COMPARING ACCURACY OF OPEN SOURCE VS. PROPRIETARY LOCALIZATION SOFTWARE

A STUDY BY:

CLEARPATH
ROBOTICS™

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SUMMARY

This report is designed to show the results of testing of localization accuracy of the open source Gmapping SLAM technology, compared to the proprietary Autonomy Research Kit (ARK) available from Clearpath Robotics.

GMAPPING BACKGROUND

As the state of the robotics industry has progressed, the availability of autonomy software for mobile robotic platforms has increased. During this time, the primary benchmark for autonomy on ROS robots has been the standard Gmapping package, documented on the ROS Wiki, which is a wrapper for Gmapping from OpenSLAM. Gmapping has one of the most widely forked ROS Perception packages in existence, and is the default go-to method to start basic autonomy and SLAM work.

While the Gmapping method has been widely used for academic papers (with over a thousand references to it via Google Scholar) it has widely been acknowledged that while easy and widespread, it is not the most accurate method of localization for autonomy.

ARK BACKGROUND

In April 2016, Clearpath launched their OTTO Motors division, which focuses on autonomous material handling with the OTTO line of Self-Driving Vehicles. The OTTO platforms are comprised of both rugged, industrial mobile platform (including a sensor suite), as well as the in-house developed autonomy software. With one of the largest teams in the world dedicated to ROS development, the Clearpath/OTTO team has spent over a man-century optimizing this autonomy software for robust and efficient localization and mapping in real world deployments.

In 2017, Clearpath Robotics packaged this software into the Autonomy Research Kit (ARK); a black-box secured solution, which includes a dedicated SLAM computer, forward and rear facing LiDAR, and an API with documentation. Currently, ARK is only available on Clearpath Robotics' line of robotic platforms.

TESTING PROCEDURE

To determine how the two software compare, a test was devised that would pit their accuracy head-to-head. To begin, a Clearpath Robotics Husky UGV was selected as the base platform on which to run the software, and a Vicon motion capture system was set up with trackers placed on the Husky to capture high accuracy location data from the robot. For robot-side data collection, SICK LMS111 2D lidars were mounted to the front and rear of the UGV. Additionally, in order to demonstrate how the software performs on real field robots, the UGV that was selected has hundreds of hours of field runtime, which would result in the small amount of mechanical backlash as typically seen by UGVs which have endured a large number of missions.

Image 1: Husky UGV with qty 5 Vicon Markers

Image 2: Husky UGV with SICK LMS111 LIDAR

Four testing scenarios were investigated:

- Running both autonomy software simultaneously, with the robot manually controlled in a random formation.
- Running both autonomy software simultaneously, with the robot manually controlled in a rectangular formation.
- Running Gmapping, with the robot autonomously controlled.

- Running ARK, with the robot autonomously controlled.

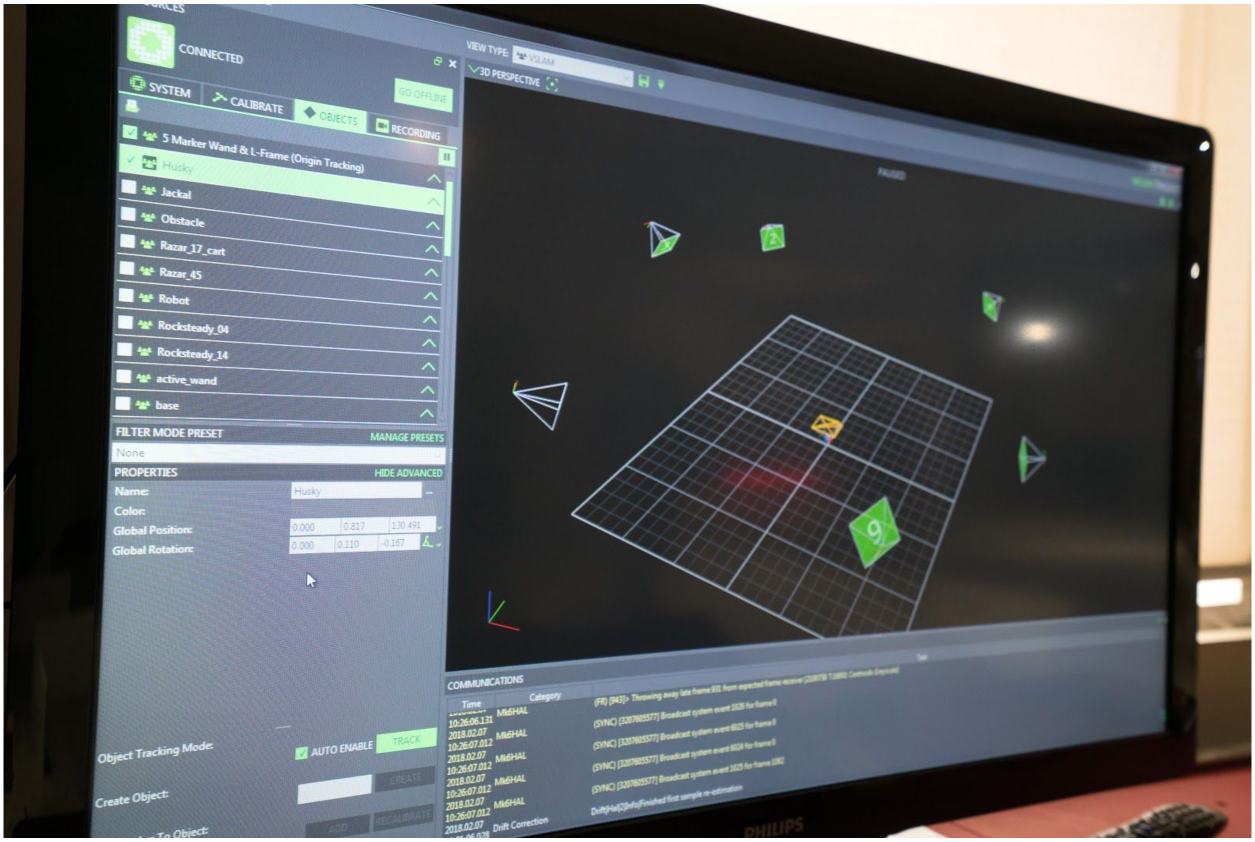


Image 3: VICON 6 Camera Motion Capture Visualization

In each instance, rosbags were collected, and (with the Vicon motion capture system data as a ground truth) localization data was compared in a Jupyter IPython notebook using NumPy, and visualized with Matplotlib.

TESTING RESULTS

In the spirit of succinctness, the above 4 tests will be presented as 2 overarching scenario results:

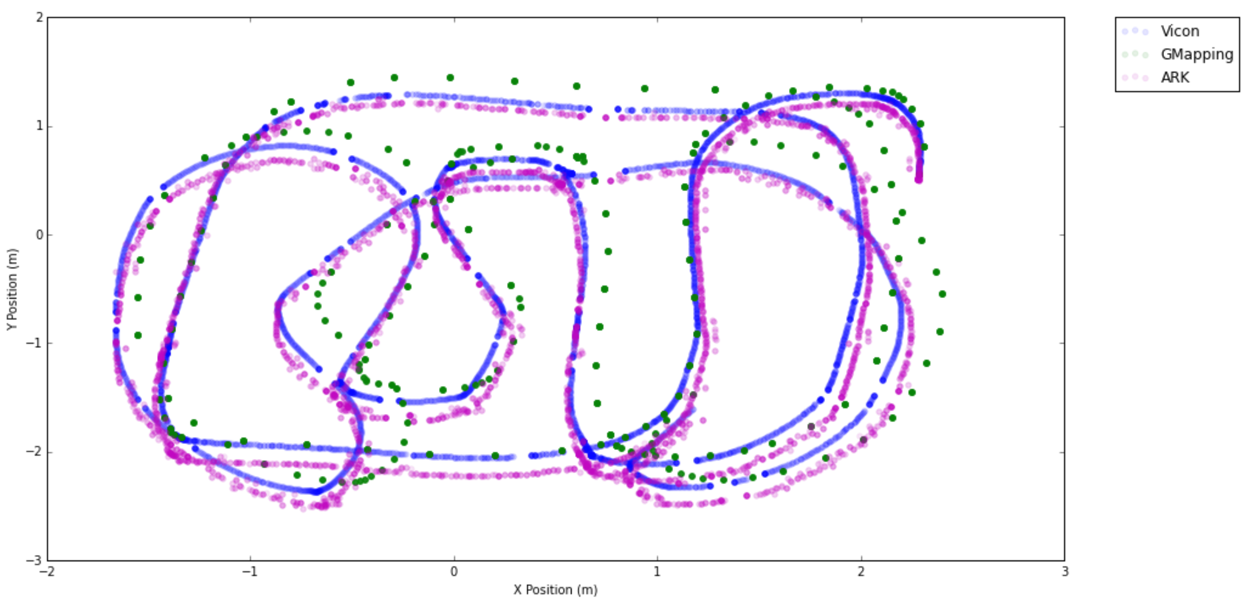
1) Manual Operation, for both
2) Autonomous Operation, for ARK and GMAP separately

SCENARIO 1: MANUAL OPERATION

Scenario 1 includes both manual operation in a random formation, as well as manual operation of the robot in a rectangular formation.

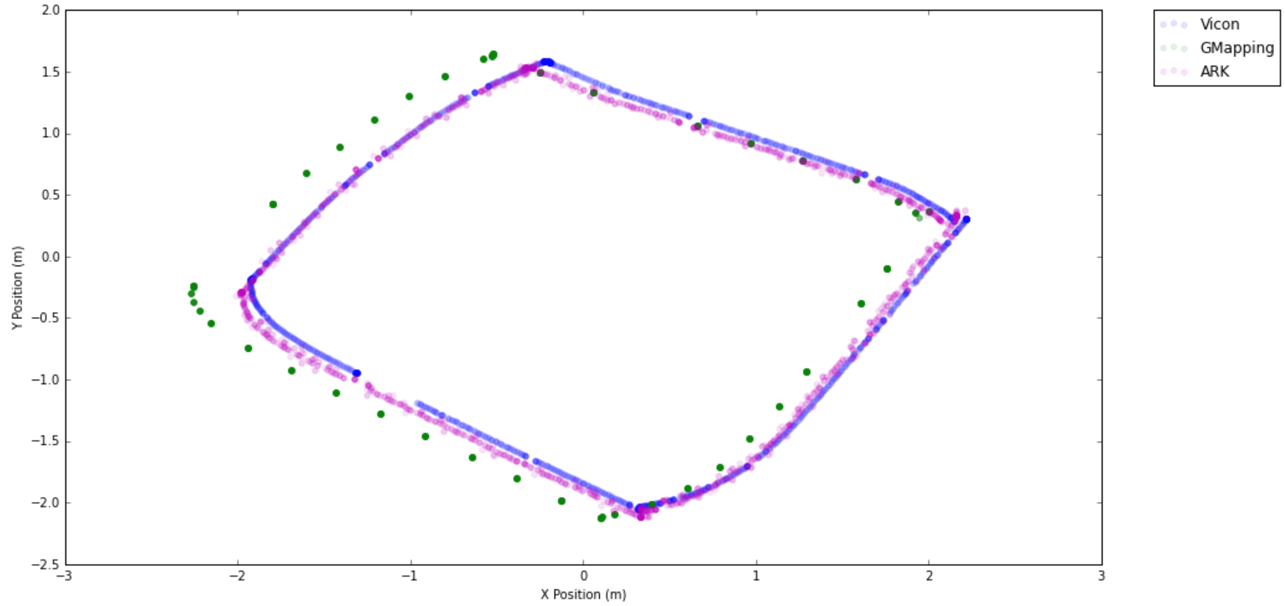
Figure 1, shows the random path of the robot, marked by blue, as well as the localization data of both ARK (Purple) and Gmapping (Green), showing the combined "random" manually controlled path of the robot for Scenario 1.

Figure 1: Random Manual Robot Operation



Similarly, in Figure 2, the same data is displayed for the rectangular, manually driven robot path for Scenario 1.

Figure 2: Rectangular Manual Robot Operation



ERRORS

In the accompanying resources, three different error datasets are available for X, Y, and Yaw axis, each comparing:

- Error Spread
- Position vs Time
- Error vs Time

For the most representative visualization, the error spread of the X Axis (Figure 3) and Y Axis (Figure 4) are shown below for Random Manual Operation

Figure 3:

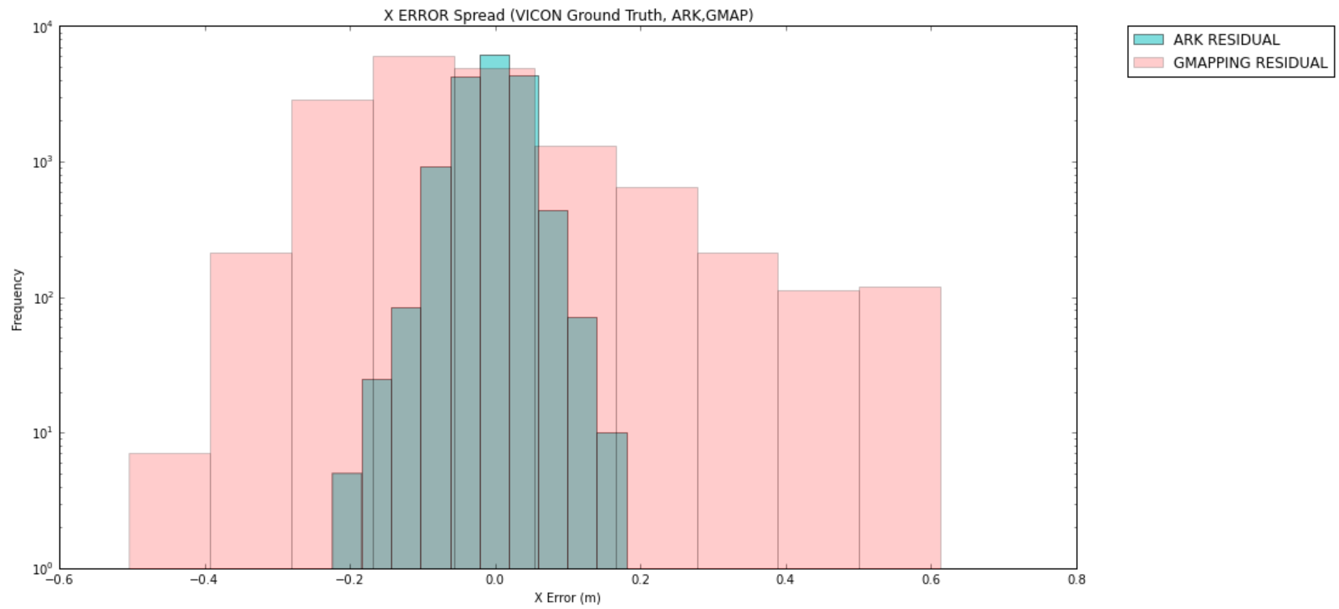
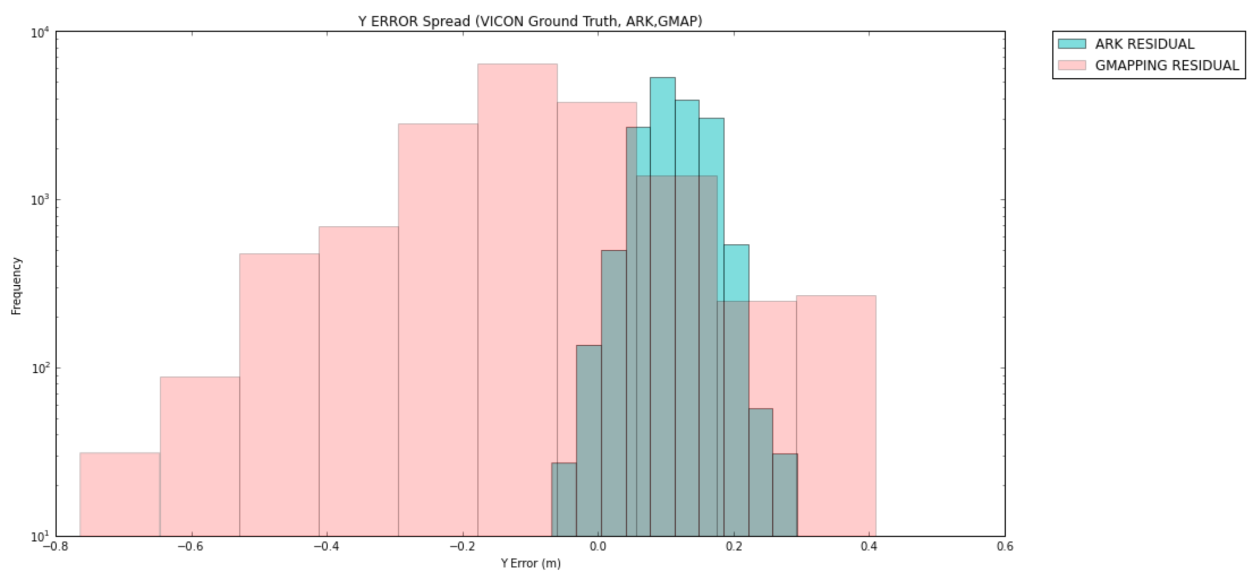


Figure 4:

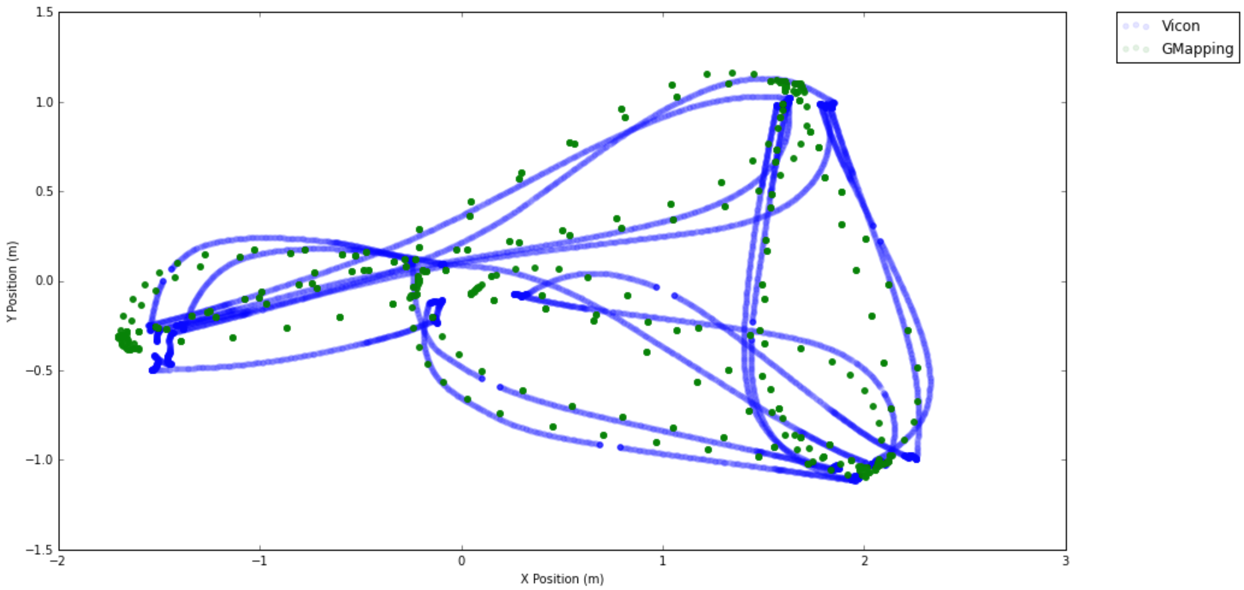


SCENARIO 2: AUTONOMOUS OPERATION

For the Autonomous Operation scenario, we will look at data from two separate autonomous missions. First, an autonomous mission given to the Gmapping software, and secondly, an autonomous mission given to the ARK software.

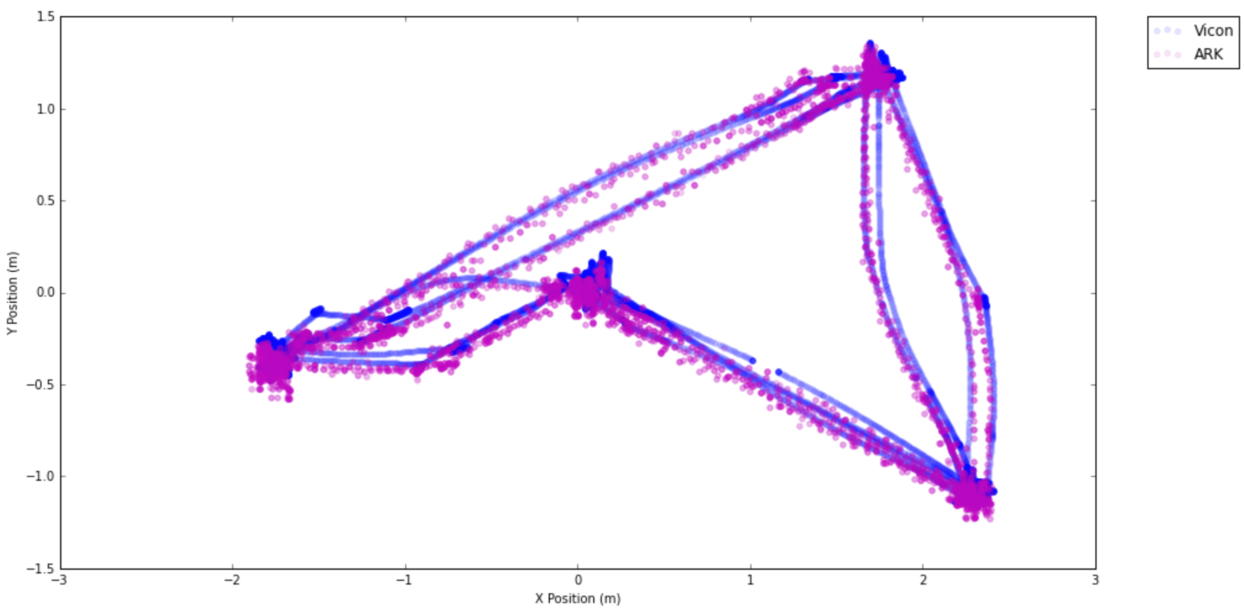
Figure 5 shows the localization data points from gmapping, marked in green compared to the ground truth Vicon Data, marked in blue.

Figure 5:



Similarly, Figure 6 shows the same data, for the ARK autonomous mission.

Figure 6:



ERRORS

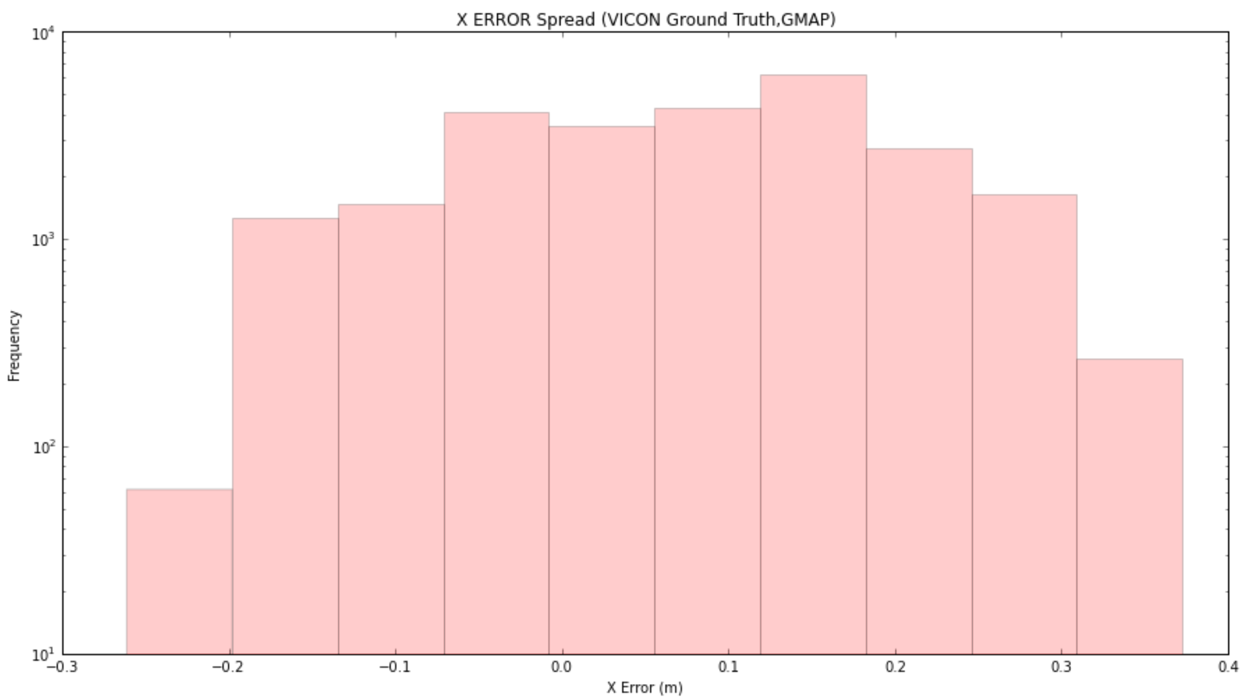
Just as with the manual operation, for Scenario 2, error data for Error Spread, Position vs Time, and Error vs Time was collected, and available in the resources.

To evaluate the most accurate software, the X and Y axis error spread data for Gmapping and ARK should be analyzed separately.

GMAPPING

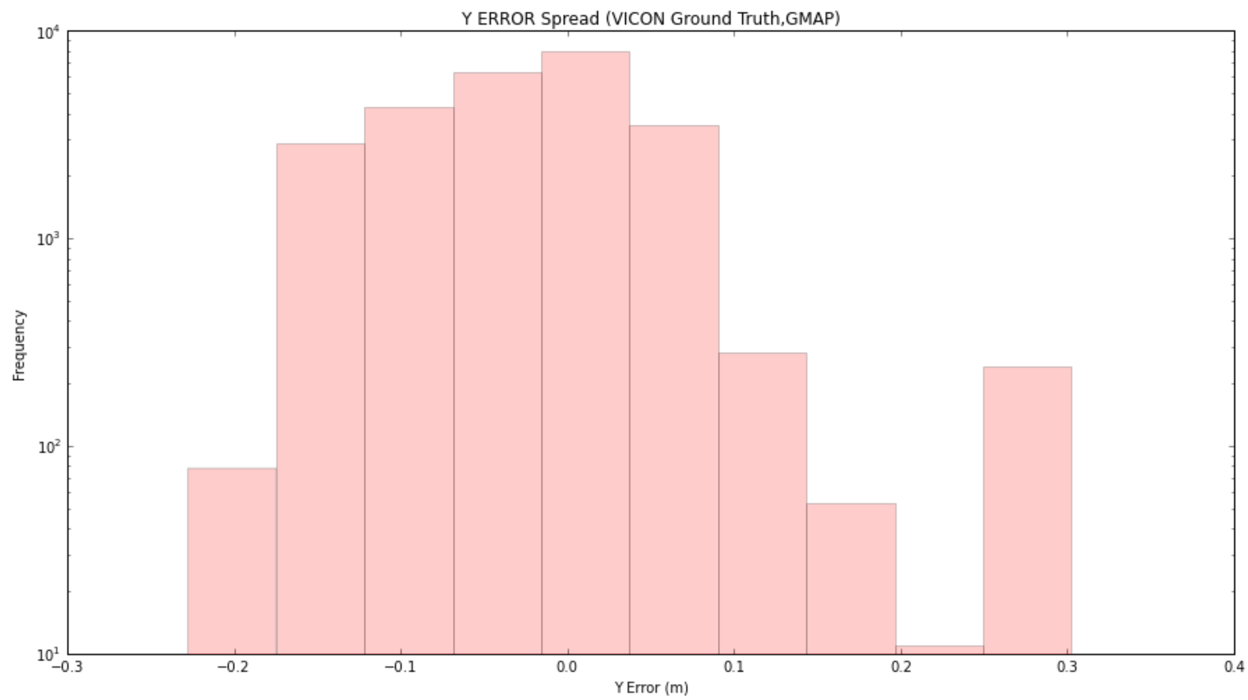
X Axis Residual Error spread for Gmapping is shown in Figure 7.

Figure 7:



Y Axis Residual Error spread for Gmapping is shown below in Figure 8.

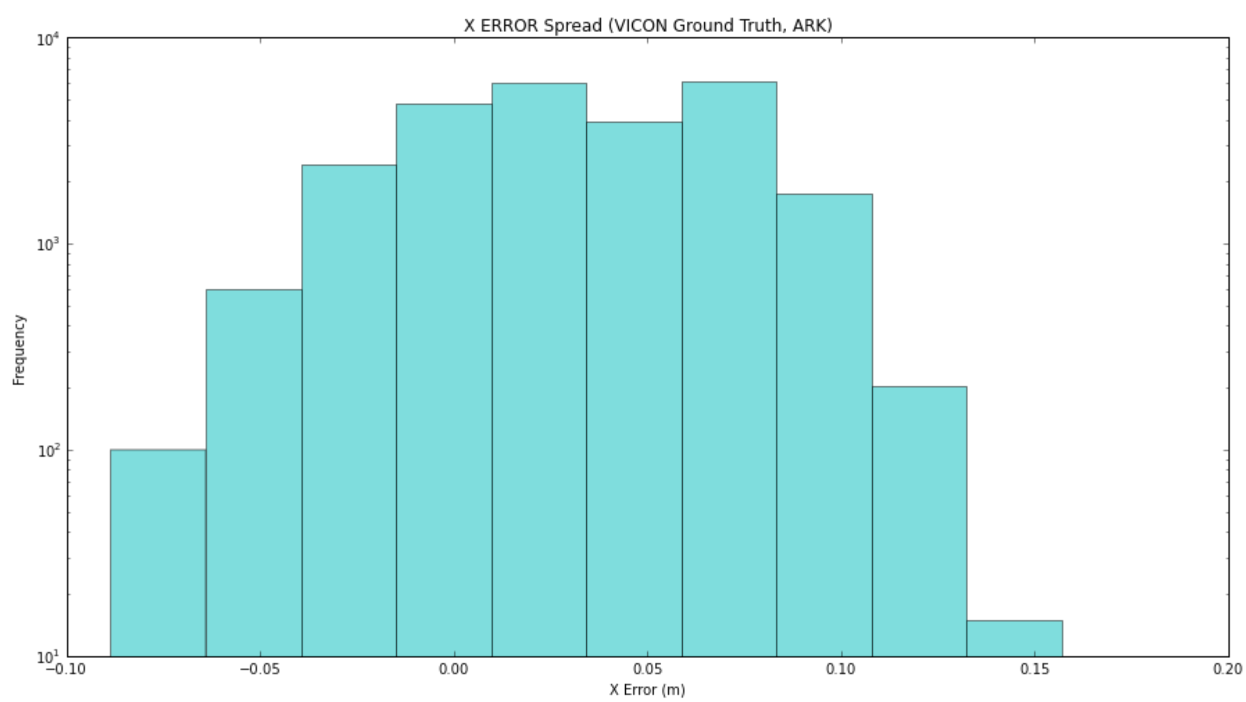
Figure 8:



ARK

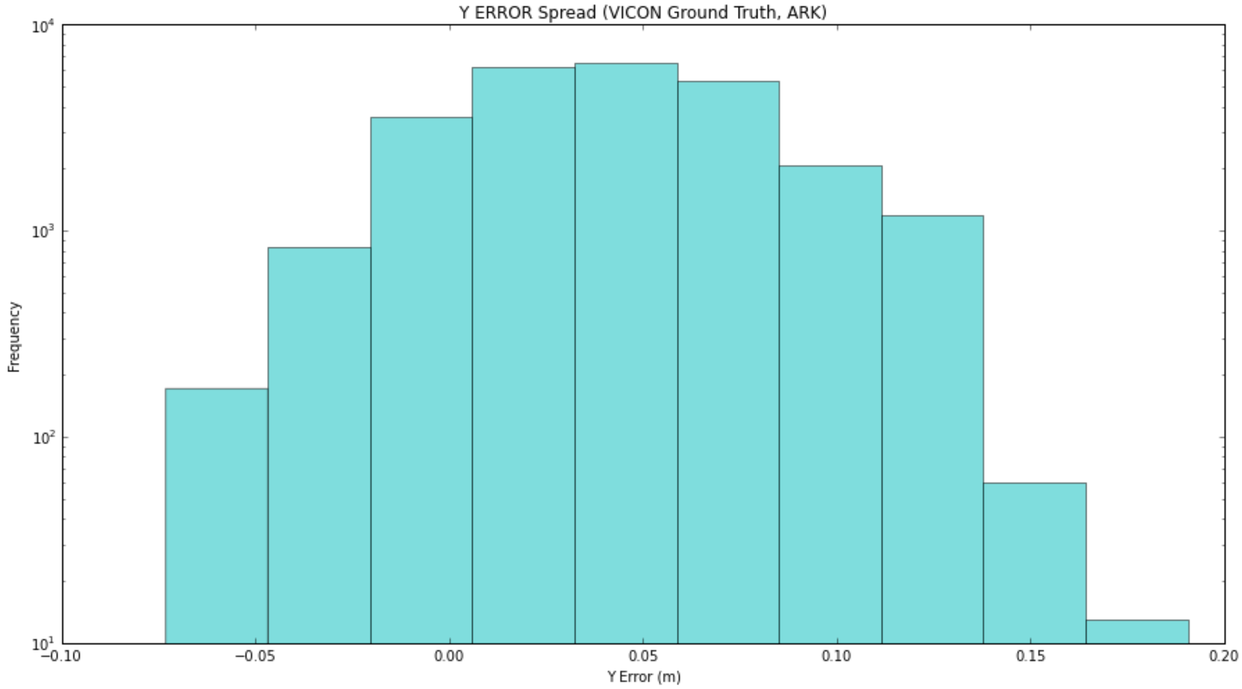
X Axis Residual Error spread for ARK is shown in Figure 9:

Figure 9:



Y Axis Residual Error spread for ARK is shown in Figure 10.

Figure 10:



ANALYSIS

Image 4: Testing space, and laptops showing software interfaces

After collecting all the data for both scenarios, the error data for the two pieces of software can be compared, to determine which is the more accurate. By taking the RMS Error data for X and Y axis, and directly comparing them, we can see which has the higher rate of error. For this testing, while Yaw axis data was collected, we are less concerned with it accuracy, since the localization accuracy being compared in this study is 2 dimensional only.
When comparing the RMS error data, the software with the lower rate of error will be marked with an asterisk (*).

SCENARIO 1: MANUAL OPERATION

Random Manual Operation:
*ARK RMS X ERROR: 0.0383
GMAP RMS X ERROR: 0.1478

*ARK RMS Y ERROR: 0.1210
GMAP RMS Y ERROR: 0.1803

Rectangular Manual Operation:
*ARK RMS X ERROR: 0.0737
GMAP RMS X ERROR: 0.2784

*ARK RMS Y ERROR: 0.0686
GMAP RMS Y ERROR: 0.1164

SCENARIO 2: AUTONOMOUS OPERATION

*ARK RMS X ERROR: 0.0497
GMAP RMS X ERROR: 0.1432

*ARK RMS Y ERROR: 0.0567
GMAP RMS Y ERROR: 0.0771

CONCLUSION

Testing both Gmapping and the Autonomous Research Kit by comparing them to a Vicon Motion Capture system ground truth allowed for the analysis of the error rate, and therefore accuracy of both systems.

The data visualized in Figures 1,2,5, and 6 shows that the ARK paths are much closer to the ground truth path.

Reviewing the graph data in the Testing Results, as well as the RMS data direct comparison, we can see that ARK consistently returns less error than Gmapping in every scenario tested, with ARK even returning error rates 2-3 times lower (better) than Gmapping. Furthermore, the ARK software returns a much higher frequency of data points, which may be vitally important for some research projects that require accurate locational data a specific point in time.

While neither software is error-free, the testing data shows that the Autonomy Research Kit from Clearpath Robotics provides much higher accuracy than the traditional Gmapping software available.

For research and prototyping projects, rather than relying on the traditional open source software, proprietary solutions like ARK provide an improvement to locational accuracy, and can help increase the accuracy of overall autonomy for robotics projects.

RESOURCES

To access the rosbag data collected during the testing, please visit:

https://s3.amazonaws.com/CPR_PUBLIC/ARK_DATA/DATA.zip
(WARNING: 500mb file size)

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