Camera Calibration Using Rectangular Textures

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Introduction

- Camera Calibration
- Problem Specification
- Rectangular Textures
- Algorithm: Compute Initial Matrix
- Iterative algorithm to sort calibration points
- Results
- Conclusion
Camera Calibration

- Position, orientation, focal length, lens distortion
- Camera parameters are used to compute world from image coordinates and vice versa
- Popular area of computer vision
- Pinhole Camera Model: Homogeneous Coordinates

\[
\begin{bmatrix}
    x \\
    y \\
    z \\
    k
\end{bmatrix} =
\begin{bmatrix}
    a_{11} & a_{12} & a_{13} & a_{14} \\
    a_{21} & a_{22} & a_{23} & a_{24} \\
    a_{31} & a_{32} & a_{33} & a_{34} \\
    a_{41} & a_{42} & a_{43} & a_{44}
\end{bmatrix}
\begin{bmatrix}
    X \\
    Y \\
    Z \\
    1
\end{bmatrix}
\]
Problem Statement

Camera calibration of buildings, cities, skyscrapers, ...

Cover a building with a calibration carpet?

Rectangular textures (width and height) occur in a lot of man–made objects

Use these feature points as calibration points
Preprocessing

- Extract feature points using color segmentation
- Noisy input images.
- Detection based on sufficient conditions
- Some of the features are missing
Compute Initial Matrix

- Sort feature points automatically.
- Chicken and Egg problem:
  If we know the orientation and position, we can easily cope with missing features, arbitrary orientations, ...
- Previously: sort by going through the image, maintain guess of distance to next feature. Strong assumptions.
- Compute a guess of the calibration matrix
Position and orientation can be represented as a 3x4 transformation matrix.

Requires a minimum of 5 points (Z=0)

Extract seed points (5 points with minimum distance in the middle of the picture)

Try both orientations (width and height) and choose the one with the best match (smallest error)
Algorithm 1 Algorithm to Assign Real World Coordinates

1: \( S = \text{extractCentres}(Image) \)
2: \( P = \text{selectSeedPoints}(S) \)
3: \( M_{XY} = \text{computeTransformationMatrix}(S, \text{realWorldCoords}(S)) \)
4: \( M_{YX} = \text{computeTransformationMatrix}(S, \text{swapCoord}(\text{realWorldCoords}(S))) \)
5: \textbf{if} \ \text{error}(M_{XY}) < \text{error}(M_{YX}) \ \textbf{then}
6: \hskip 1cm \( M_{Initial} = M_{XY} \)
7: \textbf{else}
8: \hskip 1cm \( M_{Initial} = M_{YX} \)
9: \hskip 1cm \text{swapCoordinates}(S) \)
10: \textbf{end if}
11: \( C_S = \text{assignCentres}(S, M_{Initial}) \)
Iterative Part

- Select closest feature points that have not been assigned yet in S
- Assign world coordinates based on coordinates of the assigned neighbors N. Relative assignment
- Add points to the assigned feature points N
- Compute a new transformation matrix M
Assign Real World Coordinates

Algorithm 2 Algorithm to Assign Real World Coordinates($S, M_{Initial}$)

1: $M = M_{Initial}$
2: $N =$
3: while $S \neq do$
4:    for all $s \in S$ do
5:        $s_{North}, s_{East}, s_{South}, s_{West} = \text{findNearestNeighbors}(s, M)$
6:    end for
7:    for all $n \in \{s_{North}, s_{East}, s_{South}, s_{West}\}$ do
8:        $b_x = \text{dist}((s - n)/width, M), b_y = \text{dist}((s - n)/height, M)$
9:        $n_x, n_y = s_x + b_x * width, s_y = b_y * height$
10:       $N = N + n, S = S - n$
11:       $M = \text{computeTransformationMatrix}(N, \text{realWorldCoords}(S))$
12:    end for
13: end while
14: return $N$
Tsai Calibration

- Roger Tsai developed a practical method for camera calibration (Radial Alignment Constraint)
- Gaussian Lens Model
- Compute 6 external and 5 internal parameters. Distortion parameters (k1, k2).
- Requires around 15 calibration points
- Calibration point: Image point (2D) and matching world coordinate (3D)
Conclusion

- Method for assigning real world coordinates to features in an image
- Assume a rectangular texture. Constant width and height
- Iterative algorithm to compute position, orientation, and focal length
- Cope with missing feature points
- Arbitrary position and orientation
Future Work

- Tsai calibration can not adjust the Sx parameter (Horizontal uncertainty factor) given only co-planar calibration points
- Poor generalisation to 3D objects
- Batista [2000] proposes a calibration method for co-planar calibration data
- More complex tectures