Summary:: SPM-SLAM: Simultaneous Localization & Mapping with Squared Planar Markers

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I. Introduction

SLAM has the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it (estimating the camera pose at the same time).

Problem: Distributing a set of markers printed on a piece of paper, authors estimated the marker poses from a set of images, where at least two markers are visible in each image. Black border binary coded map is drawn. Then, camera localization is done in correct scale. Visual SLAM has errors due to insufficient no. of markers, expansion of map is not possible, cannot be employed in real time, errors cannot be determined until whole process is finished. Also, Visual SLAM methods which is based on key point descriptors or texture.

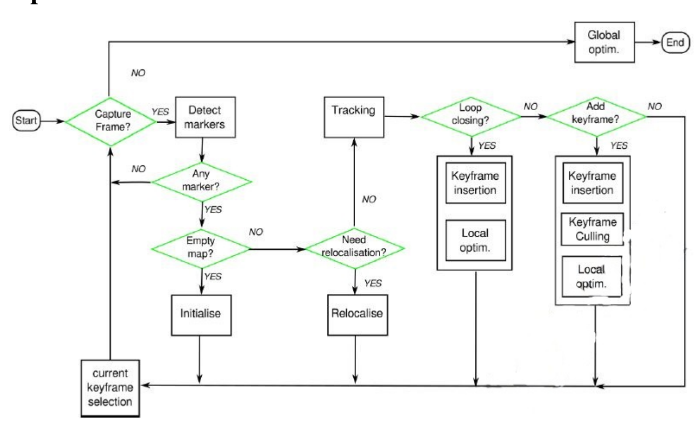
Cause: Natural features gives high degree of performance but have several real time problems like textures, viewpoints changes and repetitive patterns, scale agnostics, rotational movement requirements for the map. The corners of a single/group of markers can be employed for camera pose estimation but is limited to small areas. In practice, two solutions appear (ambiguity:unknown reflection of the plane about cameras z-axis), due to noise in localization of the corners, sometimes it is impossible distinguishing correct one.

Proposed Solution: This paper proposes a complete system enabling us to dynamically build a map (by initializing frames) of the markers and simultaneously localizing with the camera pose from a video sequence using just the information of camera w.r.t. an arbitrary reference system (g.r.s) from fiducial planar markers. By Experimentation, authors proved that their method deals ambiguity problem besides spotting marker poses/locations in the g.r.s effectively. Refer fig.1. Re-projection errors are then compared, the one with lowest error is taken as correction solution. Imaging small planes strategy is explained. Then Refer fig.2,3&5 for geometrical representations and calculations. Moreover, this method removed restriction of Monocular Visual SLAM that fail under rotational movements by some degree of translation to reliably compute the essential or homography matrices. Explanations of other SLAM techniques by testing, tabulating, comparing the results and discussions on their drawbacks (using both natural features & fiducial markers based) were stated. Experimental Setup: *ArUco library, 150 Hz using a single thread executable computer. Printed Marker Map and Calibration Object(OpenCV based), Leica Laser Scanner*(Sect.5) *To evaluate the quality of their approach* 1) Accuracy in the estimation of the marker poses (calculating Absolute Corner Error with Horns method) and 2) accuracy in the estimation of the frame poses (Absolute Trajectory Error),were measured. It is a continuous mapping process. Refer Fig8, loop closures and 3D Reconstruction with a were emphasized.(Sect 5.5).

II. Methodology

Here, authors provides a quick reference guide to notations (Refer fig.3), initial mathematical concepts, data structure for operational information and control loop. Refer Sect. 3.1 for notations. Transforming 3D point to 2D point (eqn.5), for square fiducial markers re-projection error of a marker is explained in initial concepts (Sect.3.2). Considering the rotation ambiguity, eqn.12 is the possible solution. It occurs when the ratio of projection errors is near to one. When the error ratio is above a threshold the solution is unambiguous(eq.12) and thus a reliable indication of the maker pose w.r.t. to the frame. Using information from either multiple markers or multiple views authors also proposed methods to deal ambiguity. System map is expressed in Sect. 3.3. *Test Difficulties:* 1) Repeated observations to estimate the pose and validation. 2) Marker poses - Continuous Optimization along the video sequence, 3) Registration of information for Map for visited frames called key-frames. A flowchart describes the marker-based slam *(Refer Fig.4 from now on)*

Operational Overview:



The Flow-Chart above represents Pipeline for Marker-based SLAM. It is Fig.4 observed in the paper. *Detailed system description with mathematical expressions and figures were explained clearly in Sect.4 of the journal.*

III. Conclusion

This work uses an input a video sequence shows markers placed at arbitrary locations of the environment, this system incrementally builds a precise map of the markers with correct knowledge of the scale and determines at the same time the camera pose. As output, it allows to create cost-effective and large-scale tracking systems able to operate in real-time with minimal computational requirements. This paper deals with no. of inherent ambiguities occurred when using SPM.

IV. Opinion

This technique is effective due to the fact that it gives online solution, in which the map (of marker poses in key-frames) is built incrementally as video frames are captured. Considering Absolute Trajectory Error, when compared to ORB-SLAM and LSD-SLAM, SPM-SLAM is much better and reliable. Because, unlike other methods, this method can construct scenes with trajectories with minimum ATE error besides detecting loop closures properly. Due to rapid frame capture with fixed camera poses and repetitive calculation of fiducial markers in key-frames this method may exhibit time complexity and less adaptive in real-world outdoor environments.

V. Future Work

This paper allows to mix natural features with fiducial markers. Enabling to use the markers whenever they are seen avoiding excessive markers by using key-points. Then, to develop a model that analytically describes the type of errors present in squared planar tracking in order to assists placing the markers. Recently, authors of this paper published UCO-SLAM paper to extension of SPM-SLAM (on 11th Feb 2019).