

Façade Reconstruction

An Interactive Image-Based Approach

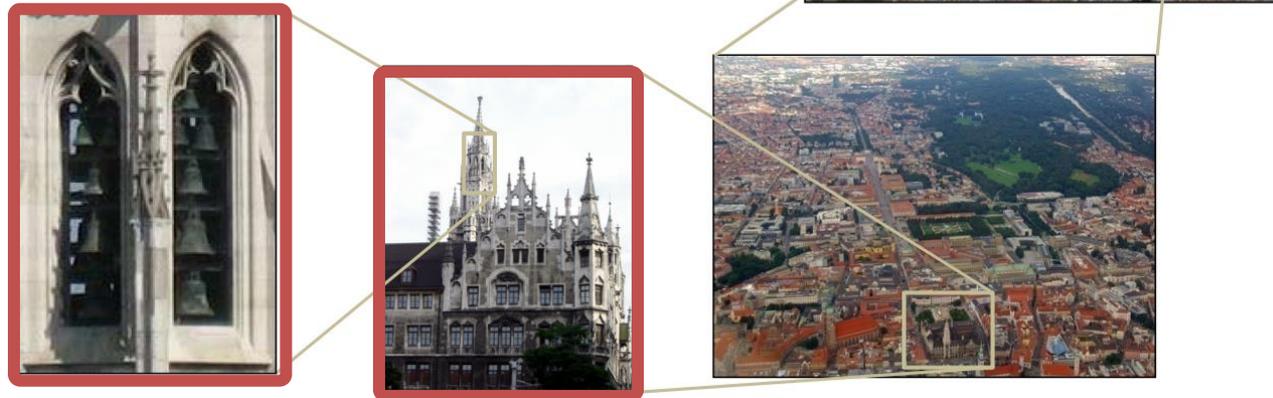
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What is Façade Reconstruction?

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



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

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

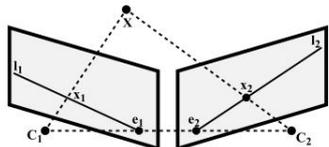


- **Quality**
 - Demand of realistic quality and high LOD
- **Scalability**
 - There are many buildings out there...
- **Ease of Creation**
 - Non-experts should be able to create content
- **Full Automation**
 - Chicken or Egg problem
(e.g. Top-Down vs. Bottom Up)

- **A Survey of Urban Reconstruction [MWA*2013]**
In EG2012 STAR Proceedings & CGF Journal 2013

A. Point Clouds & Cameras

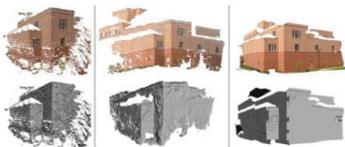
Fundamentals of Stereo



Structure from Motion



Multiview Stereo

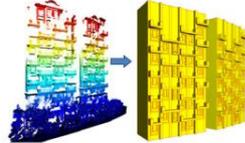


B. Buildings & Semantics

Image-Based Modeling



LiDAR-Based Modeling



Inverse Procedural Modeling

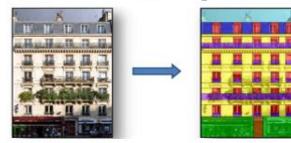


C. Facades & Images

Facade Imagery



Facade Decomposition



Facade Modeling

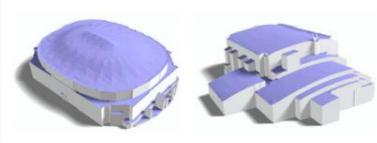


D. Blocks & Cities

Ground Reconstruction



Aerial Reconstruction



Massive City Reconstruction



- **Easy to acquire (cheap)**
- **Imagery is essential in Urban Reconstruction**
 - For a realistic look
 - As source for reconstruction



- **High-Quality**

- Interactive: **yes**

Automatic: **no**

- **Scalability** **yes?**

- Interactive: ~~no~~

Automatic: **yes**

- **Ease of Creation**

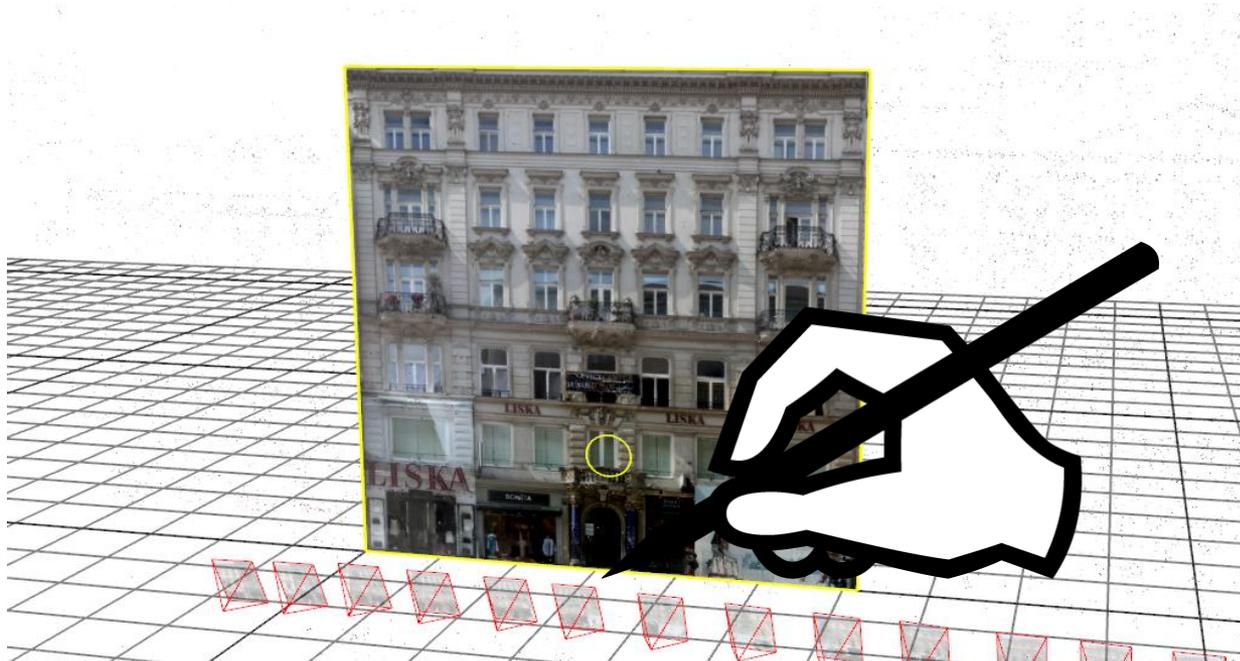
- Interactive: **somewhat**

Automatic: **somewhat**

- **Full Automation**

- Interactive: **no**

Automatic: **yes?**



Multi-View Façade Image Editing

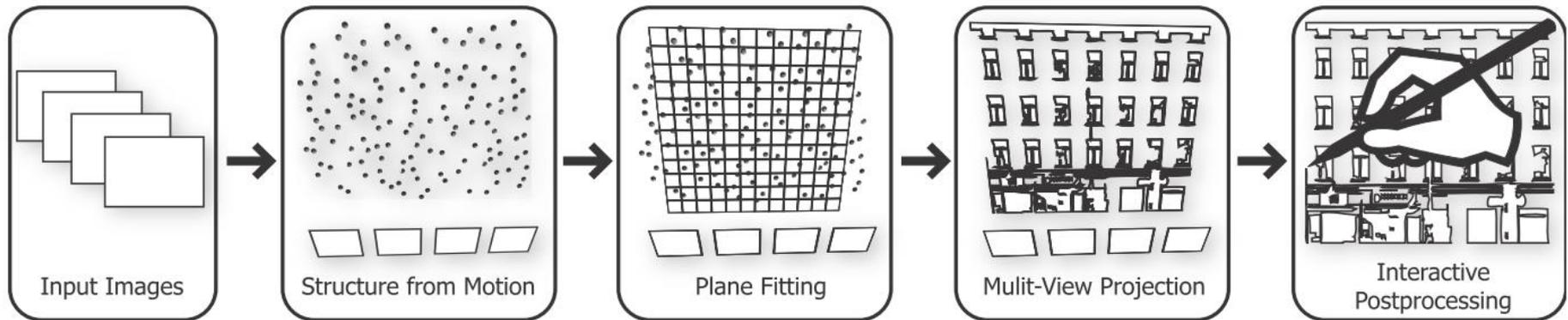


- **Texturing of urban scenes:**
 - near orthographic projection
 - from typical photos
 - high quality



- **Multiview Projective Texturing**

- Musialski et al. [MLS*10]



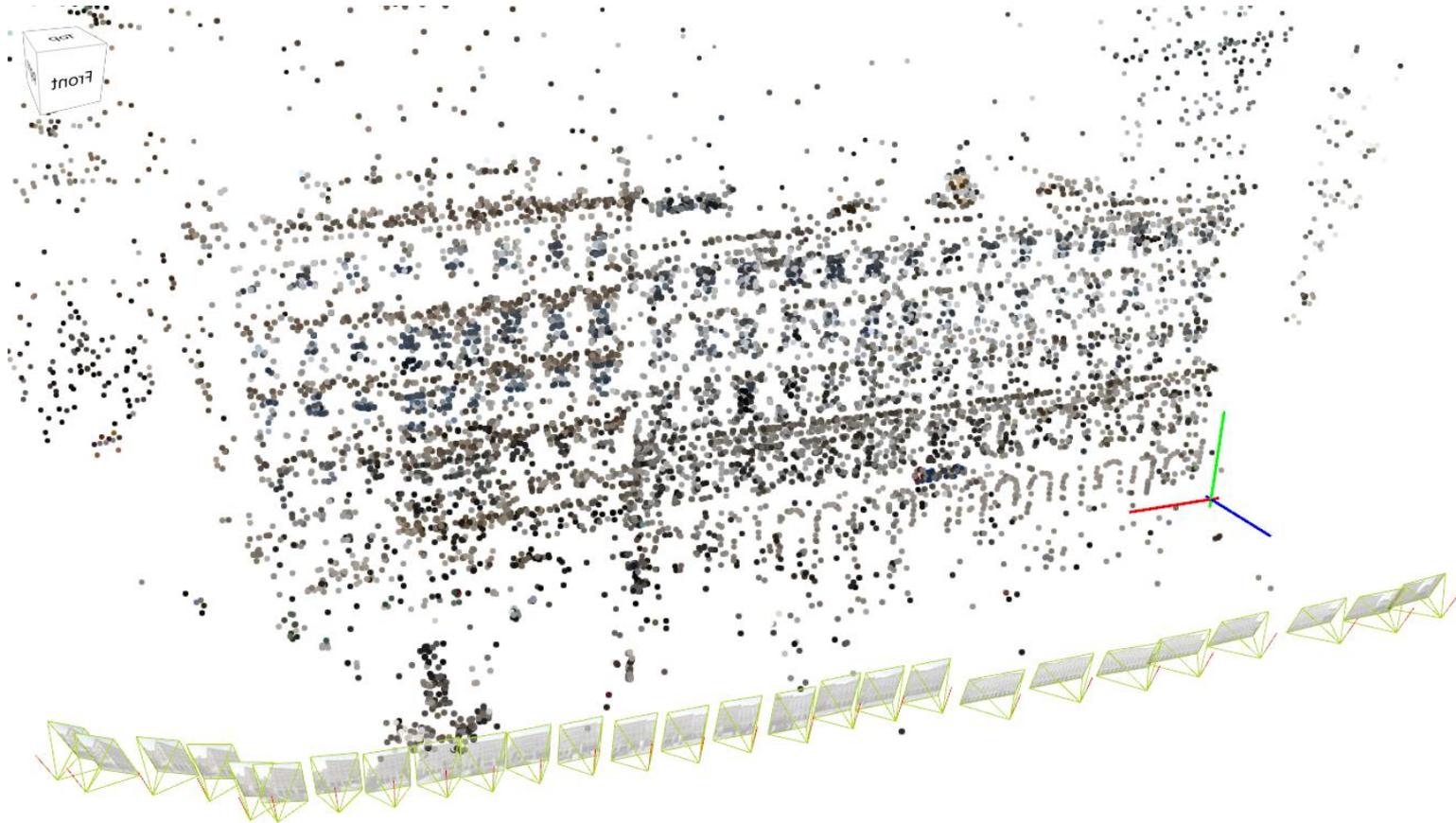
Input: Typical, perspective Photographs



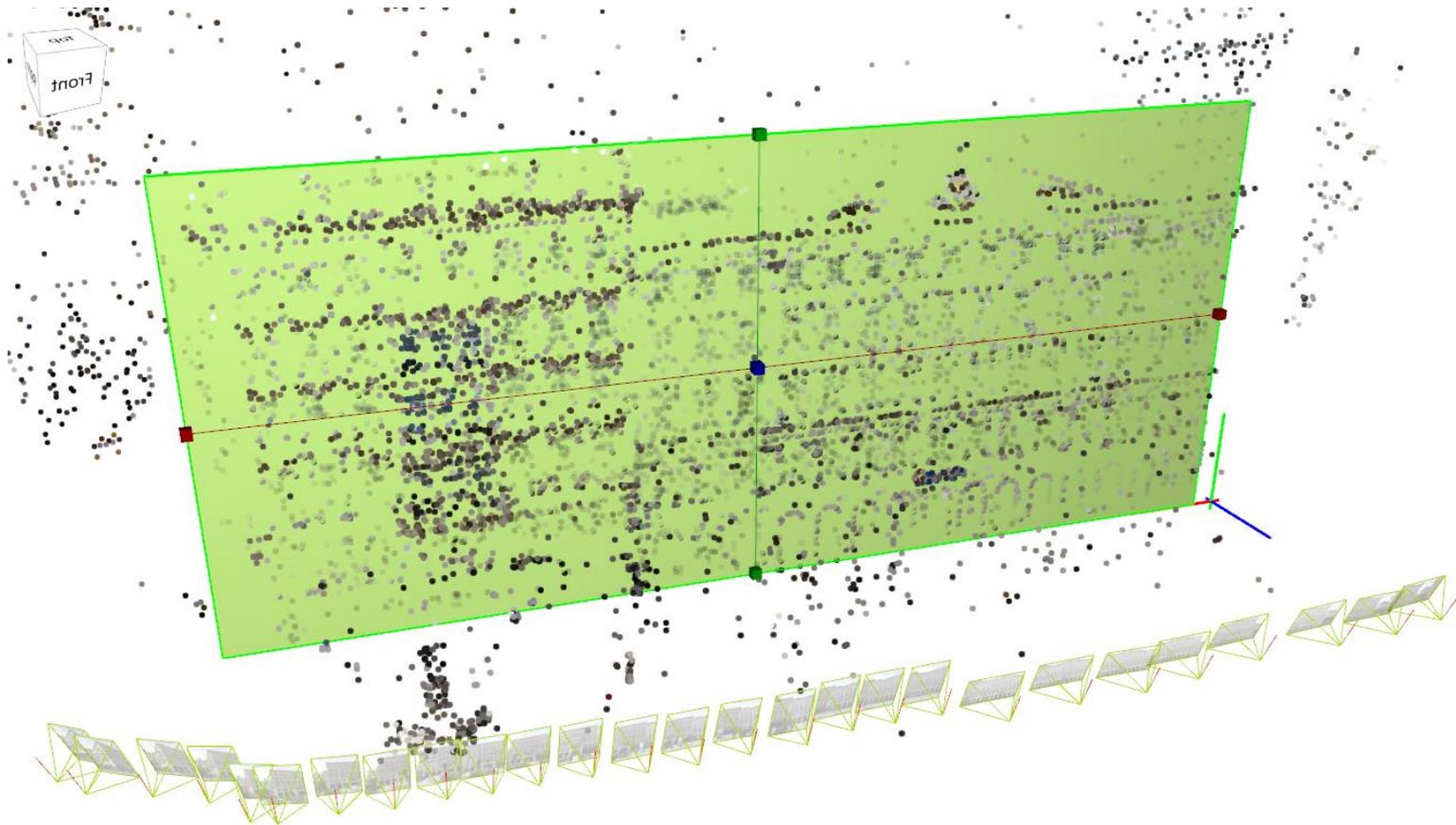
Photo View (2D)

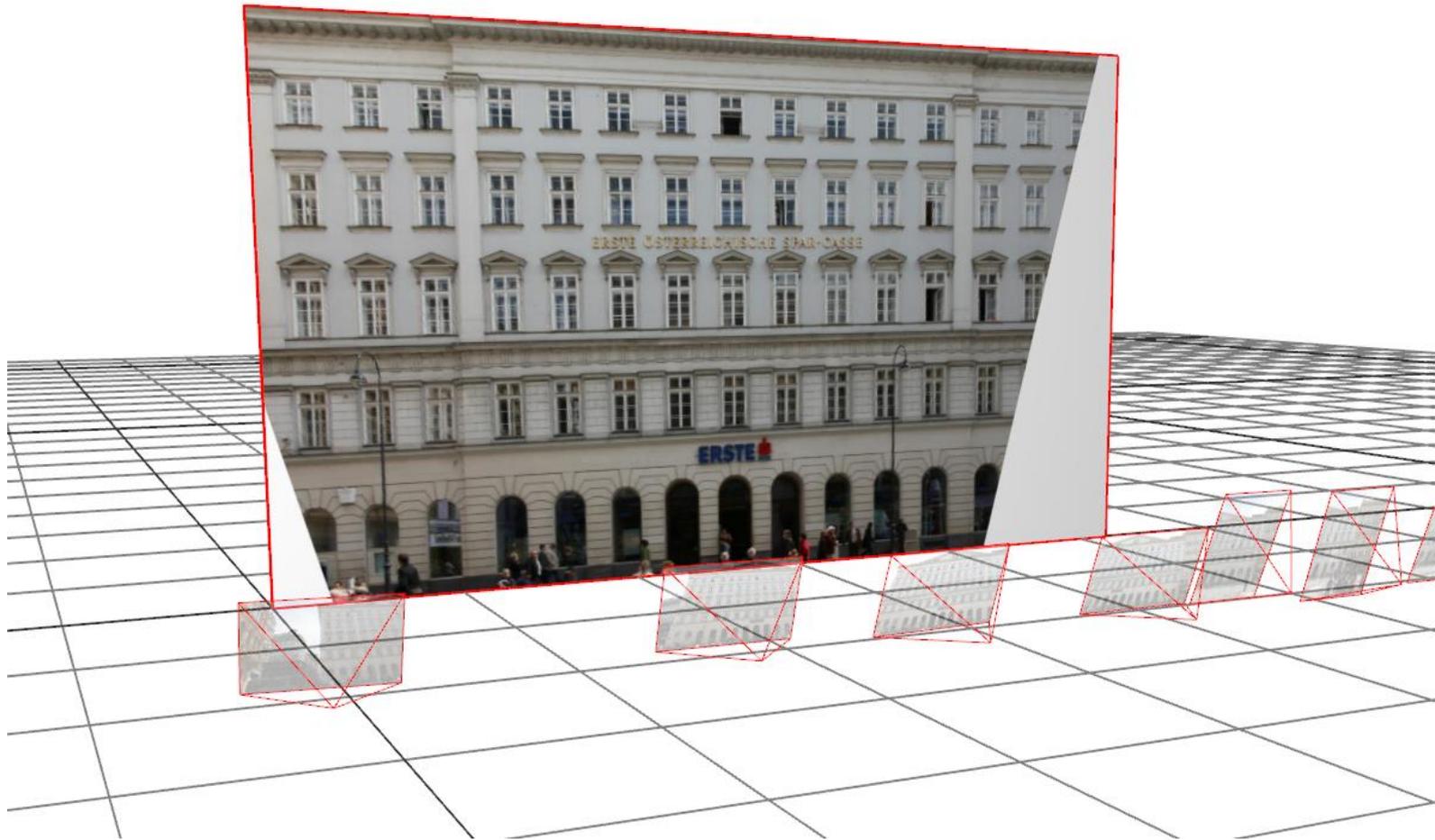


Structure-From-Motion



Plane Fitting





Interactive Boundary Adjustment

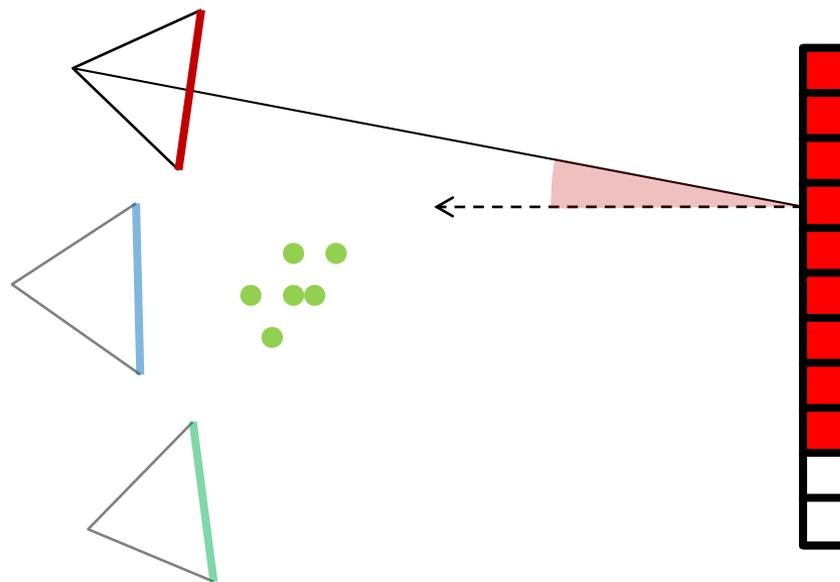


Accumulate in an “Image-Stack”



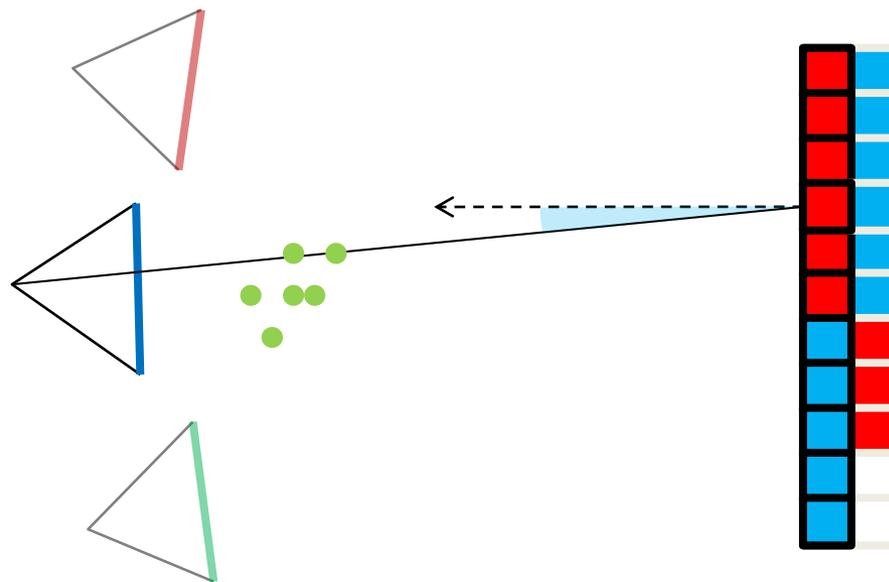
For each photo (per target pixel)

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



For each photo (per target pixel)

1. evaluate projection quality q
2. generate occlusion weight o
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For each photo (per target pixel)

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



Multi-View Stitching



- Color space stitched image



- **Stitched gradients**



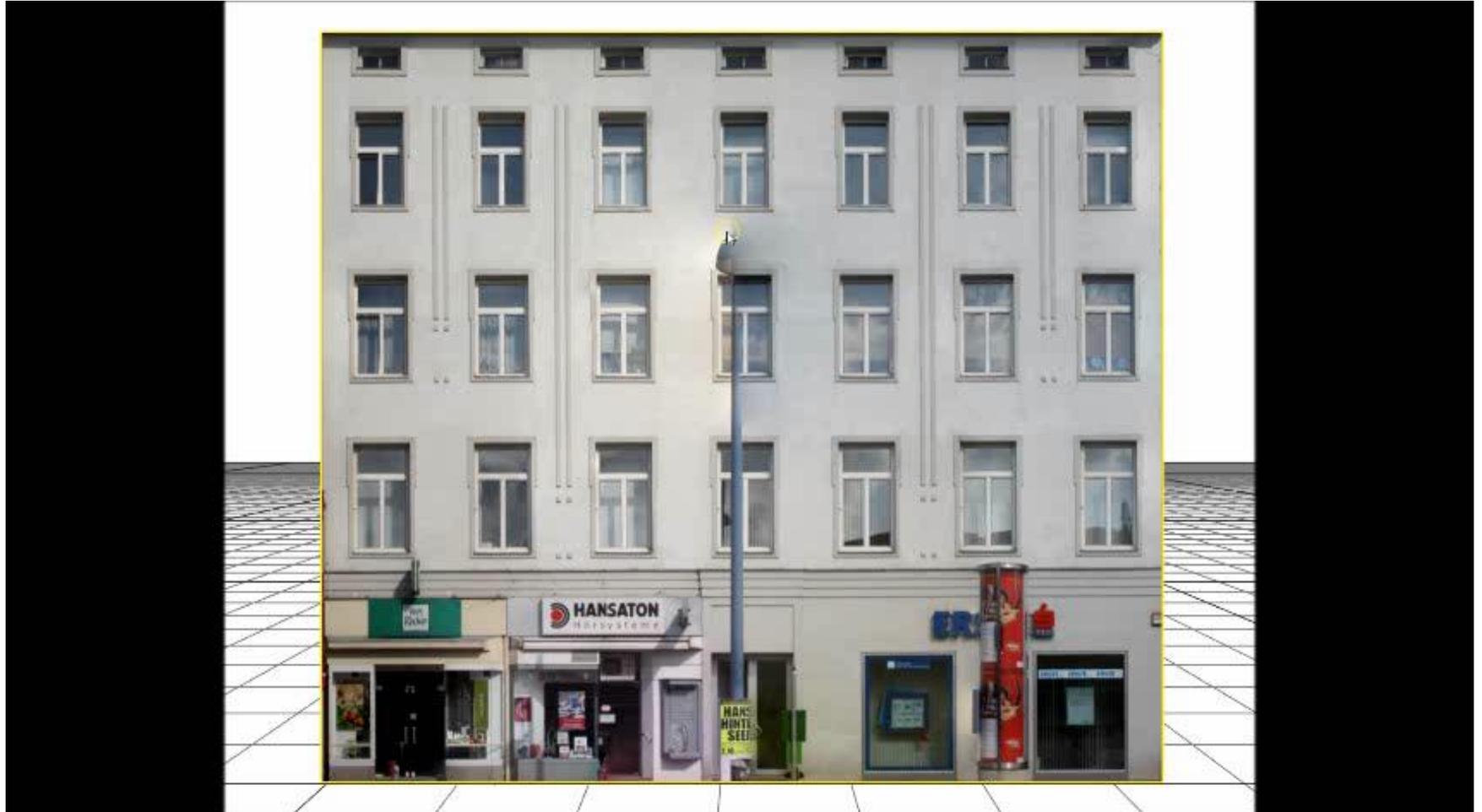
- **Reconstructed image**



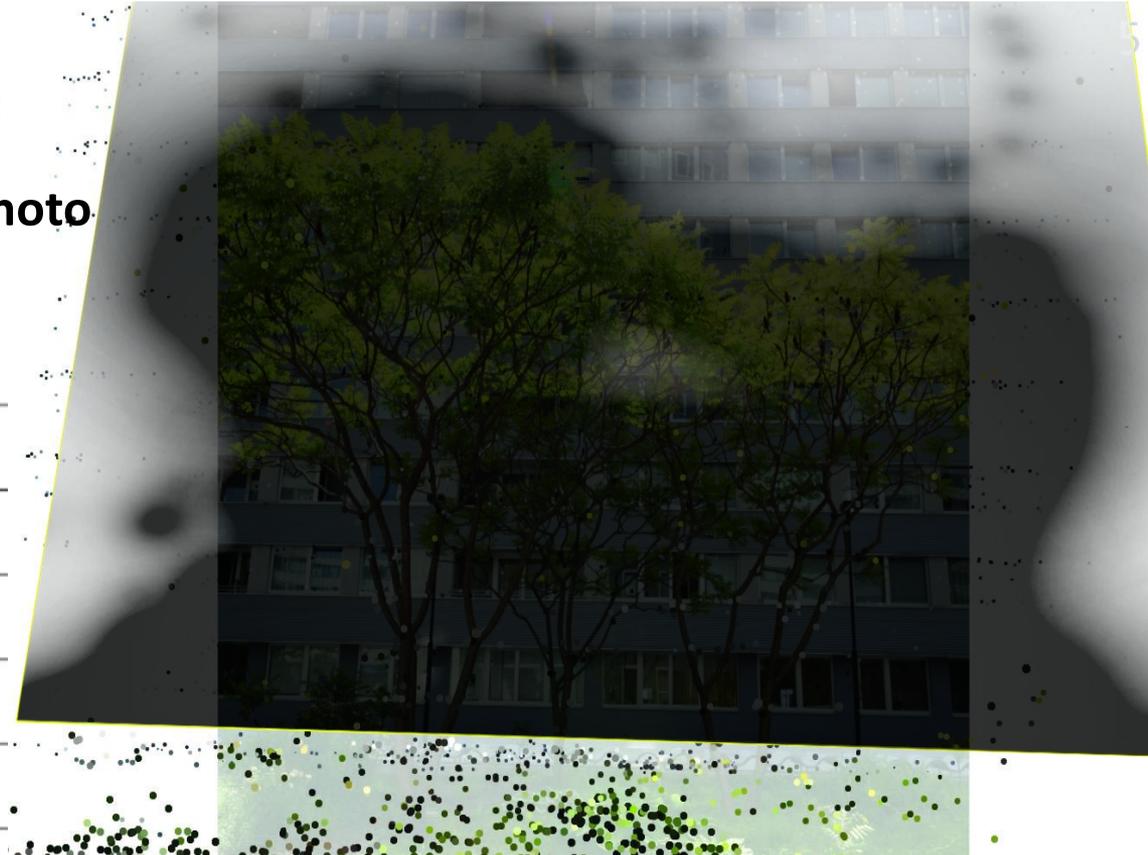
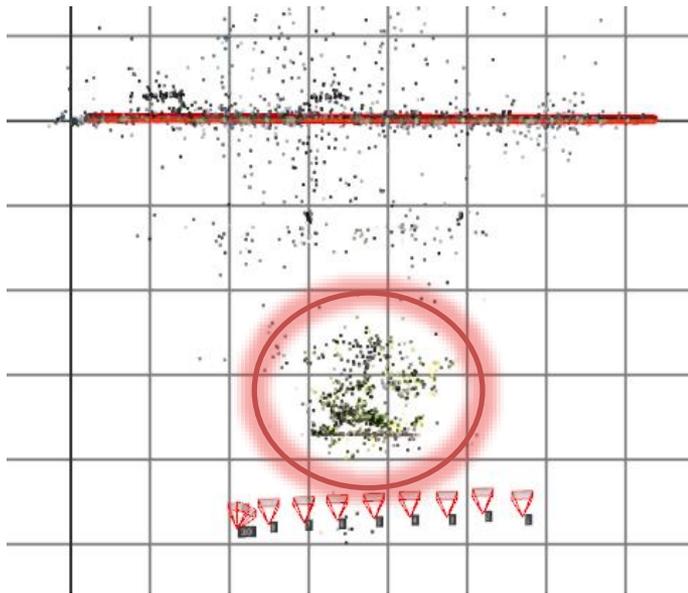


Interactive Brushing





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





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





[MWW12] Eurographics 2012

Interactive Coherence-Based Façade Modeling



- **Reconstruction of Façade Models**



Input: Ordinary Photo \Rightarrow **Output: Computer Model**

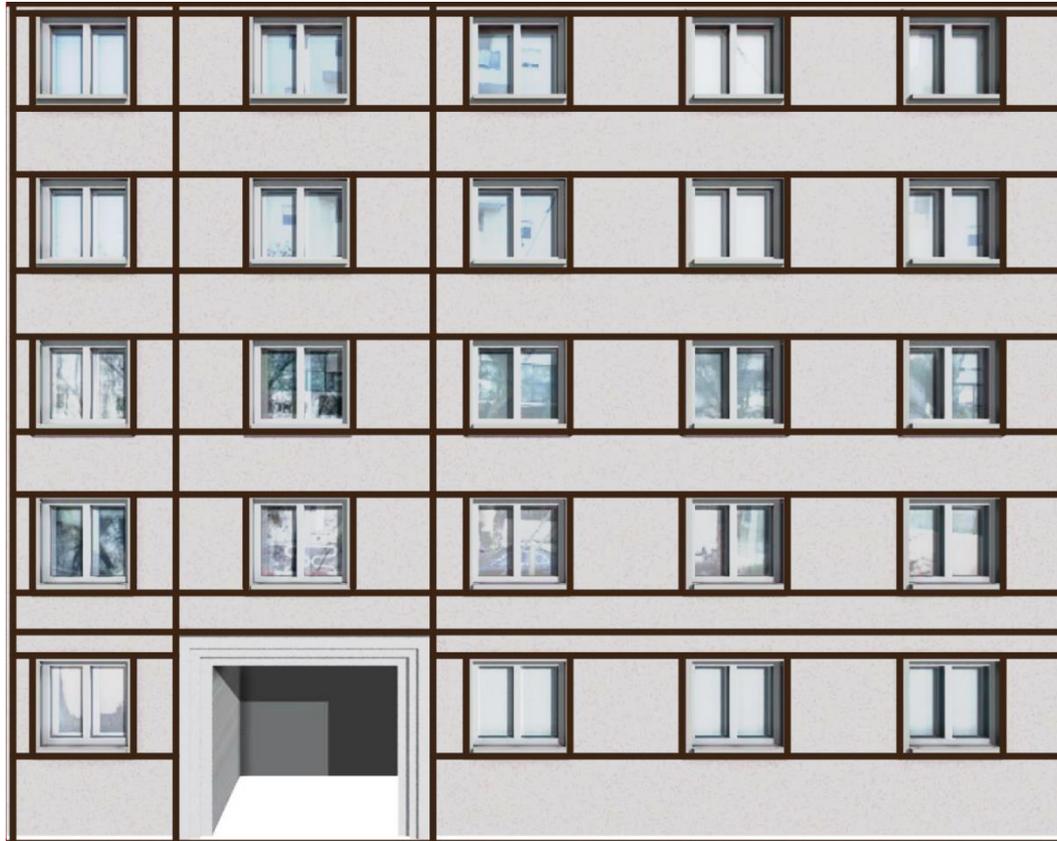
- **Interactive modeling process**
 - Input: Single rectified image
 - Incorporates the user from the beginning
- **Utilizes symmetries across the image**
 - Coherence-Based Modeling
- **Two crucial operations**
 - Automatic Façade Split Operator
 - Synchronized Group Operator





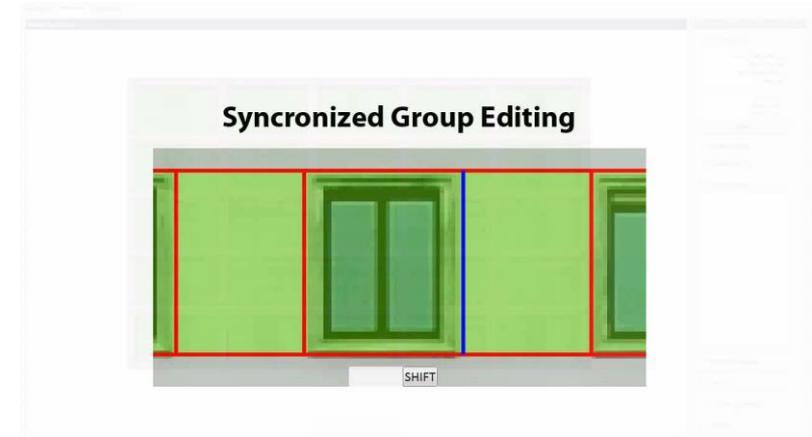
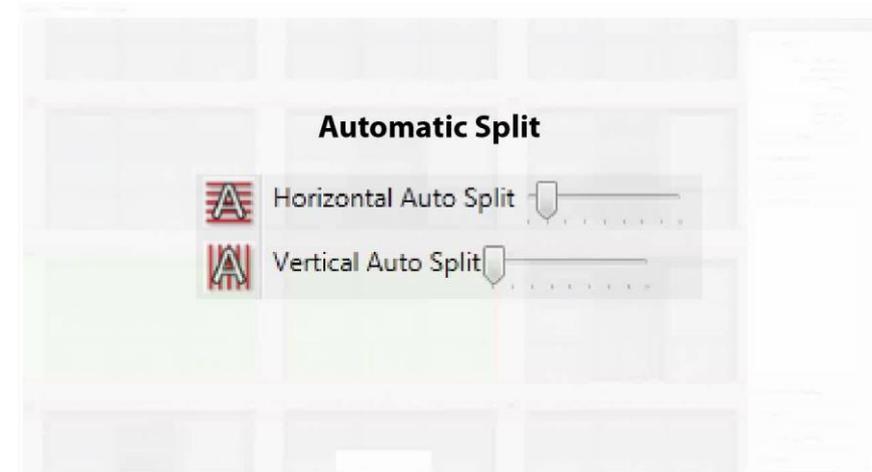
Modeling Process



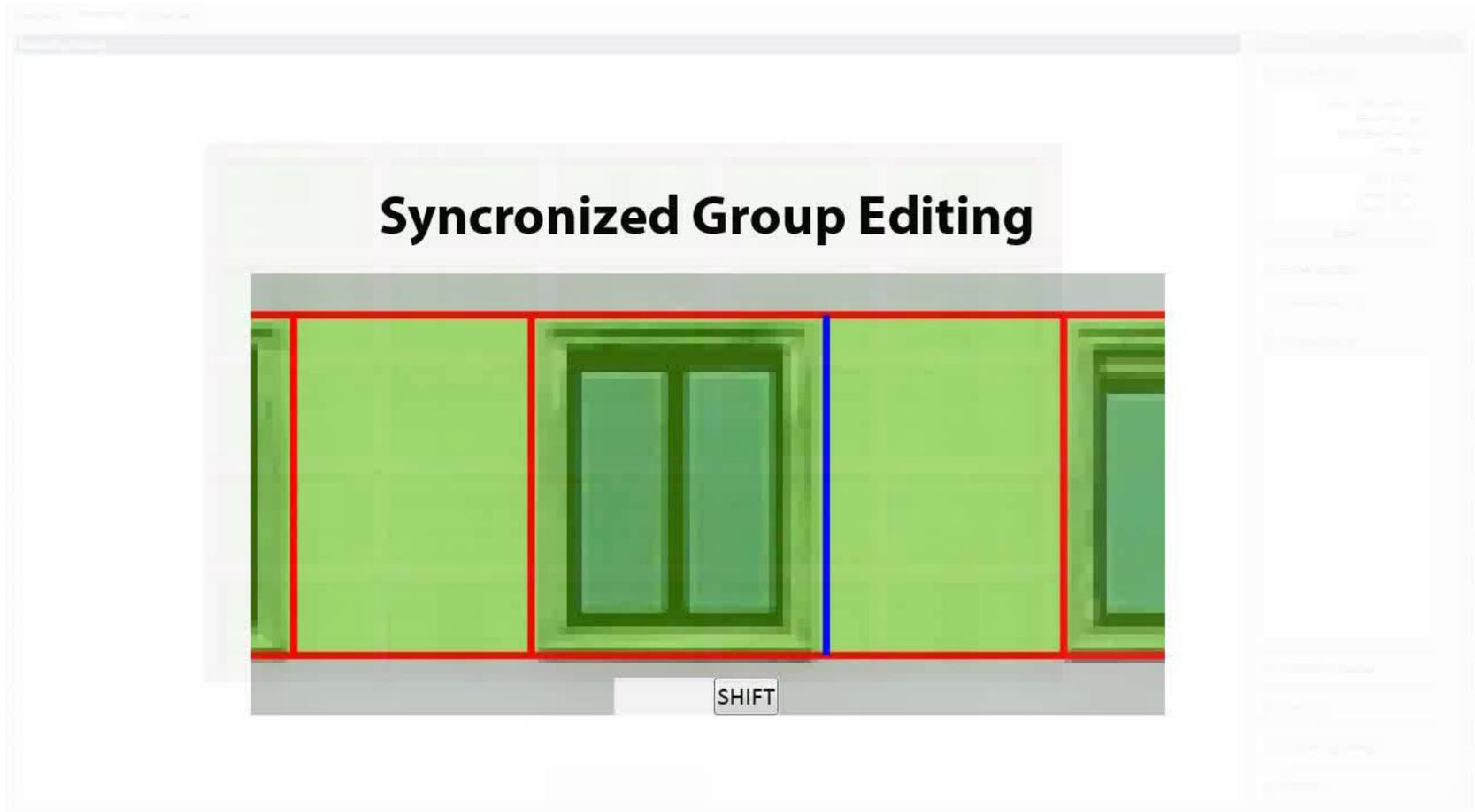


- **Automatic Façade Split Operator**
 - Also allows automatic selection of similar elements

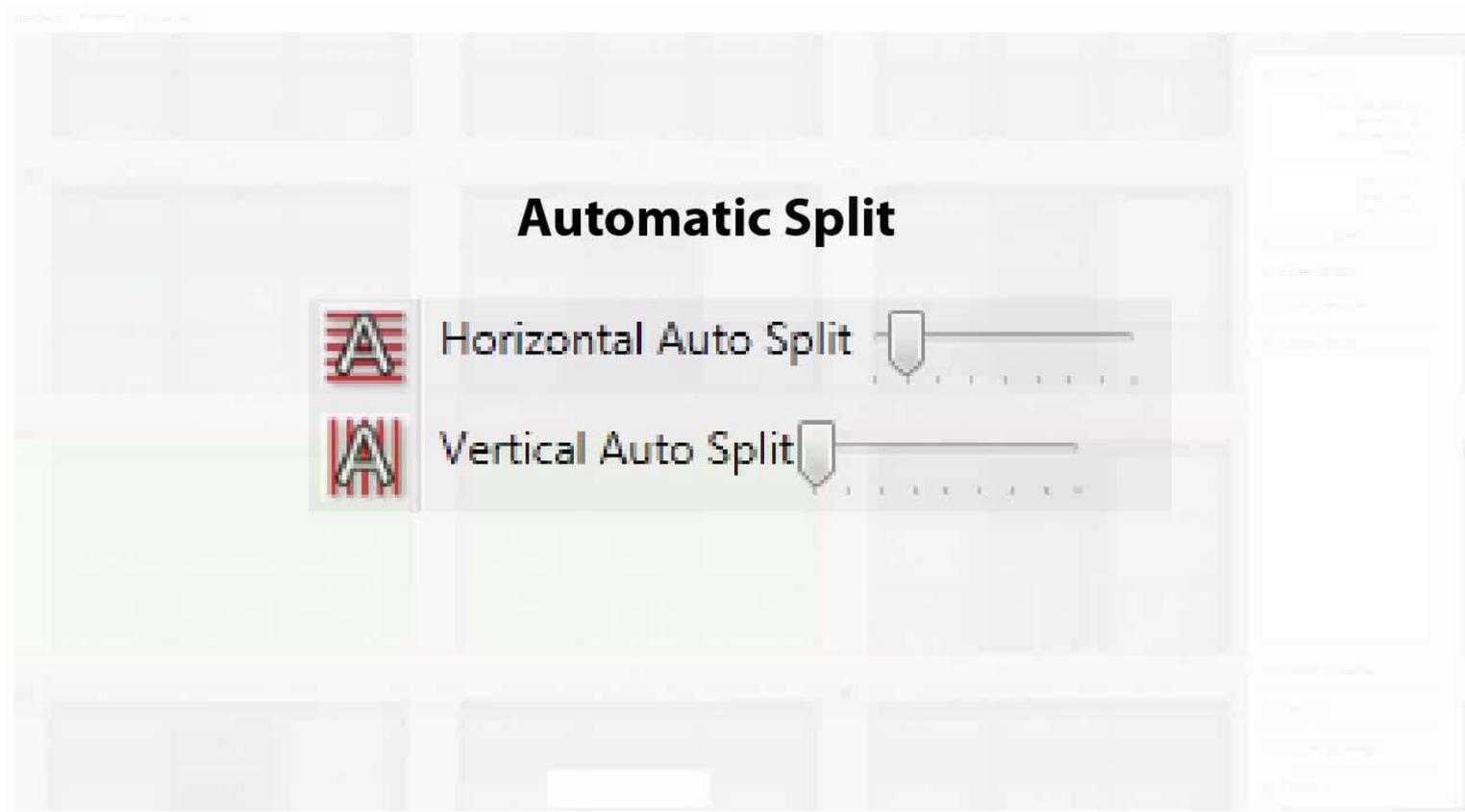
- **Synchronized Group Editing Operator**
 - Propagates splits to all instances in a group



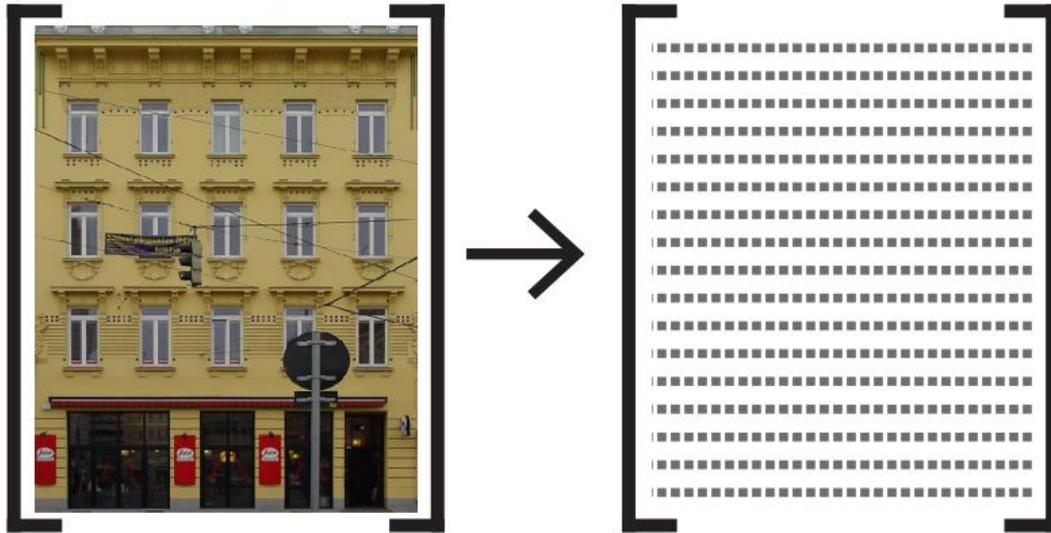
- **Synchronized Group Editing Operator**



- **Automatic Façade Split Operator**



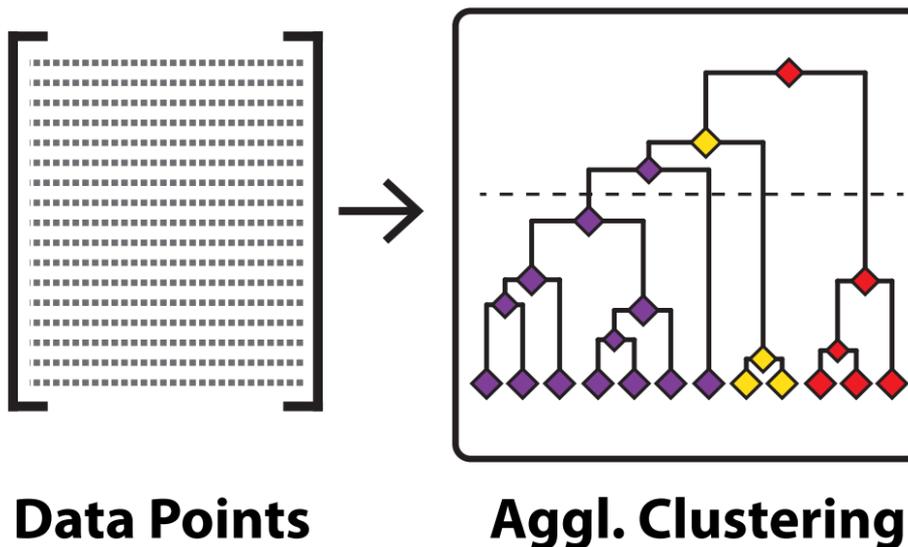
Idea: handle the pixel rows as as row vectors!



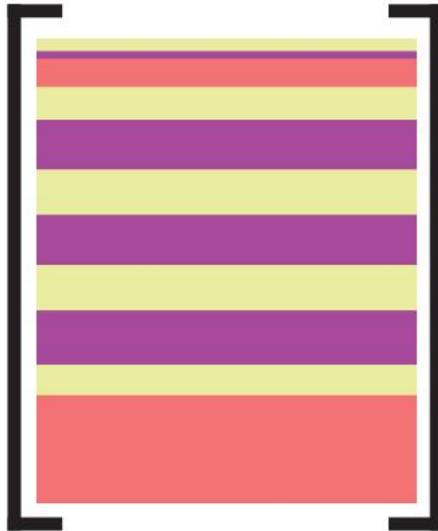
Input

Data Points

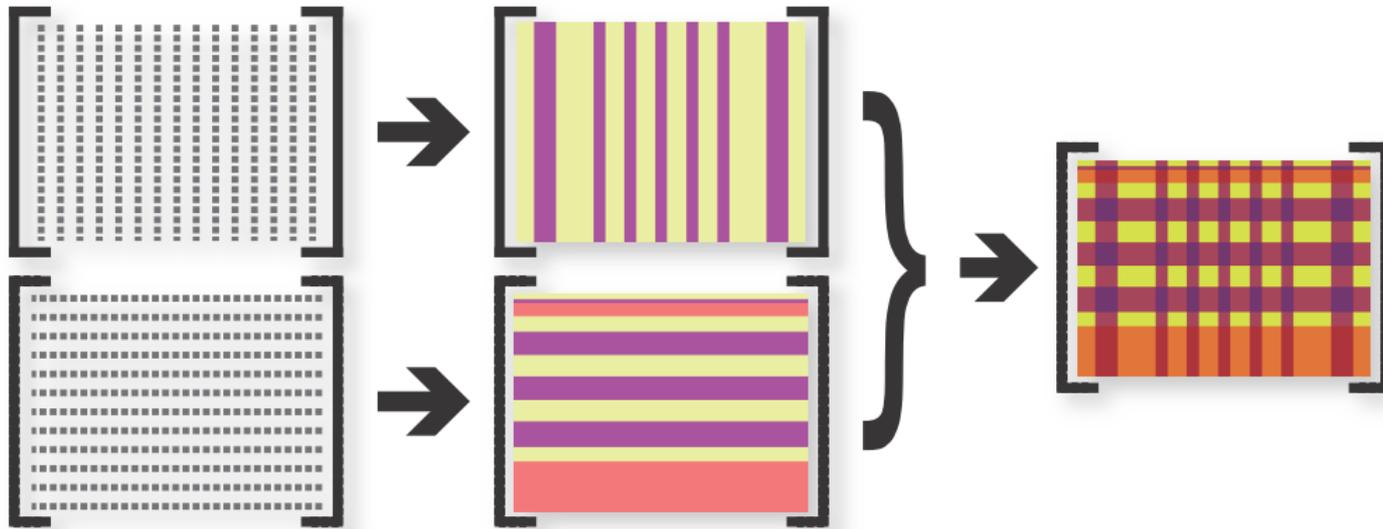
- perform **clustering** on rows of the image
- we use agglomerative bottom-up clustering
- number of clusters chosen by the user
- no connection in the spatial domain



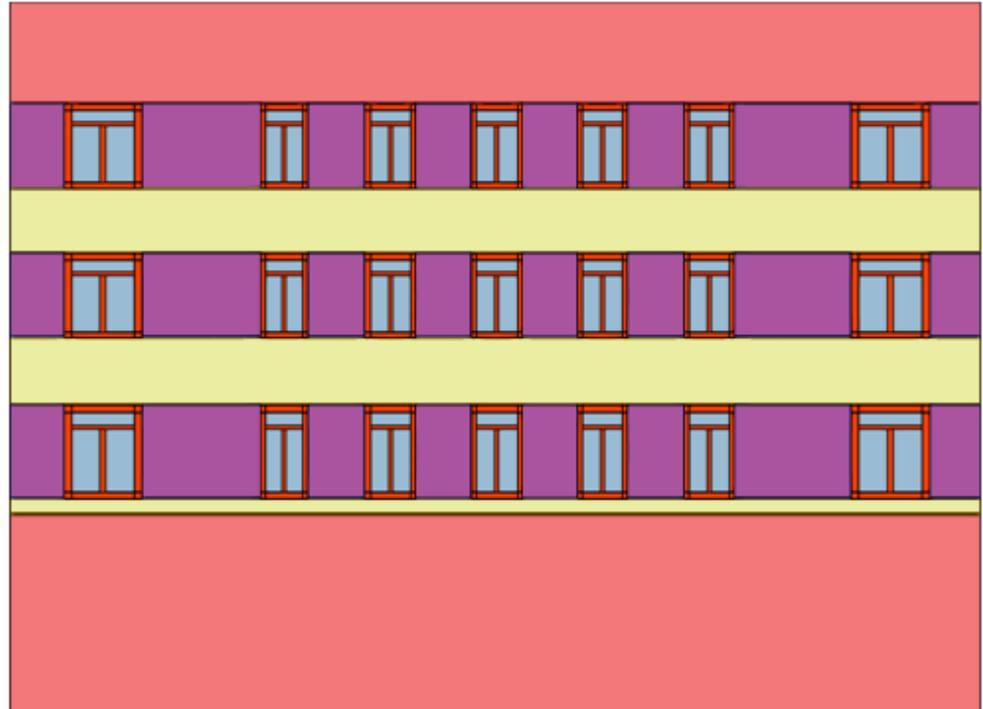
- it delivers spatial segmentation
- and, since pixel-rows have cluster IDs
→ also grouping of similar objects



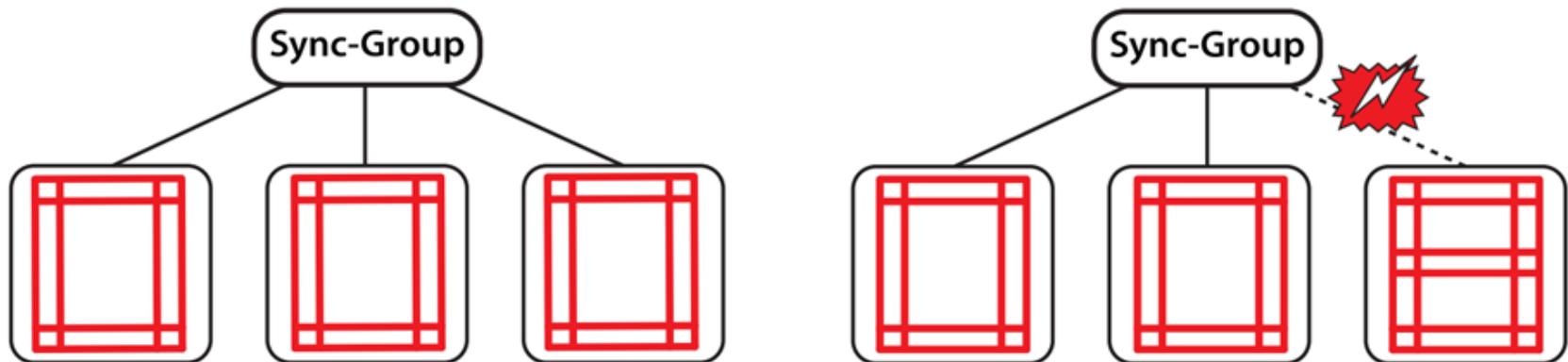
- can be performed for x and y separately



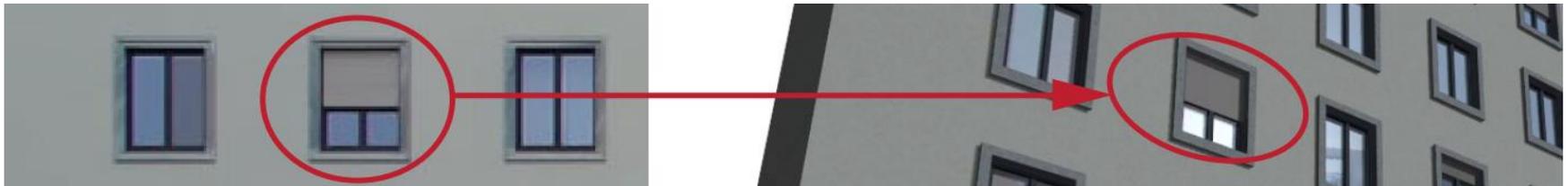
- elements with the same cluster-id provide candidates for groups
- groups can be edited in a synchronized manner



- 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



- each element is still a separate instance

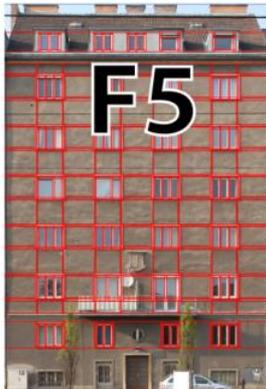


- Polygonal shapes at the lowest hierarchy level



- Can also be edited in a synchronized manner





- 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)*

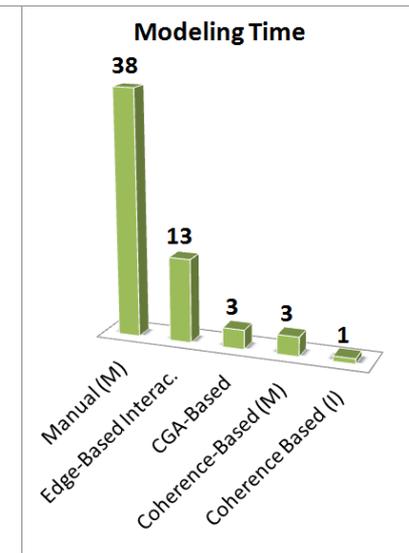
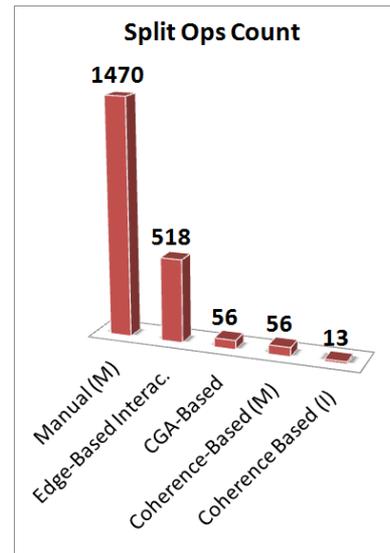
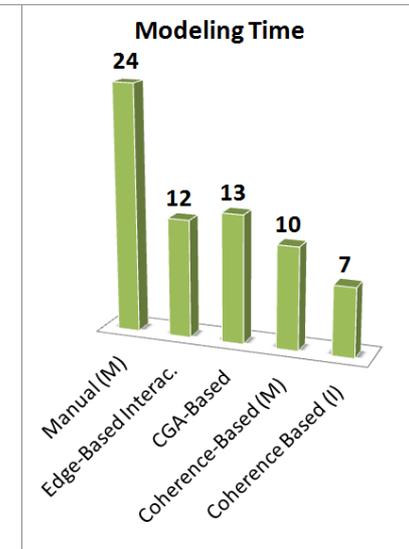
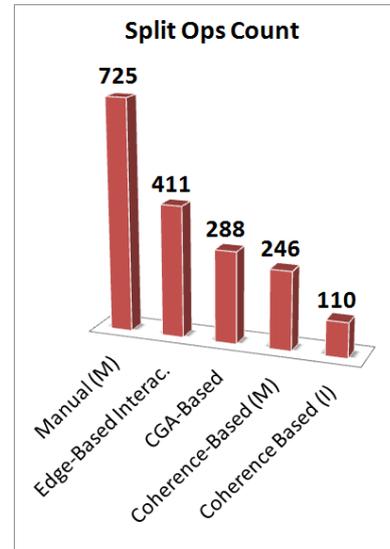




960 Shapes

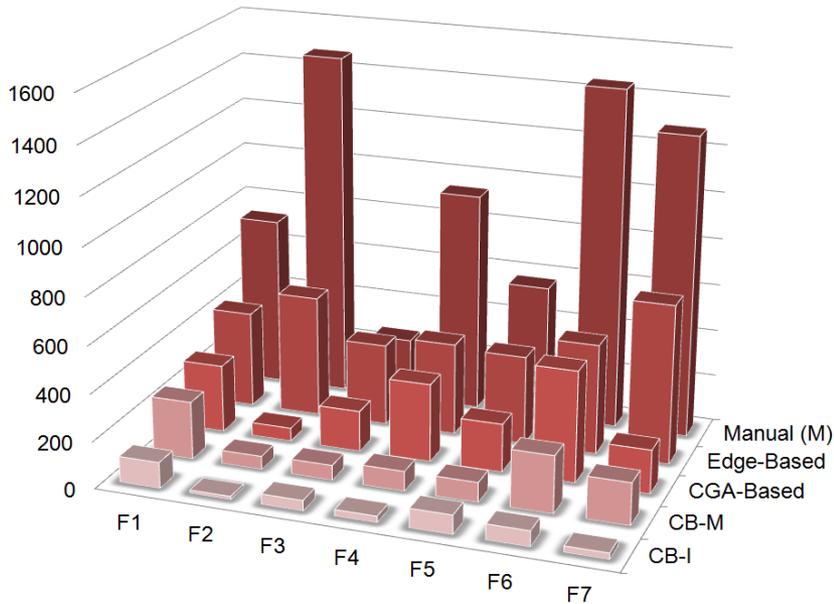


4351 Shapes

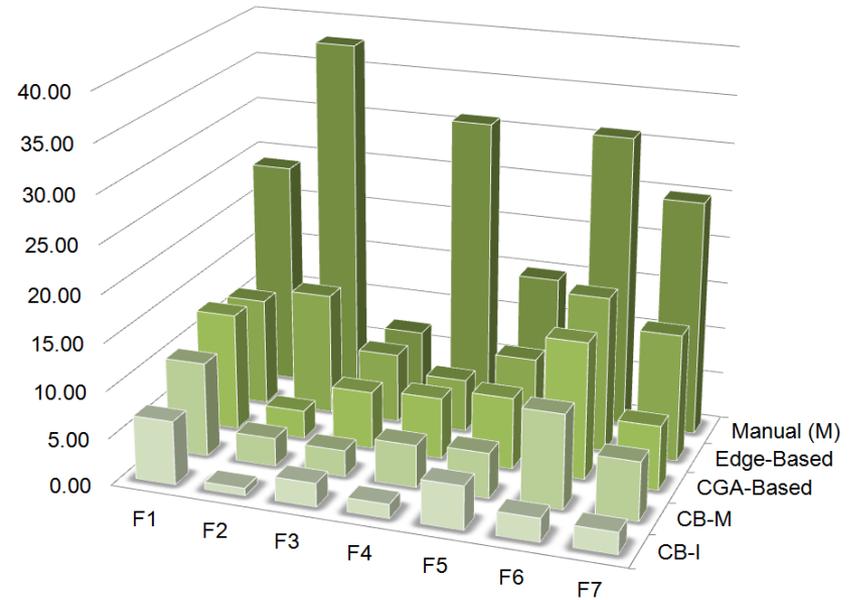


Evaluation: Split Operations

Split Operations Count



Modeling Time in Minutes



- **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

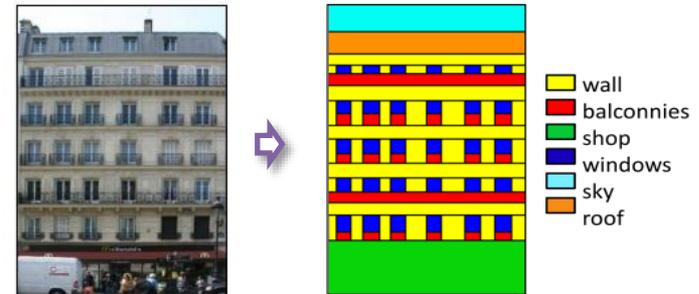


- **Yes, the presentation is over.**
- **No, there is still plenty to do in the future!**

- **Other Façade Modeling Approaches**

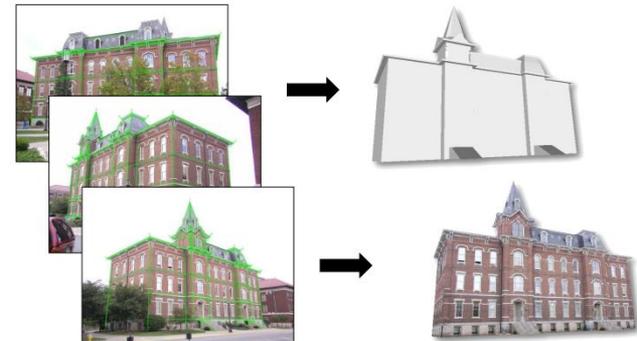
- **Façade Parsing**

- 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



Thank you! Questions?

