3D Point Cloud processing and analysis
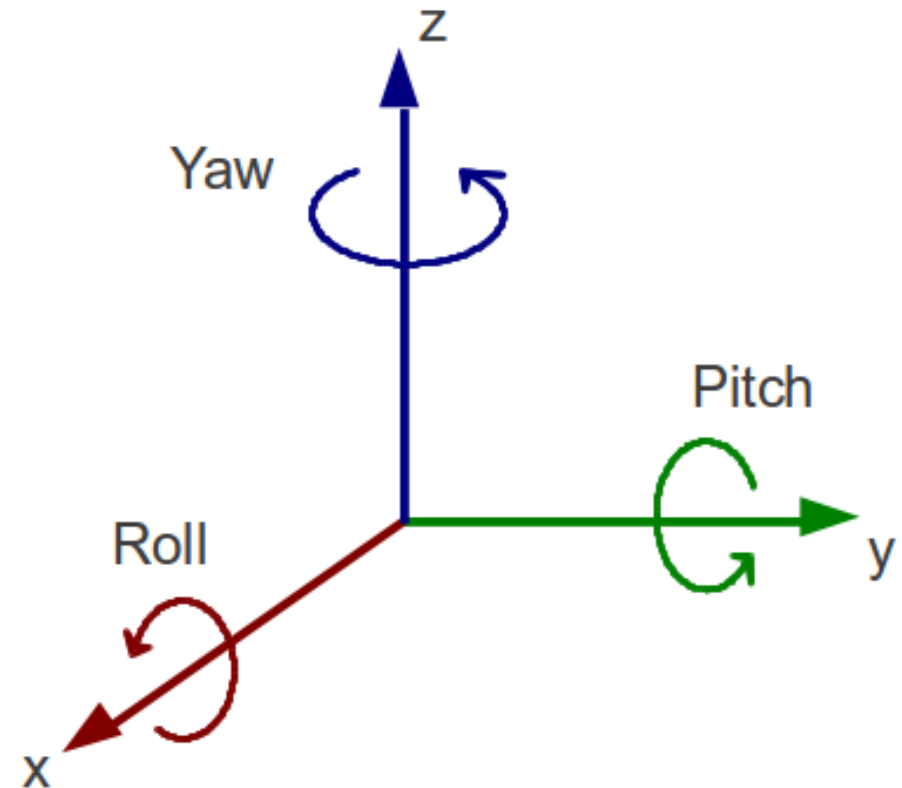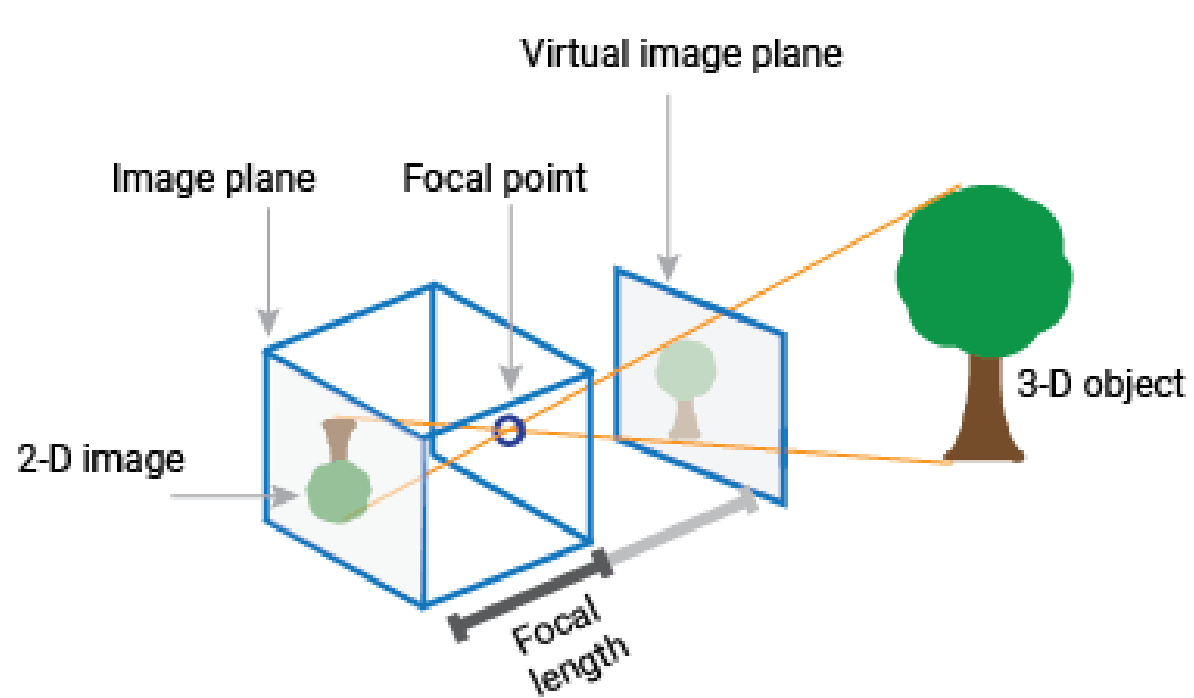# Course_01
3D Transformations

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3D Transformations

3D Transformations

- Translation:
  x' = x + t where t = [x, y, z], t $\in R^3$

- Rotation: is defined by three basic rotation orthonormal

  matrices (RR^T = I and |R| = 1) around one axis

  - Rotation Z (Yaw):
    $$\begin{pmatrix} cos(\theta) & -sin(\theta) & 0 \\ sin(\theta) & cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

3D Transformations

- Rotation X (roll):

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & cos(\theta) & -sin(\theta) \\ 0 & sin(\theta) & cos(\theta) \end{pmatrix}$$

- Rotation Y (Pitch):

$$\begin{pmatrix} cos(\theta) & 0 & sin(\theta) \\ 0 & 1 & 0 \\ -sin(\theta) & 0 & cos(\theta) \end{pmatrix}$$
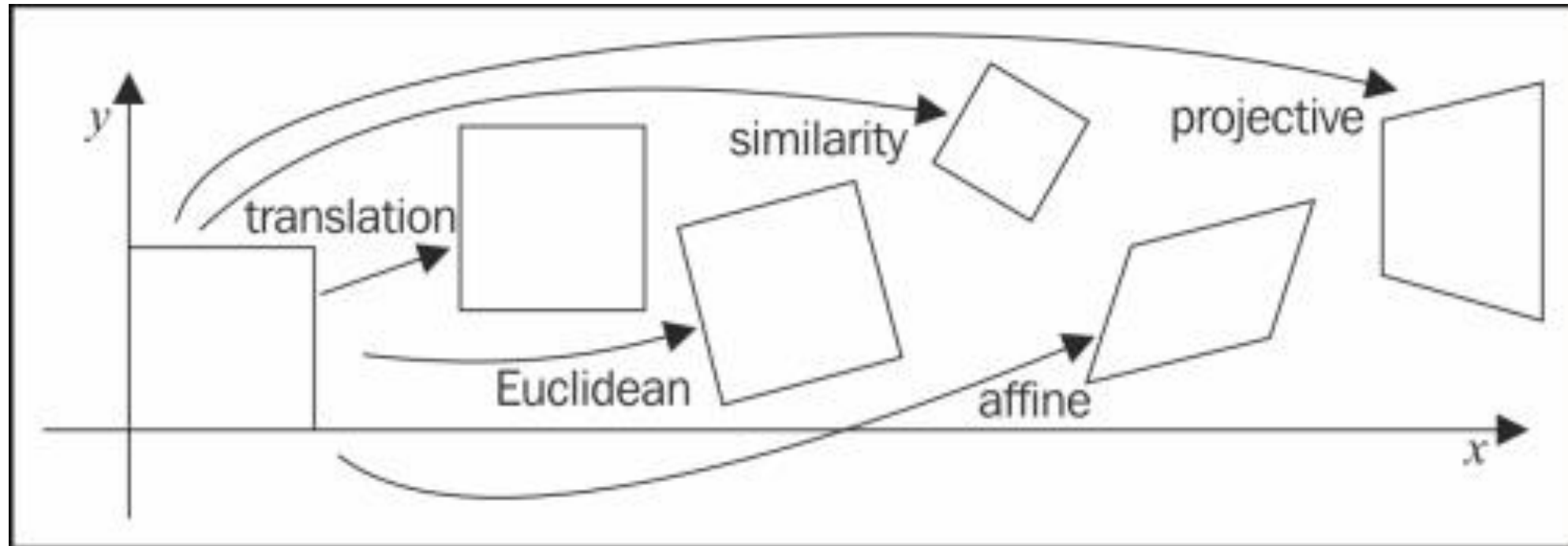
3D Transformations

R = Rz Ry Rx

$$\mathbf{R}(\phi, \chi, \psi) = \mathbf{R}_z(\phi)\mathbf{R}_y(\chi)\mathbf{R}_x(\psi)$$

$$= \begin{pmatrix} \cos\phi\cos\chi & \cos\phi\sin\chi\sin\psi - \sin\phi\cos\psi & \cos\phi\sin\chi\cos\psi + \sin\phi\sin\psi \\ \sin\phi\cos\chi & \sin\phi\sin\chi\sin\psi + \cos\phi\cos\psi & \sin\phi\sin\chi\cos\psi - \cos\phi\sin\psi \\ -\sin\chi & \cos\chi\sin\psi & \cos\chi\cos\psi \end{pmatrix}$$
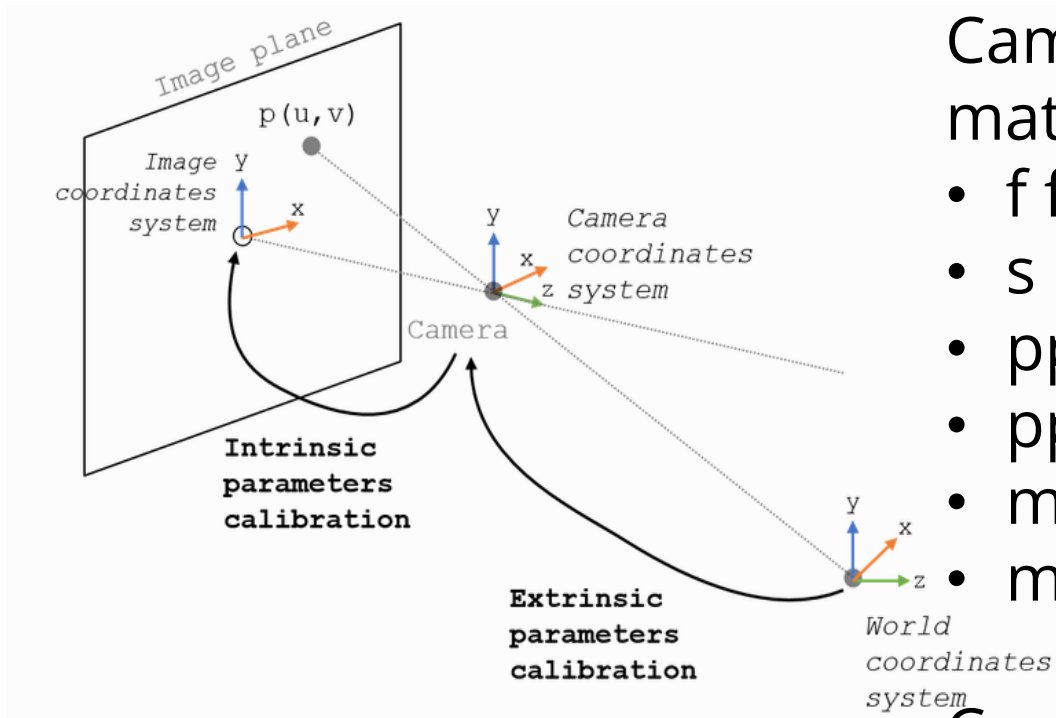
3D Euclidean transformation:

$$\begin{pmatrix} R & t \\ 0 & 1 \end{pmatrix}$$
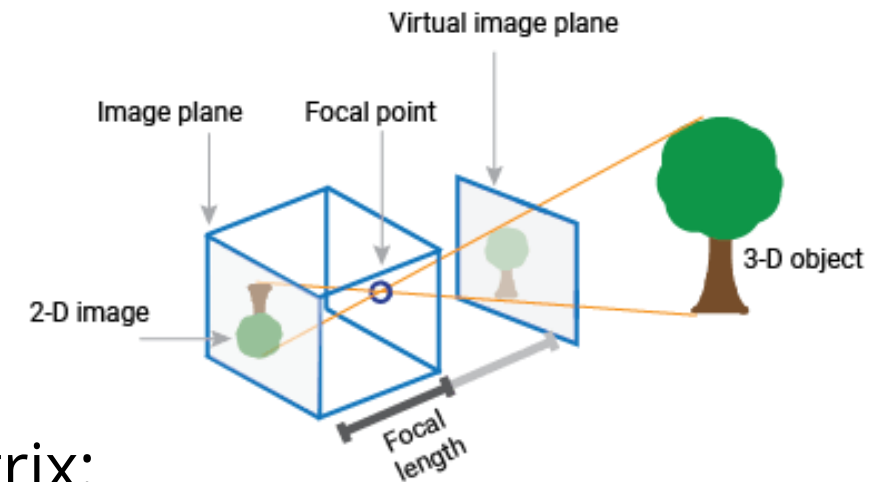
3D Transformations

Camera intrinsic Model

Camera intrinsic parameter matrix K :
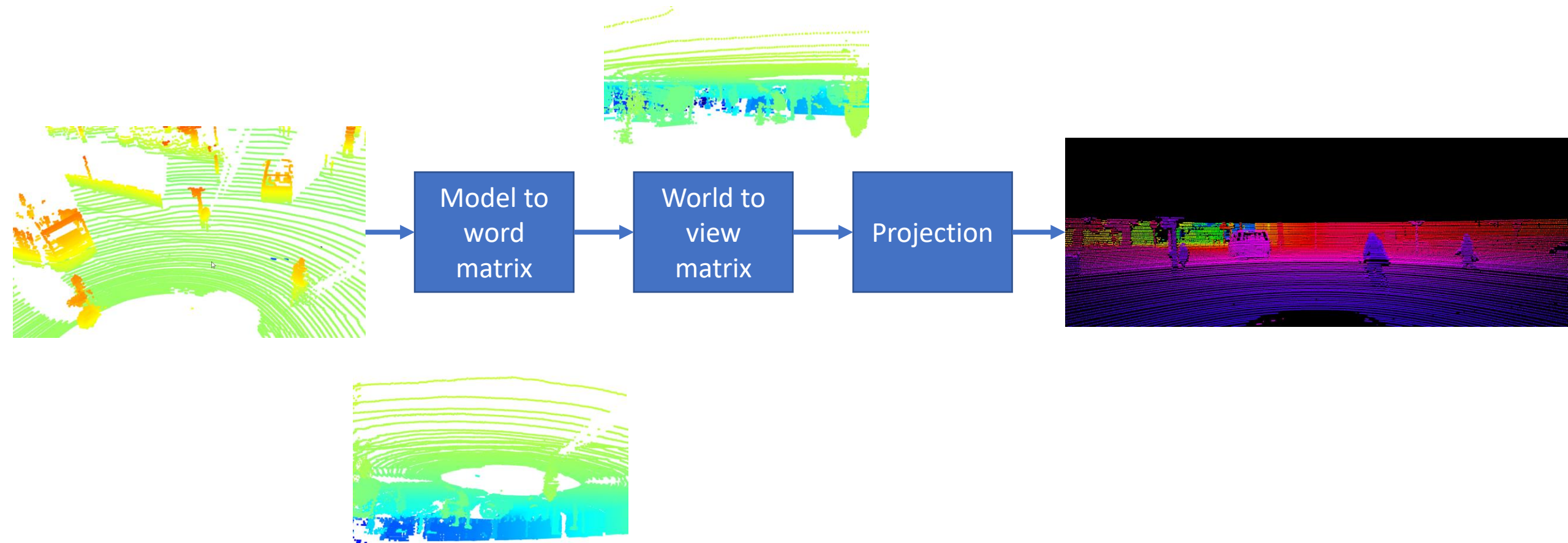- f focal length
- s skewness factor
- ppx principal point x
- ppy principal point y
- mx scaling factor x
- my scaling factor y

$$\begin{pmatrix} f * mx & s & ppx \\ 0 & f * my & ppy \\ 0 & 0 & 1 \end{pmatrix}$$

Camera projection matrix:
P = $[KR \mid t]$

Model View Projection

Model to word matrix → World to view matrix → Projection

KITTI transformation path
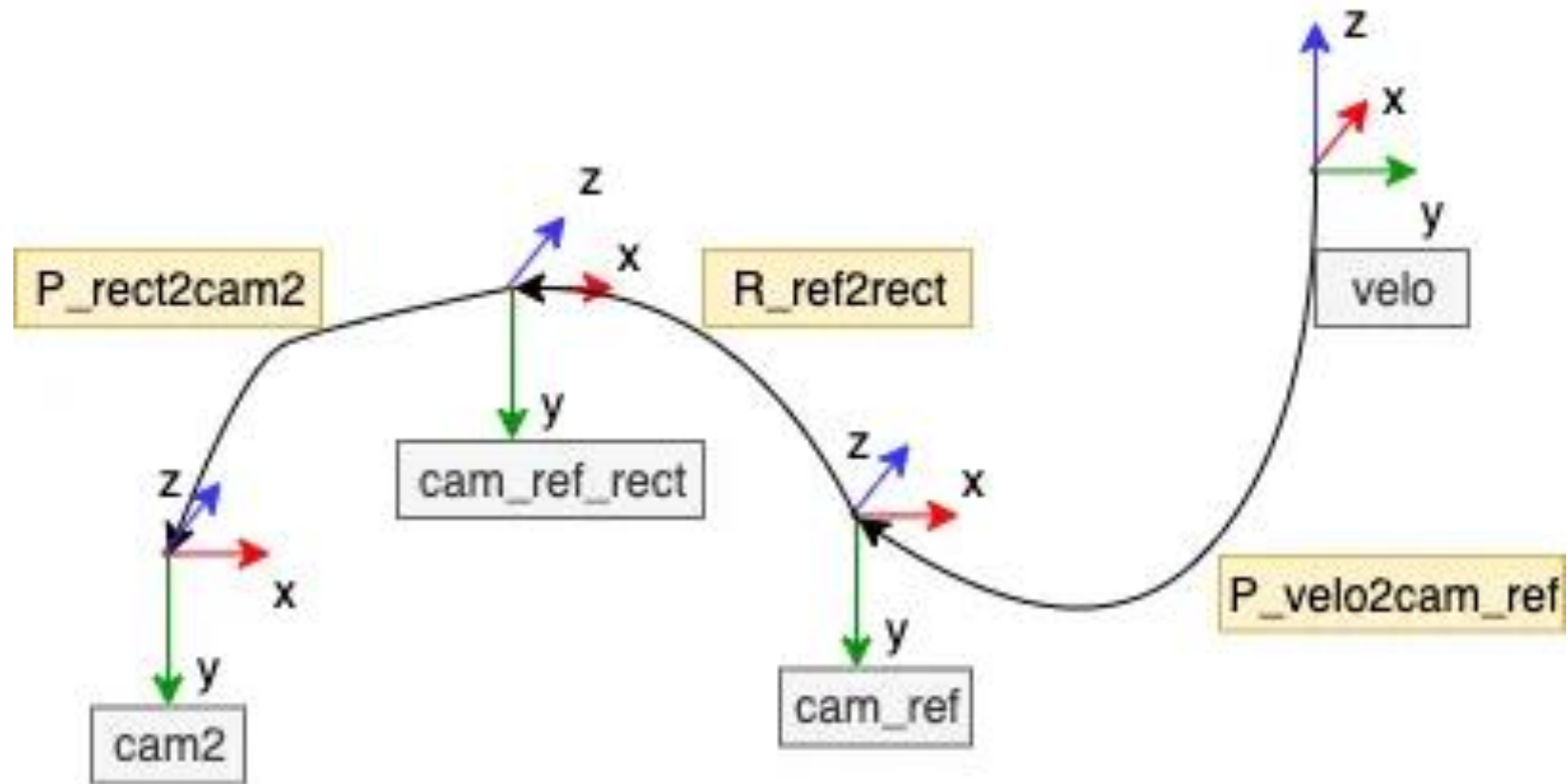
Velo2Camref

Rotation = [7.533745e-03, -9.999714e-01, -6.166020e-04, 1.480249e-02, 7.280733e-04, -9.998902e-01, 9.998621e-01, 7.523790e-03, 1.480755e-02]

Translation = [-4.069766e-03, -7.631618e-02, -2.717806e-01]

Camref2Projection

Camref2Rect =

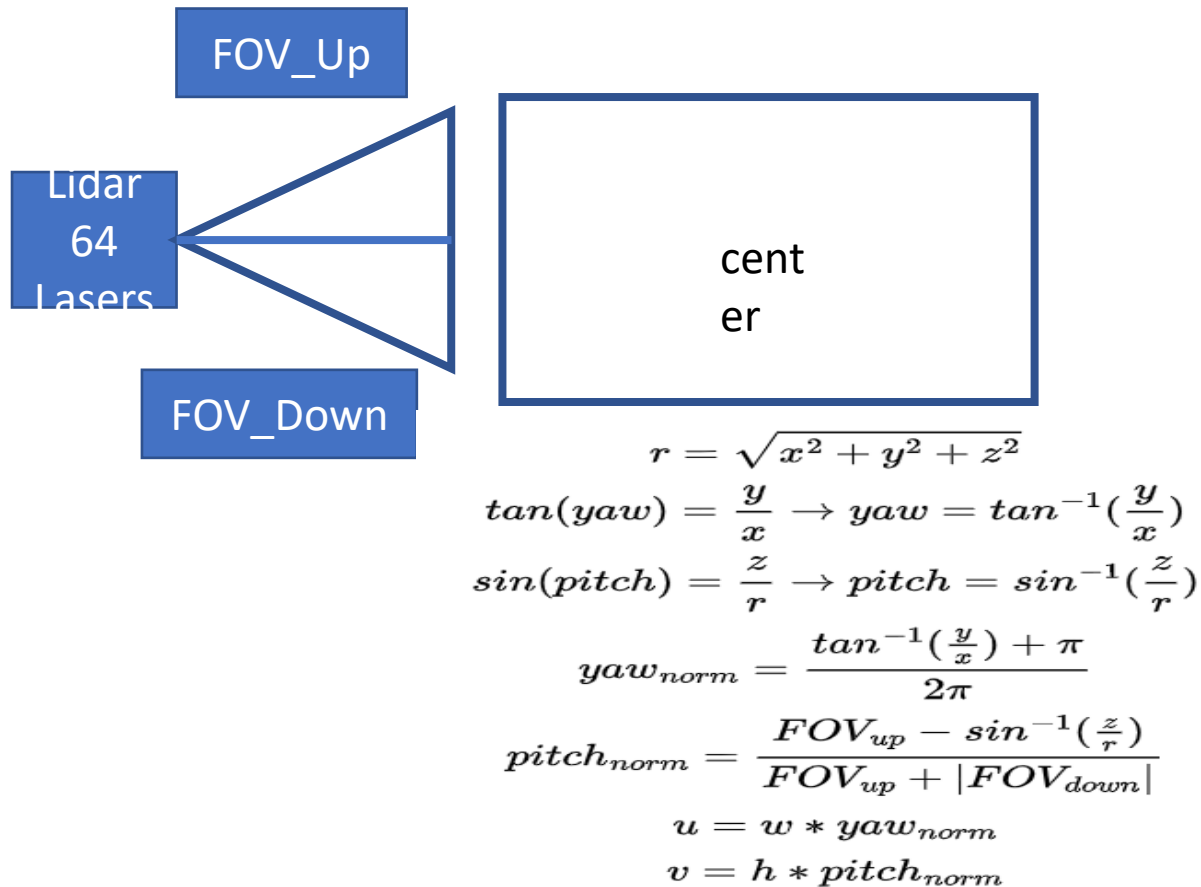[9.998817e-01, 1.511453e-02, -2.841595e-03, 0,

-1.511724e-02, 9.998853e-01, -9.338510e-04, 0,

2.827154e-03, 9.766976e-04, 9.999955e-01,   0,

0,   0,   0,   1]

Rect2Proj=

[7.215377e+02, 0.000000e+00, 6.095593e+02, 4.485728e+01,
0.000000e+00, 7.215377e+02, 1.728540e+02, 2.163791e-01,
0.000000e+00, 0.000000e+00, 1.000000e+00, 2.745884e-03]

Spherical Projection

FOV_Up

Lidar 64 Lasers

center

FOV_Down

$$r = \sqrt{x^2 + y^2 + z^2}$$

$$tan(yaw) = \frac{y}{x} \rightarrow yaw = tan^{-1}(\frac{y}{x})$$

$$sin(pitch) = \frac{z}{r} \rightarrow pitch = sin^{-1}(\frac{z}{r})$$

$$yaw_{norm} = \frac{tan^{-1}(\frac{y}{x}) + \pi}{2\pi}$$

$$pitch_{norm} = \frac{FOV_{up} - sin^{-1}(\frac{z}{r})}{FOV_{up} + |FOV_{down}|}$$

$$u = w * yaw_{norm}$$

$$v = h * pitch_{norm}$$

Sensor:

- 64 lasers/detectors
- 360 degree field of view (azimuth)
- 0.08 degree angular resolution (azimuth)
- 26.8 degree vertical field of view (elevation) - +2 up to -24.8 down with 64 equally spaced angular subdivisions (approximately 0.4)
- <2 cm distance accuracy
- 5-15 Hz field of view update (user selectable)
- 50 meter range for pavement (~0.10 reflectivity)
- 120 meter range for cars and foliage (~0.80 reflectivity)
- >1.3 M points per second
- Operating temperature - 10° to 50° C
- Storage temperature - 10° to 80° C