**Pix4D**
**Chemin des Clos 117b**
CH-1024 Ecublens
christoph.strecha@pix4d.com
http://www.pix4d.com
+41 21 6931288

# 1 Camera Externals

- $\mathbf{X} = (X, Y, Z)$ 3D point in world coordinate system
- $\mathbf{T} = (T_x, T_y, T_z)$ 3D coordinate of the camera projection center

$$\mathbf{R} = \mathbf{R}_z(\kappa)\mathbf{R}_y(\phi)\mathbf{R}_x(\omega)$$

$$\mathbf{R} = \begin{pmatrix} \cos(\kappa) & \sin(\kappa) & 0 \\ -\sin(\kappa) & \cos(\kappa) & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos(\phi) & 0 & -\sin(\phi) \\ 0 & 1 & 0 \\ \sin(\phi) & 0 & \cos(\phi) \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\omega) & \sin(\omega) \\ 0 & -\sin(\omega) & \cos(\omega) \end{pmatrix}$$

$$\mathbf{R} = \begin{pmatrix} \cos(\phi)\cos(\kappa) & \cos(\omega)\sin(\kappa) + \sin(\omega)\sin(\phi)\cos(\kappa) & \sin(\omega)\sin(\phi) - \cos(\omega)\sin(\phi)\cos(\kappa) \\ -\cos(\phi)\sin(\kappa) & \cos(\omega)\cos(\kappa) - \sin(\omega)\sin(\phi)\sin(\kappa) & \sin(\omega)\cos(\kappa) + \sin(\omega)\sin(\phi)\sin(\kappa) \\ \sin(\phi) & -\sin(\omega)\cos(\phi) & \cos(\omega)\cos(\phi) \end{pmatrix}$$

$$\begin{aligned} \mathbf{x} &= \mathbf{R}^T(\mathbf{X} - \mathbf{T}) \\ x' &= \frac{-fx}{z} + c_x \\ y' &= \frac{-fy}{z} + c_y \end{aligned} \tag{1}$$

with $f$ being the focal length, $(c_x, c_y$ the principal point and $(x', y')$ the pixel location in the image, such that $(0, 0)$ corresponds to the top-left corner of the image.

# 2 Camera Distortion

$$r^2 = \left(\frac{x}{z}\right)^2 + \left(\frac{y}{z}\right)^2$$

$$\begin{aligned} x_d &= \left(1 + k_1 r^2 + k_2 r^4 + k_3 r^6\right) \frac{x}{z} + d_x \\ y_d &= \left(1 + k_1 r^2 + k_2 r^4 + k_3 r^6\right) \frac{y}{z} + d_y \end{aligned}$$

$$
\begin{aligned}
d_x &= 2t_1 \frac{x}{z}\frac{y}{z} + t_2\left(r^2 + 2\left(\frac{x}{z}\right)^2\right) \\
d_y &= 2t_2 \frac{x}{z}\frac{y}{z} + t_1\left(r^2 + 2\left(\frac{y}{z}\right)^2\right)
\end{aligned}
$$

with $r_{1,2,3}$ being the radial distortion coefficients and $t_{1,2}$ the tangential distortions.

$$
\begin{aligned}
x'_d &= \frac{-fx_d}{z} + c_x \\
y'_d &= \frac{-fy_d}{z} + c_y
\end{aligned} \tag{2}
$$

$(x'_d, y'_d)$ is then the distorted pixel location in the image, such that $(0, 0)$ corresponds to the top-left corner.

# 3 Pix4D Output files

## 3.1 _geocal.txt

imageWidth imageHeight focalLenght[pixel] projectionCenterX[pixel] projectionCenterY[pixel] radialDist1 radialDist2 radialDist3 tangential1 tangential2
4000 3000 2837.11 2018.56 1512.34 -0.036 0.023 -0.007 0.0 0.0
imageName X Y Z Omega Phi Kappa
IMG0153.JPG 286928.53 5123269.23 544.03 7.440 -0.310 -68.630
IMG0154.JPG 286929.64 5123266.79 544.61 2.040 2.331 -55.066
IMG0155.JPG 286087.86 5123461.32 752.55 1.840 6.026 10.469
IMG0156.JPG 286204.28 5123408.26 752.32 4.712 7.352 19.220

The above example shows:

- imageWidth (width of the image)
- imageHeight (height of the image)
- focalLenght[pixel] (corresponds to $f$ in eqn.2)
- projectionCenterX[pixel] (corresponds to $c_x$ in eqn.2)
- projectionCenterY[pixel] (corresponds to $c_y$ in eqn.2)
- radialDist1 (corresponds to $k_1$ in eqn.2)
- radialDist2 (corresponds to $k_2$ in eqn.2)
- radialDist3 (corresponds to $k_3$ in eqn.2)
- tangential1 (corresponds to $t_1$ in eqn.2)
- tangential2 (corresponds to $t_2$ in eqn.2)

- imageName (filename of the image)
- X (refined $T_x$ coordinate of the camera projection center )
- Y (refined $T_y$ coordinate of the camera projection center )
- Z (refined $T_z$ coordinate of the camera projection center )
- Omega ($\omega$ as defined in eq.1 in degrees)
- Phi ($\phi$ as defined in eq.1 in degrees)
- Kappa ($\kappa$ as defined in eq.1 in degrees)

If GCP's are given $T_x, T_y, T_z$ are in the user specified coordinate system for the GCP's. Otherwize $T_x, T_y, T_z$ are provided in the user specified coordinate system for the Image locations. If image and GCP's are specified by the user in latitude, longitude and altitude $T_x, T_y, T_z$ is provided in UTM coordinates.

### 3.2 _gpscal.txt

*same as _geocal.txt but with geo coordinates in lat, lng and alt with WGS84 datum*

imageWidth imageHeight focalLenght[pixel] projectionCenterX[pixel] projectionCenterY[pixel] radialDist1 radialDist2 radialDist3 tangential1 tangential2
4000 3000 2837.11 2018.56 1512.34 -0.036 0.023 -0.007 0.0 0.0
imageName longitude latitude altitude Omega Phi Kappa
IMG0155.JPG 6.22 46.23 752.52 7.440 -0.310 -68.630
IMG0156.JPG 6.22 46.23 752.30 2.040 2.331 -55.066
IMG0157.JPG 6.22 46.23 752.44 1.840 6.026 10.469
IMG0158.JPG 6.23 46.22 751.33 4.712 7.352 19.220

The above example shows:

- imageWidth (width of the image)
- imageHeight (height of the image)
- focalLenght[pixel] (corresponds to $f$ in eqn.2)
- projectionCenterX[pixel] (corresponds to $c_x$ in eqn.2)
- projectionCenterY[pixel] (corresponds to $c_y$ in eqn.2)
- radialDist1 (corresponds to $k_1$ in eqn.2)
- radialDist2 (corresponds to $k_2$ in eqn.2)
- radialDist3 (corresponds to $k_3$ in eqn.2)
- tangential1 (corresponds to $t_1$ in eqn.2)
- tangential2 (corresponds to $t_2$ in eqn.2)

- imageName (filename of the image)
- longitude (refined $T_x$ coordinate of the camera projection center )
- latitude (refined $T_y$ coordinate of the camera projection center )
- altitude (refined $T_z$ coordinate of the camera projection center )
- Omega ($\omega$ as defined in eq.1 in degrees)
- Phi ($\phi$ as defined in eq.1 in degrees)
- Kappa ($\kappa$ as defined in eq.1 in degrees)

### 3.3 _internals.cam

This file contains camera internal information in a standart file format.

- FOCAL (focal lenght in mm $f_{mm}$, corresponds to $f_{mm} = \frac{sensorwidth \times f}{imagewidth}$)

### 3.4 _pix4d_internals.cam

This file contains camera internal information in the pix4d file format. These paramaters should be provided to the software for other projects with the same

camera, focal lenght and resolution.

### 3.5 _orima.txt

This file contains control points for all reconstructed images. It can be used directly by ORIMA to prevent the measuement of those control points by hand.

ImageName1 controlPointID1 x y 0 M
ImageName1 controlPointID2 x y 0 M
...
ImageName2 controlPointID1 x y 0 M
ImageName2 controlPointID2 x y 0 M
...

### 3.6 _bingo.txt

This file contains control points for all reconstructed images. It can be used directly by BINGO to prevent the measuement of those control points by hand.

ImageName1 cameraName1
controlPointID1 x y
controlPointID2 x y
controlPointID3 x y
...
ImageName2 cameraName2
controlPointID1 x y
controlPointID2 x y
controlPointID3 x y
...