computer Generated

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

Opinions Summary

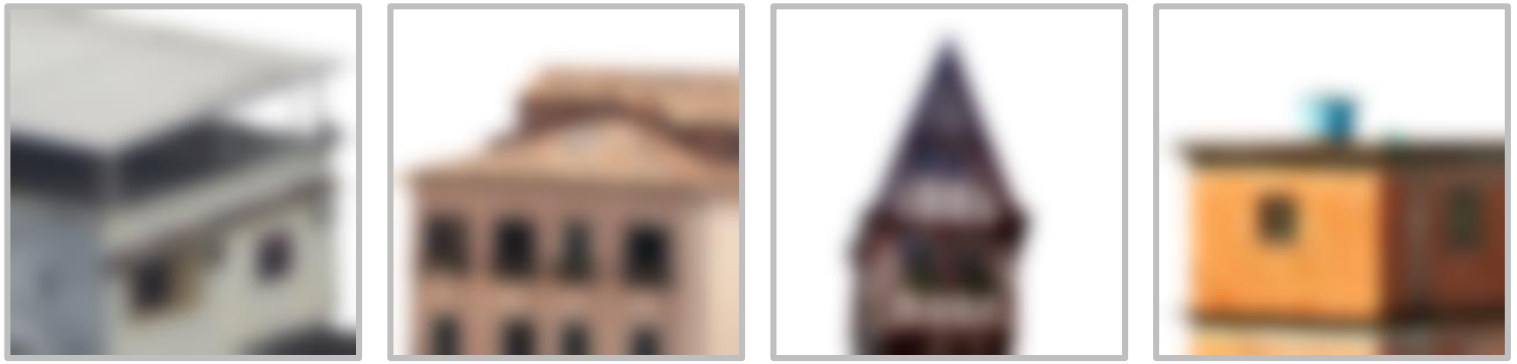
- **Multi-faceted**
  - **Guidelines, guesses**
  - **Not hard facts**
- **Biases**



More Exploration

Confounding Buildings @ 55px

Photographs

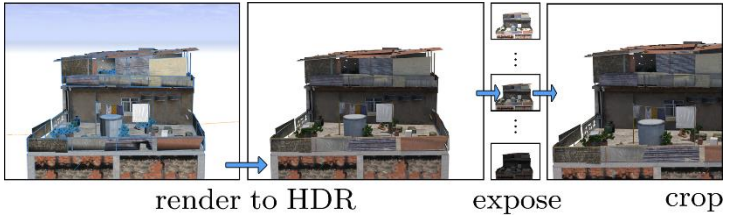


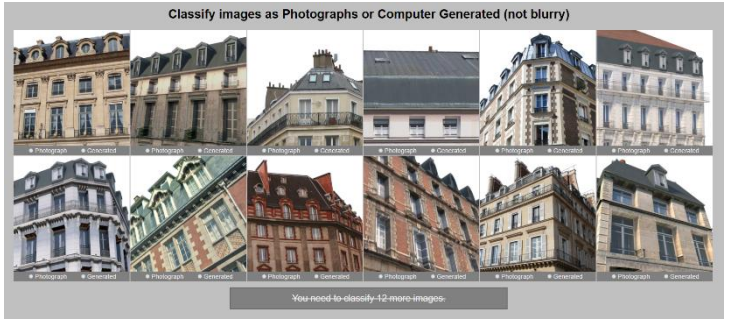
Computer Generated

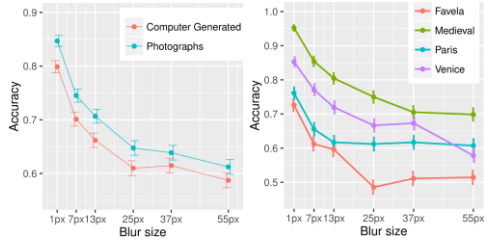
Summary and Future Work

Summary

- 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

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The Czech Academy of Sciences

- ESRI
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- vrbn.io
- Corona Renderer

Thank You!

http://JanBenes.net

Supplemental Material

Biases

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  - 18/52 ~35% – Influenced for at least one
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