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Camera Calibration

What is Camera Calibration?

- Finding quantities internal to the camera that affect the imaging process
  - Position of image center in the image (where optical axis meets image plane)
  - Focal length (Distance from camera to image plane)
  - Different scaling factors for row/column pixels
  - Skew factor
  - Lens distortion (pin-cushion effect)

Techniques

- Roger Tsai
- Linear algebra method
  - Can be used as initialization for iterative non linear methods
- Methods using vanishing points

Procedure

- Calibration target: 2 planes at right angle with checkerboard pattern (Tsai grid)
- *Incomplete*

Image Processing of Image of Target

- Canny Edge detection
- Straight line fitting
- Intersection of lines to obtain corners
- Matching image corners and 3D target checkerboard corners
  - Counting if whole target is visible in image

- Get pairs of image points and world points $(x_i, y_i) \rightarrow (X_i, Y_i, Z_i)$

Central Projection

- If world and image points are represented by homogeneous vectors, central projection is a linear transformation

$$x_i = \frac{u}{w}, y_i = \frac{v}{w}$$

$$\begin{bmatrix} u \\ v \\ w \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} u' \\ v' \\ w' \end{bmatrix} = \begin{bmatrix} \alpha_x & 0 & x_0 & 0 \\ 0 & \alpha_y & y_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_s \\ y_s \\ z_s \end{bmatrix}$$

$$\alpha_x = fk_x, \alpha_y = fk_y, x_i = f\frac{x_s}{z_s}, y_i = f\frac{y_s}{z_s}$$

$$\text{image center} \implies (x_0, y_0)$$
$$\text{scaling factors} \implies k_x, k_y$$

- α is the focal length in pixels in each direction
- s is skew parameter
- K is the *calibration matrix* $\implies$ 5 degrees of freedom
  - 3x3 upper triangular matrix

$$K = \begin{bmatrix} \alpha_x & s & x_0 \\ 0 & \alpha_y & y_0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$K[I_3|0_3] = \begin{bmatrix} \alpha_x & 0 & x_0 & 0 \\ 0 & \alpha_y & y_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$