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CAMERA CALIBRATION

DepthSenseSDK

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TABLE OF CONTENTS

TABLE OF FIGURES

1 Introduction

This document describes the camera model used in DepthSenseSDK.

The parameters provided by the SDK regarding camera calibration assume that the Y axis has a different direction in both 2D and 3D.

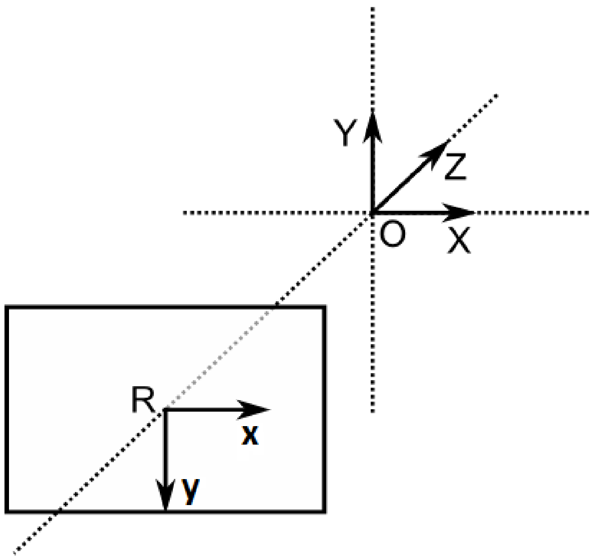

Figure 1 DepthSenseSDK Coordinate System

1.1 Definitions, acronyms and abbreviations

DSSDK: DepthSenseSDK

2 Matrix of intrinsic parameters

Each color or depth node is modeled by the following matrices:

$$A = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \text{ and } \begin{bmatrix} k_1 & k_2 & p_1 & p_2 & k_3 \end{bmatrix}$$

Where:

- f_x, f_y are respectively the focal length in pixel-related units along the x and y axis
- c_x, c_y are respectively the principal point of the camera along the x and y axis
- k_1, k_2, k_3 are the radial distortion coefficients
- p_1 and p_2 are the tangential distortion coefficients

The A matrix is the pinhole camera model of the camera and the distortion coefficients are used to correct the distortion of the lenses.

These parameters will vary depending on the frame format in use for the node.

3 Matrix of extrinsic parameters

The following matrices are used to describe the relative positions of the color and depth cameras in the system.

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} \text{ and } t = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}$$

Where:

- R is a transformation matrix
- t is the translation matrix expressed in meters

These matrices are used to convert 3D coordinates from the depth coordinate system to the color coordinate system.

These matrices are frame format invariant and doesn’t depend on the content of the scene.

4 Projecting a 3D point into the depth camera plane

Let (X_D, Y_D, Z_D) be the coordinates of a 3D point in the world coordinate space expressed in the depth coordinate system and (x_D, y_D) the coordinates of the projection point in pixels in the depth camera plane. The intrinsic parameters to be used are the one of the depth camera.

The projection point can be computed with the following formula:

$$x_D = f_{xD} * x'' + c_{xD}$$

$$y_D = -f_{yD} * y'' + c_{yD}$$

Where:

$$x'' = x'(1 + k_{1D}r^2 + k_{2D}r^4 + k_{3D}r^6) + 2p_{1D}x'y' + p_{2D}(r^2 + 2x'^2)$$

$$y'' = y'(1 + k_{1D}r^2 + k_{2D}r^4 + k_{3D}r^6) + 2p_{2D}x'y' + p_{1D}(r^2 + 2y'^2)$$

Where:

$$x' = \frac{X_D}{Z_D}$$

$$y' = \frac{Y_D}{Z_D}$$

$$r^2 = x'^2 + y'^2$$

Note that the sign of the y'' component is inverted when computing the y_D component to take into account that the Y axis of the 2D and 3D coordinate systems have different directions.

5 Projecting a 3D point into the color camera plane

Let (X_D, Y_D, Z_D) be the coordinates of a 3D point in the world coordinate space expressed in the depth coordinate system and (x_C, y_C) the coordinates of the projection point in pixels in the color camera plane. The intrinsic parameters to be used are the one for the color camera.

The projection point can be computed with the following formula:

$$x_c = f_{xC} * x'' + c_{xC}$$

$$y_C = f_{yC} * y'' + c_{yC}$$

Where:

$$x'' = x'(1 + k_{1C}r^2 + k_{2C}r^4 + k_{3C}r^6) + 2p_{1C}x'y' + p_{2C}(r^2 + 2x'^2)$$

$$y'' = y'(1 + k_{1C}r^2 + k_{2C}r^4 + k_{3C}r^6) + 2p_{2C}x'y' + p_{1C}(r^2 + 2y'^2)$$

Where:

$$x' = \frac{X_C}{Z_C}$$

$$y' = \frac{Y_C}{Z_C}$$

$$r^2 = x'^2 + y'^2$$

Where:

$$\begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} = R \begin{bmatrix} X_D \\ Y_D \\ Z_D \end{bmatrix} + t$$

Note that unlike section 4 of this document, the sign of the y'' is not inverted when computing the y_c component. This is because of the fact that the Y axis of the 2D and 3D coordinate systems are inverted is taken into account in the R transformation matrix of the extrinsic parameters.