Team F

Individual Lab Report 6

# Progress Review 7

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February 1, 2018

# 1 Individual Progress

My primary contribution to the project since the FVE is the development of an internal graph representation of the April Tag nodes. Specifically, for our project, we are representing all the "valid paths" in our use case by April Tags and thus a traversable paths is comprised for a sequence of April Tags. As a result, the ability for the drone to fly over these April Tags and piece together a map is a key component of our system. Initially, the plan was to simply take the output from April Tags ROS and feed it into TF2 transforms to construct a map of the April Tag. There are two main issues with this approach. First, at a flying height of 5-10m, the raw April Tag transforms are very noisy and concatenating noisy transforms is most likely not going to result in accurate localization at the extremities of the transform chain. In addition, the raw April Tag transforms are in reference to the drone and not with each other. However, the drone's location changes and thus it will not work for large areas where not all the April Tags can be seen at the same time. The work that I completed addresses these issues.

## 1.1 Graph implementation

To represent a graph, the adjacency list implementation in `boost` was used. The idea is to represent each April Tag as a vertex and connect all vertices that are less than 3m apart with an edge (this is a tentative constraint that we are imposing). The system is designed to be dynamic and scalable - there is no limit on the number of vertices that can be placed nor is there a requirement that the vertices be static (although for our purposes, most April Tags don't move).

At each iteration, the callback function goes through the list of transforms provided by the AprilTag ROS node. It matches each April Tag to a vertex and creates one if it doesn't exist. It then goes through each pair of vertices and checks for an existing edge, also creating one if it doesn't exist. This edge represents the transform between the two April Tags and is calculated by concatenating the transform from the first Tag to the camera and the camera to the second Tag. Importantly, this removes the dependency on the camera. The existing transform is updated with the new transform via a low pass filter ($t_i = \alpha x_i + (1-\alpha) t_{i-1}$). Careful handling of the transforms is required as although the edges are inherently undirected, the transforms specify a direction.

At this point, the system has built an undirected graph of the April Tags. The next step is to broadcast each transform so that TF2 can create a tree of the nodes. However, as the constructed graph is not a tree and may contain cycles (TF2 will not work with transforms that result in cycles), it is necessary to first create a tree from the graph. At the moment, a naive depth-first implementation is used to construct a tree. It is noted that this may not be the most accurate solution. An inherent issue with the graph design is that because the transforms are noisy, the transform from A-B-C is not necessarily the same as A-D-C. Ideally, we want to create a tree such that the total error between different paths is minimized.

Two figures are shown below. The first is a panoramic view of the B-Floor in NSH with a chain of April Tags. A drone was flown (or in our case, we held it in our hands) over them and generated an internal graph of the April Tags. Figure 2 shows the TF tree of the graph.

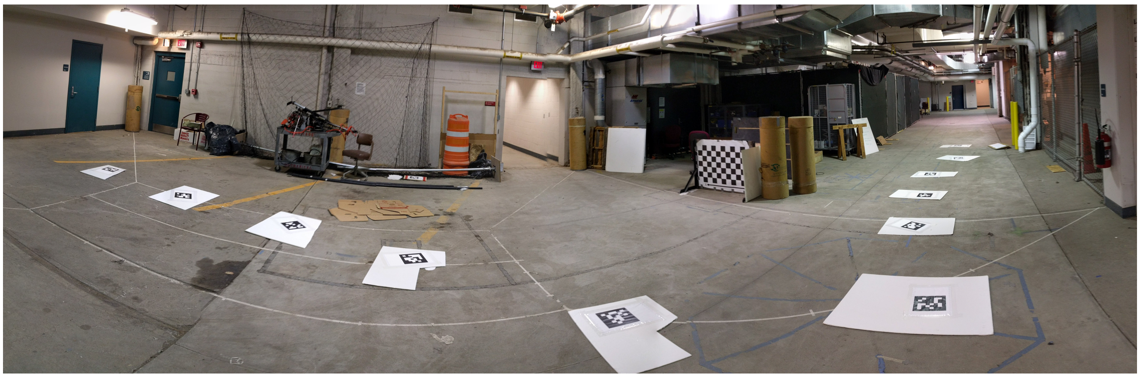

Figure 1: Panoramic view of April Tags

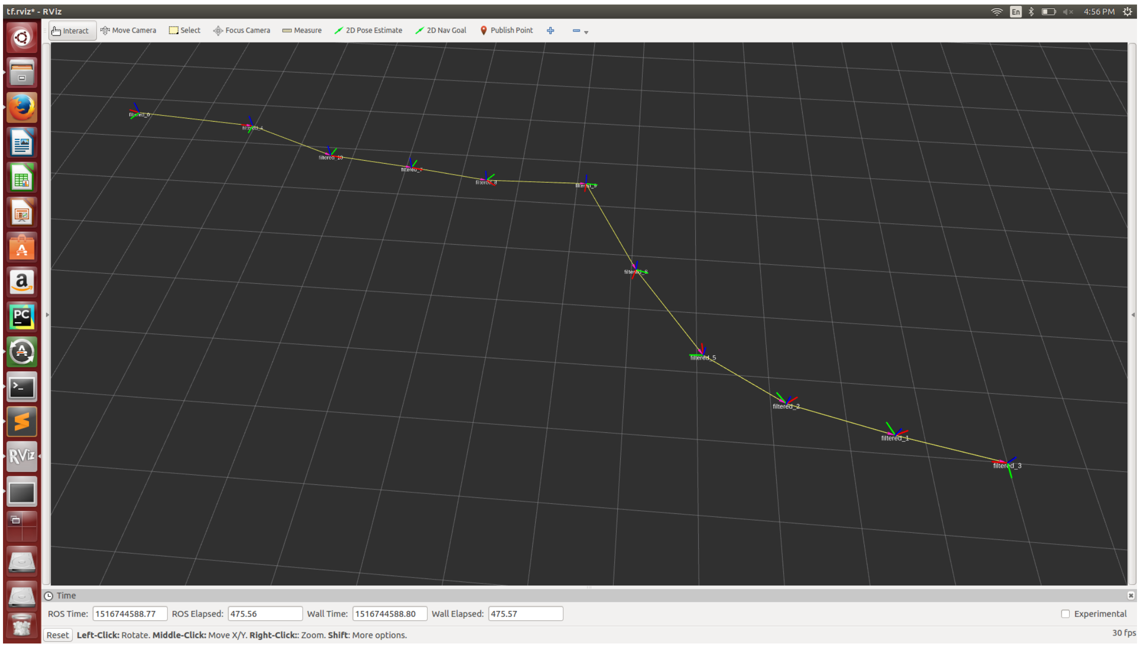

Figure 2: TF representation of April Tags

## 2 Challenges

The biggest challenge for this progress review was designing and choosing an implementation that would allow us to dynamically map an area simply from using April Tags. Although this was discussed briefly earlier, I will enumerate some of the other options that were considered along with their flaws.

- Simplest solution is to simply daisy chain the individual transforms obtained from the April Tags node. At each time step, we can calculate the relative transform between any two April Tags and broadcast that to the TF engine. The problem is - as described earlier - the lack of a stabilization process for the April Tags and the creation of cycles. TF will simply not work with cycles. As well, consider that we have a chain of Tags from A-B-C-D-E-F. Any instability in the link from A-B will cause significant instability in the transform A-F.
- We can also map GPS coordinates to each April Tag. This will enable us to create a global map that does not depend on the relative transform between successive April Tags. This is another possibility that we are considering. The first problems with this approach is that the drone's GPS

signal is significantly less accurate than the localization obtainable from April Tags. In addition to short-term inaccuracy, there is also long-term drift. The second issue is that GPS requires us to be outdoors. While we plan to be outdoors eventually, it is much easier for us to test indoors. Nevertheless, we do plan on incorporating the GPS to help localize in the future. Using only April Tags runs into the problem of losing localization if the April Tags were to drift out of the field of view.

- Use a predefined April Tag sequence such that only transforms for A-B, B-C, C-D (etc...) will be broadcasted. This solves the cyclic issue described earlier. Unfortunately, this places a heavy assumption on our system and as our PhD mentor pointed out, it doesn't allow for a fair comparison. We would like the system to be general and work regardless of how we place the April Tags.
- Instead of representing valid paths with April Tags, we can represent obstacles instead. This was an idea that was brought up as an alternative. It would have more work to implement as the path planning is more open-ended. We are considering this as a possible upgrade if we manage to finish our project early and are looking for an extra challenge.

In terms of technical difficulties, the main challenge was getting `boost` to work. We wanted to use an undirected graphical model since the relation between two objects is inherently bidirectional. The transform from A-B corresponds to a unique transform B-A. However, there is still directionality involved (A-B $\neq$ B-A). Some work was necessary to ensure that the graph recognized both directions.

# 3 Team work

My teammates focused on solving the issues that were encountered during FVE. Danendra and Pratibha worked on solving the IMU issues by using a new Arduino-based IMU. This IMU normally only works when connected to the Arduino but we found an ROS package with an Arduino firmware update. In addition, Danendra worked with the Ubiquiti Bullet network module to test its effectiveness. We borrowed a version from Shivang for this purpose. He was able to set it up as a wireless access point and we were able to test its range on B-Floor. Pulkit and Rahul worked on showing point cloud data with the Puck. They were able to run the PCL ROS package and show the point cloud in real time on the computer. Pratibha also backed up our minipc as an insurance for unforeseen accidents in the future.

# 4 Future plans

We need to focus on the AGV for this semester. The UAV has been flying well and much of the infrastructure relating to localization with April Tags is complete. The only part left for the UAV is the path planning and search functionality and that requires collaboration with the AGV to fully achieve. As a result, we will work mostly on the AGV for the next PR. Rahul and Pulkit will begin by classifying the point clouds as obstacles and segmenting them into individual objects. Then they will be implementing a local planner for the AGV that will see the obstacles of a certain size and avoid them. Danendra and Pratibha will continue their work with the IMU and fully integrate it onto the Husky. I will stay on the Bebop2 and begin implementing a tree search algorithm that will continuously expand the node closest to the target. In addition, I will look into solving the glare issues seen with April Tags in outdoor environments.