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A Robust Camera Pose Estimation Method for an Inaccurate 3D Map

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***Abstract*— The camera pose estimation method is one of the most essential techniques for autonomous robot navigation. Based on 3D-to-2D correspondences between a 3D map and a query image, the 6-DoF (degree-of-freedom) camera pose is estimated. However, it is hard to estimate the camera pose robustly if the 3D map is inaccurate. In this paper, a robust camera pose estimation method is proposed for an inaccurate map by employing Mahalanobis distance. The proposed algorithm is demonstrated through simulations and experiments.**

I. INTRODUCTION

The Structure-from-Motion technology is widely utilized for the camera pose estimation [1]. The conventional method [2] solves PnP (perspective-n-point) problem by minimizing residual error of correspondences. However, the conventional method does not consider uncertainty of the correspondences. In this paper, a novel camera pose estimation method is proposed by considering uncertainty of the map using Mahalanobis distance.

II. THE PROPOSED METHOD

To estimate camera pose, a map consisting of 3D probabilistic features is generated in advance. Let (X_j, C_j) and (x_j, c_j) denote 3D probabilistic points on the map and their projected points onto an image plane, respectively, where X_j is a 3D point, C_j is its covariance, x_j is a projected 2D point,and c_j is its covariance. Fig. 1 illustrates the concept of projection of the map onto the image plane. As the projection transformation is non-linear, a Jacobian method at the spherical coordinate system is employed for linearization. Based on the known 3D-to-2D correspondences, Fig. 1 shows the projected 3D probabilistic points onto the image plane (x_j, c_j) and matched correspondences, $\bar{x_j}$, from a query image. The proposed method estimates the camera pose of the query image by minimizing Mahalanobis distance error between (x_j, c_j) and $\bar{x_j}$ on the image plane. To minimize of the error, non-linear optimization for 6-DoF variables is performed. The conventional PnP method is utilized for getting an initial pose in non-linear optimization. To remove mismatching results, null-hypothesis is employed by restricting the maximum Mahalanobis distance error during the optimization process. Through optimization process for 6-DoF variables, the camera pose is estimated by considering uncertainty of matching correspondences.

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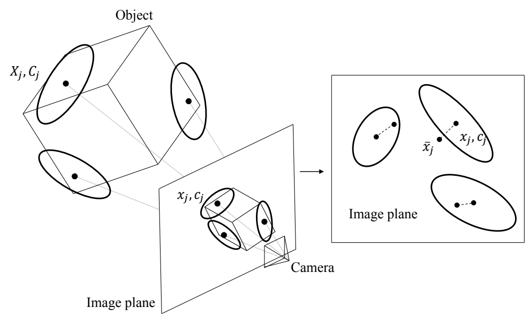

Fig. 1. Concept of the projection results of uncertain objects and its projected results onto the image plane.

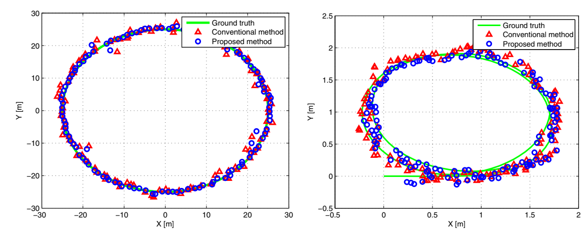

Fig. 2. The results of conventional and proposed method for simulations (left) and experiment (right).

III. RESULTS AND CONCLUSIONS

The proposed method was demonstrated through simulations and experiments. Fig. 2 and Table I show comparison results of the conventional and the proposed method, where the superiority of the proposed method is verified.

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[2] X. S. Gao, X. R. Hou, J. Tang, and H. F. Cheng, H. F. “Complete solution classification for the perspective-three-point problem,” IEEE Trans. on Pattern Analysis and Machine Intelligence, vol. 25, no. 8, pp. 930-943, 2003.

TABLE I

COMPARISON RESULTS OF CONVENTIONAL AND PROPOSED METHODS. (UNIT: M, DEG)

	Conventional PnP algorithm		The proposed algorithm	
	Simulation	Experiment	Simulation	Experiment
x	0.634	0.281	0.292	0.224
y	0.714	0.254	0.279	0.208
z	0.801	0.022	0.706	0.024
θ_{roll}	1.368	0.586	1.227	0.788
θ_{pitch}	1.527	0.650	1.273	0.679
θ_{yaw}	1.070	4.978	0.493	2.042