Calibrated Image Acquisition for Multi-view 3D Reconstruction

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Motivation

Given pictures of an object, how can I place the object in a virtual environment?

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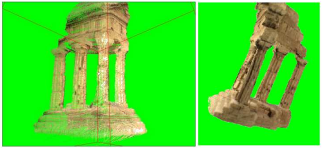

SCATTERPLOT RENDERED

Traditional Graphics

- Render a 3D world on a 2D screen
- The world is authored using modeling tools, by artists

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Going backwards: 2D to 3D

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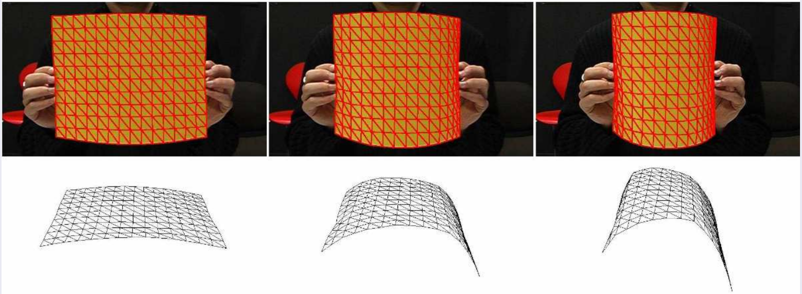
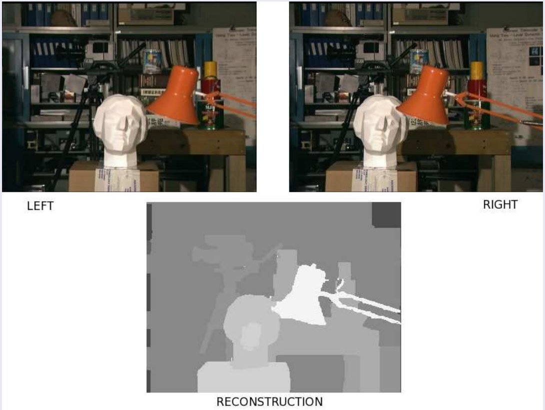
Monocular reconstruction



Salzmann et al. Local deformation models for monocular 3D shape recovery. CVPR 2008

Going backwards: 2D to 3D

Stereo Reconstruction



http://www.cs.washington.edu/homes/indria/project/CSE576finalproject/

Going backwards: 2D to 3D

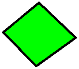
Multi-view Reconstruction

vision.middlebury.edu

Visual Hull

Visual hull is an approximate 3D structure obtained from reconstruction algorithms based on object silhouettes.

- Given a camera, a silhouette defines a back-projected generalized cone that contains the actual object
- Each camera gives us one such generalized cone
- The intersection of these cones is the Visual Hull



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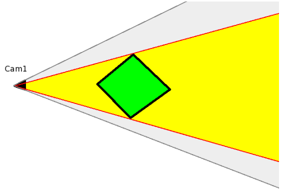

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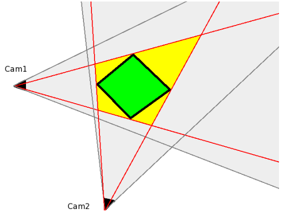

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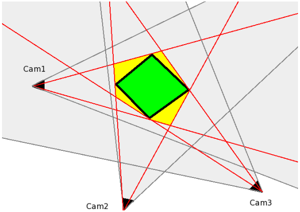

Simulating multiple cameras

- Object is placed on a turntable
- Camera is fixed
- Camera captures frames as the table rotates

Issues in visual hull construction

- Image segmentation: Obtain silhouette information from images
- Camera calibration: Find the camera projection matrix for each camera

Segmentation

Background Subtraction

- Capture object and background images
- If background and object image pixels are similar, mark pixel as background
- Similarity tests performed in RGB and YCbCr color spaces

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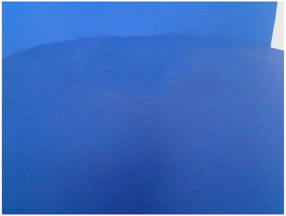
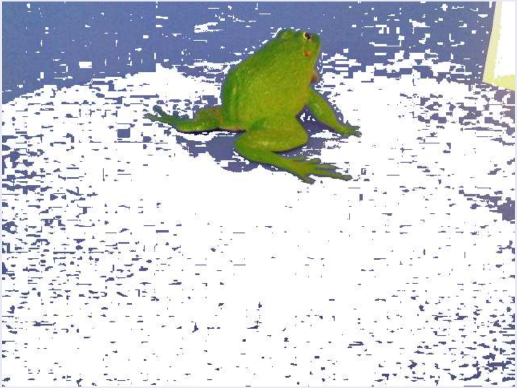
OBJECT



BACKGROUND

Segmentation

Segmented image



What went wrong?

- We are using a webcam
- Camera exposure, white balance, noise, compression artifacts
- What is the correct threshold value? This may vary from image to image

Adaptive thresholding

Can we provide more information to the system?

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Adaptive thresholding

Can we provide more information to the system?

- Ratio of object pixels to total number of pixels remains within certain bounds
- Provide the expected upper bound for this ratio
- Start with a low threshold value
- Increase the threshold till the ratio is below this upper bound

Adaptive thresholding

Segmented image (foreground ratio=0.07)

Camera Calibration

Calibration

Find the projection matrix corresponding to each camera view

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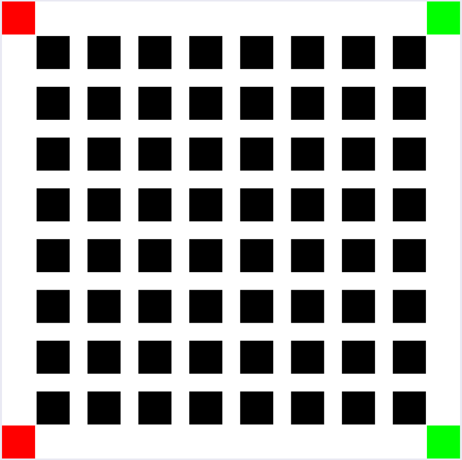
Calibration

Find the projection matrix corresponding to each camera view

- Find a set of 2D to 3D point correspondences
- Use existing tools to compute matrices from these correspondences

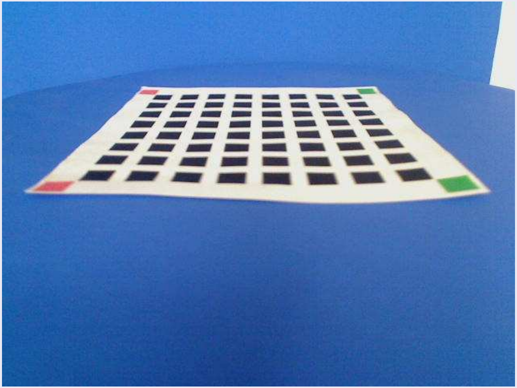
Point Correspondences

Calibration Pattern



Point Correspondences

Calibration Pattern



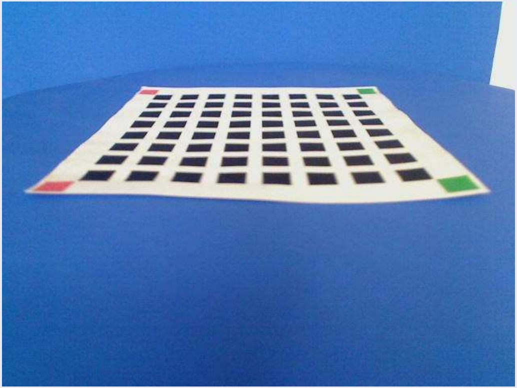
Point Correspondences

- Feature to find: Centers of black squares
- Centers are easier to find and more robust against errors

- Fix an absolute ordering of boxes
- Use colored boxes to find orientation
- Thresholding to locate the boxes
- Find centers of these boxes

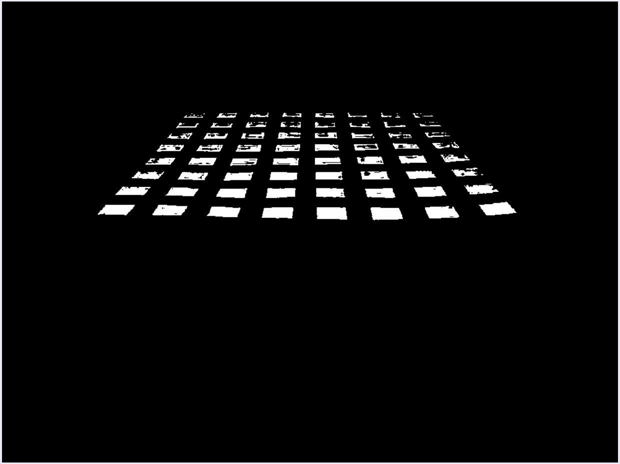
Example

Calibration Pattern



Example

Black threshold, first pass



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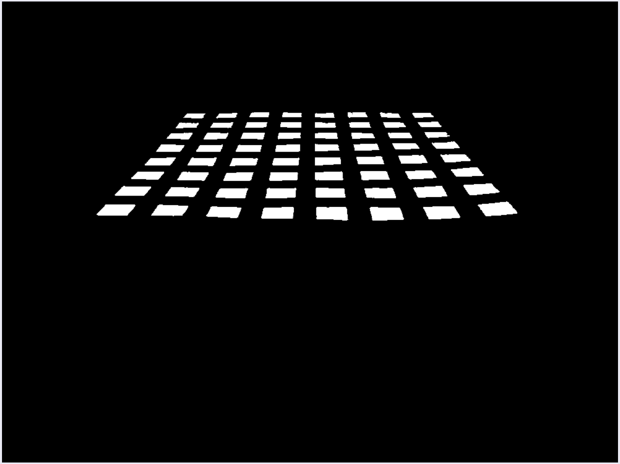
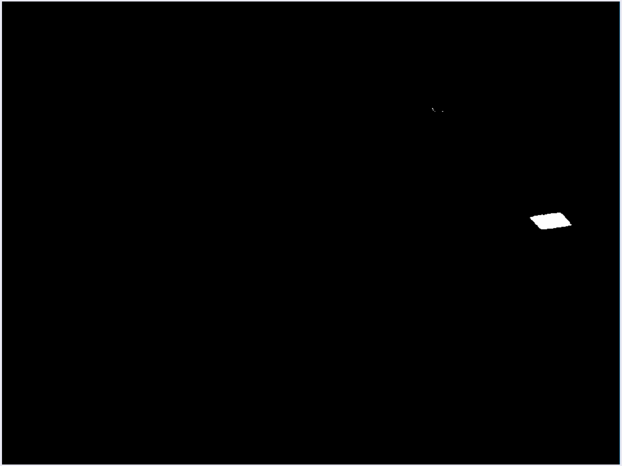


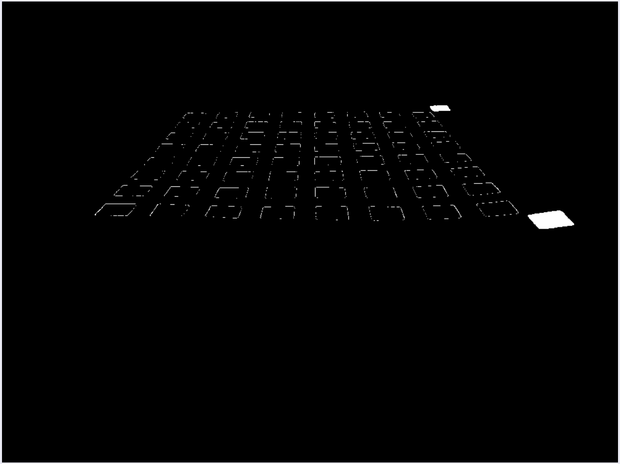
Example

Green threshold, first pass



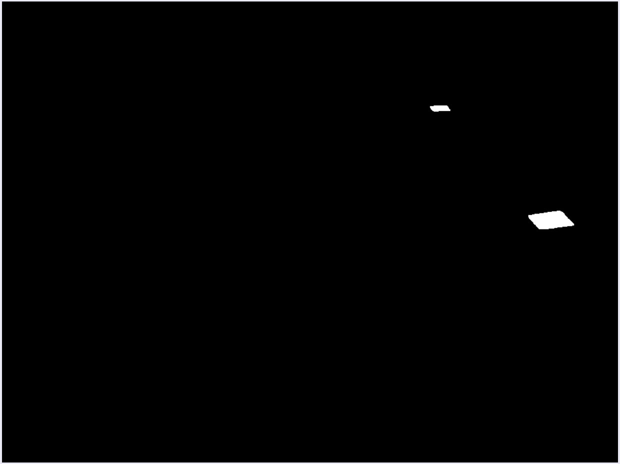
Example

Green threshold, second pass



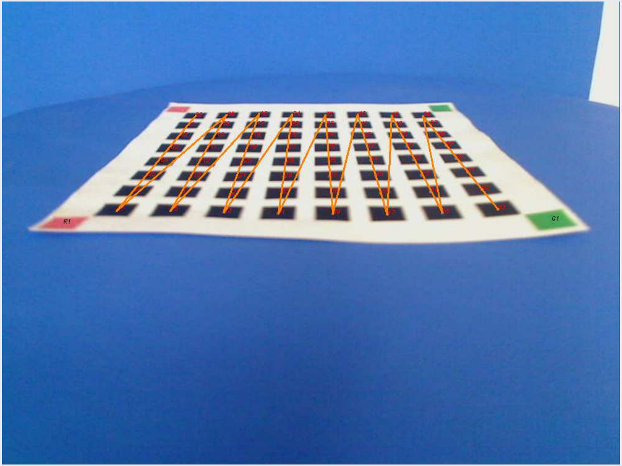
Example

Green threshold, final pass



Example

Labeled calibration pattern



Camera Calibration

- In some cases, the algorithm may explicitly fail(vision is uncertain)
- Discard such views automatically

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- In some cases, the algorithm may explicitly fail(vision is uncertain)
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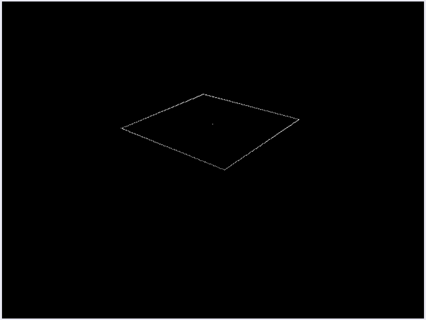
- In some cases, the algorithm may fail silently (returns an incorrect, but mathematically valid matrix)
- Cannot automatically discard such views, although tools can be written to help find bad views

Camera Calibration

Visualizing a camera matrix

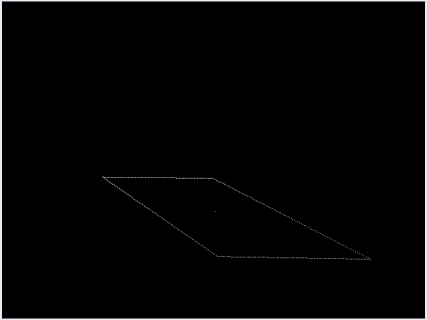
$$\begin{pmatrix} 216.201 & 634.052 & -44.0839 & 3922.02 \\ 36.6629 & -52.2481 & 394.727 & 3119.24 \\ -0.69624 & 0.685745 & -0.212142 & 12.13 \end{pmatrix}$$



Camera Calibration

Visualizing a camera matrix

$$\begin{pmatrix} 591.256 & -313.573 & -52.8837 & 3893.9 \\ -5.06723 & -59.6318 & -395.35 & 3148.67 \\ -0.0399772 & 0.974564 & -0.220515 & 11.9781 \end{pmatrix}$$

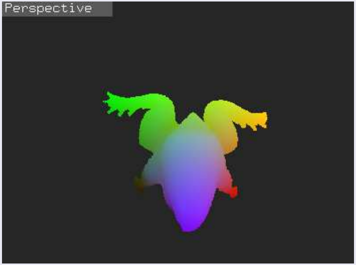


Results

Actual object

Results

Reconstruction



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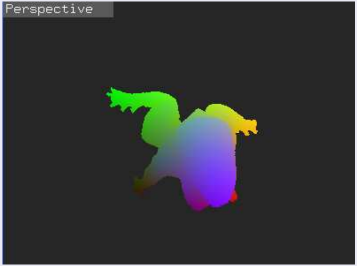

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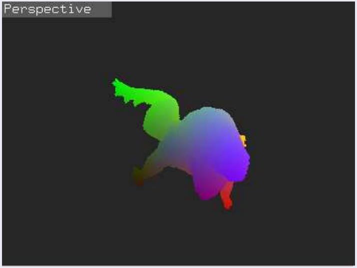

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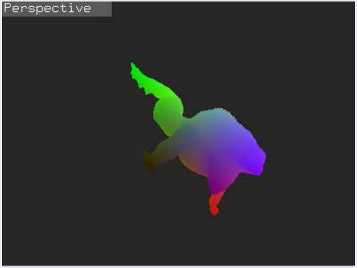
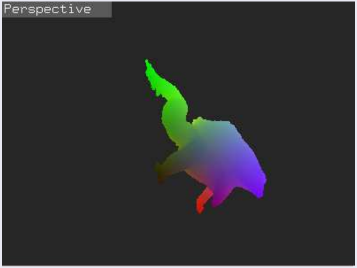


Results

Reconstruction



Results

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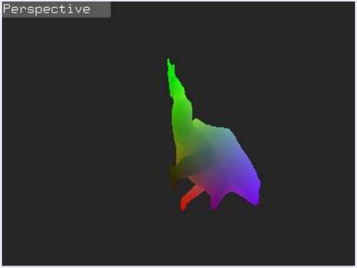

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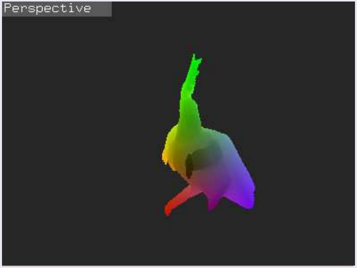

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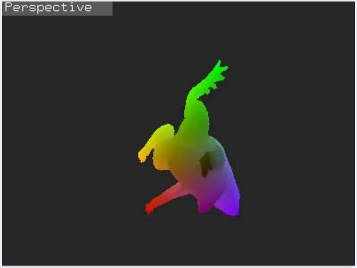

Future Work

1. Better calibration using optimization techniques
2. Textured rendering of visual hull
3. Image based Relighting support

References

1. OpenCV camera control and calibration: opencv.willowgarage.com/
2. Image based Animation: http://www.cse.iitb.ac.in/biswarup/projects/Motion/