Real-time 3D Scene Reconstruction with Surface Optimization

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Real-time 3D Scene Reconstruction with Surface Optimization

INTRODUCTION

Real-time 3D scene reconstruction is to recover the structure of scenes from a sequence of images online. Many applications such as robot navigation, augmented reality and virtual reality require the ability to acquire 3D maps of the environment and to estimate the camera localization of this model.

PLATFORM

We designed a compact mobile robot system based on the NVIDIA Jetson TX2 Developer Kit as shown in Fig. 1a and the iRobot Create2 mobile robot base as shown in Fig. 1b. Modified 3-layer plates and standoff kits as shown in Fig. 1c are mounted on the drilled robot top case. The Jetson TX2 Dev Kit, the battery system and the RGB-D camera are mounted at the bottom, middle and top plate, respectively as shown in Fig. 1d.

METHODOLOGY

The proposed real-time 3D scene reconstruction and localization with surface optimization that can be divided into three steps: the pre-processing, camera pose estimation and surface optimization as illustrated in Fig. 2. The reconstruction system is based on pinhole camera model that requires that the camera is calibrated as shown in table:

Table: Kinect v2 intrinsic parameters

<table>
<thead>
<tr>
<th>Camera</th>
<th>( f_x )</th>
<th>( f_y )</th>
<th>( u_0 )</th>
<th>( v_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGB</td>
<td>1057.161</td>
<td>1057.241</td>
<td>965.920</td>
<td>547.472</td>
</tr>
<tr>
<td>Depth</td>
<td>364.518</td>
<td>364.493</td>
<td>252.595</td>
<td>208.973</td>
</tr>
</tbody>
</table>

The camera pose is optimized by:

\[
\xi^* = \arg \min_\xi \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{m} \|\mathbf{p}_j^i - \mathbf{K} \exp(\xi^\wedge)\mathbf{P}_j\|^2
\]

where \( \xi \) is camera pose in Lie-algebra and \( \wedge \) represents mapping from vector to matrix.

Employing the calibrated camera intrinsic parameters, combining the RGB and depth images with the estimated camera extrinsic parameters, a dense point cloud model is reconstructed in real-time.

RESULTS

Fig. 1. Reconstruction system hardware

Fig. 2. Flowchart of the reconstruction system