SLAM Algorithm for ArUco Landmark Array Based on Synchronization Optimization

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High precision mapping algorithm is the core of two-dimensional(2D) landmark array(the ArUco landmark is used in this paper) localization application. In most of the existing mapping algorithms, the accumulated errors of online methods can not be eliminated, meanwhile, the manual calibration and off-line methods are inefficient and time-consuming. In order to overcome those shortcomings, a real-time simultaneous localization and mapping(SLAM) algorithm for landmark array based on synchronized optimization is proposed in this paper.

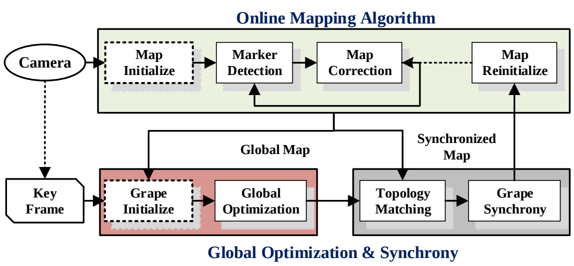

Fig. 1. ArUcoSLAM Framework

Fig.1 shows the proposed synchronized optimization framework. The online mapping updates and corrects the global map in real time, meanwhile, the key frame sequence is captured during the online mapping process. The global optimization uses the map generated by the online mapping tread as the initial pose graph to optimize the accumulated errors. Finally, the optimized map is synchronized to the global map. In order to verify the performance of the proposed algorithm, several comparison experiments are presented in this paper and the results show that the proposed algorithm achieves high-precision map and real-time localization.

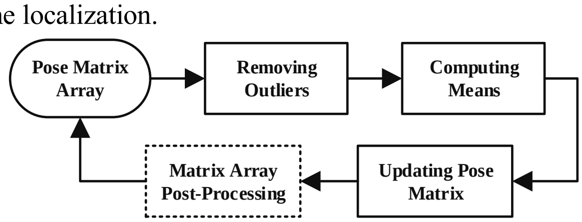

Fig. 2. Flow Chart of the Online Mapping Algorithm.

In order to realize the online mapping and correction the following algorithm is shown in Fig.2. The coordinate system {n} is initialized by the first recognized landmark. The new landmark's pose is estimated based on the CPT method. Ideally, the camera's pose in {n} calculated by any landmarks should be consistent. Thus, the pose of the landmark can be estimated by the existing landmark's pose when they are recognized in one frame. For the global optimization, it is optimized by minimizing the re-projection error of the landmarks' vertexes and the optimization problem is given as follows:

$$
\begin{aligned}
& \min \sum \left\| \boldsymbol{t}^{*} - \boldsymbol{t}^{'} \right\| \\
& \text{s.t.} \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (1) \\
& \boldsymbol{v}_k = \boldsymbol{R}^{*}_{k,k+1}(\boldsymbol{R}^{*}_{k+1,j+2}(\ldots(\boldsymbol{R}^{*}_{k-1,k}\boldsymbol{v}_k + \boldsymbol{t}^{*}_{k-1,k})\ldots) + \boldsymbol{t}^{*}_{k+1,k+2}) + \boldsymbol{t}^{*}_{k,k+1}
\end{aligned}
$$

In order to verify the overall performance of the proposed algorithm three simultaneous localization and mapping experiments are carried out, which prove the proposed system can update and correct the global map online. By comparing with the existing mapping system, the experiment results verify that the proposed algorithm has the ability to update and optimize the map online while ensuring the real-time camera localization.

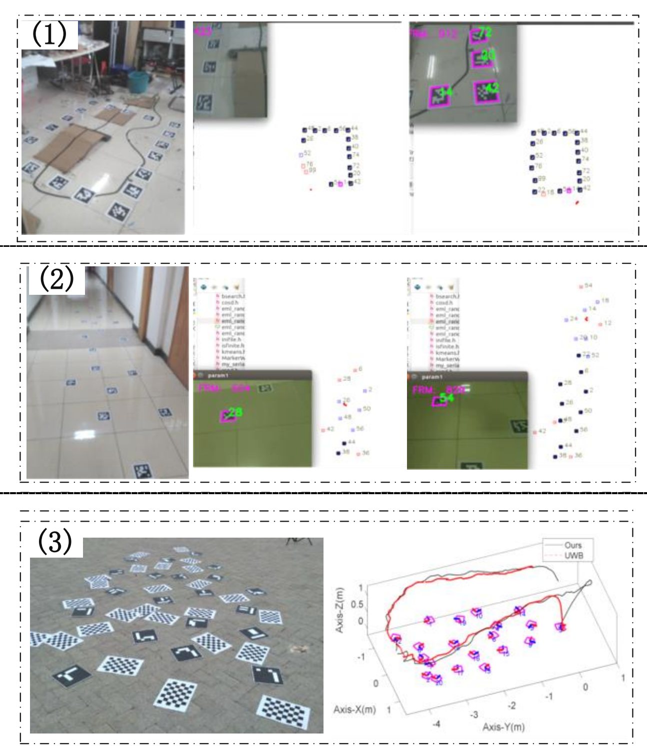

Fig. 3. Simultaneous Localization and Mapping Experiment.