Point Cloud Registration Using Geometric Transformation of Turntable

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Abstract

In this paper, we propose a method of acquiring point cloud registration by using the geometric transformation of a turntable. ICP algorithm, which is one of the most well-known registration methods, produces weak results when used on symmetric objects. Therefore, in this paper, we propose a fast and accurate registration method that overcomes the shortcomings of ICP algorithm by converting point clouds from multi viewpoints into one turntable.

1. Introduction

In order to reconstruct a real object into a 3D model of the final object, an optimal posture alignment for 3D point clouds from several viewpoints is required. In the 3D registration method, the ICP (Iterative Closet Point) algorithm uses the least square method in order to estimate six rigid motion parameters between two different three-dimensional point clouds. ICP, however, may result in unsatisfactory registration results if it requires appropriate initial values for the convergence of the objective function in the 6-dimensional search space, or if the objective function is confined to the local minimum during the search. It is also nearly impossible to estimate the six parameters for a symmetrical object.

In this paper, we propose a method of physically reducing the search space by using a turntable and the proposed geometric correction below. This paper also shows that the registration of multiple point cloud can be performed quickly by estimating the geometric transformation between the 3D reconstruction system and the turntable, and using this estimated geometric transformation to search the one-dimensional rotation space.

2. Relative Position Estimation of the Turntable

If we know the rotation angle of the turntable in the system shown in Fig. 1 (a), we can estimate three rotation parameters among six rigid body motion parameters. The parameters can convert the multiple point cloud data into estimated positions of the turntable and the movement conversion between the respective point cloud data would infinitely become close to 0. The transformation matrix of the turntable for each pattern in Figure 1 can be defined as:

\[
X^c = \begin{bmatrix}
A & 0 & 0 \\
0 & B & 0 \\
0 & 0 & 1
\end{bmatrix}
\]

There is only rotation in the rigid transformation within a turntable. Thus, we can see that the transformation matrix equation between two turntable viewpoints is the same as \(X_f = RX_c\). R can be defined as \(\begin{bmatrix}
Z & 0 \\
0 & 1
\end{bmatrix}\) because there is only rotation transformation on the Z axis, which has no
transformation. Using two correlations, we can estimate translation and rotation transformation of the turntable that we want:

\[
\begin{align*}
X_d^2 &= RX_c^2 \\
\begin{bmatrix}
R & T \\
0 & 1
\end{bmatrix}^{-1} \begin{bmatrix}
A \\
1
\end{bmatrix} &= \begin{bmatrix}
Z \\
0 \\
1
\end{bmatrix} \begin{bmatrix}
R & T \\
0 & 1
\end{bmatrix}^{-1} \begin{bmatrix}
B \\
0 \\
1
\end{bmatrix} \\
\begin{bmatrix}
A \\
1
\end{bmatrix} &= \begin{bmatrix}
R & T \\
0 & 1
\end{bmatrix} \begin{bmatrix}
Z \\
0 \\
1
\end{bmatrix} \begin{bmatrix}
R & T \\
0 & 1
\end{bmatrix}^{-1} \begin{bmatrix}
B \\
0 \\
1
\end{bmatrix} \\
D &= R2R^T, a = -R2R^TT + T
\end{align*}
\]

In order to perform the registration of the point clouds acquired through the different viewpoints from the rotation of the turntable, all the acquired 3D point clouds are first converted into camera coordinates. Then, all 3D point clouds obtained through the camera coordinate system are converted into geometric correction pattern coordinates. Then, the point clouds that are converted into geometric correction pattern coordinates are reconverted into the turntable coordinates. Thus, the registration for the point clouds obtained through the turntable coordinates are affected only by the rotation of the turntable in the Z axis. Therefore, if we know the actual rotation angle of the turntable, it is possible to intuitively know the conversion between multiple point clouds, and to perform the registration for symmetric objects.

3. Experimental Results and Analysis

The actual object of the experiment was a symmetrically shaped porcelain, and the point cloud data was acquired (in 3D form) by using a structured light system. Also, four point clouds were obtained by rotating the turntable at 0, 90, 180, and 270 angles and determining each positions. The relative positional relationship between the structured light system and the turntable is estimated for the real data, and the 3D point cloud acquired from the structured light system is converted into turntable coordinates. It was found that registration of 3D point cloud is possible by simply exploring the one-dimensional rotational space. The conversion between each point cloud using the four point clouds obtained at each point exists only in the rotation conversion to the Z axis. Since we know the angle of rotation, we can easily estimate the rotation transformation formula, and we can obtain the final point cloud registration by performing the geometric correction on the estimated rotation transformation point cloud.

4. Conclusion

We propose a method of registration using the turntable geometric transformation in order to overcome ICP algorithm’s shortcomings on symmetrical objects. As a result of implementing this method, we were able to perform the registration of the model of a symmetrical pottery and obtain the final integrated point cloud. Future work will be to make a mesh model using a point cloud registration from multiple view points, and to be mapping a texture to it.

참고문헌