

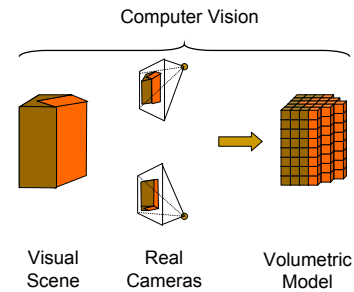
ECE6258 Lecture 42

Volumetric Scene Reconstruction

Source: Greg Slabaugh, Siemens

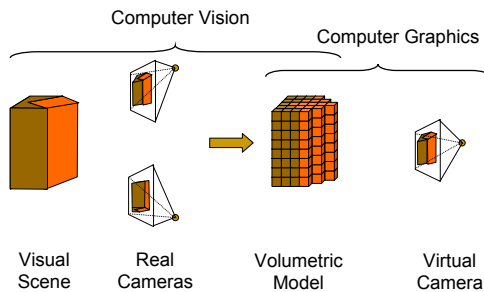
Motivation

- Volumetric Scene Reconstruction
 - Produce a 3D digital model of a visual scene

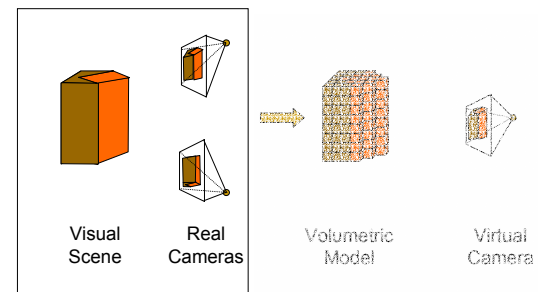


Motivation

- New View Synthesis
 - Render model to produce new views



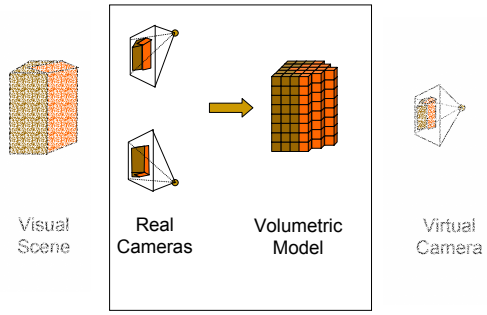
Motivation



Imaging



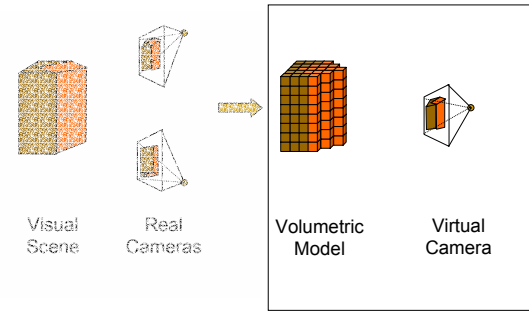
Motivation



Reconstruction



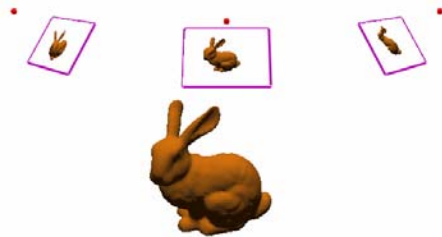
Motivation



New View Synthesis



Visual Hull



Imaging

Visual Hull

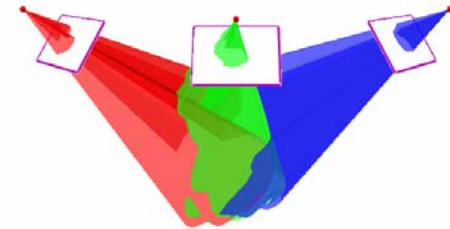


Segmentation

Visual Hull

- Visual hull: 3D shape computed from multiple 2D silhouettes
- Each silhouette constrains the location of the 3D reconstruction

Visual Hull



3D Intersection

Photo Hull

- Use color as additional constraint
 - Goal - compute a 3D model that reproduces photographs
 - Ill-posed problem
- Photo hull [Kutulakos '00]
 - The largest 3D shape consistent with photographs
 - True Scene \subseteq Photo Hull \subseteq Visual Hull
 - Reconstructed via *voxel coloring* or *space carving*
 - Reconstruction approach:
 - Start with a volume that contains surfaces being reconstructed (*reconstruction volume*)
 - Remove (*carve*) inconsistent voxels until convergence

Photo Hull

- Consistency
 1. Does not project to background
 2. When visible, the light exiting point = observed color
 - Lambertian: point projects to same color in all views

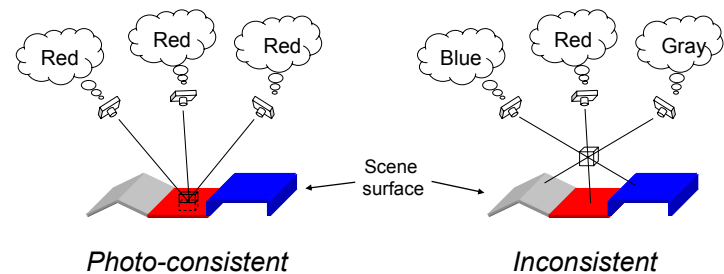
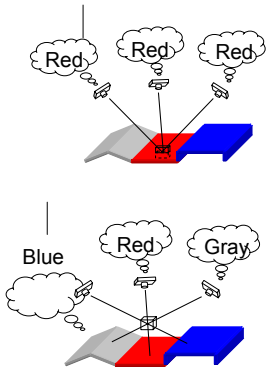


Photo Hull



	R	G	B
Image 1	255	0	0
Image 2	255	0	0
Image 3	255	0	0
Mean	255	0	0
Std Dev	0	0	0

$$\sigma = \sqrt{0^2 + 0^2 + 0^2} = 0 < T$$

consistent

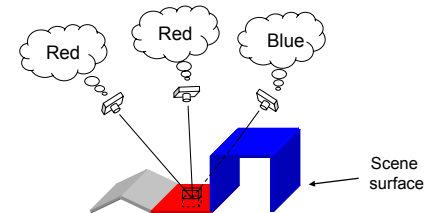
	R	G	B
Image 1	0	0	255
Image 2	255	0	0
Image 3	180	180	180
Mean	145	60	145
Std Dev	131	104	131

$$\sigma = \sqrt{(131)^2 + (104)^2 + (131)^2} = 212 > T$$

inconsistent

Photo Hull

■ Visibility



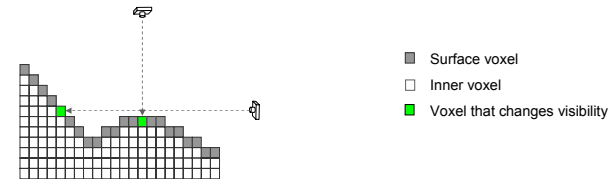
- Need to know which cameras can see a voxel
- Subtle aspect of this class of algorithms – variations

Generalized Voxel Coloring

- GVC is a space carving algorithm that uses generalized visibility computations



Generalized Voxel Coloring



- Voxels that change visibility
 - Must be re-evaluated for consistency
 1. Nearby inner voxels – become surface voxels
 2. Possibly faraway surface voxels

Generalized Voxel Coloring

Broccoli data set

- 17 reference views
- 576 x 436 resolution



Reconstruction

- 168 x 136 x 184 resolution
- GVC-IB: 1:22, 45.5 MB
- GVC-LDI: 0:39, 178 MB



12/5/2003

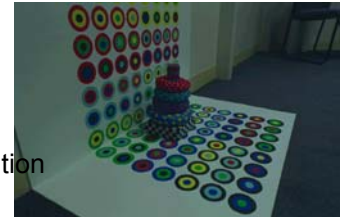
ECE 6258 Russell M. Mersereau

17

Generalized Voxel Coloring

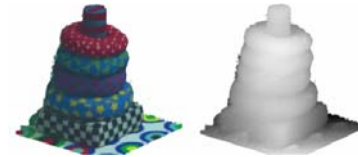
Tower data set

- 36 reference views
- 1536 x 1024 resolution



Reconstruction

- 141 x 141 x 176 resolution
- GVC-IB: 2:19, 472 MB
- GVC-LDI: 1:04, 725 MB



12/5/2003

ECE 6258 Russell M. Mersereau

18

Generalized Voxel Coloring

Ghirardelli data set

- 17 reference views
- 1152 x 872 resolution



Reconstruction

- 168 x 104 x 256 resolution
- GVC-IB: 1:28, 157.2 MB
- GVC-LDI: 0:37, 285 MB



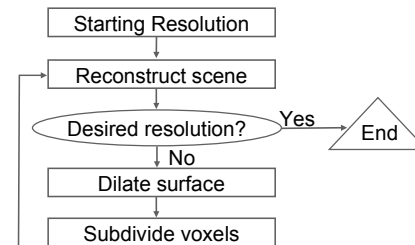
12/5/2003

ECE 6258 Russell M. Mersereau

19

Generalized Voxel Coloring

Multi-resolution [Prock '98]



1.5x for Broccoli
1.9x for Ghirardelli

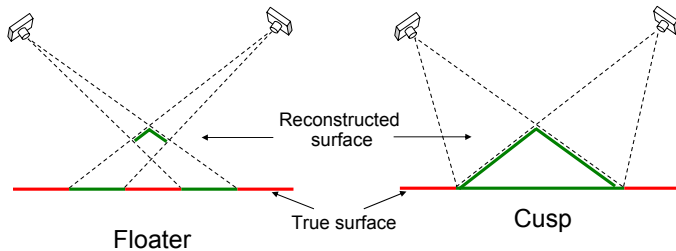
12/5/2003

ECE 6258 Russell M. Mersereau

20

Post-Processing

- Sources of error in theory:
 - Algorithm finds surface consistent with photos, but not necessarily the true surface: floaters, cusps



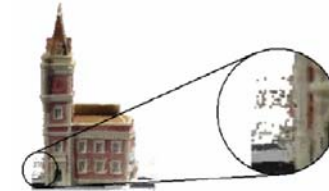
12/5/2003

ECE 6258 Russell M. Mersereau

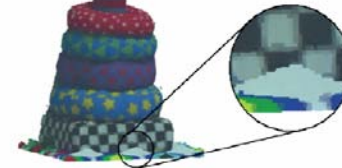
21

Post-Processing

Floaters



Cusp



12/5/2003

ECE 6258 Russell M. Mersereau

22

Post-Processing

- Sources of error in practice
 - Camera calibration errors
 - Geometric
 - Photometric
 - Different cameras – different settings
 - Lighting variations
 - Invalid photo-consistency measures
 - Thresholds
 - Poor photographic sampling
 - Camera placement
 - Image resolution
 - Image quality
 - Insufficient voxel resolution

12/5/2003

ECE 6258 Russell M. Mersereau

23

Post-Processing

- Simple 3D morphological filtering
 - Opening (erosion, dilation) – removes floaters
 - Closing (dilation, erosion) – fills holes
 - Connected components analysis



12/5/2003

ECE 6258 Russell M. Mersereau

24

Post-Processing

- Implicit surface modeling with radial basis functions
 - Fit implicit surface to noisy point cloud data

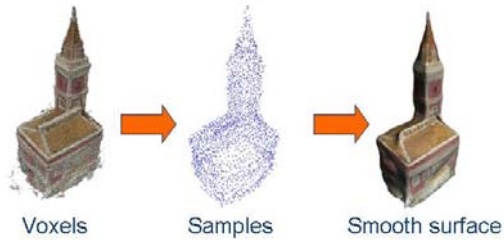


Image-Based Photo Hulls

- Experimental setup:
 - 5 synchronized Firewire video cameras
 - Reconstruction on a dual processor 2 GHz machine (4 GHz total CPU)

