Image-Based Approaches for Façade Modeling

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What is Façade Modeling?

- **Part of Urban Reconstruction**
- **Creating digital models of real cities**
- **Cities are large collections of man-made objects at many LODs**

Possible Applications

- Cyber-Tourism
- Computer Games
- Movie-Industry and Entertainment Industry
- Digital Maps and Routing

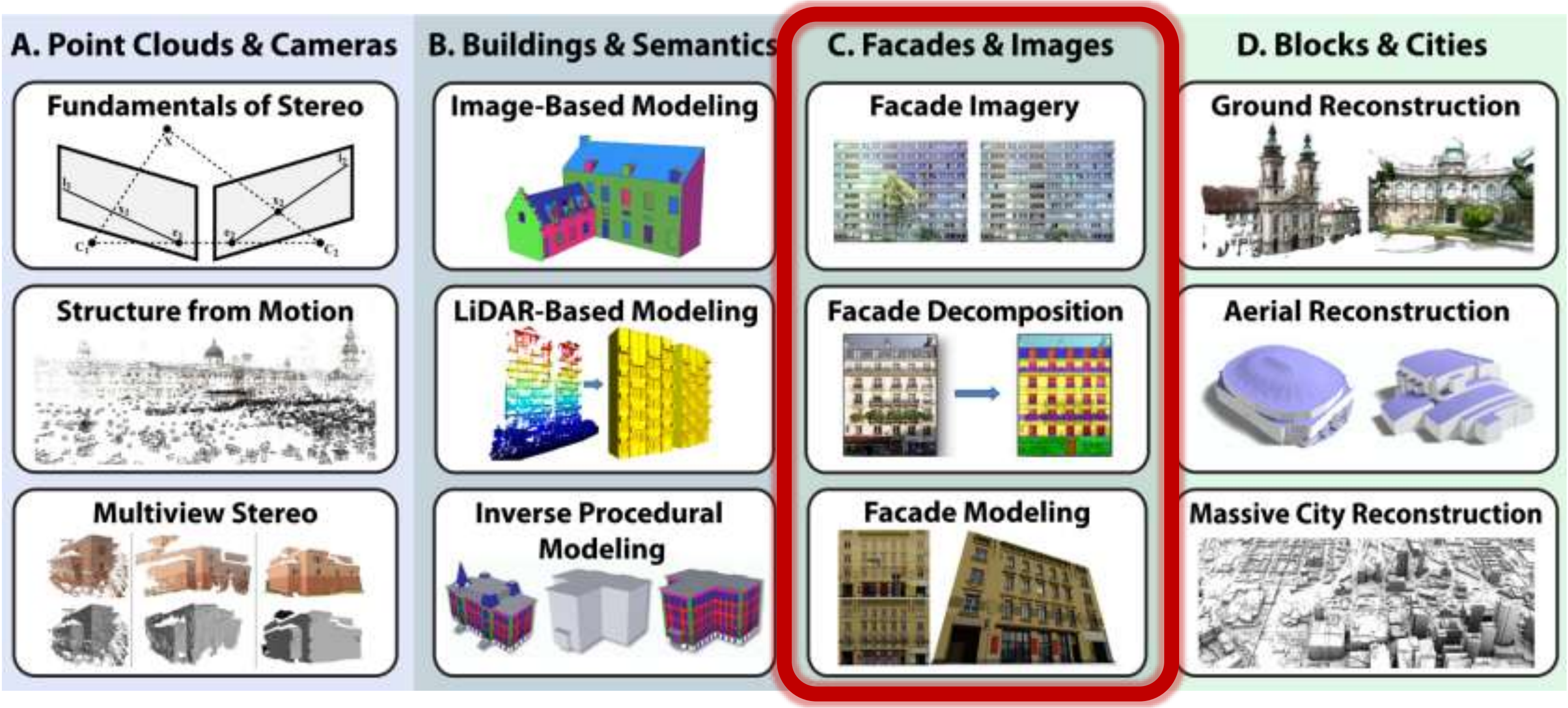
- City-Planers and Architects
- Archeological Research
- More Sciences (Sociology,…)

Challenges

- **Quality**
  - Demand of realistic quality and high LOD
- **Scalability**
  - There are many buildings out there…
- **Ease of Creation**
  - Non-experts should be able to create content
- **Full Automation**
  - Chicken or Egg problem
    (e.g. Top-Down vs. Bottom Up)

Overview

- **A Survey of Urban Reconstruction [MWA*2012] In EG2012 STAR Proceedings**



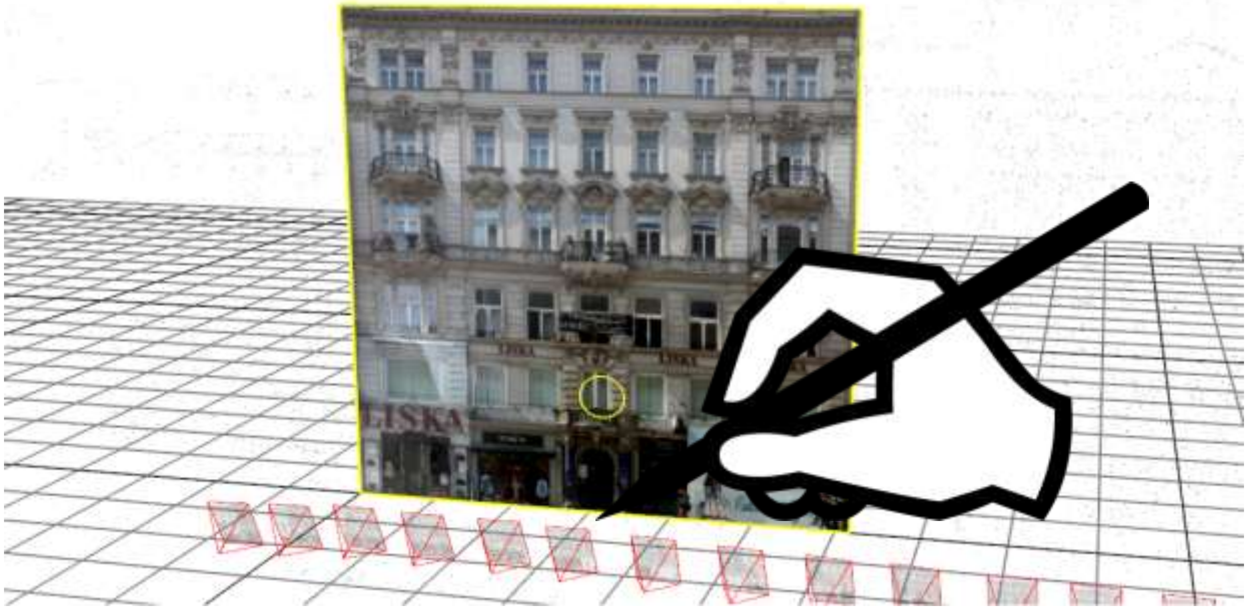
Why Image-Based?

- **Easy to acquire (cheap)**

- **Imagery is essential in Urban Reconstruction**
  - For a realistic look
  - As source for reconstruction

Why Interactive Modeling?

- **Quality**
  - Interactive: yes — Automatic: no
- **Scalability**
  - Interactive: ~~no~~ yes? — Automatic: yes
- **Ease of Creation**
  - Interactive: somewhat — Automatic: somewhat
- **Full Automation**
  - Interactive: no — Automatic: yes?



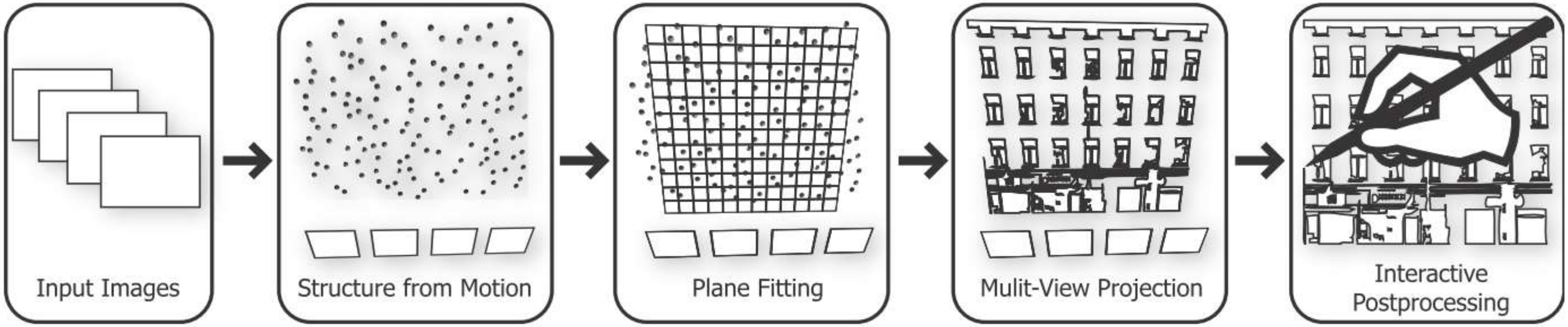
Multi-View Façade Image Editing

Motivation

- **Texturing of urban scenes:**
  - near orthographic projection
  - from typical photos
  - high quality

Multi-View Façade Image Processing

- **Multiview Projective Texturing**
  - Musialski et al. [MLS*10]



Input: Typical, perspective Photographs

Sparse Reconstruction

Structure-From-Motion

Sparse Reconstruction

Plane Fitting

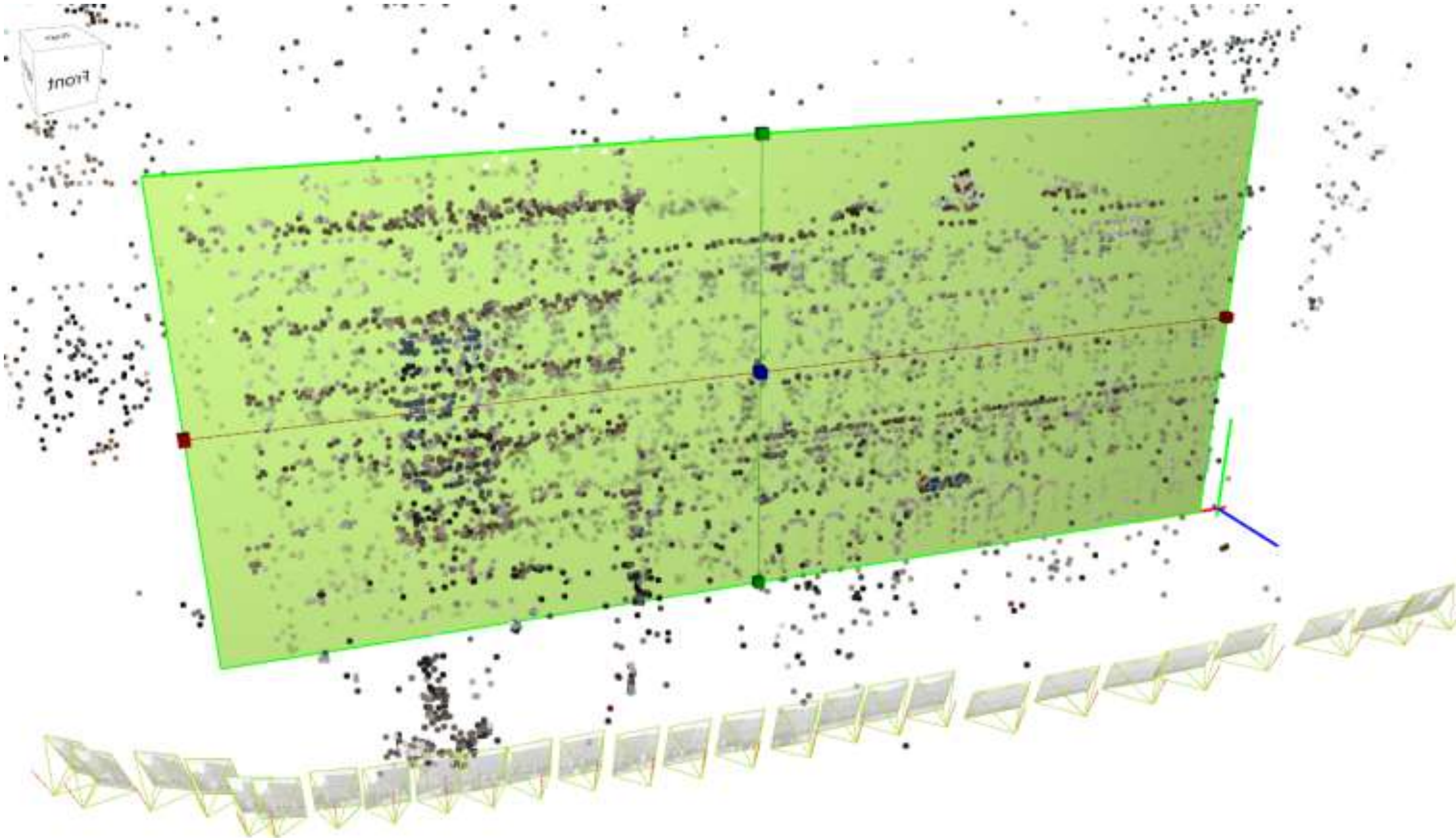
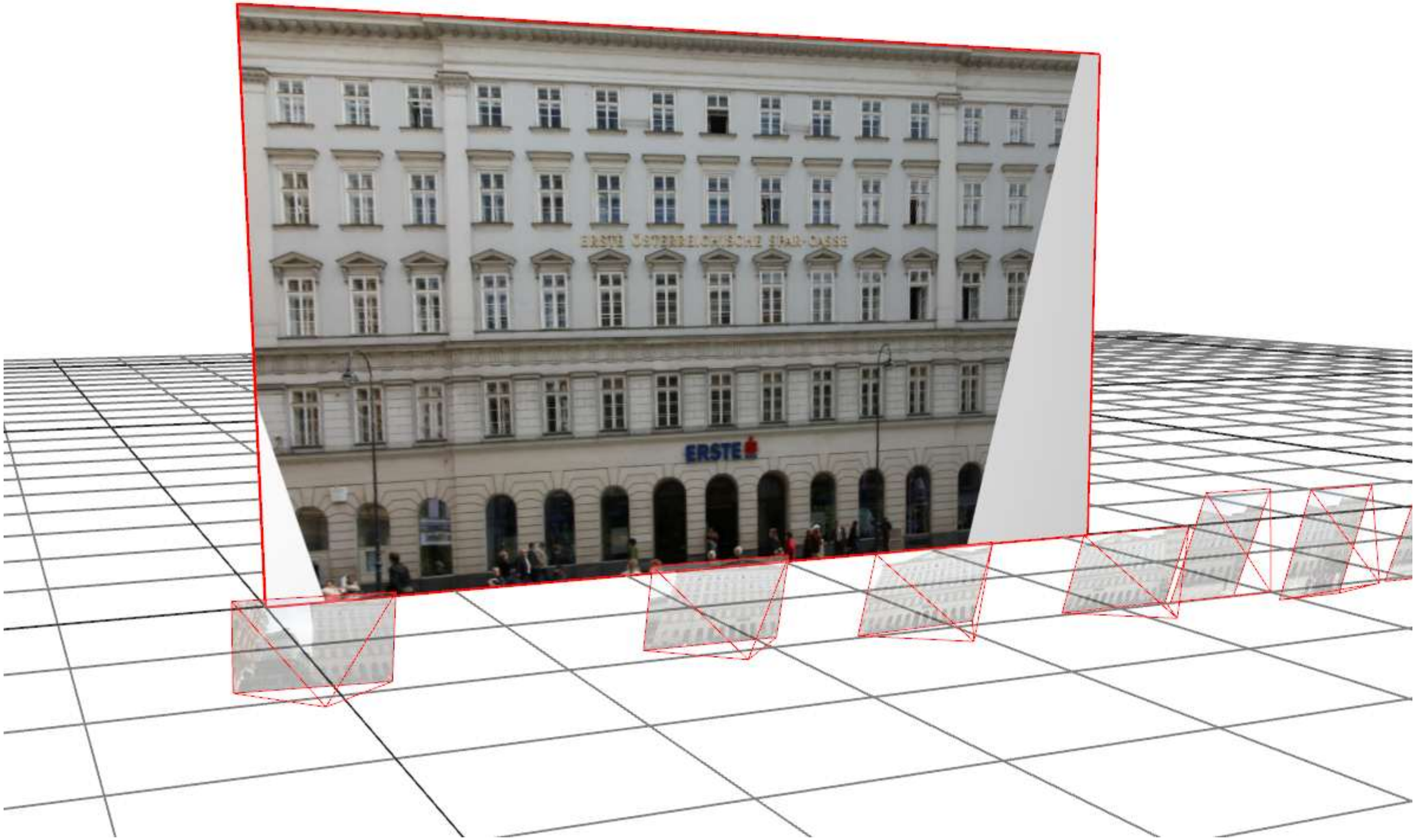


Image Projection



Interactive Boundary Adjustment

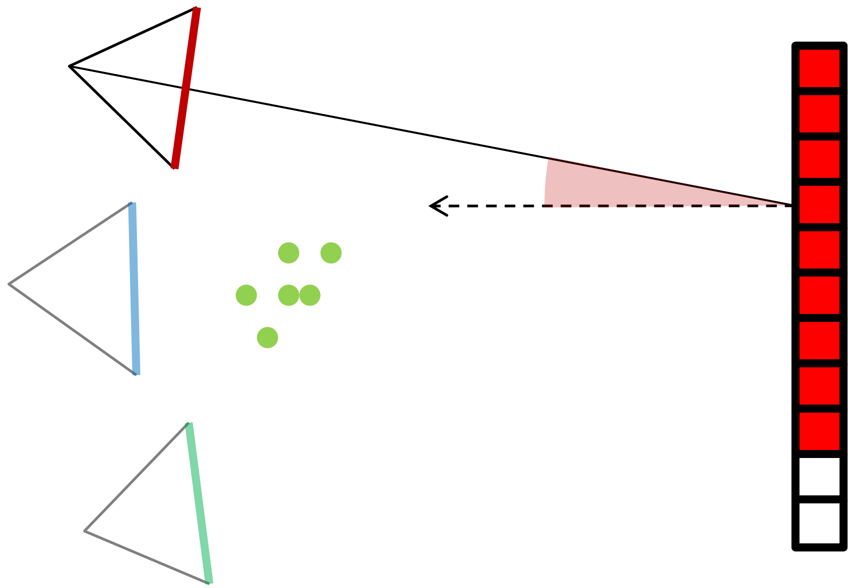
Multi-View Projection

Accumulate in an "Image-Stack"

Image Stack

For each photo (per target pixel)

1. evaluate projection quality ***q***
2. generate occlusion weight ***o***
3. insert to sorted image stack with ***oq***



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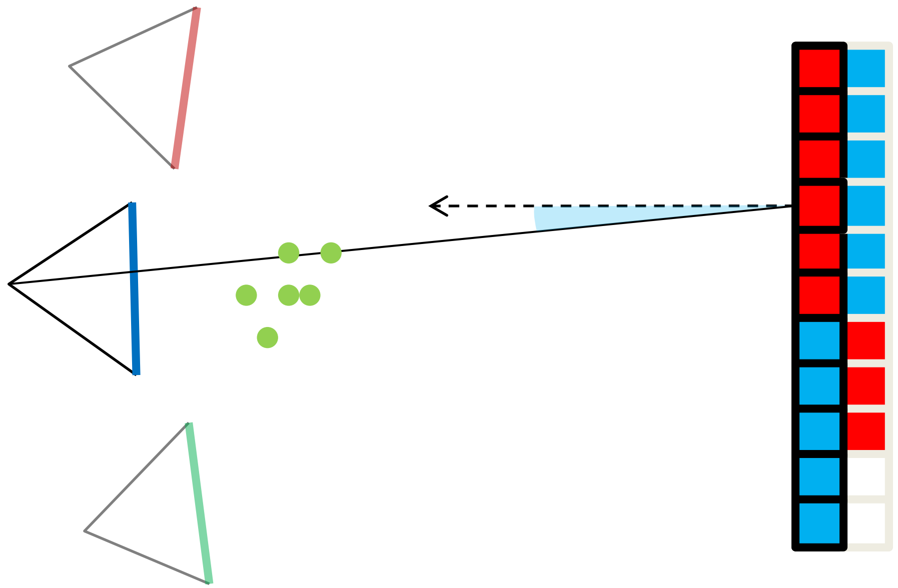

Image Stack

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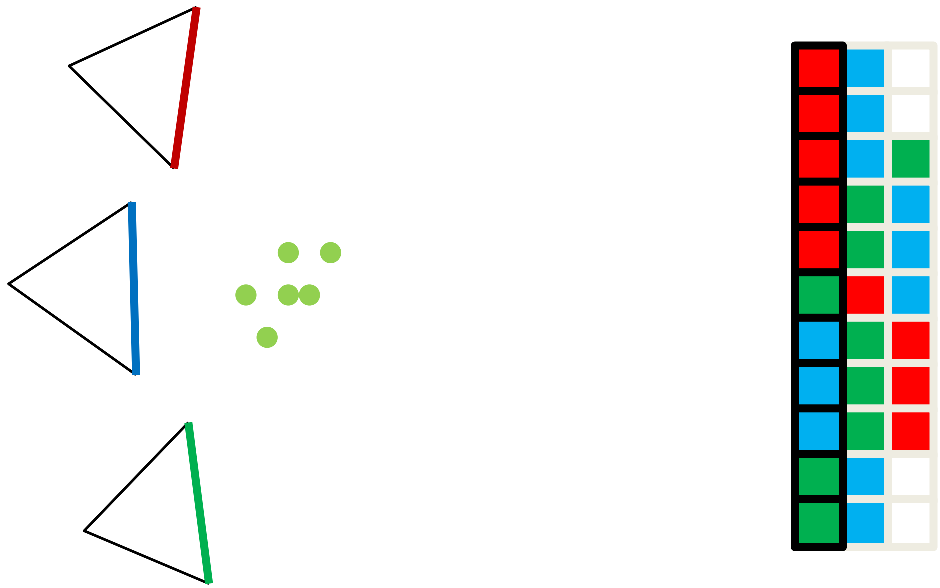


Multi-View Stitching

Gradient Domain Stitching

- **Color space stitched image**

Gradient Domain Stitching

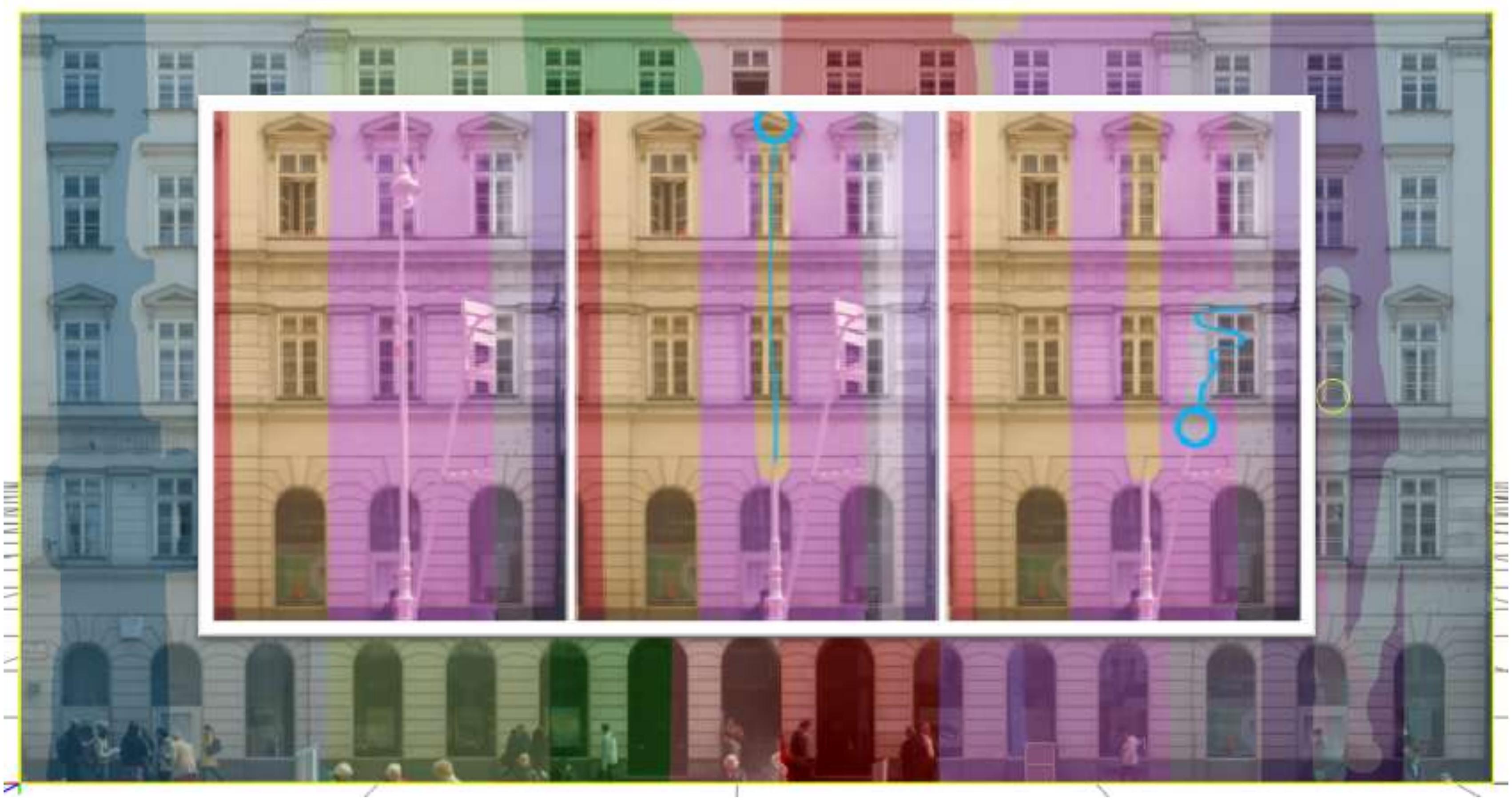
- **Stitched gradients**

Gradient Domain Stitching

- **Reconstructed image**

Gradient Domain Stitching

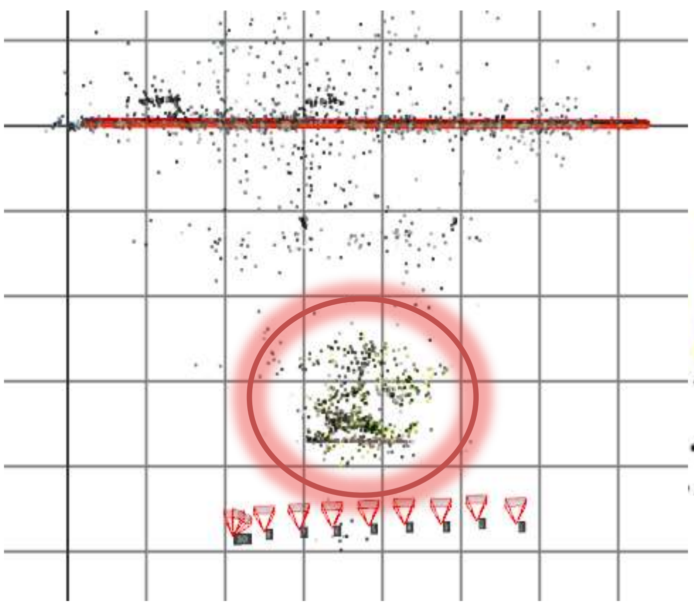
Interactive Brushing

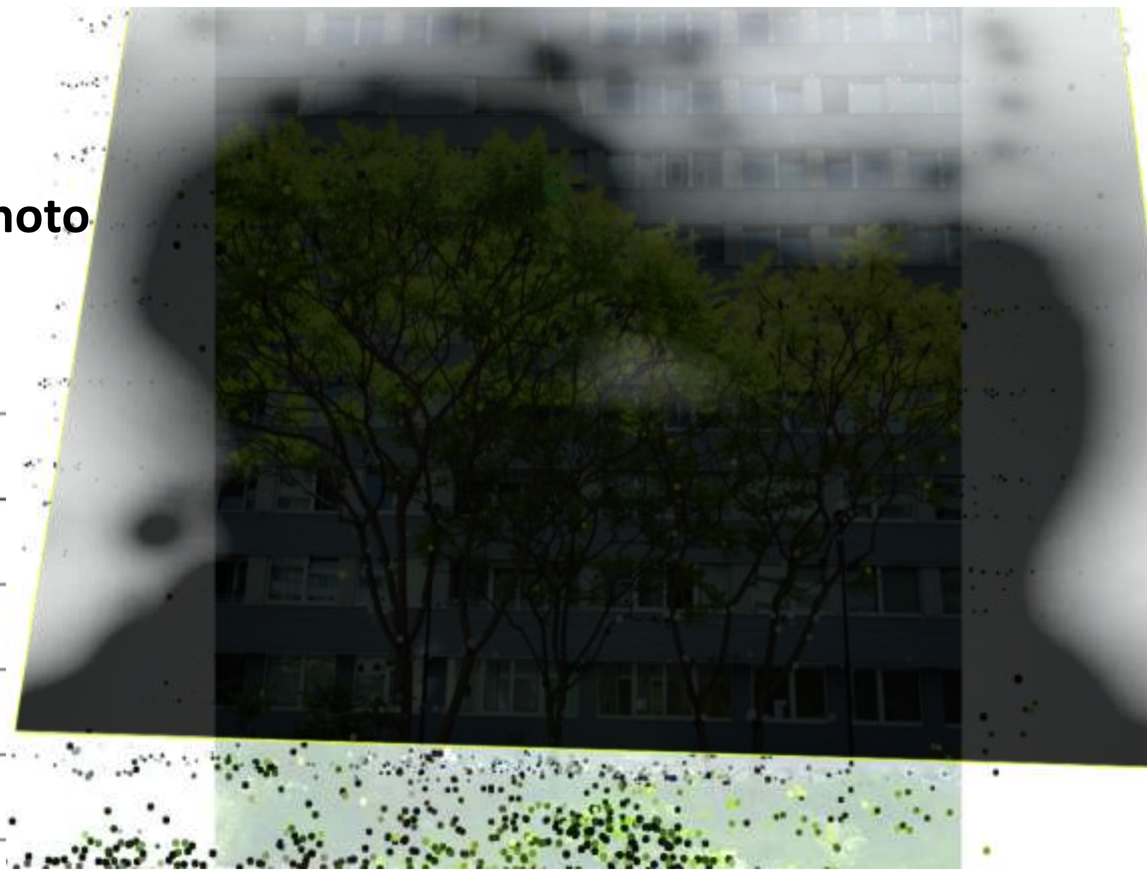


Interactive Brushing Video

Point Occlusion

- points in front of buildings not part of the facade
- project points to target
- occlusion weight per photo

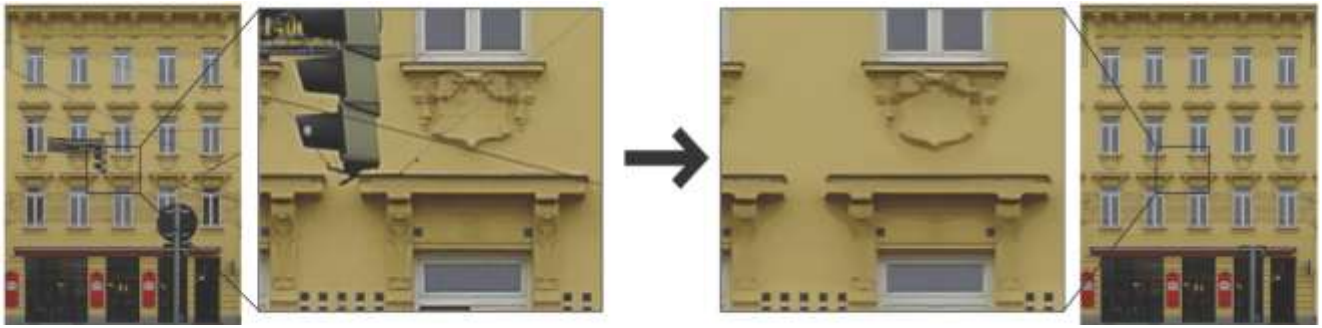




Occlusion

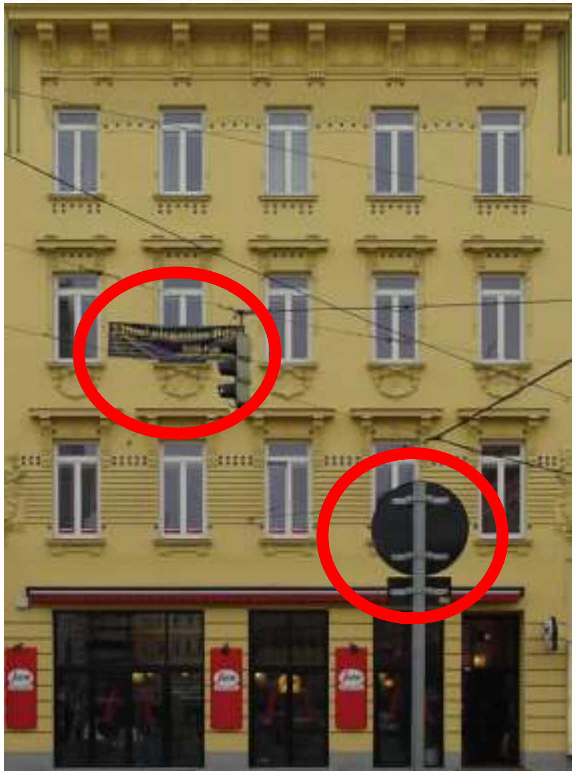
Summary

- fast high-quality façade textures
- interactive texture cleanup
- part of complex urban reconstruction pipeline

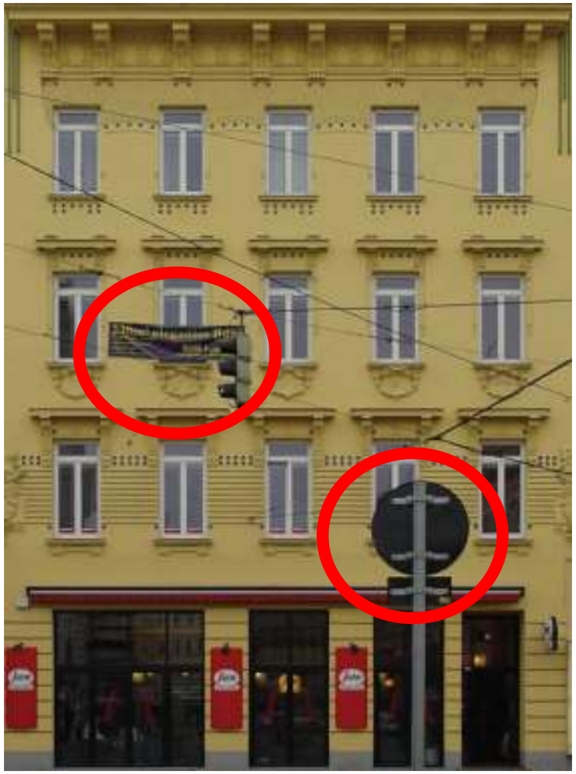


Façade Image Repair

Motivation: Occlusion in Images

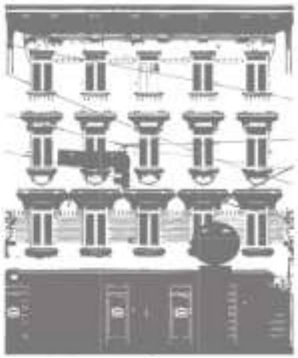


Motivation: Occlusion in Images



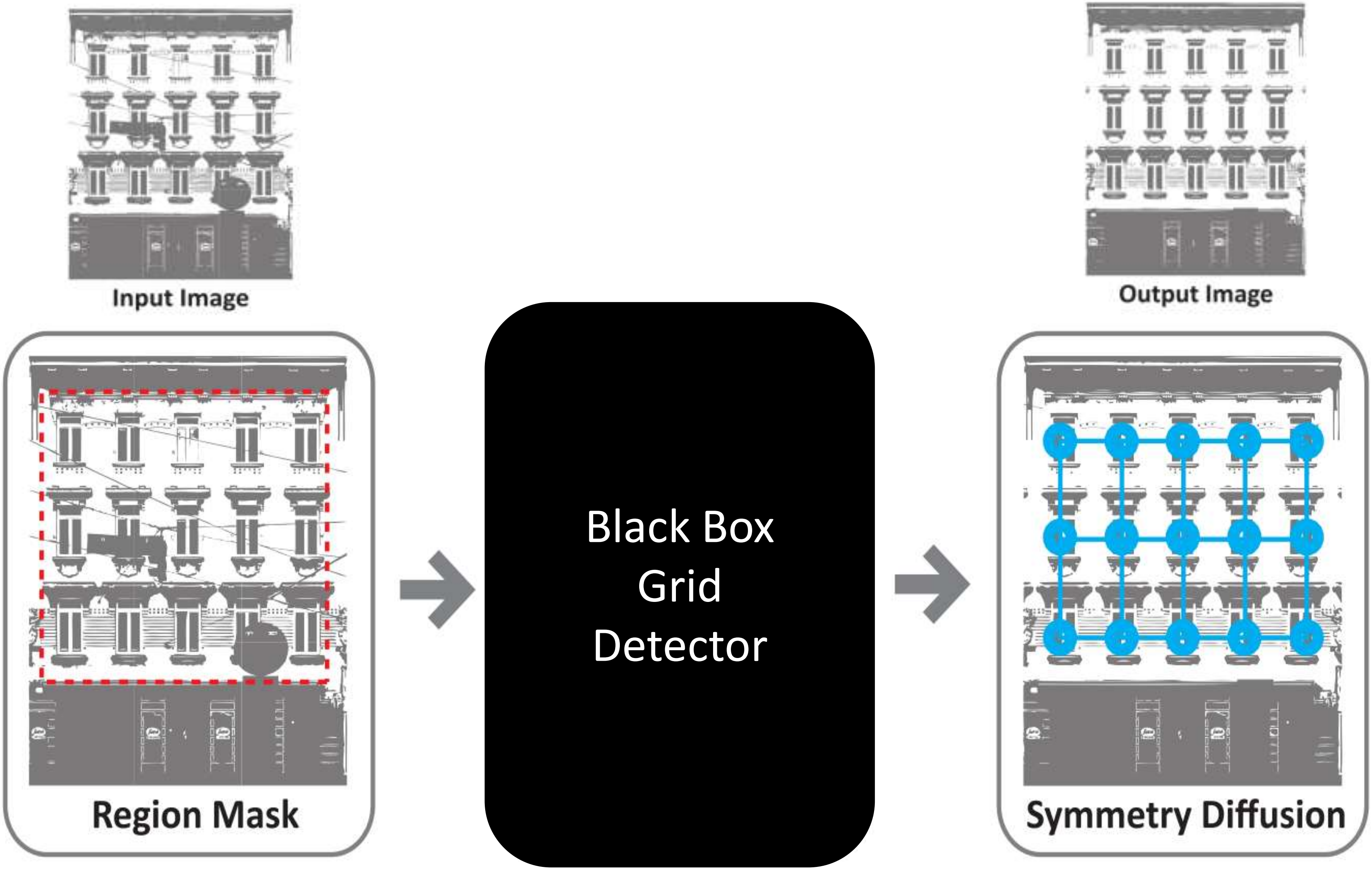
- **occluders are a common problem**
- **especially if only a single view is available**

Overview



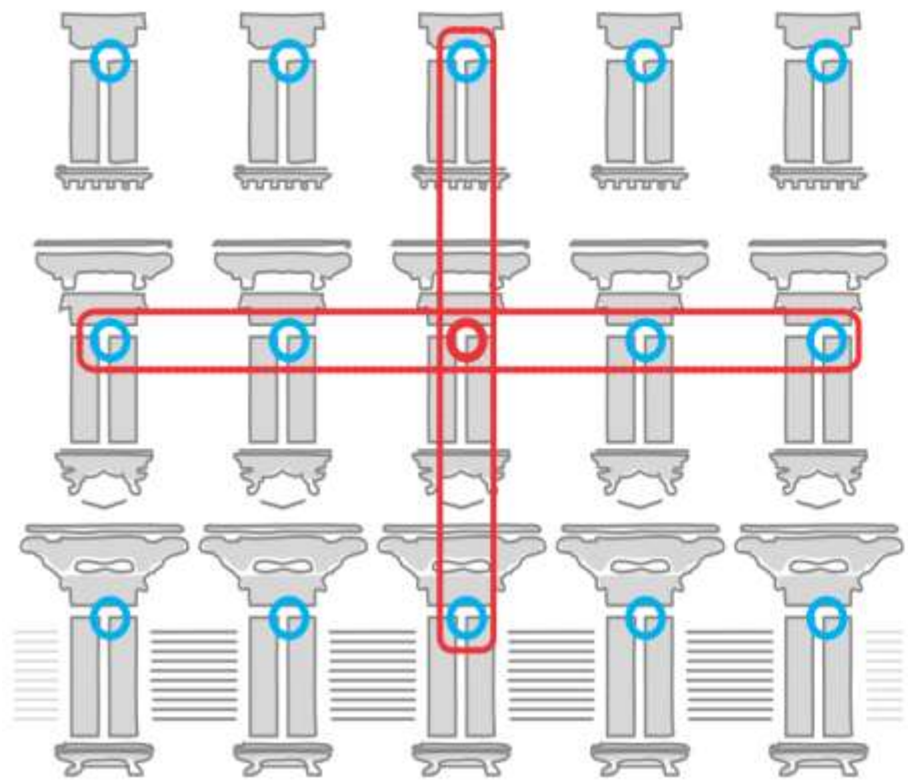
Input Image

Overview


Input Image
Output Image
Region Mask
Black Box
Grid
Detector
Symmetry Diffusion

Symmetry Propagation

- process in x and in y directions independently
- we consider only translations
- infer the symmetry neighborhood for each pixel from the dominant offsets
- collect the symmetry neighborhood of each pixel



Optimization: Outlier Detection

Optimization inspired by Expectation Maximization:

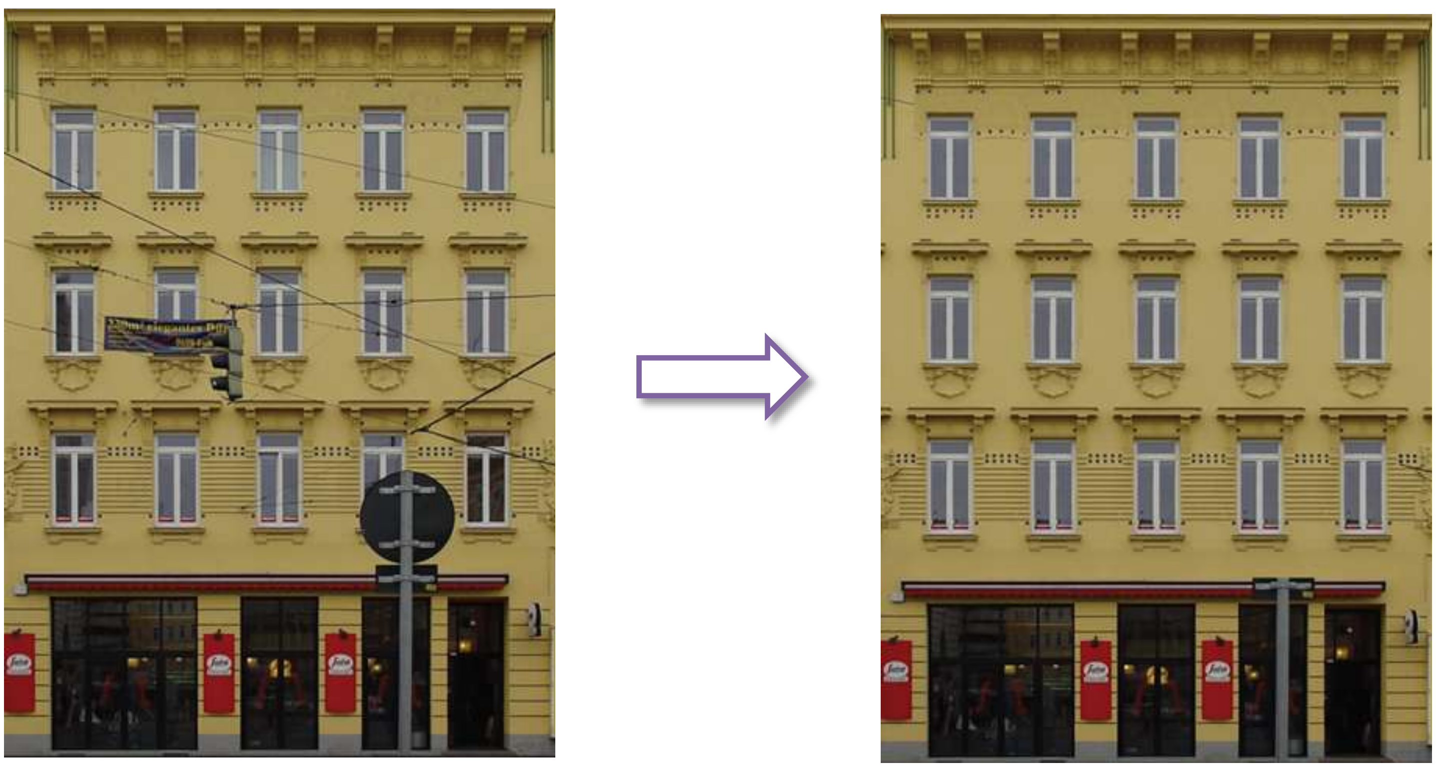
- **Iteratively compute**

$$\mathbf{x}_i = \underset{\mathbf{x}_i \in \mathcal{S}_x}{\arg\max}\, K\left(\|\mathbf{x_i} - \bar{\mathbf{x}}\|^2\right)$$

- **Remove $\mathbf{x}_i$**
- **Recompute mean $\bar{\mathbf{x}}$**
- **Proceed until $\bar{\mathbf{x}}$ does not change below some threshold**

Results

- **Symmetry-based façade image repair**



Results

- **Symmetry-based façade image repair**

Results

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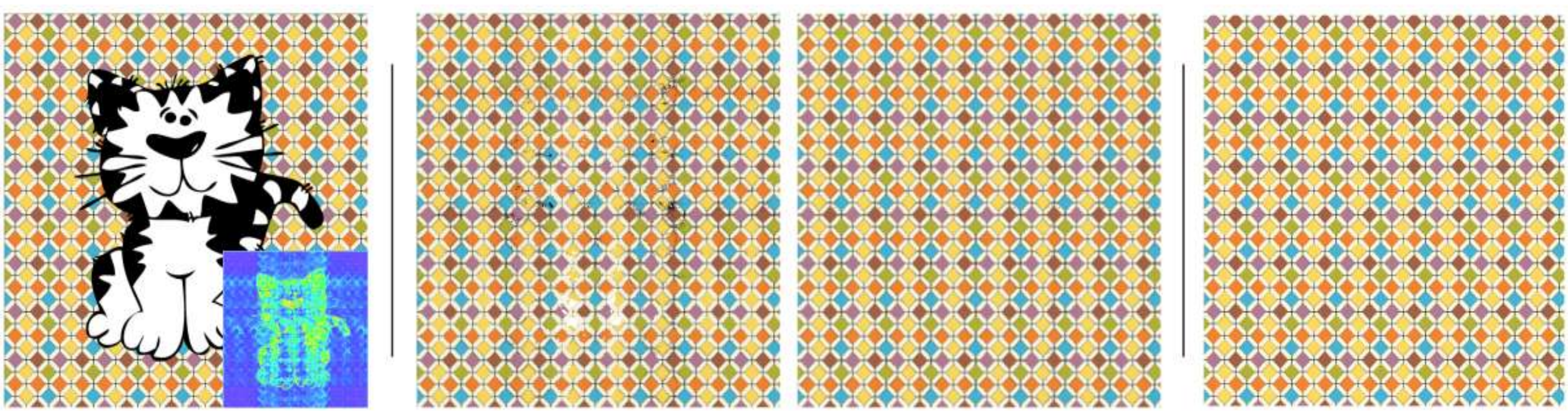


Results

- limited
  to regular facades

- optimization does
  not always converge
  to a nice result

Interactive Coherence-Based Façade Modeling

Goal

- **Reconstruction of Façade Models**

Input: Ordinary Photo ⇨ Output: Computer Model

Our Approach

- **Interactive modeling process**
  - Input: Single rectified image
  - Incorporates the user from the beginning
- **Utilizes symmetries across the image**
  - Coherence-Based Modeling
- **Two crucial operations**
  - Automatic Façade Split Operator
  - Synchronized Group Operator

Modeling Process

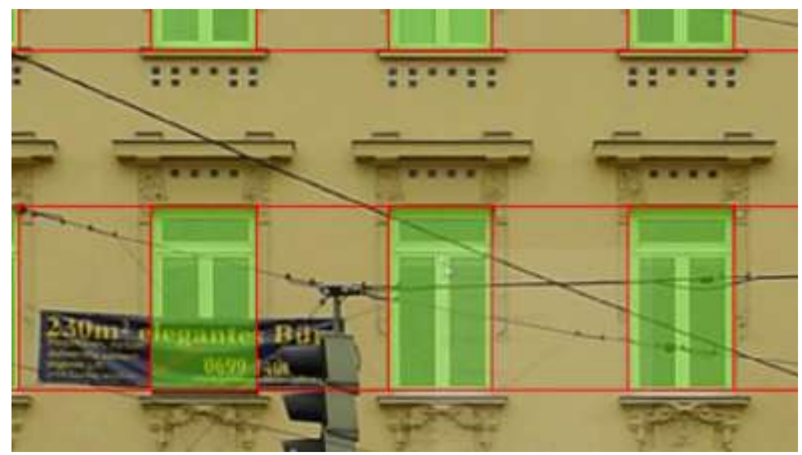
Modeling Process

Coherence-Based Modeling

Two Crucial Operations

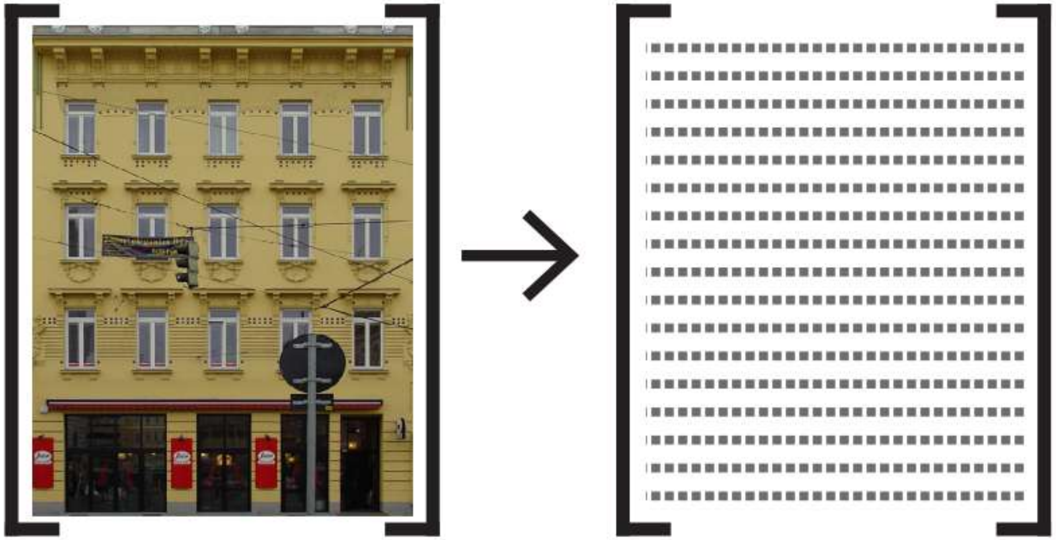
- **Automatic Façade Split Operator**
  - Also allows automatic selection of similar elements

- **Synchronized Group Editing Operator**
  - Propagates splits to all instances in a group



Automatic Façade Split

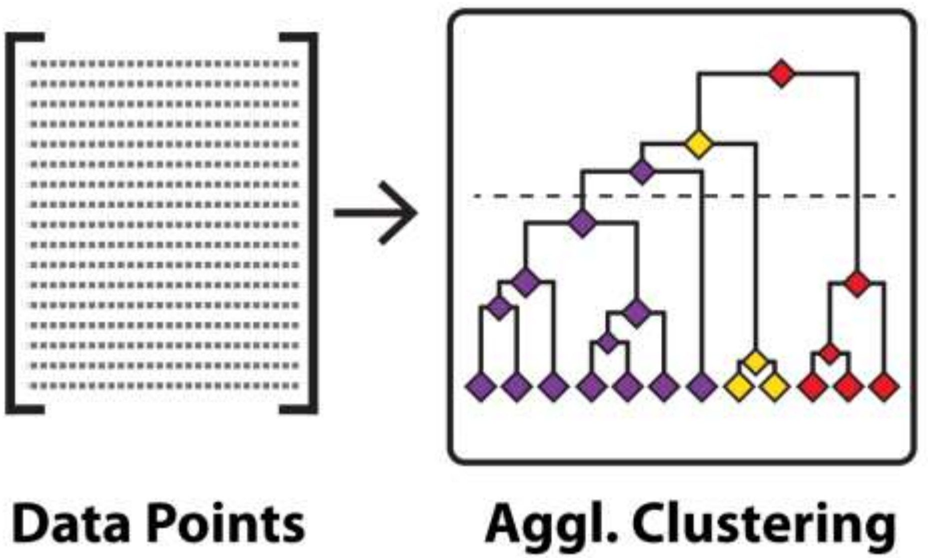
Idea: handle the pixel rows as as row vectors!



Input **Data Points**

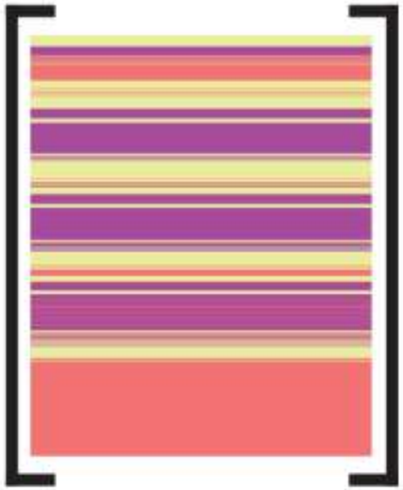
Automatic Façade Split

- perform **clustering** on rows of the image
- we use agglomerative bottom-up clustering
- number of clusters chosen by the user
- no connection in the spatial domain



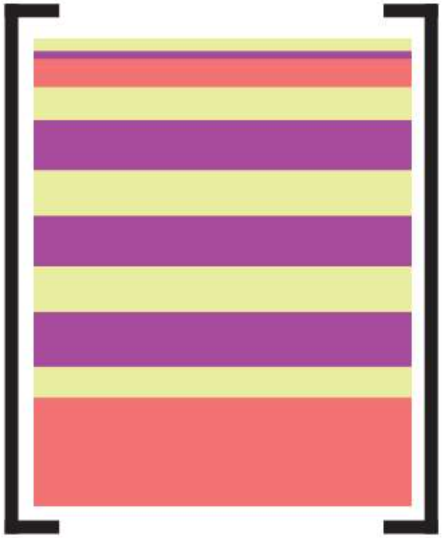
Automatic Façade Split

- perform a regularization process to the clustering result
  - → minimize the boundary between the clusters
- we use **dynamic programming (DP)**
  - → finds minimal energy path between cluster in spatial domain



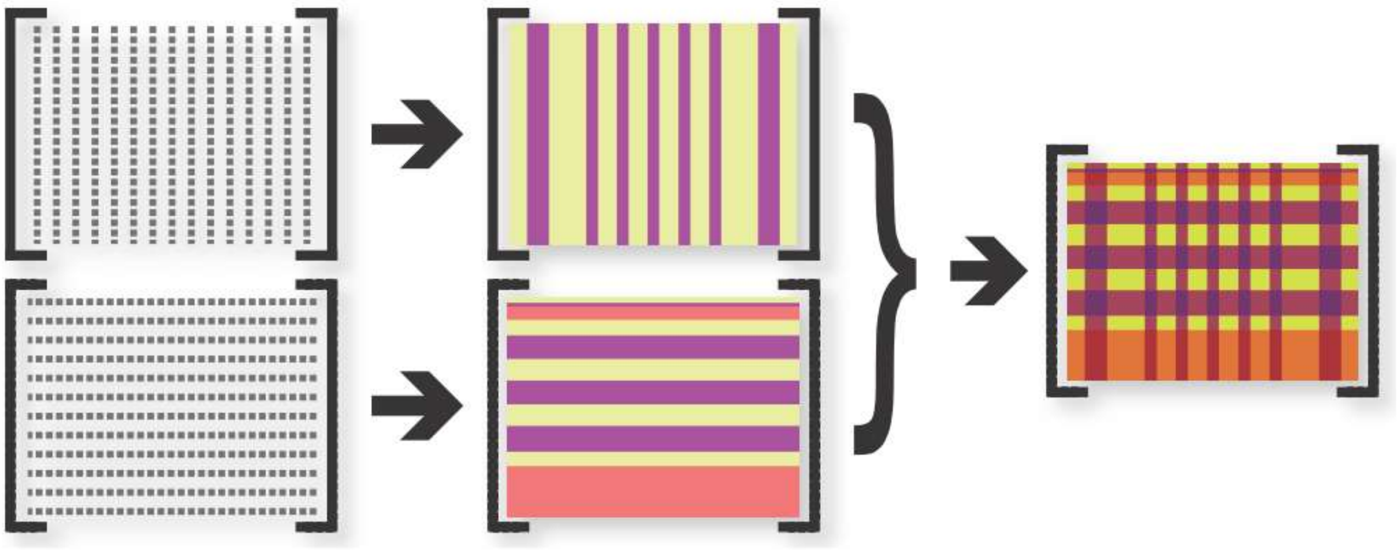
Automatic Façade Split

- it delivers spatial segmentation
- and, since pixel-rows have cluster IDs
  → also grouping of similar objects



Automatic Façade Split

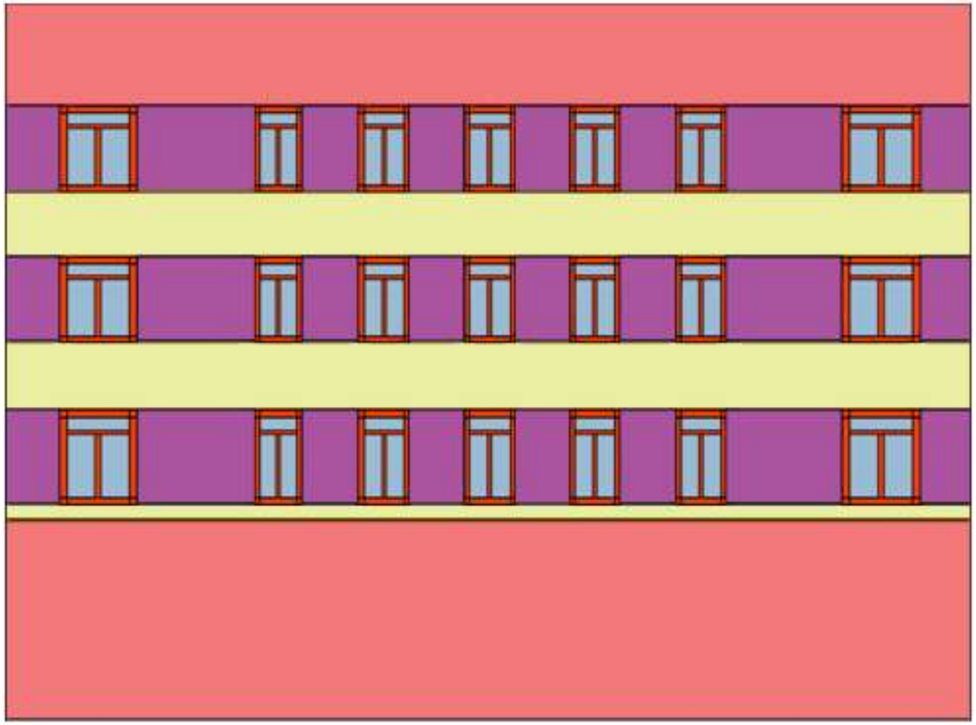
– can be performed for x and y separately



Synchronized Group Editing

- elements with the same cluster-id provide candidates for groups

- groups can be edited in a synchronized manner

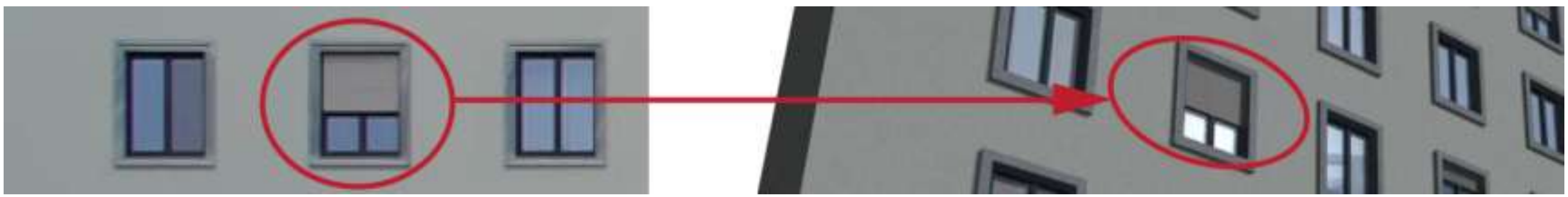


Synchronized Group Editing

- Simply propagate the relative split positions to all members in a group
- Works only if the topology of all shapes is the same
- Other splits possible, but release the grouping

Synchronized Group Editing

– each element is still a separate instance



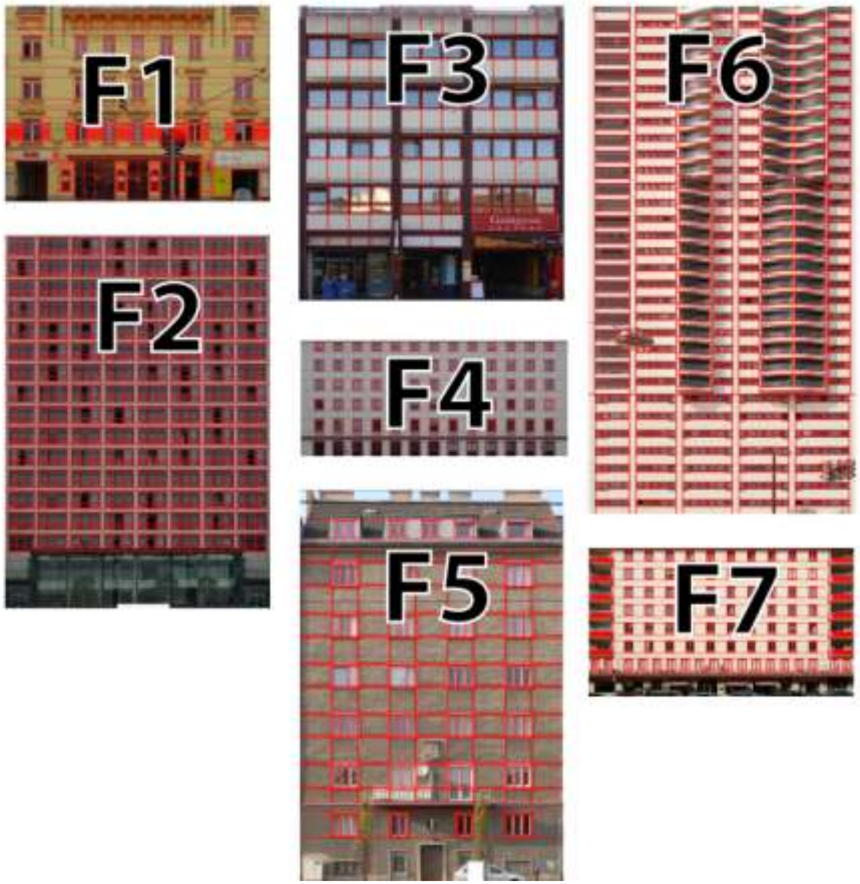
Complex Shapes

– Polygonal shapes at the lowest hierarchy level

– Can also be edited in a synchronized manner

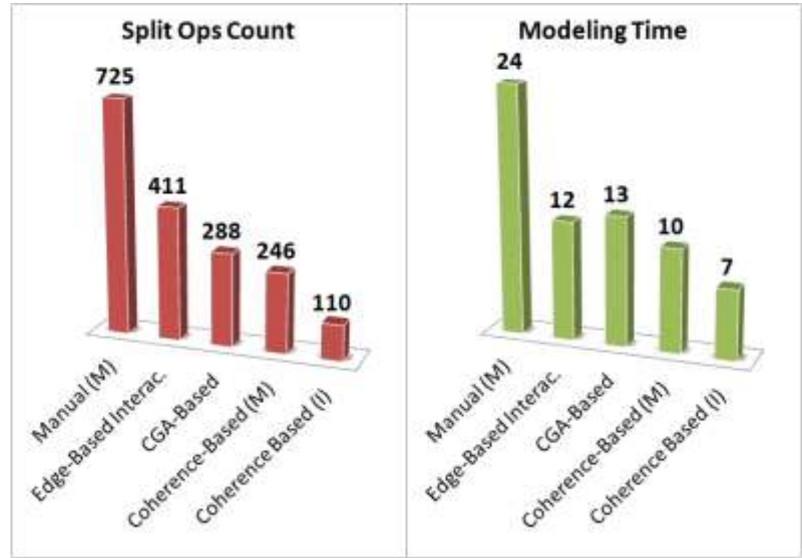
Evaluation



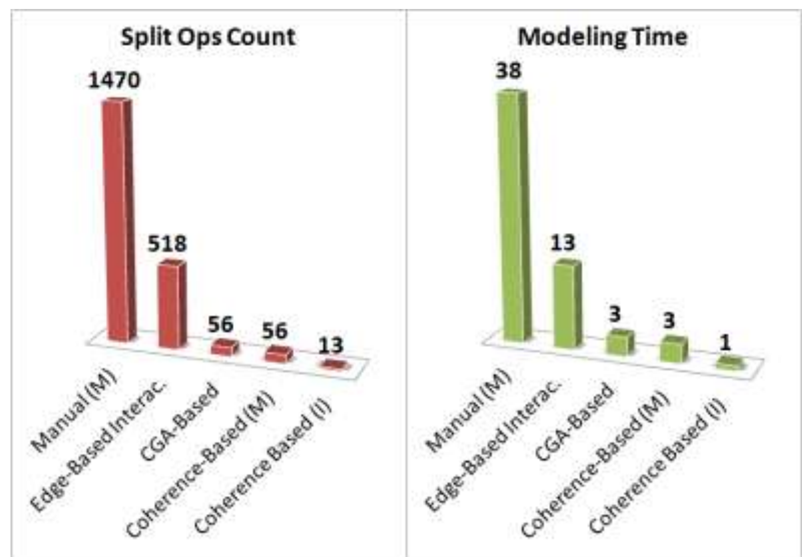
- **7 Test Façades edited to the same LOD**
- **5 Modeling Modes:**
  - **Manual Modeling**
  - **Edge-Based Interactive**
  - *(CGA-Grammar-Based)*
  - *(Coherence-Based Manual)*
  - **Coherence-Based Interactive**
- **Metric:**
  - **Split Ops Count**
  - **Modeling Time**
  - *(Select Ops Count)*

Evaluation: Split Operations

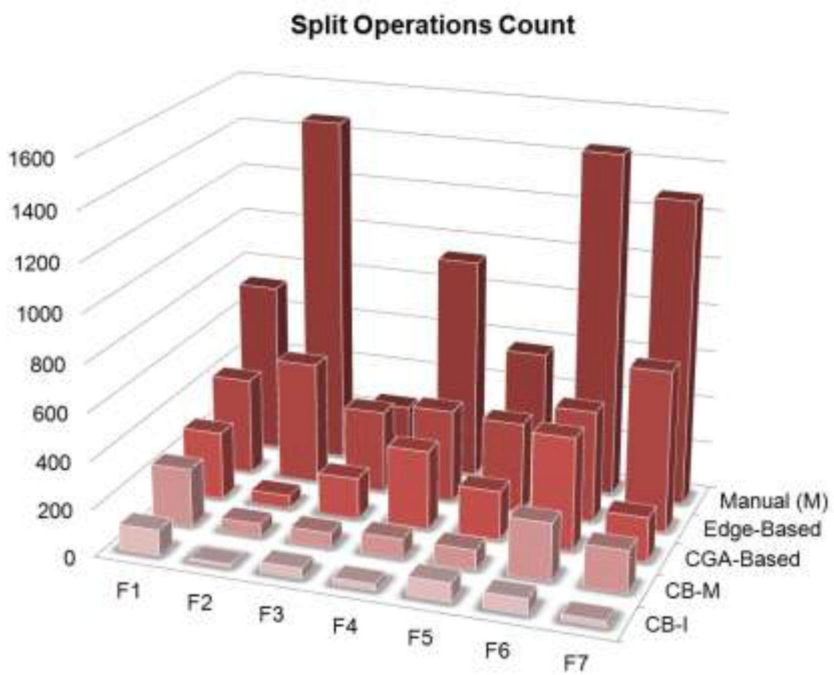
960 Shapes

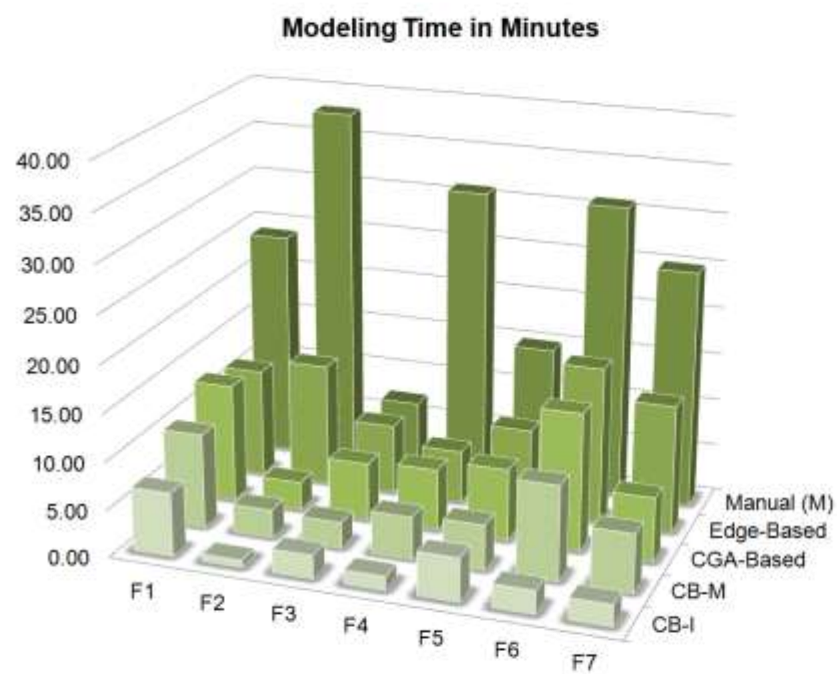


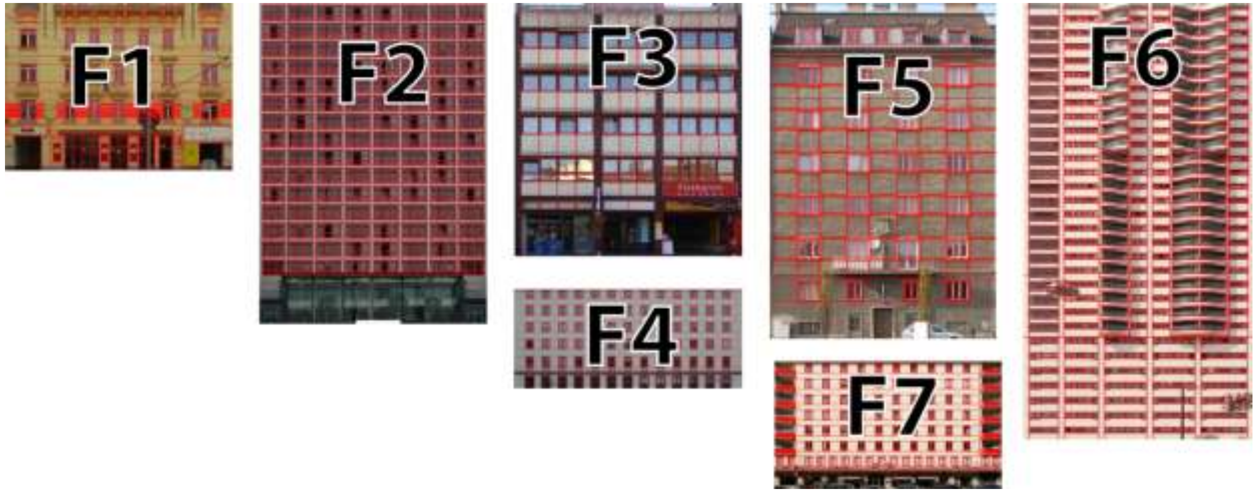
4351 Shapes



Evaluation: Split Operations







Conclusions

- **Problems of automatic segmentation:**
  - Splitting heuristics are not robust enough
  - Post-processing of automatic segmentation is time consuming, since errors have to be:
    - localized
    - fixed
- **Advantages of the incorporation of the user:**
  - Much better high-level structure
  - Less time consuming than fixing
  - Higher LOD and quality
- **Advantages of coherence-based modeling:**
  - More flexibility to combine partial symmetries
  - More stable splitting results

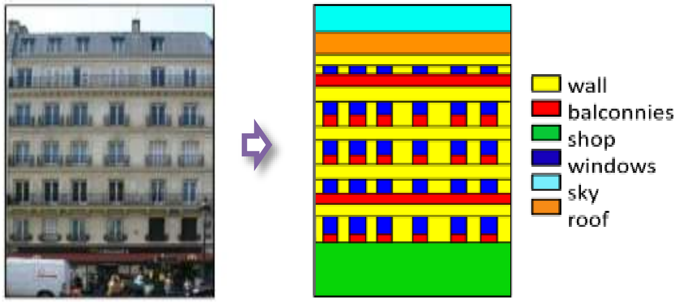
That's it??

- **Yes, the presentation is over.**

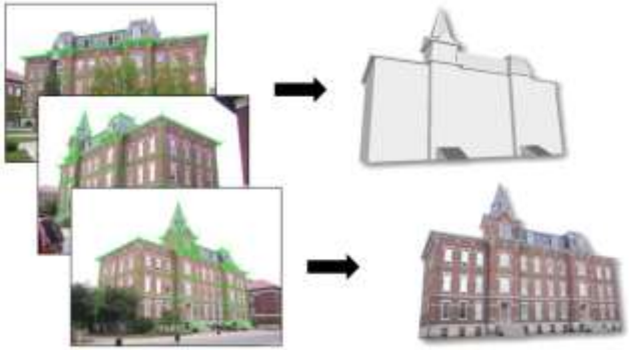
- **No, there is still planty to do in the future!**

Future Work

- **Other Façade Modeling Approaches**
  - **Façade Parsing**
    - Teboul et al. [TKS*11]
    - Grammar + Machine Learning



  - **Inverse Procedural Modeling**
    - Aliaga et al. [ARB07]
    - Interactive + Grammar Rules



- **Explore further, integrated methods for**
  - Scalable and easy user interaction (e.g. sketching)
  - As automatic as possible methods

The End

Thank you! Questions?