Introducción a la Fotografía 3D
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Clase 7: Miercoles Abril 10

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Course Schedule

- Structured Lighting
- Robust Pixel Classification
- Projector Calibration / Structured Light Reconstruction
- Projector Calibration / Structured Light Reconstruction
- Surface Reconstruction from Point Clouds
- Elementary Mesh Processing
**Summary of Camera Calibration**

Camera Calibration Procedure

- Use the *Camera Calibration Toolbox for Matlab* or *OpenCV*

<table>
<thead>
<tr>
<th>Normalized Ray</th>
<th>Distorted Ray (4th-order radial + tangential)</th>
<th>Predicted Image-plane Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x'_n = \begin{bmatrix} X_n/Z_n \ Y_n/Z_n \end{bmatrix} )</td>
<td>( x_4 = \begin{bmatrix} x_n(0) \ x_n(2) \end{bmatrix} ) ( \left( 1 + k_1 r^2 + k_2 r^4 + k_3 r^6 \right) x_n + \alpha x )</td>
<td>( x_4 = fc(0) + \alpha x_c x_4(2) + cc(1) )</td>
</tr>
<tr>
<td>( dx = \frac{2 k_3 x y + k_4 (r^2 + 2x^2)}{k_0 (r^2 + 2y^2) + 2 k_4 x y} )</td>
<td>( y_4 = fc(2) x_4 + cc(2) )</td>
<td></td>
</tr>
</tbody>
</table>

**Demo: Camera Calibration in OpenCV**

Calibration parameters:
- Intrinsic parameters:
  - 1311.368
  - 0.951 0.007 0.976
  - 0.006 1.015 1.001
  - 0.006 0.006
- Distortion coefficients:
  - 0.085 0.085 0.004 -0.005 0.000
Calibration Procedure

- Consider projector an inverse camera (maps intensities to 3D rays)

- Identify printed fiducials in each image
Calibration Procedure

- Consider projector an inverse camera (maps intensities to 3D rays)
- Identify printed fiducials in each image
- Use fiducials to find 3D calibration plane

Projector Calibration

- Project checkerboard on calibration board
Calibration Procedure
- Consider projector an inverse camera (maps intensities to 3D rays)
- Identify printed fiducials in each image
- Use fiducials to find 3D calibration plane
- Project checkerboard on calibration board
- Find ray-plane intersection for each corner
Projector Calibration

Calibration Procedure
- Consider projector an inverse camera (maps intensities to 3D rays)
- Identify printed fiducials in each image
- Use fiducials to find 3D calibration plane
- Project checkerboard on calibration board
- Find ray-plane intersection for each corner
- Use 2D→3D correspondences to estimate intrinsic/extrinsic projector calibration (and radial distortion model)

Projector-Camera Calibration Results
- Implemented complete toolbox for projector-camera calibration (available for Matlab and OpenCV)
- Sufficient accuracy for structured lighting applications
- Software and documentation available on the course website
Demo: Projector Calibration in OpenCV

Structured Lighting Reconstruction Results
Additional Reconstruction Examples

Demo: Putting it All Together
Chapter 5
Structured Lighting

In this chapter we describe how to build a structured light scanner using one or more digital cameras and a single projector. While the “desktop scanner” [EIT] implemented in the previous chapter is inexpensive, it has limited practical utility. The scanning process requires manual manipulation of the stick, and the time required to sweep the shadow plane across the scene limits the system to reconstructing static objects. Manual translation can be eliminated by using a digital projector to sequentially display patterns (e.g., a single stripe translated over time). Furthermore, various structured light illumination sequences, consisting of a series of projected images, can be used to efficiently solve for the camera pixel to projector column (or row) correspondences.

By implementing your own structured light scanner, you will directly extend the algorithms and software developed for the swept-plane systems in the previous chapter. Reconstruction will again be accomplished using ray-plane triangulation. The key difference is that correspondences will now be established by decoding structured light sequences. At the time of writing, the software accompanying this chapter was developed in MATLAB. We encourage the reader to download that version, as well as any updates, from the course website at http://mesh.brown.edu/glamous/scan3d.

5.1 Data Capture
5.1.1 Scanner Hardware
As shown in Figure 5.1, the scanning apparatus contains one or more digital cameras and a single digital projector. As with the swept-plane systems,