Multi-Agent Autonomous Mapping of Unknown GPS-Denied Environments Using a Relative Navigation Framework

Jacob M. Olson[1], Timothy W. McLain[2] [TODO: include Matthiew Labbe?]

***Abstract*—[TODO: write the abstract]**

I. Introduction

The remainder of the paper is organized as follows: Section II describes framework used to map the environment and background on what previous work has made this research possible. Section III details the planning and control schemes used to successfully navigate the unknown area. Then method used to combine maps of multiple agents are then explained in Section IV. Results showing and evaluating the generated maps are presented in Section V. Finally, conclusions are presented in Section VI.

II. Technical Approach

A. Problem Statement

The goal of

B. Sensors

Since we are operating in a GPS-denied environment, we are not able to rely on GPS measurements to give us global information about where the UAVs are located. As shown in Fig. 1 the sensors used by the UAV to estimate its state are an RGB-D camera, a planar laser scanner, a LiDAR pencil-beam sensor and an IMU on the onboard flight controller. [TODO: how much do I talk about sensors here?]

C. Estimation

Estimation is the most critical element in enabling autonomous flight. Without good position and attitude estimation, autonomous navigation algorithms do not function.

1) RTAB-Map: RTAB-Map is a powerful open source library that uses graph-based SLAM with appearence based loop closures to generate high-quality, dense 3D maps of environments without the use of GPS. As part of this is able to accurately estimate position within the map with little error. This has been extended to work with multi-session mapping, but currently not simultaneous multi-agent mapping. This paper proposes a method to extend the functionality of RTAB-Map to combine the maps of multiple agents into a single map in near real time.

RTAB map does not estimate the attitude of a UAV with enough frequency to autonomously navigate so we used the relative navigation framework to estimate attitude and relative state.

2) RMEKF: the RMEKF was shown to successfully estimate the UAV's state sufficient to autonomously navigate in GPS-denied environments that had been previously mapped, but has thus far not been extended to estimation and navigation in unknown and unmapped environments, this paper proposes a method to extend the functionality to these environments.

D. Control

E. Inputs/Outputs

III. Planning

A. Global Goal Following with Relative Estimation

B. Reactive Path Planning

IV. Map Merging

V. Results and Discussion

VI. Conclusions

References

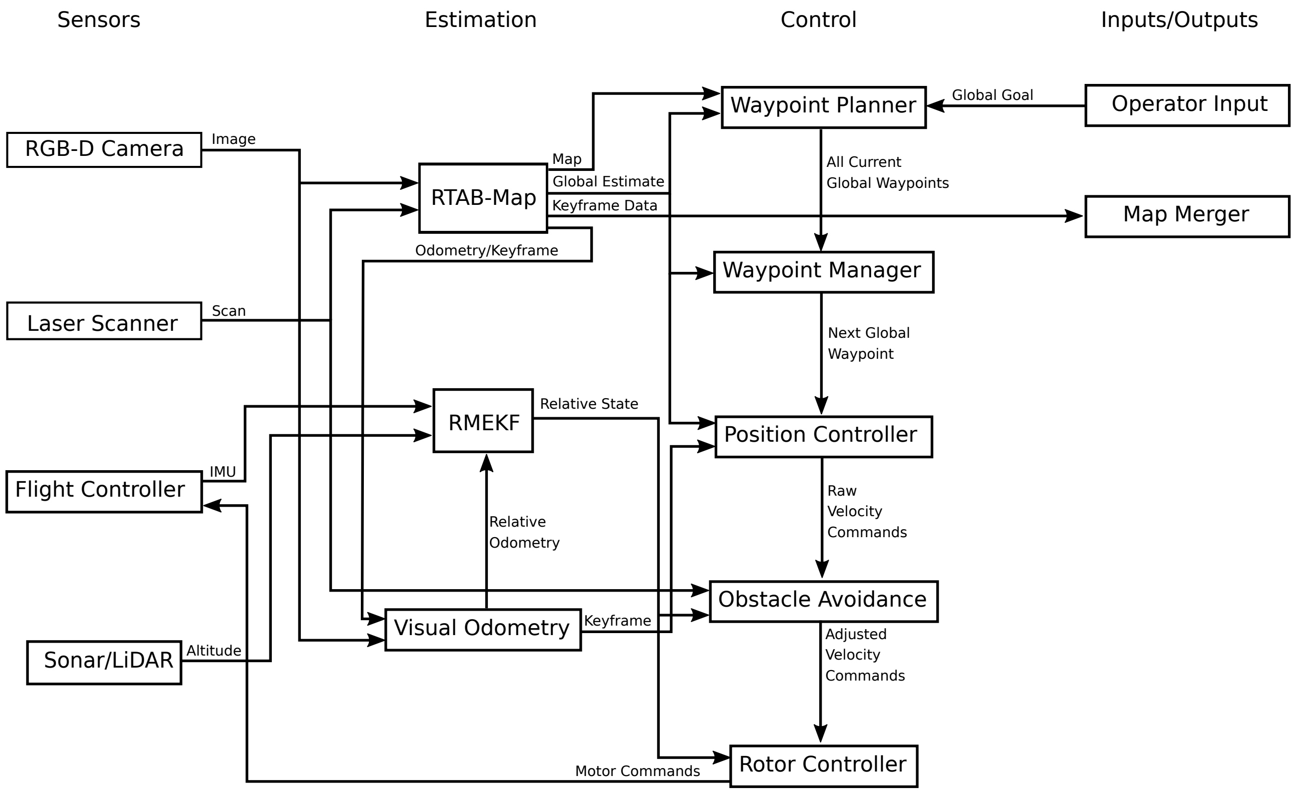

Fig. 1. The network diagram of the relative navigation framework proposed in this paper

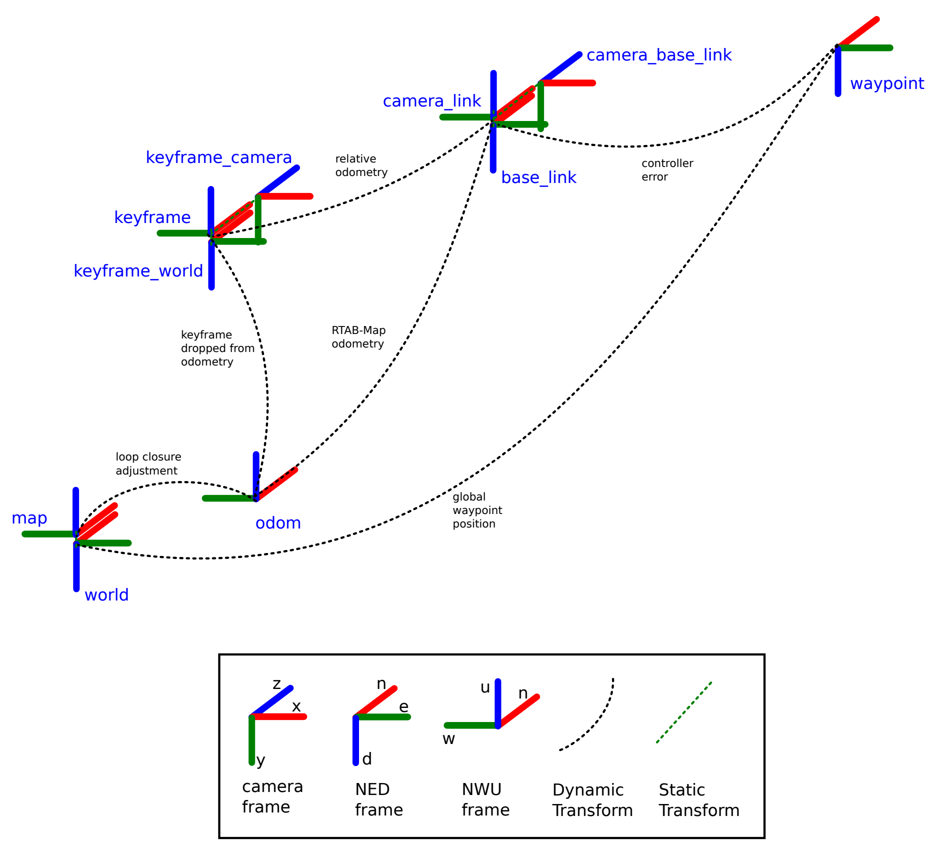

Fig. 2. The transformation tree of the reference frames used in estimation and control.

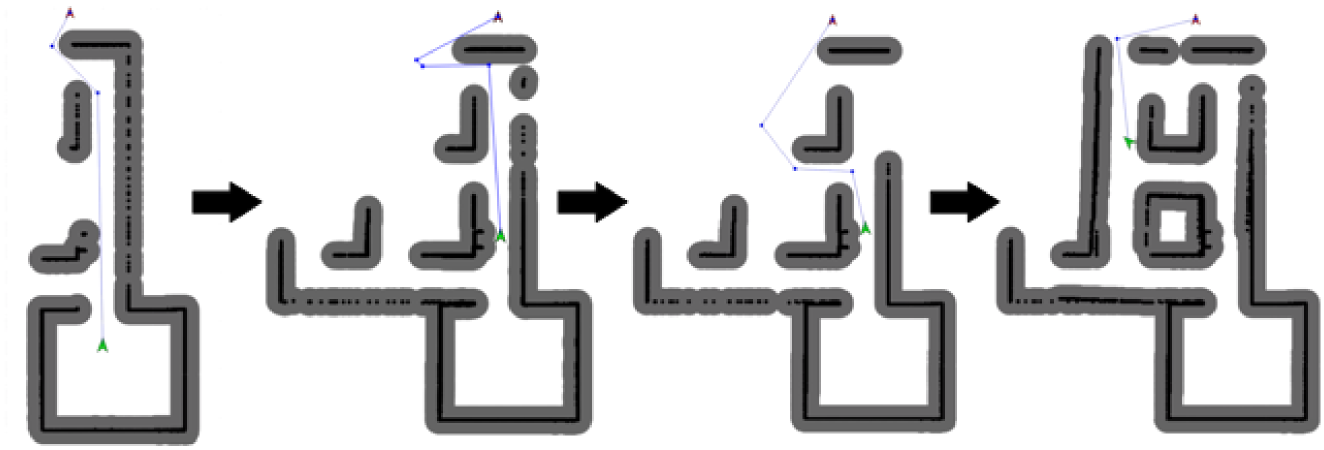

Fig. 3. An example of how the reactive path planner works as the UAV flies the planned path. The current extimated position is marked by the green arrow, the current goal position is marked by the red arrow, and the current path planned is marked with the blue lines. Detected obstacles with their respective safety buffers are represented with black and grey respectively.

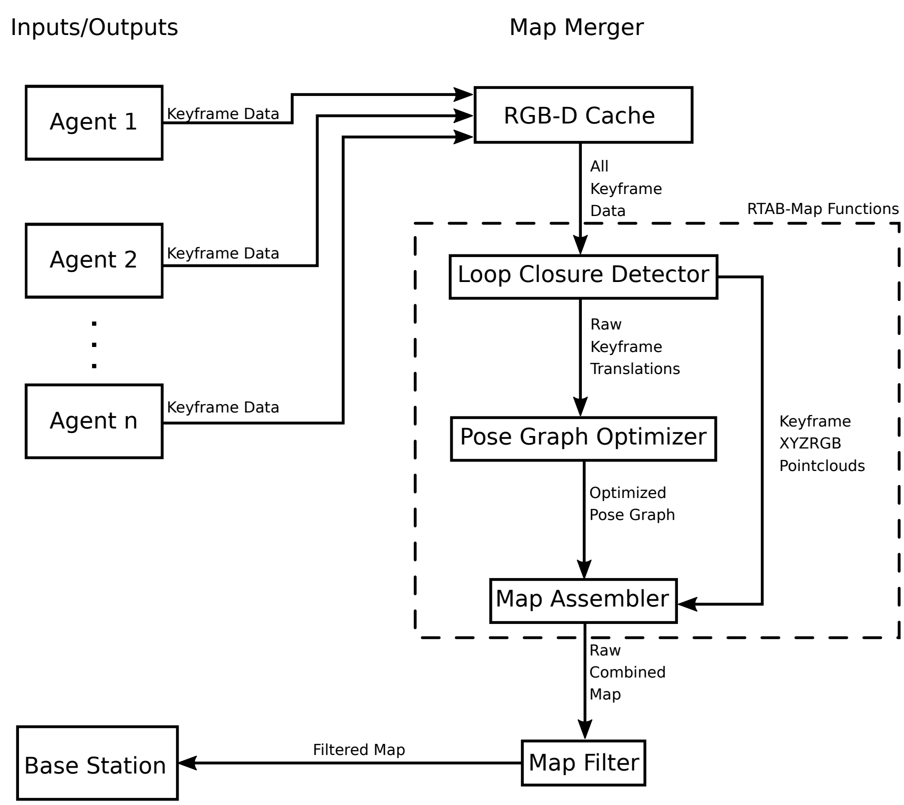

Fig. 4. The network diagram for the multi-agent map merging node proposed in this section.