Façade Reconstruction
An Interactive Image-Based Approach

Przemyslaw Musialski
Institute of Computer Graphics and Algorithms
Vienna University of Technology
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
Possible Applications

- Cyber-Tourism
- Computer Games
- Movie-Industry and Entertainment Industry
- Digital Maps and Routing
- City-Planers and Architects
- Archeological Research
- More Sciences (Sociology, ...)

6/6/2013 Facade Reconstruction
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*2013]  
In EG2012 STAR Proceedings & CGF Journal 2013
Why Image-Based?

• Easy to acquire (cheap)

• Imagery is essential in Urban Reconstruction
  – For a realistic look
  – As source for reconstruction
Why Interactive Modeling?

• High-Quality
  – Interactive: yes
  – Automatic: no

• Scalability
  – Interactive: no
  – 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

Facade Reconstruction
Sparse Reconstruction

Plane Fitting
Interactive Boundary Adjustment
Multi-View Projection

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 \( o \)
3. insert to sorted image stack with \( oq \)
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 $oq$
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
Interactive Coherence-Based Façade Modeling

[MWW12] Eurographics 2012
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
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
Two Crucial Operations

• Synchronized Group Editing Operator

Syncronized Group Editing
Two Crucial Operations

• Automatic Façade Split Operator

Automatic Split

Horizontal Auto Split

Vertical Auto Split
Idea: handle the pixel rows 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

![Diagram of data points and agglomerative clustering](image)
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
– 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

Split Operations Count

Modeling Time in Minutes
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
• Yes, the presentation is over.

• No, there is still plenty 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?