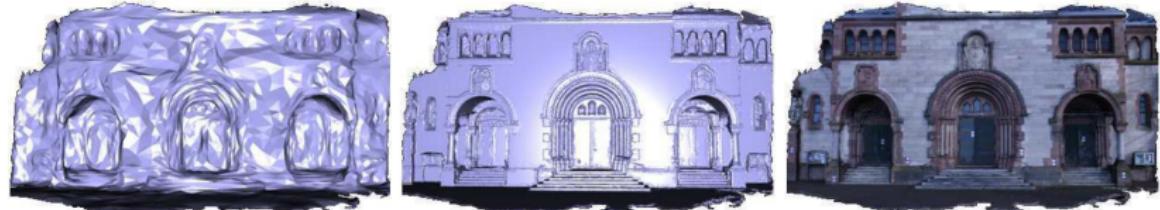


# A hybrid multi-view stereo algorithm for modeling urban scenes

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April 24, 2017



# Overview

1 Introduction: meshes and primitives

2 Hybrid model: 2-step strategy with iterative refinement

- Step 1: Mesh-based surface segmentation
- Step 2: Stochastic hybrid reconstruction

3 Experiments

4 Conclusions

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# Introduction

- Urban scenes are difficult to analyze
  - Structures are very different within the same scene...
  - ... but created with man-made rules (piecewise planar, shape repetition)
- Urban scene reconstruction: 2 approaches
  - Meshes
  - 3D primitive arrangements

# Introduction: Meshes

- **Meshes:** set of vertices, edges and faces that defines the shape of polyhedral objects
- Several methods for generating a mesh from multi-view stereo images
  - Region growing based methods
  - Fusing a set of depth maps
  - Variational methods
  - 3D Delaunay triangulations
- **Pro:** highly detailed scene reconstruction
- **Cons:**
  - Regular structures not optimally modeled
  - Semantic not taken into account

# Introduction: 3D-primitive arrangements

- **3D primitives:** planes, spheres, cylinders, cones and tori
- Exploit the **Manhattan-world assumption**
  - Predominance of three mutually orthogonal directions in the scenes
- **Pro:**
  - particularly well adapted to describe urban environments
  - Semantic taken into account
  - Easy to store and render
- **Cons:** Fail to model fine details and irregular shapes

**Solution:** hybrid (meshes + primitives) model approach!

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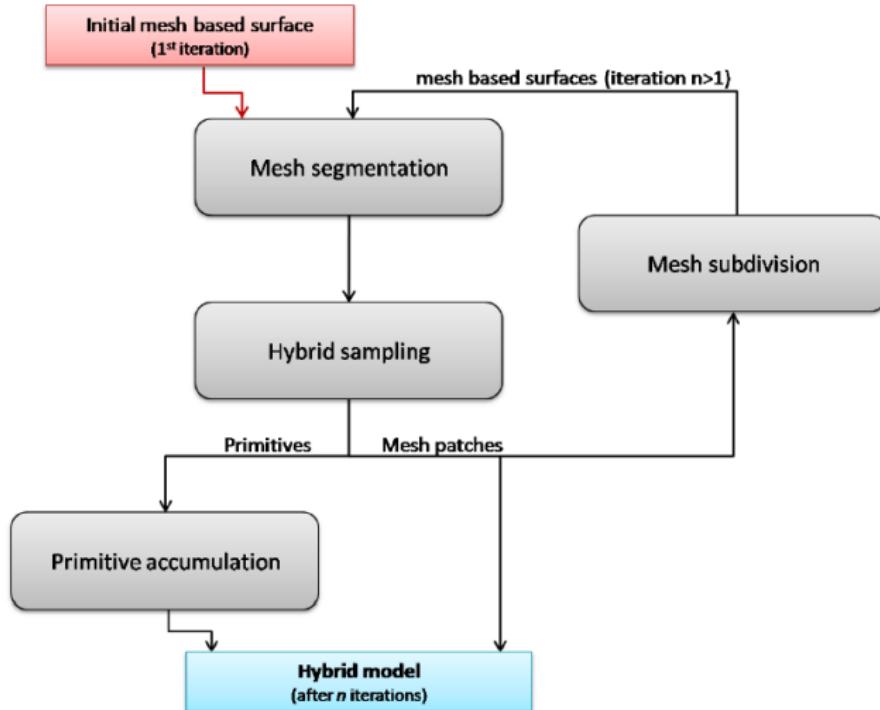
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# Hybrid model: pipeline

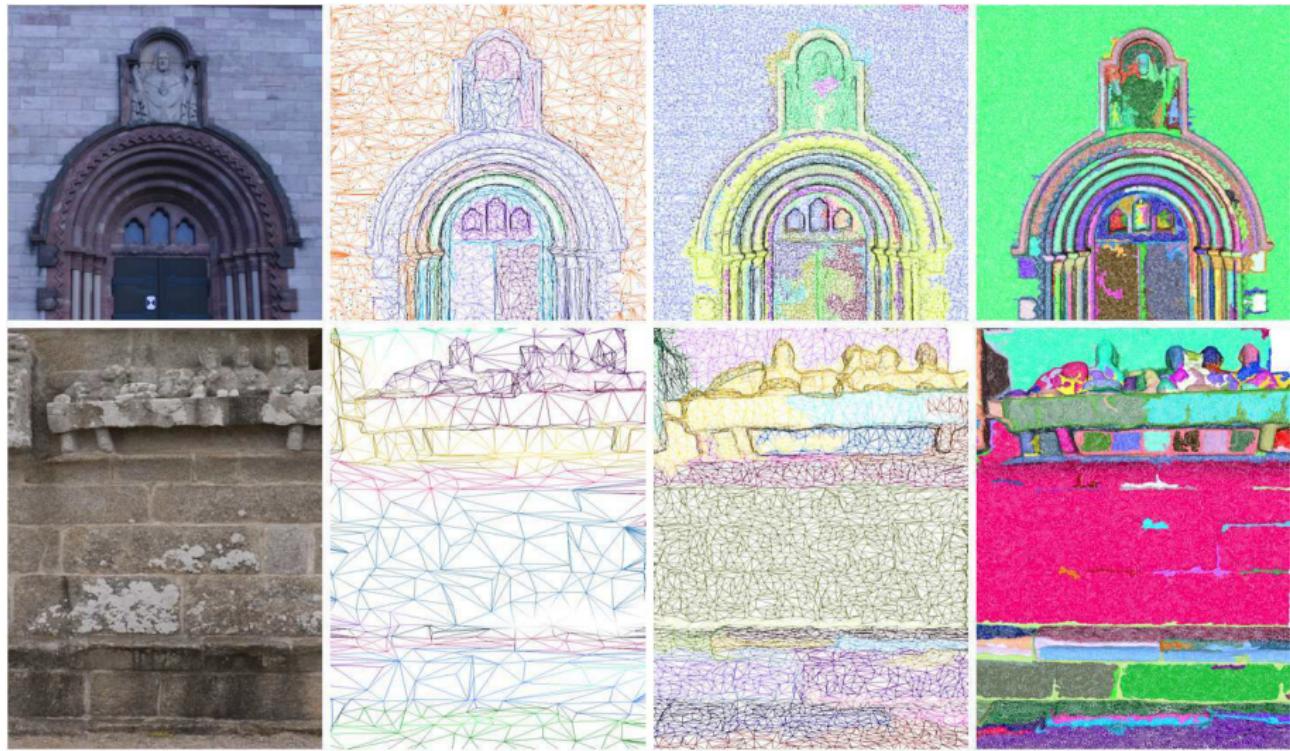


Preliminary segmentation: reduces the complexity of the problem  
The procedure stops when the generated facets become too small

## Step 1: Mesh-based surface segmentation

- Segmentation problem formulated with a Markov Random Field
  - Vertex set and edge adjacency as in the mesh
- Label for each vertex
  - Planar, developable convex, developable concave, non developable
- Quality of a label configuration: energy
  - Energy given by curvature distributions, label homogeneity and edge preservation
- Subdivision into clusters (using label as discriminant)

# Step 1: Mesh-based surface segmentation



## Step 2: Stochastic hybrid reconstruction

- $H$ : configuration space of the hybrid models given the segmented initial mesh-based surface  $\mathbf{x}^{(0)}$
- $U(\mathbf{x})$ : energy measuring the quality of a hybrid model  $\mathbf{x} \in H$
- Optimal hybrid model:  $\hat{\mathbf{x}} = \arg \min_{\mathbf{x} \in H} U(\mathbf{x})$
- Multi-object energy model:

$$U(\mathbf{x}) = \sum_{i=1}^N U_{pc}(x_i) + \beta_1 \sum_{i=1}^{N_m} U_s(m_i) + \beta_2 \sum_{i \bowtie i'} U_a(p_i, p_{i'})$$

with  $m_i, p_i$  meshes respectively primitives in  $\mathbf{x}$  and  $N_m + N_p = N$

## Step 2: Photo-consistency $U_{pc}$

$$U(\mathbf{x}) = \sum_{i=1}^N U_{pc}(x_i) + \beta_1 \sum_{i=1}^{N_m} U_s(m_i) + \beta_2 \sum_{i \bowtie i'} U_a(p_i, p_{i'})$$

$U_{pc}$  is the image back-projection error with respect to the object surface

$$U_{pc}(x_i) = A(x_i) \sum_{\tau, \tau'} \int_{\Omega_{\tau, \tau'}^S} f(I_\tau, I_{\tau, \tau'}^S)(s) ds$$

with  $A(x_i)$  a function tuning the occurrence of primitives/meshes

## Step 2: Mesh smoothness $U_s$

$$U(\mathbf{x}) = \sum_{i=1}^N U_{pc}(x_i) + \beta_1 \sum_{i=1}^{N_m} U_s(m_i) + \beta_2 \sum_{i \bowtie i'} U_a(p_i, p_{i'})$$

$U_s$  allows the regularization of mesh patches and penalizes strong bending using the thin plate energy  $E_{TP}$

$$U_s(m_i) = \sum_{\nu \in V_{m_i}} E_{TP}(\nu, \{\bar{\nu}\})$$

with  $\{\bar{\nu}\}$  the set of adjacent vertices to the vertex  $\nu$

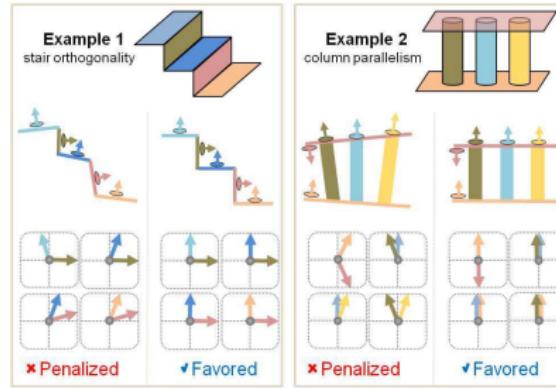
## Step 2: Priors on shape layout $U_a$

$$U(\mathbf{x}) = \sum_{i=1}^N U_{pc}(x_i) + \beta_1 \sum_{i=1}^{N_m} U_s(m_i) + \beta_2 \sum_{i \bowtie i'} U_a(p_i, p_{i'})$$

$U_a$  favors both perpendicular and parallel primitive layouts and object repetition in a scene

$$U_a(p_i, p_{i'}) = \omega_{ii'}(1 - \cos(2\gamma_{ii'}))^{2\alpha}$$

with  $\gamma_{ii'}$  the angle between the direction of revolution of the two primitives and  $\omega_{ii'}$  weight which favors repetitiveness



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Thanks for your attention!

Questions?