Aug 17 2020
Jungwon Kang

Getting a BEV (Bird-Eye View) image from an original perspective image

Here, we would like to get a BEV (Bird-Eye View) image from an original perspective image.
This is formulated as a problem of finding $(x_{\mathrm{bev}}, y_{\mathrm{bev}})$ corresponding to $(x_{\mathrm{ori}}, y_{\mathrm{ori}})$.
To solve this problem, we introduce the following four coordinate systems for:

- ori: original perspective image space
- cam: camera space
- world: world space
- bev: BEV image space

We would have the following three transformations between coordinate systems.

- bev → world : T_b
- world → cam : T_m
- cam → ori : K

Note that the red-color symbols are parameters.

$$\begin{bmatrix} x_{\mathrm{ori}} \\ y_{\mathrm{ori}} \\ 1 \end{bmatrix} \simeq K \begin{bmatrix} X_{\mathrm{cam}} \\ Y_{\mathrm{cam}} \\ Z_{\mathrm{cam}} \end{bmatrix}$$

Transformation from cam to ori

$$\begin{bmatrix} x_{\mathrm{ori}} \\ y_{\mathrm{ori}} \\ 1 \end{bmatrix} \simeq \underbrace{\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}}_{K} \begin{bmatrix} X_{\mathrm{cam}} \\ Y_{\mathrm{cam}} \\ Z_{\mathrm{cam}} \end{bmatrix}$$

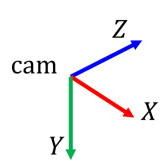
$$\begin{bmatrix} X_{\mathrm{cam}} \\ Y_{\mathrm{cam}} \\ Z_{\mathrm{cam}} \end{bmatrix} = T_m \begin{bmatrix} X_{\mathrm{W}} \\ Y_{\mathrm{W}} \\ 1 \end{bmatrix}$$

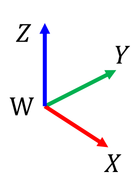
Transformation from world to cam

$$\begin{bmatrix} X_{\mathrm{cam}} \\ Y_{\mathrm{cam}} \\ Z_{\mathrm{cam}} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_x \\ r_{21} & r_{22} & r_{23} & t_y \\ r_{31} & r_{32} & r_{33} & t_z \end{bmatrix} \begin{bmatrix} X_{\mathrm{W}} \\ Y_{\mathrm{W}} \\ Z_{\mathrm{W}} \\ 1 \end{bmatrix}$$

Supposing $Z_{\mathrm{w}} = 0$ for all the points in the world space

$$\begin{bmatrix} X_{\mathrm{cam}} \\ Y_{\mathrm{cam}} \\ Z_{\mathrm{cam}} \end{bmatrix} = \underbrace{\begin{bmatrix} r_{11} & r_{12} & t_x \\ r_{21} & r_{22} & t_y \\ r_{31} & r_{32} & t_z \end{bmatrix}}_{T_m} \begin{bmatrix} X_{\mathrm{W}} \\ Y_{\mathrm{W}} \\ 1 \end{bmatrix}$$





$$\begin{bmatrix} X_{\mathrm{w}} \\ Y_{\mathrm{w}} \\ 1 \end{bmatrix} = T_b \begin{bmatrix} x_{\mathrm{bev}} \\ y_{\mathrm{bev}} \\ 1 \end{bmatrix}$$

Transformation from bev to world

$$\begin{bmatrix} x_{\mathrm{bev}} \\ y_{\mathrm{bev}} \\ 1 \end{bmatrix} = \underbrace{\begin{bmatrix} \alpha_{\mathrm{bev}} & 0 & \beta_x \\ 0 & -\alpha_{\mathrm{bev}} & \beta_y \\ 0 & 0 & 1 \end{bmatrix}}_{(T_b)^{-1}} \begin{bmatrix} X_{\mathrm{w}} \\ Y_{\mathrm{w}} \\ 1 \end{bmatrix}$$

- α_{bev} : pixel/meter
- β_x : $w_{\mathrm{bev}}/2$
- β_y : $h_{\mathrm{bev}} - 1$