Fig1. Before calibrating
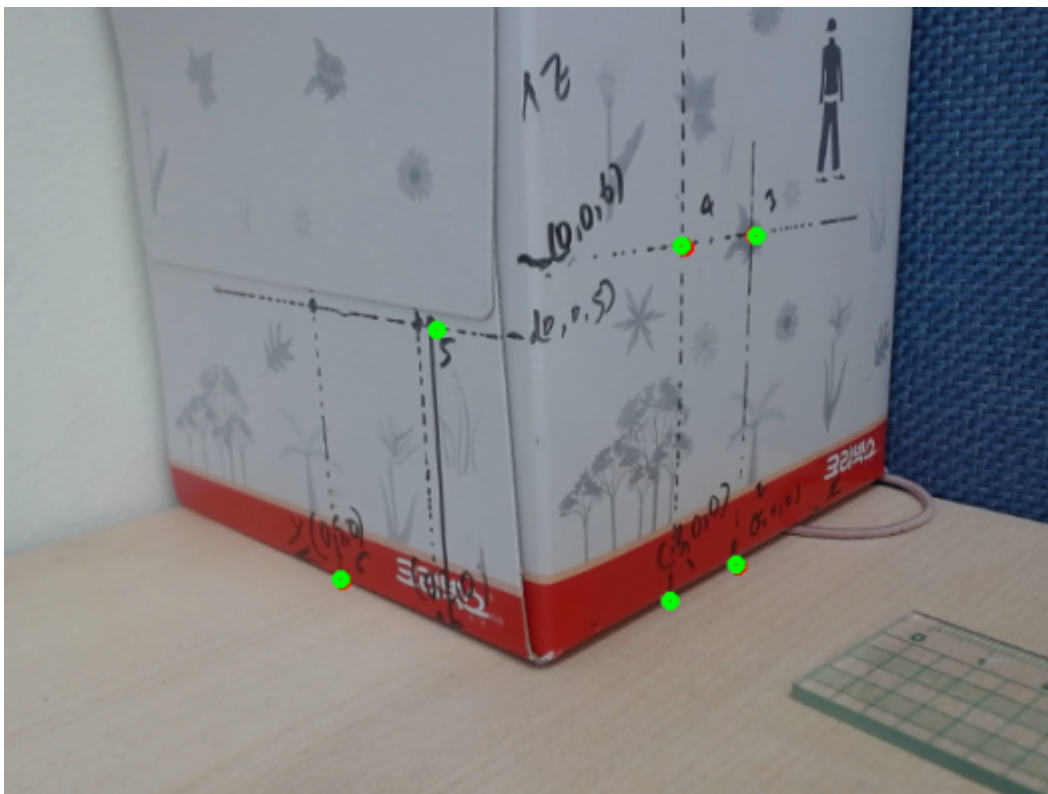

Fig2. After Calibrating, Reproject points

1. 3d points 의 위치 = $(3,0,0), (5,0,0), (5,0,6), (3,0,4), (0,2,5), (0,5,0)$

   2d points의 위치 = $(402,324), (434,300), (451,113), (414,124), (270,172), (208,315)$

2. find homography matrix

$$
\begin{bmatrix}
3,0,0,1, & 0, & 0,0,0, & -1206, & 0, & 0 \\
0,0,0,0, & 3,0,0,0, & 1, & -972, & 0, & 0 \\
5,0,0,1, & 0,0,0,0, & -2170, & 0, & 0 \\
0,0,0,0, & 5,0,0,1, & -1500, & 0, & 0 \\
5,0,6,1, & 0,0,0,0, & -2255, & 0, & -2706 \\
0,0,0,0, & 5,0,6,1, & -565, & 0, & -678 \\
3,0,4,1, & 0,0,0,0, & -1242, & 0, & -1656 \\
0,0,0,0, & 3,0,4,1, & -372, & 0, & -496 \\
0,2,5,1, & 0,0,0,0, & 0, & -540, & -1350 \\
0,0,0,0, & 0,2,5,1, & 0, & -344, & -860 \\
0,5,0,1, & 0,0,0,0, & 0, & -1040, & 0 \\
0,0,0,0, & 0,5,0,1, & 0, & -1515, & 0
\end{bmatrix}
\begin{bmatrix}
h_1 \\ h_2 \\ h_3 \\ h_4 \\ h_5 \\ h_6 \\ h_7 \\ h_8 \\ h_9 \\ h_{10} \\ h_{11}
\end{bmatrix}
=
\begin{bmatrix}
402 \\ 324 \\ 434 \\ 300 \\ 451 \\ 113 \\ 414 \\ 124 \\ 270 \\ 172 \\ 208 \\ 315
\end{bmatrix}
$$

$\therefore$ h mat $= \begin{bmatrix} -79.61 & -173.09 & -43.35 & 381.38 \\ -20.21 & -59.27 & -36.32 & 308.72 \\ -0.668 & -0.1862 & -0.1089 & 1 \end{bmatrix}$

3. find R & t

   (i) $t_3 = \dfrac{1}{\sqrt{h_{31}^2 + h_{32}^2 + h_{33}^2}} = 4.42$

   (ii) $\vec{R_3} = t_3 (h_{31}\ h_{32}\ h_{33}) = (-0.3001, -0.8233, -0.4817)$

   (iii) $u_0 = t_3^2 R_3^T (h_{11}\ h_{12}\ h_{13}) = 384.4$

   (iv) $V_0 = t_3^2 R_3^T (h_{21}\ h_{22}\ h_{23}) = 312.6$

   (v) $f_x = \| t_3 (h_{11}\ h_{12}\ h_{13}) - u_0 \vec{R_3} \| = 30.134$

   (vi) $f_y = \| t_3 (h_{21}\ h_{22}\ h_{23}) - V_0 \vec{R_3} \| = 11.173$

   (vii) $\vec{R_1} = \dfrac{t_3}{f_x} (h_{11}\ h_{12}\ h_{13}) - \dfrac{u_0}{f_x} \vec{R_3} = [0.9513\ \ -0.2214\ \ -0.2143]$

   (ix) $\vec{R_2} = \dfrac{t_3}{f_y} (h_{21}\ h_{22}\ h_{23}) - \dfrac{V_0}{f_x} \vec{R_3} = [0.3847\ \ \ 0.3778\ \ -0.8510]$

(X) $t_x = \dfrac{t_z}{f_x} (h_{14} - u_0) = -0.4482$

(XI) $t_y = \dfrac{t_z}{f_y} (h_{24} - v_0) = -1.485$

4. reproject points

$$S_i \begin{bmatrix} u_i \\ v_i \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{32} & 1 \end{bmatrix} \begin{bmatrix} X_i \\ Y_i \\ Z_i \\ 1 \end{bmatrix} \qquad i = 1 \sim 6$$

Calculate u_i, v_i for each i.

$u_1, v_1 = 405, 311$

$u_2, v_2 = 428, 314$

$u_3, v_3 = 451, 113$

$u_4 v_4 = 437, 211$

$u_5 v_5 = 222, 151$

$u_6 v_6 = 230, 324$

[Logitech C922 Pro Stream Webcam 960-001088](#)

The camera you see now is the one I used for my assignment. This camera has very little distortion, so it seems to have shown good reproduction results as above Fig2. But if you use a camera with a lot of distortion, I don't think you'll see such a good result. For example, if you use the fisheye camera, the given formula does not take distortion into account, so there will be inappropriate results.