Probabilistic Voxel Mapping using Stereo Matching Confidence

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Abstract - There has been meaningful research into the development of 3D world modeling techniques that are important requisite for intelligent vehicle navigation. In this paper we describe a 3D probabilistic voxel mapping process using stereo matching confidence. Proposed 3D probabilistic voxel map is more reliable representation than general voxel map that just contains the occupancy information. To get the matching confidence value, we evaluate stereo matching costs and its propagation. We test the proposed method in large-scale outdoor environment.

Keywords - probabilistic voxel, 3D world model, matching confidence, intelligent vehicle.

1. Introduction

The 3D world model of environment is important to the development of several applications of intelligent vehicle navigation. If we can get a suitable 3D world model of target environment then we can use that for real world navigation.

There exist a variety of approaches to generate 3D point cloud world models using stereo vision. S. J. Kim, et al. proposed a method that generates a robust vision based 3D world model by switchable stereo matching technique [1]. They also proposed a method that improves a vision based 3D world modeling result using an LRF (Laser Range Finder) disparity image [2]. P. Mordohai, et al. have discussed an approach for automatic 3D reconstruction of urban environment using computer vision technique [3]. The stereo vision based world models that represented 3D point cloud form need large memory and contain stereo errors. Therefore, it is necessary that the 3D world model of environment be represented by more compact and efficient form like as voxel map.

While most of the traditional range-sensor based voxel mapping approaches are focused on occupation in 3D space, the proposed stereo vision based approach is focused on reflection of stereo matching confidence. For this purpose, we suggested a 3D world modeling method that generates a probabilistic voxel map using stereo matching confidence.

The remainder of this paper is organized as follows. Section 2 presents a proposed method that generates a probabilistic voxel map. Section 3 describes experimental results in real environment. Conclusions and further work are discussed in Section 4.

2. Probabilistic Voxel Mapping

The proposed method is based on our previous works [1]. In the current approach, the 3D point cloud is transformed into probabilistic voxels for more compact and efficient map representation.

2.1 Stereo matching confidence

Stereo matching results contain matching errors. In the reconstruction process, these errors are represented as 3D point uncertainties. If the stereo matching confidence value is high then the 3D point uncertainty is low. For more reasonable stereo vision based mapping, uncertainty (confidence) modeling is important.

The confidence value of stereo matching is calculated by evaluation of stereo matching costs and its propagation. The left-right consistency (LRC) check is effective metric in occlusion detection. And the peak ration (PKR) is effective on poorly textured regions.

\[
C_{\text{LRC}}(x, y) = -[d_1 - D_R(x - d_1, y)]
\]

\[
C_{\text{PKR}} = \frac{c_{\text{min}}}{c_1}
\]

In outdoor scene, the occluded and poorly textured regions are often appeared. So we suggested a combined confidence metric (\(\omega\) is weight factor). The proposed combined confidence is well performed in our outdoor experiment.

\[
C_{\text{combined}} = \omega \times \frac{|d_2 - c_1|}{c_1} + (1 - \omega) \times \frac{1}{|d_1 - D_R(x - d_1, y)|}
\]
2.2 Probabilistic voxel mapping

The confidence value of stereo matching is used to assign the probability of a relative voxel. If the voxel’s probability is higher than predefined threshold value then the voxel is determined as occupied voxel.

Method 1 : A decision method of voxel's occupancy

given: a set of probabilities of relative 3D points (N)
output: voxel's occupancy
if ( max( prob.(1~N) ) > threshold1 )
   occupancy = 1
else if ( mean( prob.(1~N) ) > threshold2 )
   occupancy = 1
end

3. Experimental Results

We tested proposed method in large-scale outdoor environment. Fig. 2 shows the experimental environment. The red line represents a data acquisition route.

3.1 Stereo matching confidence in real environment

The result of stereo matching (middle) and its confidence (bottom) is shown in Fig. 3. In the confidence image, the bright pixel means high confidence value.

3.2 Probabilistic voxel mapping

We performed probabilistic voxel mapping process using results of stereo matching and its confidence. An example is shown in Fig. 4. It is more compact representation of map and reflects stereo uncertainty.

4. Conclusions and Further Work

In this paper, we described a method that generates probabilistic voxel map. To calculate confidence value, we proposed a novel confidence metric. We tested the proposed method in large-scale outdoor environment.

To generate more compact and efficient probabilistic voxel map, it is necessary to analyze the proposed metric and the results in real environment. And the deal of dynamic objects should also be addressed further.

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References