Reconstructing the World's Museums

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Hello, Florence!

Ciao, Firenze!
That is great!

Florence = Renaissance Center of Art

Uffizi museum = one of the most famous art galleries

What about indoors?
Uffizi Museum

Where is “The Birth of Venus”?
Photorealistic Indoor Maps

Where is "The Birth of Venus"?
Data-driven Brute-force Approach
2-step algorithm

Data-driven Brute-force Approach
1. Remove ceiling.
2. Take pictures from aerial viewpoints.

Data-driven Brute-force Approach
What is wrong?
What is wrong?
I don't own the museums.
1. Remove ceiling.
2. Take pictures from aerial viewpoints.
1. Remove ceiling.
2. Take pictures from aerial viewpoints.

0. New Approach

Own the museums.
1. Remove ceiling.
2. Take pictures from aerial viewpoints.

New Approach
Reconstruct the museums.
Our Goal

• Global texture-mapped 3D model
• Optimize for aerial viewing
• Enable effective indoor navigation
Existing methods

- Require accurate calibration
- Produce a "dense" model
- Susceptible to errors
- Not scalable

Size matters!
1. Take pictures inside the rooms
2. Reconstruct the 3D shape
3. Render from aerial viewpoints
2. Reconstruct the 3D shape
3. Render from aerial viewpoints
1. Take pictures inside the rooms

3. Render from aerial viewpoints
1. Take pictures inside the rooms

3. Render from aerial viewpoints
1. Take pictures inside the rooms
2. Reconstruct the 3D shape
1. Take pictures inside the rooms
2. Reconstruct the 3D shape
Reconstruction
- Images (> 40,000)
- Laser points (> 200,000,000)
- Input collected over multiple sessions
Noisy Laser Points

top-down view of input laser points
(two different colors represent two vertical laser range sensors)
Challenges for Indoor Scenes

Prevalence of thin structures
Opportunities for Indoor Scenes

Structural: regularizes (planarity/orthogonality)
Summary on Previous Work

• Structure prior enforced in 2D (depth or façade)
• Visualization limited to ground level
• Assume near-perfect calibration
Inverse CSG Algorithm

Constructive Solid Geometry (CSG)
InverseCSG

Constructive Solid Geometry (CSG)

Xiao et al. NIPS 2012

Xiao et al. Siggraph Asia 2012a
Cut into Slices

gravity

side view
2D CSG Reconstruction

1. Generate primitives
2. Choose a subset
2D CSG Reconstruction

1. Generate primitives
point $\rightarrow$ line
2D CSG Reconstruction

1. Generate primitives

From 4 line segments
2D CSG Reconstruction

1. Generate primitives
2. Choose a subset
2D CSG Reconstruction

1. Generate primitives

2. Choose a subset

Repeat in each slice
2D CSG Reconstruction

- Free space
- Laser points
- Regularization
\[
\begin{align*}
E_1(T) &= \frac{\text{Sum of free-space scores inside } T}{\text{Total sum in the domain without negative scores}} \\
E_2(T) &= \frac{\# \text{ of points on the surface of } T}{\text{total # of points}} \\
E_3(T) &= \frac{\text{perimeter of } T \text{ near laser points (within 0.2 meters)}}{\text{total perimeter of } T} \\
E(T) &= w_1 E_1(T) + w_2 E_2(T) + w_3 E_3(T)
\end{align*}
\]
3D CSG Reconstruction

1. Generate primitives (cuboids)
2. Choose a subset (out of primitive candidates)
3D

cuboids

3D point cloud ➔ 2D CSG (floorplan) ➔ 3D CSG model ➔ Wall model ➔ Final textured model
3D CSG Reconstruction

1. Generate primitives (cuboids)

2D CSG

Rectangle primitive

3D point cloud → 2D CSG (floorplan) → 3D CSG model → Wall model → Final textured model
3D

1. Generate primitives (cuboids)

Rectangle primitive
3D CSG Reconstruction

1. Generate primitives (cuboids)

Rectangle primitive
3D

cuboids
Step-by-step visualization of 3D CSG model reconstruction
1. Remove Ceiling
2. Texture Mapping
View-independent model

View-dependent models (different height thresholds)
Technical Contribution  Conceptual Contribution
Technical Contribution
Inverse CSG for Large-scale Reconstruction

Conceptual Contribution
Technical Contribution

Inverse CSG for Large-scale Reconstruction

Conceptual Contribution

Indoor Photorealistic Maps + Aerial $\rightarrow$ Ground Transition for Effective Navigation
Technical Contribution
Inverse CSG for Large-scale Reconstruction

Conceptual Contribution
Indoor Photorealistic Maps + Aerial → Ground Transition for Effective Navigation

Visualization
Technical Contribution
Inverse CSG for Large-scale Reconstruction
Reconstruction
Let machine see

Conceptual Contribution
Indoor Photorealistic Maps + Aerial → Ground Transition for Effective Navigation
Visualization
Let human see better
Technical Contribution

Inverse CSG for Large-scale Reconstruction

Conceptual Contribution

Indoor Photorealistic Maps + Aerial → Ground Transition for Effective Navigation

Visualization

Let human see better
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Where is “the birth of venus”? Google Art from bird’s-eye view

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Time: Friday Oct 12, 2:30PM
Location: Room C 2F Affari