CE 503 Image Measurement + Coordinate Refinement
13 Sept 2005

1. get calibrated fiducial coordinates from the calibration report, assume we have 4 fiducial marks. $(x_{c_1}, y_{c_1}, x_{c_2}, y_{c_2}, x_{c_3}, y_{c_3}, x_{c_4}, y_{c_4})$

2. configure image viewer application (for example photoshop) to display image coordinates in <u>pixel</u> units, be careful about labeling of line, sample or row, column coordinates.

3. observe the 4 fiducial marks and all data points, then using only the fiducial measurements, solve by least squares for the 6 parameters of the coordinate transformation:

$$\begin{bmatrix} l_1 \\ s_1 \\ l_2 \\ s_2 \\ l_3 \\ s_3 \\ l_4 \\ s_4 \end{bmatrix} + \begin{bmatrix} v_{l_1} \\ v_{s_1} \\ v_{l_2} \\ v_{s_2} \\ v_{l_3} \\ v_{s_3} \\ v_{l_4} \\ v_{s_4} \end{bmatrix} = \begin{bmatrix} 1 & x_{c_1} & y_{c_1} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x_{c_1} & y_{c_1} \\ 1 & x_{c_2} & y_{c_2} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x_{c_2} & y_{c_2} \\ 1 & x_{c_3} & y_{c_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x_{c_3} & y_{c_3} \\ 1 & x_{c_4} & y_{c_4} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & x_{c_4} & y_{c_4} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ b_0 \\ b_1 \\ b_2 \end{bmatrix}, \quad l + v = Ax$$

$x = (A^T A)^{-1} A^T l$, $v = Ax - l$, units of l and v are pixels

inspect v for quality assurance

4. if v's are ok (= expected magnitudes) then invert the transformation

$$\begin{aligned} l &= a_0 + a_1 x_c + a_2 y_c \\ s &= b_0 + b_1 x_c + b_2 y_c \end{aligned}, \quad \begin{pmatrix} l \\ s \end{pmatrix} = \begin{pmatrix} a_1 & a_2 \\ b_1 & b_2 \end{pmatrix} \begin{pmatrix} x_c \\ y_c \end{pmatrix} + \begin{pmatrix} a_0 \\ b_0 \end{pmatrix}$$

$$l = M x + t$$

$$x = M^{-1}(l - t)$$

5. use that inverse transformation to transform all data points from raw pixel measurements into the fiducial coordinate system.

6. obtain x_p, y_p (offsets to principal point of symmetry) from the calibration report

7. $\bar{x} = x - x_p$

$\bar{y} = y - y_p$

8. $r = \sqrt{(\bar{x})^2 + (\bar{y})^2}$

9. obtain K_0, K_1, K_2, K_3 for radial lens distortion, and P_1, P_2, P_3, P_4 for decentering distortion from the camera calibration report. Also find the calibrated focal length, f.

10. compute radial lens distortion correction

$$dx_r = \bar{x}(K_0 + K_1 r^2 + K_2 r^4 + K_3 r^6)$$

$$dy_r = \bar{y}(K_0 + K_1 r^2 + K_2 r^4 + K_3 r^6)$$

11. compute decentering lens distortion correction

$$dx_d = (1 + P_3 r^2 + P_4 r^4)(P_1(r^2 + 2\bar{x}^2) + 2P_2 \bar{x}\bar{y})$$

$$dy_d = (1 + P_3 r^2 + P_4 r^4)(P_2(r^2 + 2\bar{y}^2) + 2P_1 \bar{x}\bar{y})$$

12. get mean terrain height (above sea level) in <u>km</u> $\rightarrow h$

get flying height (above sea level) in <u>km</u> $\rightarrow H$

compute

$$K = \left[\frac{2410\,H}{H^2 - 6H + 250} - \frac{2410\,h}{h^2 - 6h + 250}\left(\frac{h}{H}\right)\right] \times 10^{-6}$$

$$dr = K\left(r + \frac{r^3}{f^2}\right)$$

$$dx_{ref} = \bar{x} \cdot dr/r$$

$$dy_{ref} = \bar{y} \cdot dr/r$$

13. compute refined image coordinates

$$x_{refined} = \bar{x} - dx_r - dx_d - dx_{ref}$$

$$y_{refined} = \bar{y} - dy_r - dy_d - dy_{ref}$$