Towards Accurate Deep-Sea Localization in Structured Environments based on Perception Quality Cues

Extended Abstract

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ABSTRACT

In recent years, the number of maritime exploration and exploitation activities has rapidly increased, and with it the necessity to perform more complex tasks underwater, e.g., floating manipulation and mapping with Remote Operated Vehicles (ROVs). The first step to perform these activities in a reliable manner, is to obtain an accurate robot localization estimate. Localization approaches based on multi-robot systems or complex acoustic infrastructures have been favored in the literature, but alternatively visual modalities are pursued when these options are not feasible. In this work, we present a two-stage navigation scheme that initially generates a coarse probabilistic map of the workspace that is used to refine localization accuracy and filter noise in the second stage. Additionally, an adaptive decision-making approach is introduced that determines which perception cues to incorporate into the localization filter, i.e., tracked 2D features or plane representations, to ensure high accuracy and reduce computation times. Our approach is thoroughly investigated in simulation and validated with deep-sea field trial data originated from oil & gas commercial operations.

KEYWORDS

Localization; Navigation; Marine robotics; Field robotics; Multimodal perception; Adaptive behavior; Long-term autonomy

ACM Reference Format:

1 INTRODUCTION

In the present work, we propose a navigation scheme that uses visual odometry (VO) methods based on stereo camera imagery [5] and an initial probabilistic map of the working space to boost localization accuracy in challenging conditions. As an example, we use the EU-DexROV project [1, 2, 4] in which the final objective is the monitoring and dexterous manipulation of an oil & gas panel (Fig. 1). However, the nature of underwater scenarios where the light behavior produces low contrast, blurred and color attenuated images highly impacts the performance of VO approaches.

To solve this, we combine plane registration and feature tracking methods to obtain odometry values. 3D planes are extracted from dense point cloud (DPC) generators which produce complete disparity maps at the cost of depth accuracy, but their density is key to find reliable 3D planes. This is useful in structured environments which predominantly contain planar surfaces that can be represented as plane primitives to reduce localization drift. Likewise, a decision-making strategy based on image quality is used to select which visual odometry method to perform in order to obtain more reliable measurements and improve computation times.

Figure 1: ROV performing oil & gas valve manipulation.
2 METHODOLOGY

Figure 2 illustrates the proposed two-stage navigation scheme:

**First stage - Workspace definition with loose localization**

1.1. Approach the target until its global 3D pose is determined with confidence based on a priori knowledge; see Fig. 2(a).
1.2. Navigate using odometry from navigation sensors and visual landmarks (baseline localization); see Fig. 2(a)(b).
1.3. Compute a probabilistic map from stereo input of the target while navigating based on the odometry uncertainty; see examples in Fig. 2(c).

**Second stage - Optimized localization**

2.1. Evaluate the quality and reliability of the visual input, i.e., stereo imagery, based on image quality measures (Fig. 2(h)) and determine which of the next VO modalities to use to extend the localization inputs:

2.2.a Extract planes [8] from dense point clouds [3], filtered using the probabilistic map computed in the first stage to avoid huge drifts and noise artifacts as shown in Fig. 2(g).
2.2.b Extract/track 2D features from imagery; see Fig. 2(f).
2.3. Compute VO either from plane registration [7] or feature tracking [5] depending on the image quality assessment (IQA) [6] and integrate the results into the localization filter.

3 EXPERIMENTAL RESULTS

Using the IQA to decide which VO inputs to integrate into the localization filter (EKF-adaptive) reduces the pose error and increases the smoothness of the followed trajectory. Simply integrating all odometry inputs (EKF-all) does not boost performance as the kalman filter does not reason about the quality of the sensor data except for examining the inputs covariance matrix, see Table 1(b). Table 1(a) shows the higher computational costs of the plane-based VO.

<table>
<thead>
<tr>
<th>VO-ORB</th>
<th>VO-planes</th>
</tr>
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<tbody>
<tr>
<td>CPU [%]</td>
<td>3.2</td>
</tr>
<tr>
<td>GPU [%]</td>
<td>0.1</td>
</tr>
<tr>
<td>Time [s]</td>
<td>0.145</td>
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</tbody>
</table>

(a) Computation performance

<table>
<thead>
<tr>
<th>EKF-all</th>
<th>EKF-adaptive</th>
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</thead>
<tbody>
<tr>
<td>Translation [m]</td>
<td>0.73 ± 0.38</td>
</tr>
<tr>
<td>Orientation [°/sec]</td>
<td>8.93 ± 4.22</td>
</tr>
<tr>
<td>Autocorrelation (Smoothness)</td>
<td>0.92</td>
</tr>
</tbody>
</table>

(b) Pose error and trajectory autocorrelation [4]
REFERENCES


