TE1 $P_1 = [I\ 0]$ $\quad P_2 = \begin{bmatrix} 1 & 1 & 0 & 2 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 0 \end{bmatrix}$

$F = [e^2]_\times P_2\, inv(P_1)$ $\quad\quad inv(P_1) = \begin{bmatrix} I \\ 0 \end{bmatrix}$

$e^2 = P_2 \times \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 2 \\ 0 \end{bmatrix}$ $\quad\quad [e^2]_x = \begin{bmatrix} 0 & 0 & 2 \\ 0 & 0 & -2 \\ -2 & 2 & 0 \end{bmatrix}$

$F = \begin{bmatrix} 0 & 0 & 2 \\ 0 & 0 & -2 \\ -2 & 0 & 0 \end{bmatrix}$

$l = Fx_1 = F \begin{bmatrix} 0 \\ 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ -2 \\ 0 \end{bmatrix}$

To check if x_1 and x_2 are the same pt

$x_2^T F x_1 = 0$

when $x_2^T = [1, 0, 1]$ then $x_2^T F x_1 = 2$

" $x_2^T = [3, 2, 1]$ " " $= 2$

" $x_2^T = [1, 1, 1]$ " " $= 0$

Thus $(1,1)$ could be the projection of x_1 in P_2.

TE2 $P_1 = [I\ 0$

$P = [R|t]$ $\quad C =$

$C_2 = inv(R_2)\, t_2$

$e_1 = P_1 C_2 = P$

$e_2 = P_2 C_1 =$

$F = [e_2]_\times P_2$

$[e_2]_\times = \begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix}$

$F = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 6 & 3 \end{bmatrix}$

$e_2^T F =$

$F e_1 = F$

$$\begin{bmatrix} 1 & 1 & 0 & 2 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

$$inv(P_1) = \begin{bmatrix} I \\ 0 \end{bmatrix}$$

$$[e^2]_x = \begin{bmatrix} 0 & 0 & 2 \\ 0 & 0 & -2 \\ -2 & 2 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 2 \\ -2 \\ 0 \end{bmatrix}$$

2 are the same pt

0 .

$x_2^T F x_1 = 2$

" $= 2$

" $= 0$

projection of x_1 in P_2.

TE2 $\quad P_1 = [I \; 0] \quad P_2 = \begin{bmatrix} 0 & 1 & 1 & 2 \\ 3 & 2 & 0 & 1 \\ 0 & 0 & 3 & 0 \end{bmatrix}$

$P = [R|t] \quad C = inv(R)\, t, \; C_1 = inv(I)[0] = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

$C_2 = inv(R_2)\, t_2 = \begin{bmatrix} -1 \\ 2 \\ 0 \end{bmatrix}$

$e_1 = P_1 C_2 = P_1 \begin{bmatrix} -1 \\ 2 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 \\ 2 \\ 0 \end{bmatrix}$

$e_2 = P_2 C_1 = P_2 \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \\ 0 \end{bmatrix}$

$F = [e_2]_x P_2\, inv(P_1) \qquad inv(P_1) = \begin{bmatrix} I \\ 0 \end{bmatrix}$

$$[e_2]_x = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & -2 \\ -1 & 2 & 0 \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & 0 & 3 \\ 0 & 0 & -6 \\ 6 & 3 & -1 \end{bmatrix}$$

$e_2^T F = [2 \; 1 \; 0] F = [0 \; 0 \; 0]$

$F e_1 = F[-1 \; 2 \; 0]^T = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$

TE4 $F = N_2^T \tilde{F} N_1$

TE5 $e_2^T F = 0$, let $e_2^T = [a \; b \; c]$

$$F = \begin{bmatrix} 0 & 1 & 1 \\ 2 & 0 & 4 \\ 0 & 1 & 1 \end{bmatrix} \qquad P_1 = [I \;\; 0]$$

$$e_2^T F = [2b \quad a+c \quad a+4b+c] = [0, 0 \; 0]$$

$b = 0, \quad a = -c$

$$e^T F = 0 \Rightarrow (e^T F)^T = 0^T$$

$$= F^T e = 0 \Rightarrow e = null(F^T)$$

$$e_2 = [-1 \;\; 0 \;\; 1]^T \qquad [e_2]_x = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}$$

~~R2~~

$$P_2 = [[e_2]_x F \;\; e_2]$$

$$= \begin{bmatrix} -2 & 0 & -4 & -1 \\ 0 & 2 & 2 & 0 \\ -2 & 0 & -4 & 1 \end{bmatrix}$$

$x_2^T F x_1 = (F$

when $X = \begin{bmatrix} 0 \\ 3 \\ 1 \\ 1 \end{bmatrix}$

" $X = \begin{bmatrix} -1 \\ 2 \\ 0 \\ 1 \end{bmatrix}$

$c_2 = inv(R_2)$

$= R_2$ is

thus c_2 is

TE7 $UV^T =$

$det(UV^T) =$

$E = U \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$

$= \begin{bmatrix} \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{}} \end{bmatrix}$

$= [a \ b \ c]$

$[I \ 0]$

$4b+c) = [0, 0 \ 0]$

0^T

$\Rightarrow e = null(F^T)$

$= \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}$

$$x_2^T F x_1 = (P_2 X)^T F (P_1 X)$$

When $X = \begin{bmatrix} 0 \\ 3 \\ 1 \\ 1 \end{bmatrix}$, $(P_2 X)^T F (P_1 X) = 0$

" $X = \begin{bmatrix} -1 \\ 2 \\ 0 \\ 1 \end{bmatrix}$, $(P_2 X)^T F (P_1 X) = 0$

$C2 = inv(R_2) \times t$

$=$ R_2 is not invertible as $\det(R_2) = 0$

thus $C2$ is at infinity.

TE7 $UV^T = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} \\ 0 & 1 & 0 \end{bmatrix}$

$\det(UV^T) = 1$

$$E = U \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} V^T$$

$$= \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} \\ 0 & 0 & 0 \end{bmatrix}$$

$x_2^T E x_1$ should be 0

$[1, -3\ 1]\ E \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix}$ is equal to 0

thus valid points

$x_1 = P_1 X$, $P_1 = [I\ 0]$

if $x = [2\ 0\ 1]$ then X must be $\begin{bmatrix} 2 \\ 0 \\ 1 \\ s \end{bmatrix}$

$P_1 X$ become $[2\ 0\ 1]$

$$P_2 = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ \frac{-1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \text{ or } \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ \frac{-1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix}$$

$$\text{or } \begin{bmatrix} \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \text{ or } \begin{bmatrix} \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix}$$

$P_2 X = \begin{bmatrix} \frac{1}{\sqrt{2}} \\ \frac{-3}{\sqrt{2}} \\ s \end{bmatrix}$

Thus

$s = \frac{1}{\sqrt{2}}$

X is

s

Thus the

[uw

be 0

equal to 0

0]

] then x

]

1]

$$\begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ \frac{-1}{\sqrt{2}} & 0 & \frac{-1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix}$$

$$\begin{bmatrix} \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} & 0 \\ 0 & 1 & 0 & -1 \end{bmatrix}$$

$$P_2 X = \begin{bmatrix} \frac{1}{\sqrt{2}} \\ \frac{-3}{\sqrt{2}} \\ s \end{bmatrix} \text{ or } \begin{bmatrix} \frac{1}{\sqrt{2}} \\ \frac{-3}{\sqrt{2}} \\ -s \end{bmatrix} \text{ or } \begin{bmatrix} \frac{-1}{\sqrt{2}} \\ \frac{3}{\sqrt{2}} \\ s \end{bmatrix} \text{ or } \begin{bmatrix} \frac{-1}{\sqrt{2}} \\ \frac{3}{\sqrt{2}} \\ -s \end{bmatrix}$$

Thus

$$s = \frac{1}{\sqrt{2}} \text{ or } \frac{-1}{\sqrt{2}} \text{ or } \frac{-1}{\sqrt{2}} \text{ or } \frac{1}{\sqrt{2}}$$

X is in front of P_2 when s is +ve (positive)

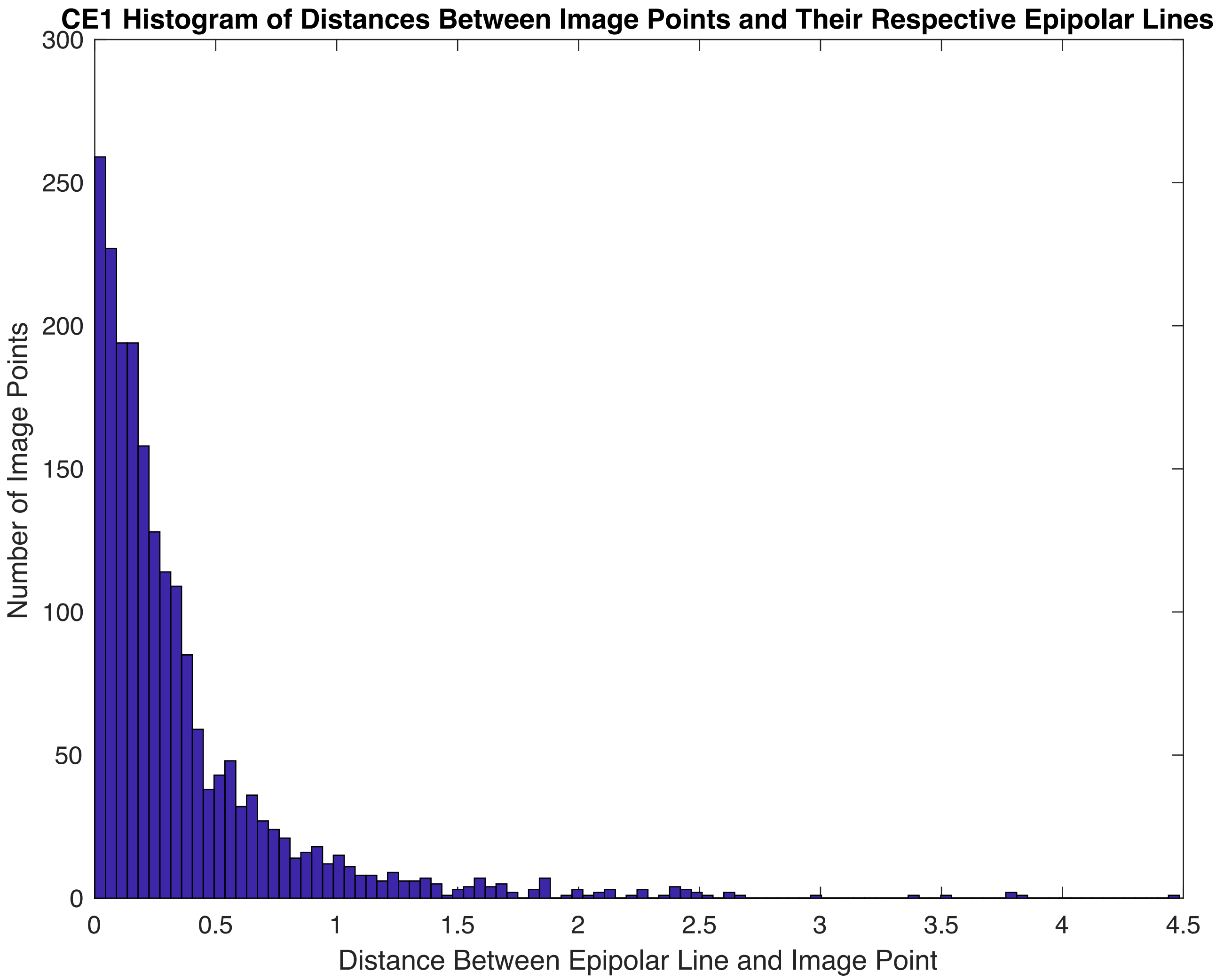
Thus the choices are

$$[UWV^T \; u_3] \text{ and } [UW^TV^T \; -u_3]$$

Part I - Normalized points

CE1 Image points and epipolar lines

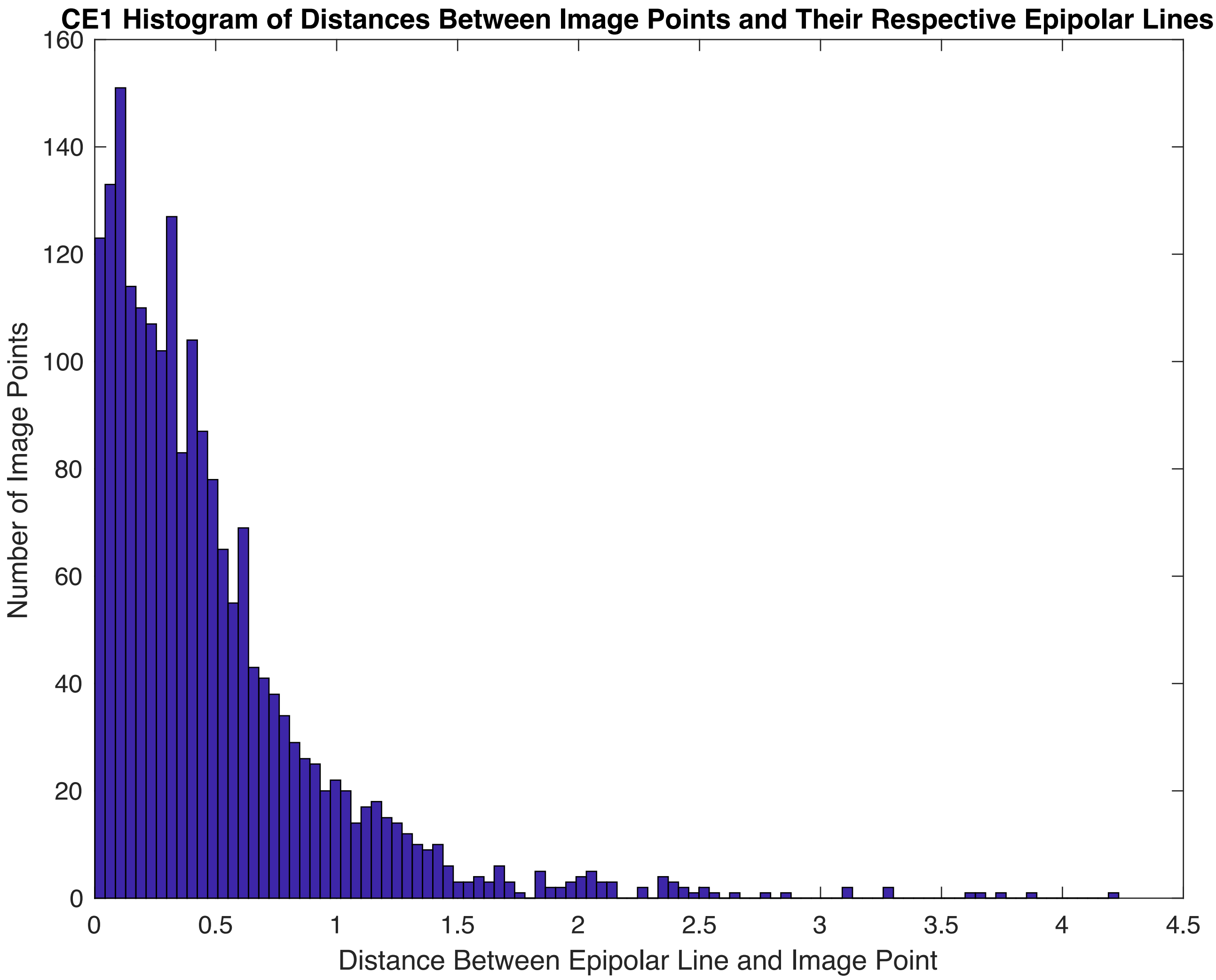
Part I - Normalized points
Mean distance = 0.36123



Part II - Unnormalized points

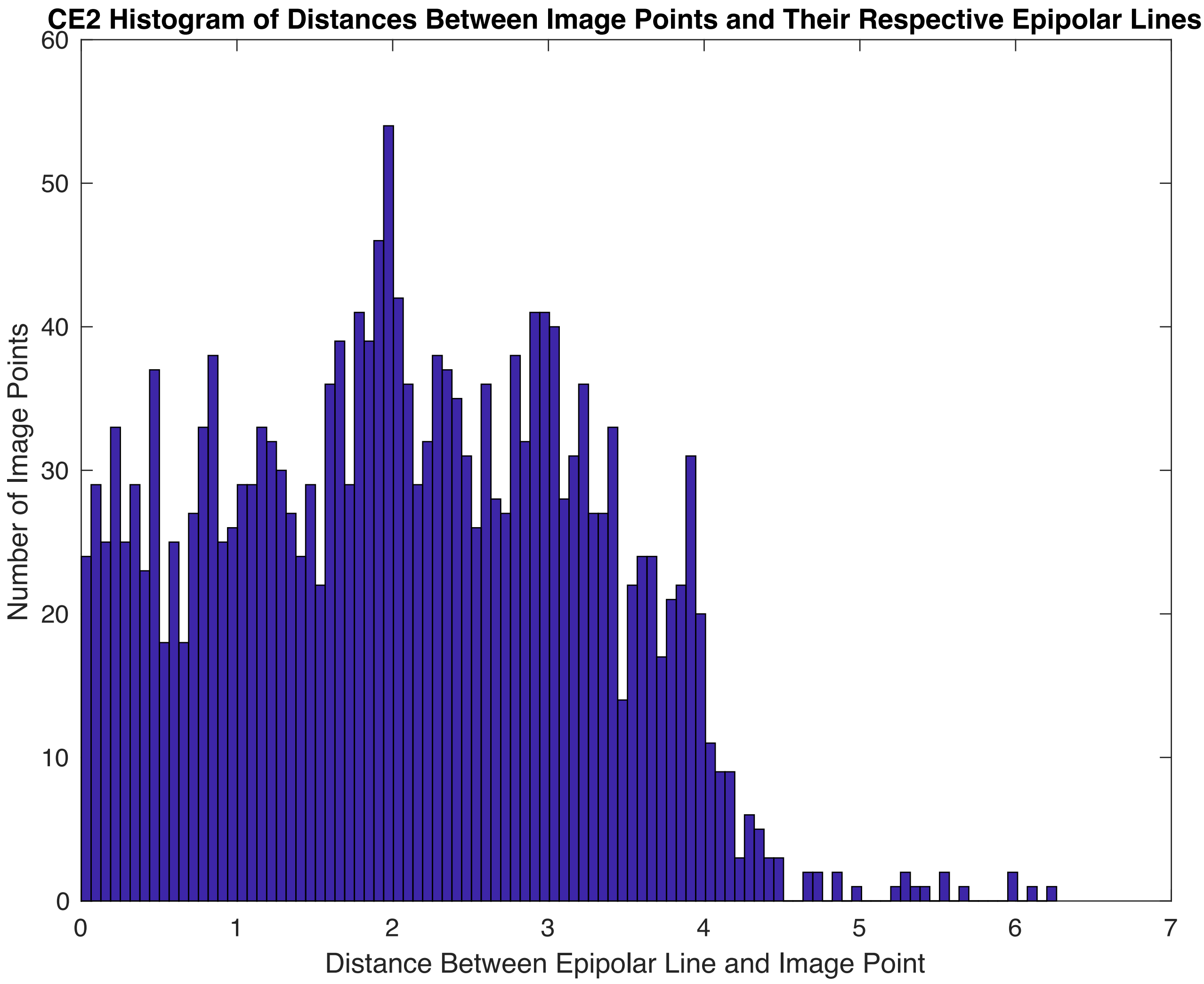
CE1 Image points and epipolar lines

Part II - Unnormalized points
Mean distance = 0.48784

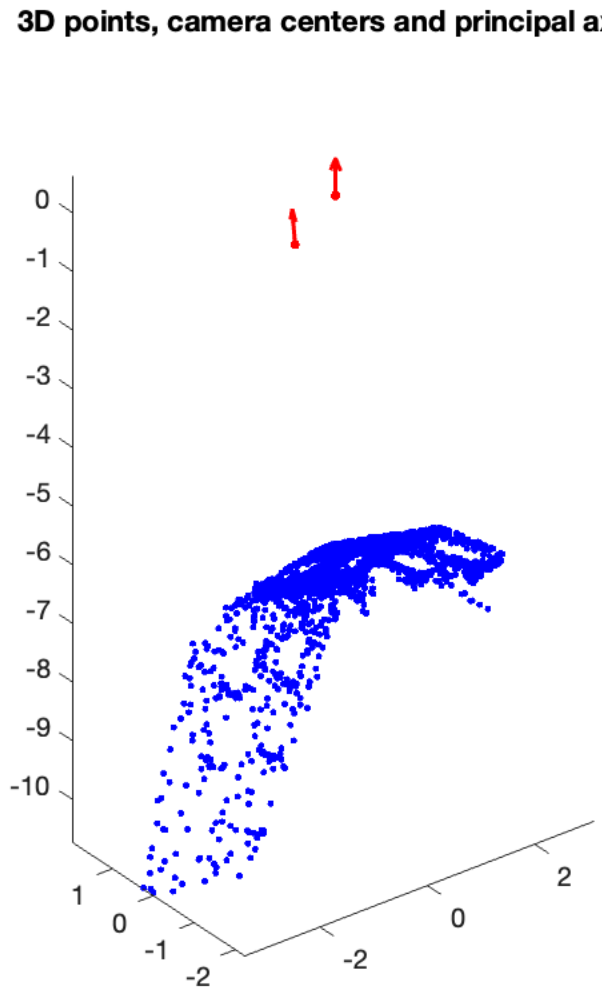


CE2 Image points and epipolar lines

Mean distance = 2.0838
The result in CE2 is much worser than in CE1 as we can see from the histogram and the mean distance.

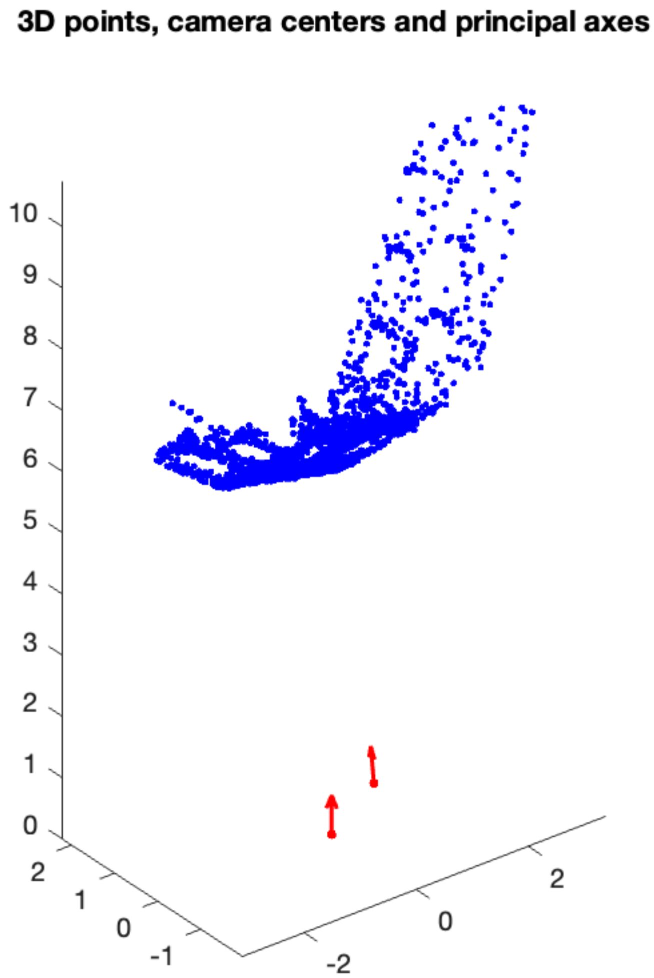


P2{1}=[U*W*V',U(:,3)];


3D points, camera centers and principal axes
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1
0
-1
-2
-2
0
2

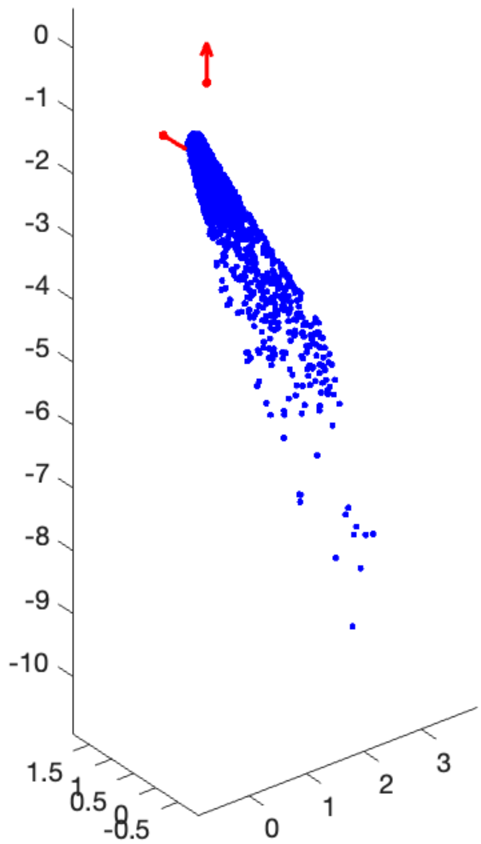
P2{2}=[U*W*V',-U(:,3)];

P2{2} is chosen as it's clearly visible that it has the best 3D projection and the points are clearly in front of the camera

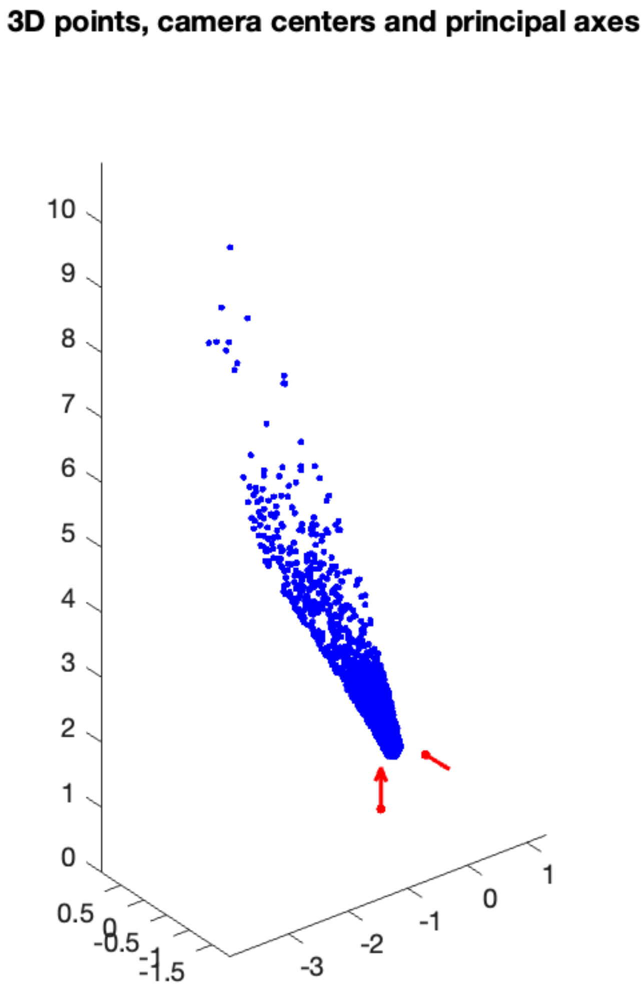


```
P2{3}=[U*W'*V',U(:,3)];
```

3D points, camera centers and principal axes



```
P2{4}=[U*W'*V',-U(:,3)];
```


3D points, camera centers and principal axes
10
9
8
7
6
5
4
3
2
1
0
0.5
0
-0.5
-1
-1.5
-3
-2
-1
0
1

With P2{2} chosen, the 3D points here are projected into the image with P2{2} alongside the original image points. As we can see below the projections are well aligned with the image points and errors look small.

Image points vs Projected points