Range image and platform calibration of Microsoft Kinect

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KEY WORDS: Microsoft Kinect, 3D reconstruction, point cloud, IR Camera, Range sensor

ABSTRACT:

The new imaging sensor which will significantly effect on close range photogrammetry capabilities and applications is Kinect- XBOX360 made by Microsoft. Kinect includes both optical and range imaging sensors. The sensors can take images with size of 480*640 in 30 frames per second simultaneously. It means that it is possible to collect 307200 colored 3D points for each 1/30 second.

In this study, we did initial experiments for calibration of Kinect optical and range sensors. Before calibration, the optical image and range image are not geometrically consistent. It is due to interior geometric distortions and relative position and situation of both sensors. There are also some unknown parameters to produce range image from raw data. The calibration is done via a special test field including several 3D circular targets. After taking both optical and range images from test field, the calibration parameters are estimated in a multi-sensor bundle adjustment process. After calibration, the precise geometric relationship between corresponding optical and range image pixels is made. That makes it possible to generate precise colored 3D point clouds. The experiments show that the Kinect sensor has a high geometric stability and accuracy so that after calibration its accuracy is about sub-millimeters in range of some meters.

1. Introduction

Nowadays optical and laser scanners play a significant role in 3D object reconstruction. These scanners have some disadvantages such as high cost, weight, massive point clouds as well as high processing power required. Microsoft Kinect is an accessory for Microsoft Xbox 360 that is designed for skeleton recognition but can be used for 3D scanning and reconstruction with medium accuracy. This device has 2 sensors, a passive CMOS VGA resolution RGB camera and an active CMOS VGA resolution IR range camera. IR range camera has an effective range of 1 to 8 meters and radiometric resolution of 11bits.

In order to use of this platform in close range photogrammetry, the relation of the RGB and IR camera coordinate systems should be resolved. In other words the exterior orientation parameters between these two coordinate systems should be calculated. In last few years calibration of similar devices such as PMDs has been done, but because of differences in architecture and accuracy their calibration procedure cannot be used on Kinect. In addition achieving higher accuracy needs calculation of calibration parameters of RGB and IR cameras. In this study we offer a close range photogrammetry based calibration technique in order to reach higher accuracy.

2. The calibration technique

2.1 Software platform

The technique which recommended in this study uses Australis software to calculate exterior orientation parameters. After data acquisition section RGB and IR images imported into Australis project and processed to solve the exterior orientation problem. So that like e regular close rang photogrammetry project marking of target centers and solving orientation parameters are done.

2.2 Test field

In this study a custom test field is created. The structure should be designed in such a way that targets can be recognized in both RGB and range Images. So for range image target recognition, they should be designed in order to satisfy elevation difference condition and also have the structure of simple close range photogrammetry targets. So the appropriate test field consists of many simple targets that have height difference with background plate.

2.3 Technique definition

This technique consists of two steps; the first step is calculating the transformation of 11 bit depth values to real distances by solving a curve fitting problem. The next step is to transform 11bit depth values into real distances. The last step is to extract 3d coordinates of target centers and to determine the exterior orientation parameters between RGB and IR camera coordinate systems.

3. Technique details

This section is going to describe the details of the technique which used in this study.

Data acquisition

The data acquisition software has been developed based on CLNUI Kinect driver in Microsoft C# platform. 10 images have been captured during the test, 2 stereo images and 8 images with 90 degree of rotation in 4 sides of test field (as shown in figure1).

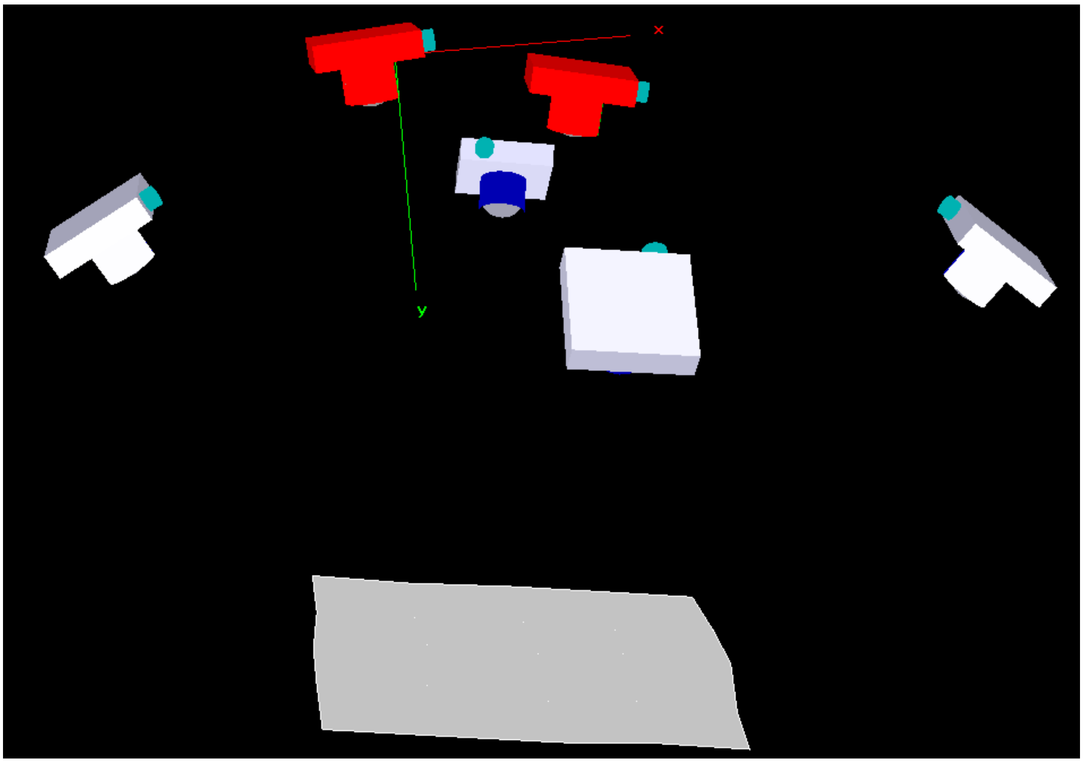

Figure 1- Imaging geometry.

Target center extraction

In this session target centers should be extracted. It can simply be done in RGB images because of high contrast difference but in range images targets should be transformed into high contrast form by threshold operator. It is necessary because targets are not at same distance of camera, so that they cannot be recognized by gray values. Transformed targets are shown in figure2.

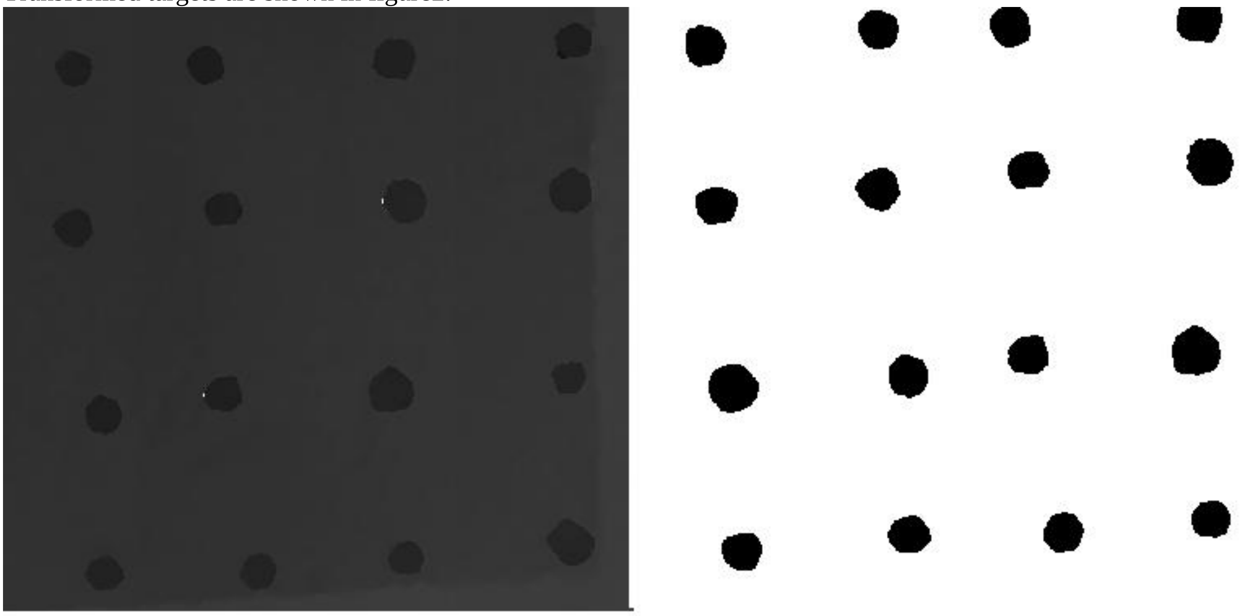

Figure 2- transformation of targets by threshold operator.

Test field

Test field contains a 5 * 5 grid of white targets on 10cm pins based on black background as shown in figure 3. Since the active range sensor depth value is material consistent and the reflectivity of white color in infrared spectral band is more than the black color, we used white targets on black background. The diameters of circular targets have been set to 5cm so that center of targets can be extracted with desired accuracy due to density of infrared projected rays.

Figure 3- Designed test field.

4. Results

Platform calibration

The relative orientation parameters between these two coordinate systems have been calculated as shown in table 4.1. These results have been obtained by marking similar targets in depth and RGB pairs acquired before.

	Omega(degree)	Phi(degree)	Kappa(degree)	Xc(mm)	Yc(mm)	Zc(mm)
Parameter value	0.15	-0.1	-0.55	-27	2	7
Error	0.1	0.1	0.1	2.5	5	2.5

Range image calibration

The equation which fitted to the range dataset is eq.1. Using MATLAB curve fitting toolbox the curve fitting problem has been solved and the equation has been obtained. Dataset which used in fitting operation contains 800 points with range code and known real distance values. The curve fitting results is shown in figure 4.

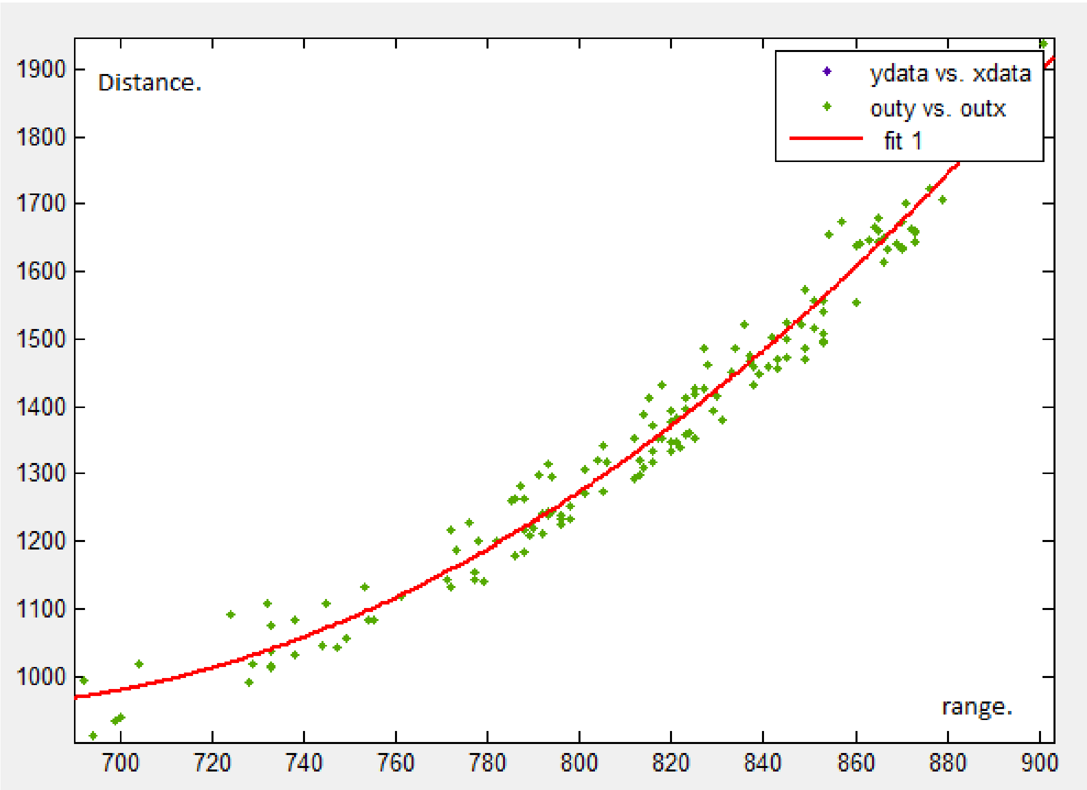

Figure 4- Range to distant result.

As it shown on figure 4.1 the equation fitted is a quadratic equation which has 3 parameters. The results of calibration are shown below.

$$f(x) = p1*x^2 + p2*x + p3$$

Coefficients (with 95% confidence bounds):

	P1	P2	P3
Value	0.01628	-21.47	8032

→ RMSE: 35.87

Using more complicated equations may result on lower RMSE value but there is no assurance that the resulting equation can operate more accurately.

References

http://nicolas.burrus.name/index.php/Research/KinectCalibration