Three-Dimensional Environmental Mapping and Imaging for AUVSI RoboBoat

BRADLEY University

Department of Electrical & Computer Engineering

By: David Bumpus, Dan Kubik, Juan Vazquez | Advisor: Dr. José Sánchez

I. Introduction

Bradley University has twice sent a team to compete in the international AUVSI RoboBoat competition in Virginia. The boat must navigate around a small lake and complete challenges without human aid. One difficulty teams have encountered is measuring distances to objects relative to their boat. A digital camera was previously used to estimate distance.

Lidar is a laser surveying technique that can be used to measure distance to objects using a laser scanner.

Objective

To create an accurate real-time measurement system that uses lidar to measure the distance to objects in the boat's surroundings.

Motivation

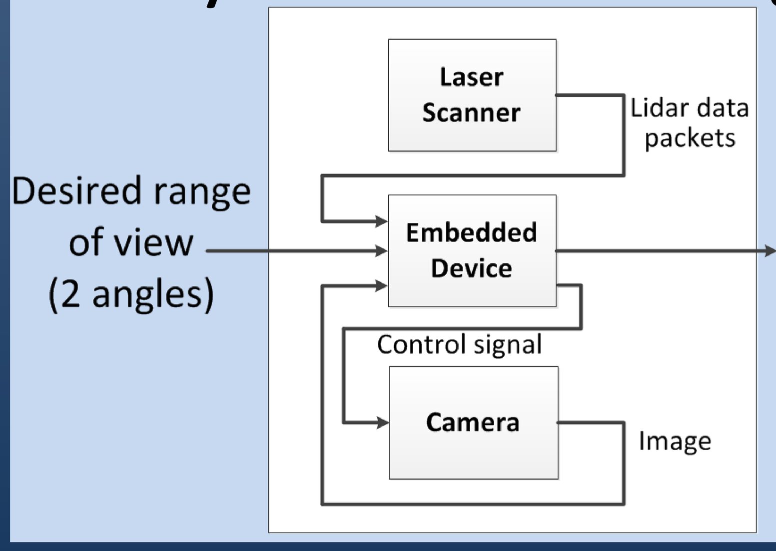
Accurate distance measurements allow the boat's control system to create informed navigational decisions. In a timed competition, this accuracy will help reduce decisional errors and improve the team's final runtime.

Significance

Autonomous vehicles have the potential to decrease human error in many industries including shipping and transportation. The autonomous vehicle industry is growing and the use of lidar is growing as well.

II. Methods

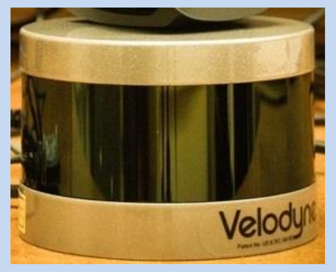
System Block Diagram



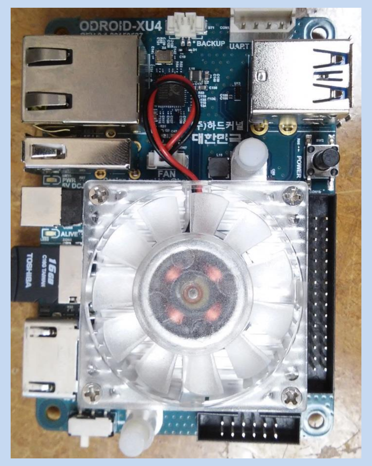
Outputs:

- Distance measurements
- Camera image
- Image with distance information (colors)
- Location of nearest object

Component Selection



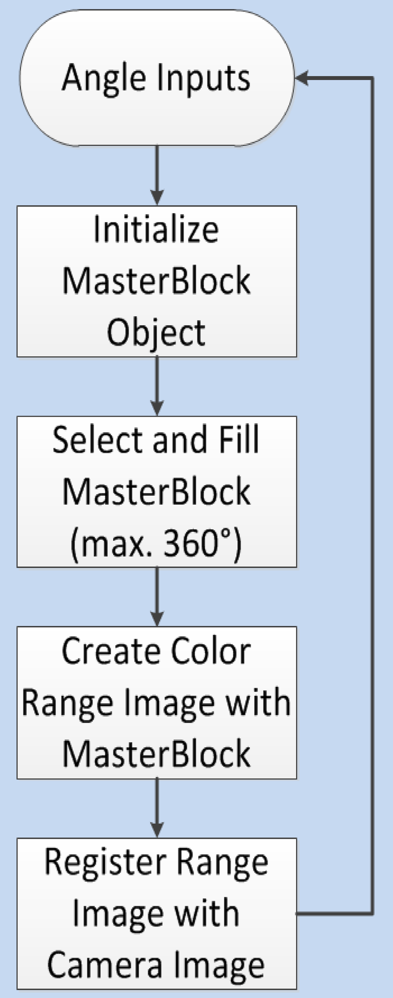
Velodyne VLP-16
- Three-dimension
- Weight
- Price



Odroid-XU4:
- Processing abilities
- Memory capability
- Communication diversity

Logitech C500 Webcam
- USB capability
- Linux capability

System Flowchart



Two angle inputs set the range of interest for each cycle of 360° collected.

As lidar data enters the system it is temporarily organized and stored in a hierarchy of nested C++ classes. 'MasterBlock' is the apex of this hierarchy; its function is to separate lidar data by angle.

Data Acquisition

Image capture is performed by storing frames of a live video feed from the camera in portable pixmap format (.PPM) using The Open Source Computer Vision (OpenCV) library. Ethernet packet detection is performed by storing incoming lidar data into text files using User Datagram Protocol and the libpcap library.

Barnes Interpolation

Barnes' method [1] is designed to take unevenly distributed data and interpolate to a grid. This is especially applicable for this project as lidar data is unevenly distributed and a color image is desired (with pixels in a grid).

Distance value in grid: $g(x,y) = \frac{\sum_{j=0}^{M} \eta(r_j) f_j}{\sum_{j=0}^{M} \eta(r_j)}$,

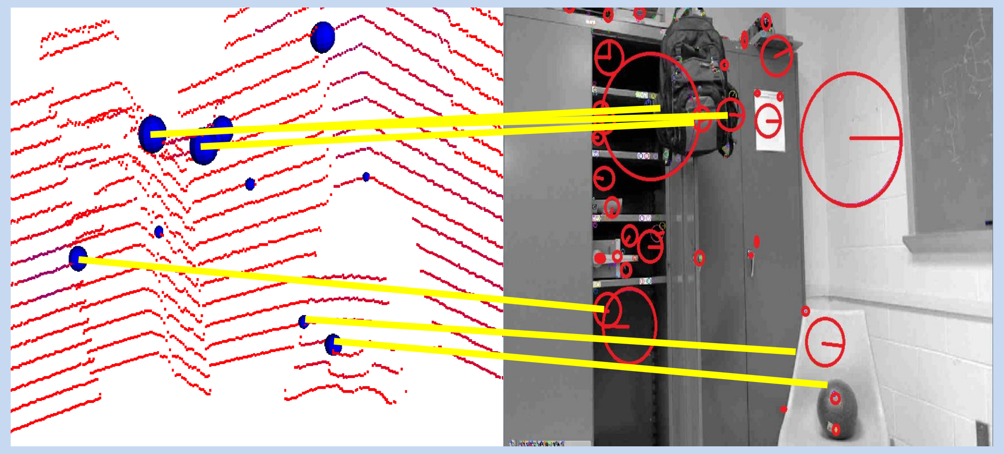
where:

- $\eta = e^{\frac{-r^2}{4k}}$,
- M is the number of known values,
- r is the radius to known value from grid point,
- k is the "weight factor",
- (x,y) are the coordinates of griddled data,
- f is the value of the known datum.

SIFT Algorithm

The scale invariant feature transform (SIFT) [2] is used to determine the location of objects within a dataset using keypoint detection. Descriptors of these keypoints can be matched to similar descriptors for registration. The OpenCV and point cloud library (PCL) libraries were used to implement the algorithm in C++. The SIFT Algorithm Consists of five steps [3]:

1. **Scale space extrema detection** (Determine potential keypoints)
2. **Keypoint localization** (Eliminate weak keypoints)
3. **Orientation assignment** (Using gradient of nearby pixels)
4. **Generate descriptors** (128 element array of gradient vectors)
5. **Match keypoint descriptors**



Demonstration of SIFT matching with keypoints

III. Results

Renaissance Coliseum (RC) set-up

RC Barnes Interpolation with colored thresholds

Test data was obtained in the lobby of Bradley's basketball arena, the Renaissance Coliseum. Foam 'buoys' were placed to see if they could be detected. By thresholding the Barnes Interpolation, both buoys and the three main pillars are clearly revealed. Keypoints were successfully used to identify objects, but could not be used for registration.

IV. Conclusion

From the sensors, distance measurements and camera images are easily accessible. The results from the Barnes interpolation successfully demonstrates a color image indicating depth. Keypoint detection has been used to identify nearest object coordinate location. Further exploration of registration techniques and Ethernet protocol will aid the continuation of this project.

Acknowledgments

This work was partially funded by a grant from Bradley University

References

[1] Stanley L. Barnes, "A Technique for Maximizing Details in Numerical Weather Map Analysis," *Journal of Applied Meteorology*, vol. 3, pp. 396–409, 1964.

[2] Lowe, David G. "Distinctive Image Features from Scale-Invariant Keypoints."*International Journal of Computer Vision* 60.2, pp. 91–110, 2004.

[3] http://docs.opencv.org/master/da/df5/tutorial_py_sift_intro.html#gsc.tab=0

[4] docs.opencv.org/modules/highgui/doc/reading_and_writing_images_and_video.html

[5] http://www.binarytides.com/packet-sniffer-code-in-c-using-linux-sockets-bsd-part-2/