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Two-step Registration in 3D Human Body Scanning Based on Multiple RGB-D Sensors ⋆

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Abstract

In this paper, we propose a universal registration method for the body scanner consists of multiple fixed sensors. Firstly, a new double-faced checkerboard is designed to apply calibration method into the initial estimations of the relative poses of point clouds. Secondly, ICP (Iterative Closet Point) algorithm is utilized for further registration. Since ICP algorithm may fail in situations of outliers, ambiguity or missing data, we make full use of the geometry feature of creased papers to solve these problems. A new body scanning system with fast capture speed is also proposed to validate our method. The experiment results demonstrate our approach is robust and fast.

Keywords: Body Scanning; RGB-D Sensor; Calibration; Registration; ICP

1 Introduction

RGB-D sensors has recently been used to capture human body [1, 2], several methods and two commercial systems (i.e. Styku [3] and Bodymetrics [4]) based on the RGB-D sensor have been proposed for body modeling. Ruizhe Wang et al. [5] classify these methods in the following scenarios: 1) multiple fixed sensors with static person; 2) multiple fixed sensors with moving person; 3) single moving sensor with static person; 4) single fixed sensor with moving person.

We design a new double-faced checkerboard to estimate the poses of RGB-D sensors synchronously. A popular approach to achieve fine registration is the Iterative Closest Point (ICP) algorithm [6] and its variants [7]. However, these ICP methods will fail due to the little overlap or ambiguity among models. The accuracy of registration also drops due to outliers or missing data.

To scan the whole subject, we design a new double-faced checkerboard. To register point clouds with low overlap, outliers, ambiguity or missing data, a creased paper which we call registration paper is used to help to apply ICP. It is compared to conventional method of extraction of local

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features using two RGB-D sensors. A new rigid human body scanning system is presented to validate our approach.

2 Registration Pipeline

2.1 Initial Estimate of Relative Pose of Point Clouds

In our work, the intrinsic parameters of the color camera are modeled as in [8]. If using (O_W, X_W, Y_W, Z_W) denotes the world coordinate frame and (O_C, X_C, Y_C, Z_C) denotes the camera coordinate frame, the relation between the two coordinate frames can be shown in Eq. (1) in the form of homogeneous coordinates.

$$\begin{pmatrix} X_C \\ Y_C \\ Z_C \\ 1 \end{pmatrix} = \begin{pmatrix} R & T \\ 0^T & 1 \end{pmatrix} \begin{pmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{pmatrix} \tag{1}$$

Conventional checkerboard [9] can only be used to calibrate cameras located in the same side of the checkerboard. Our custom double-faced checkerboard is aimed to solve this problem. A 9 RGB-D sensors model is taken as an example to state the achievement of initial estimation of relative pose of point clouds, as illustrated in Fig. 1.

By using Eq. (1) all 9 camera coordinate frames are converted to 6 world reference frames attached to 6 grids. Therefore, lower double-faced checkerboard generates two different world coordinate frames (O, X, Y, Z) and (O', X', Y', Z') because of its double-faced patterns.

$$\begin{pmatrix} X' \\ Y' \\ Z' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & -d_y \times n \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix} \tag{2}$$

where d_y denotes the width of the unit grid and n denotes the number of the unit grid between O and O'. The lower 3 cameras coordinate systems are converted in the same world coordinate frame (O', X', Y', Z'), as shown in Fig. 2. The same procedure may be easily adapted to convert

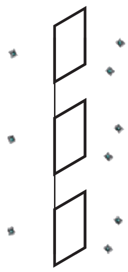

Fig. 1: 9 RGB-D sensors model

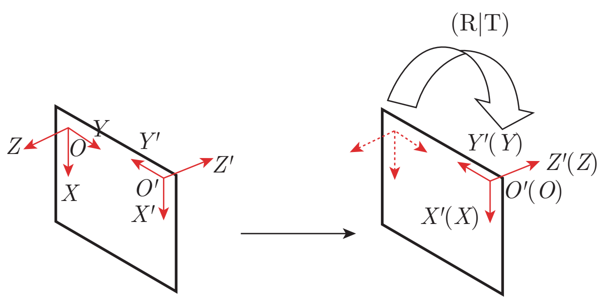

Fig. 2: Two world coordinate frames on the double-faced checkerboard