Design of Virtual Home Decoration Indoor Scene Automatic Reconstruction System Based on Three-dimensional Vision

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Abstract: Because indoor scenes are structured, even small errors can lead to obvious visual differences in image-based indoor scene automatic reconstruction. Aiming at the specific requirements of automatic indoor scene reconstruction in virtual home decoration, this paper designs an automatic indoor scene reconstruction system based on image, including the calibration of image acquisition platform, the matching and reconstruction of feature features and feature lines, and the fusion of reconstruction results from multiple perspectives. In the overall optimization of reconstruction results, feature features and feature lines are integrated. The system is convenient and practical, and can get better reconstruction results.

1. Introduction
At present, the three-dimensional modelling of indoor scene is mainly based on laser scanning method. Because of the regularity and structure of indoor scenes, the 3D modelling of indoor scenes based on images usually needs human-computer interaction, such as selecting several planes or specifying several key points. The self-developed image acquisition platform can automatically complete the three-dimensional modelling of indoor scenes and achieve the fusion of reconstruction results from multiple perspectives on the premise that the camera internal parameters have been calibrated. For 3D reconstruction based on image sequence, the final bundling adjustment is an indispensable step. At present, the bundling adjustment technology only optimizes the three-dimensional spatial points and camera parameters. Mixing the reconstructed spatial lines, spatial points and camera parameters can effectively improve the effect of indoor scene reconstruction.

2. Automatic calibration of acquisition platform

2.1 Introduction of image acquisition platform
Aiming at the requirement of virtual indoor scene reconstruction, an image acquisition platform is developed as shown in Figure 1. The platform connects the camera with the rotating platform through a movable handle. The movable handle can adjust the attitude of the camera and the rotating platform, and control the rotating platform to realize the planar rotating motion of the camera. The platform bracket can rise and fall freely. The controller can read the rotation angle of the rotating platform. The error of each rotation of the device is less than 0.02 degree, and there is no accumulated error.
2.2 Automatic calibration of acquisition platform

Figure 2 (a) shows a schematic diagram of the planar rotation motion, in which \( d \) represents the distance from the camera's center of light to the axis of rotation, and \( \mu \) represents the turntable angle. When the camera rotates in plane, if the rotation angle is small, the baseline between the cameras before and after rotation is short. At this time, the result of three-dimensional reconstruction is poor. If the rotation angle is large, the common field of vision of the camera before and after rotation will be very small, and the matching points between images will be significantly reduced, and the matching points will be concentrated on the image edge. Figure 2 (b) shows a schematic diagram of the axial motion, in which \( T \) represents the axial translation vector and \( \alpha \) represents the axial pure rotation angle. In this way, there are not only wide baselines but also enough matching features between the upper and lower cameras. In order to reconstruct the indoor scene of home decoration, the three-dimensional reconstruction of upper and lower image pairs is realized first, and then the registration of all viewpoints is completed by the horizontal layer.

3. Automatic matching and reconstruction of lines

For structured indoor scenes, the reconstruction of spatial lines is particularly important to maintain the shape and structure of objects. Line matching not only takes into account the depth constraints of indoor scenes, but also uses the structural information of scenes. Considering the influence of the motion of the acquisition platform on the performance of line matching, the system separates the reconstruction of horizontal line from that of vertical line.

3.1 Automatic extraction of vertical lines in space

Since the direction of the rotation axis of the system is basically parallel to the direction of the vertical line in space, and the direction of the rotation axis remains unchanged when the system moves, the back projection plane corresponding to the space line is parallel to the rotation axis. As shown in Figure 3, if the parameters of the system are \( K \) and the equation of the image line is \( l \), the normal vector of the back projection plane can be expressed as \( n = KTl \). Using this property, the reliability of spatial line extraction can be improved.
3.2 Automatic matching and reconstruction of horizontal lines

After separating the vertical line images, in order to obtain more matching numbers and better reconstruction effect, the axial motion of the platform is used to match and reconstruct the horizontal line for the retained line images. As shown in Fig. 4, since the normal direction of the horizontal plane of space is parallel to the axis of rotation, if the horizontal plane of space is stratified along the normal direction, the single strain between the image planes induced by each layer is replaced by:

\[ H_i = K R + T_a T_d i K^{-1}, \quad i = 1, 2, \ldots, n \]

Among them, \( K \) is the camera internal parameter, \( R, T \) is the calibrated axial motion parameter, \( a \) is the calibrated system rotation axis direction, \( d_i \) represents the depth along the normal direction.

Because only the lines in the horizontal plane are matched, the mismatched lines can be removed even from the two images, and the depth information of the spatial lines can be obtained at the same time.

3.3 Automatic matching and reconstruction of vertical lines in space

Because the axial rotation angle is small, it is difficult to reconstruct the vertical line from the axial motion. The reconstruction of vertical line in space is realized by plane rotation motion. The matching of vertical line is the same as that of horizontal line. Thus, single strain transformation can remove the mismatched line in vertical direction and obtain the depth information of vertical line in space. For horizontal and vertical lines in space, the single strain transformation mentioned above makes use of the depth information and the structure information of spatial lines, so it can basically remove mismatched lines.

4. Fusion of point and line features

After the parameterization of spatial lines is completed, the reconstructed quasi-dense three-dimensional points, spatial lines and estimated motion parameters are optimized as a whole. The strategy of alternate optimization is adopted. Firstly, the system motion parameters are kept unchanged, and the three-dimensional space points and space lines are optimized and updated. Then, the three-dimensional space points and space lines are kept unchanged, and the system motion parameters are optimized and updated. For the optimization of space straight line, the strategy adopted is to minimize
the distance from the end point of matching straight line segment to the re-projected straight line. The test results show that the system has a good 3D reconstruction effect, and can basically meet the actual application requirements of the automatic reconstruction of the indoor scene of the home decoration. Especially because of the use of vertical and horizontal line information, the visual effect of the reconstruction scene has been significantly improved.

5. Conclusions
This paper studies the method of indoor design virtual reality based on three-dimensional vision. The reconstructed indoor scene is intuitive and has good visual effect. It realizes high efficiency and high precision reconstruction of indoor three-dimensional virtual scene and has high application value. Aiming at the practical application requirement of indoor scene reconstruction in virtual home decoration, an automatic indoor scene reconstruction system is designed, including automatic calibration of image acquisition platform, automatic matching and reconstruction of image features and feature lines, and integration of point and line features. For structured indoor scenes, the system can automatically complete better scene reconstruction.

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