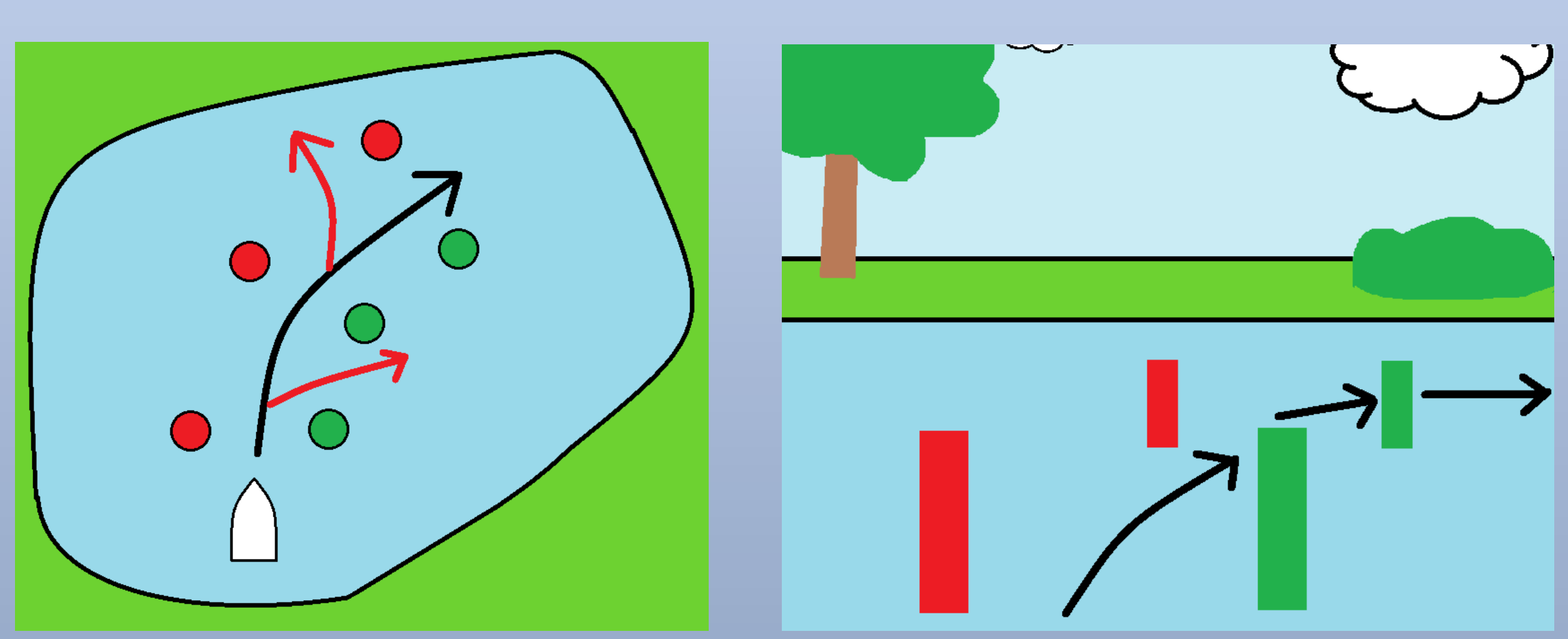
Three-Dimensional Environmental Mapping and Imaging for AUVSI RoboBoat

BRADLEY University
Department of Electrical & Computer Engineering

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

I. Introduction

Since 2013, Bradley has twice sent a team to compete in the international AUVSI RoboBoat competition in Virginia. The boat must navigate around a 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.



Paths the RoboBoat may take in competition

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

Objective

To create an accurate, easy to use, 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.

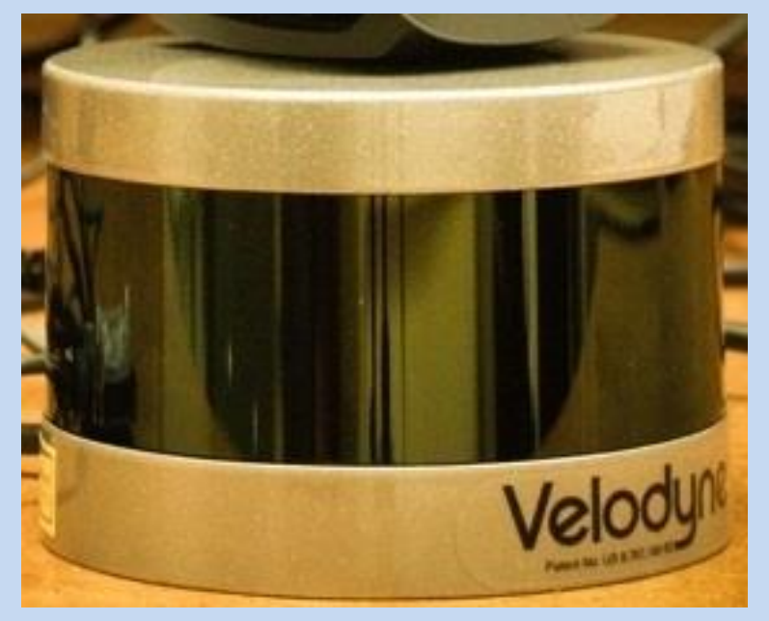
Significance

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

Component Selection

Velodyne VLP-16 "Puck":



Odroid-XU4:

Logitech C500 Webcam:

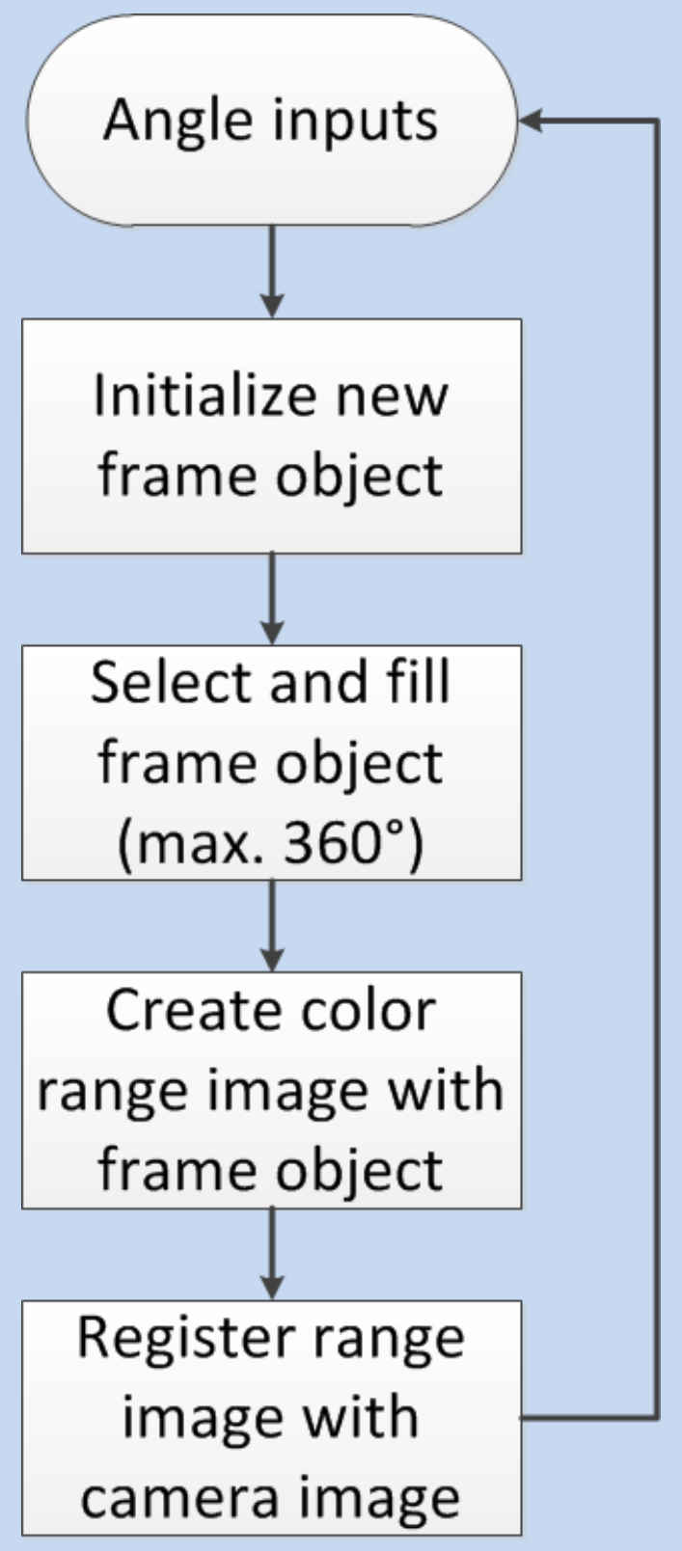
Outputs

- Distance information
- Camera image
- Image with color overlay representing distance

Data Acquisition

Image capture is performed by storing frames of a live video feed from the camera as individual pictures using the Open Source Computer Vision (OpenCV) library. Lidar data is received in data packets using Ethernet detection.

System Flowchart



Angle inputs

Initialize new frame object

Select and fill frame object (max. 360°)

Create color range image with frame object

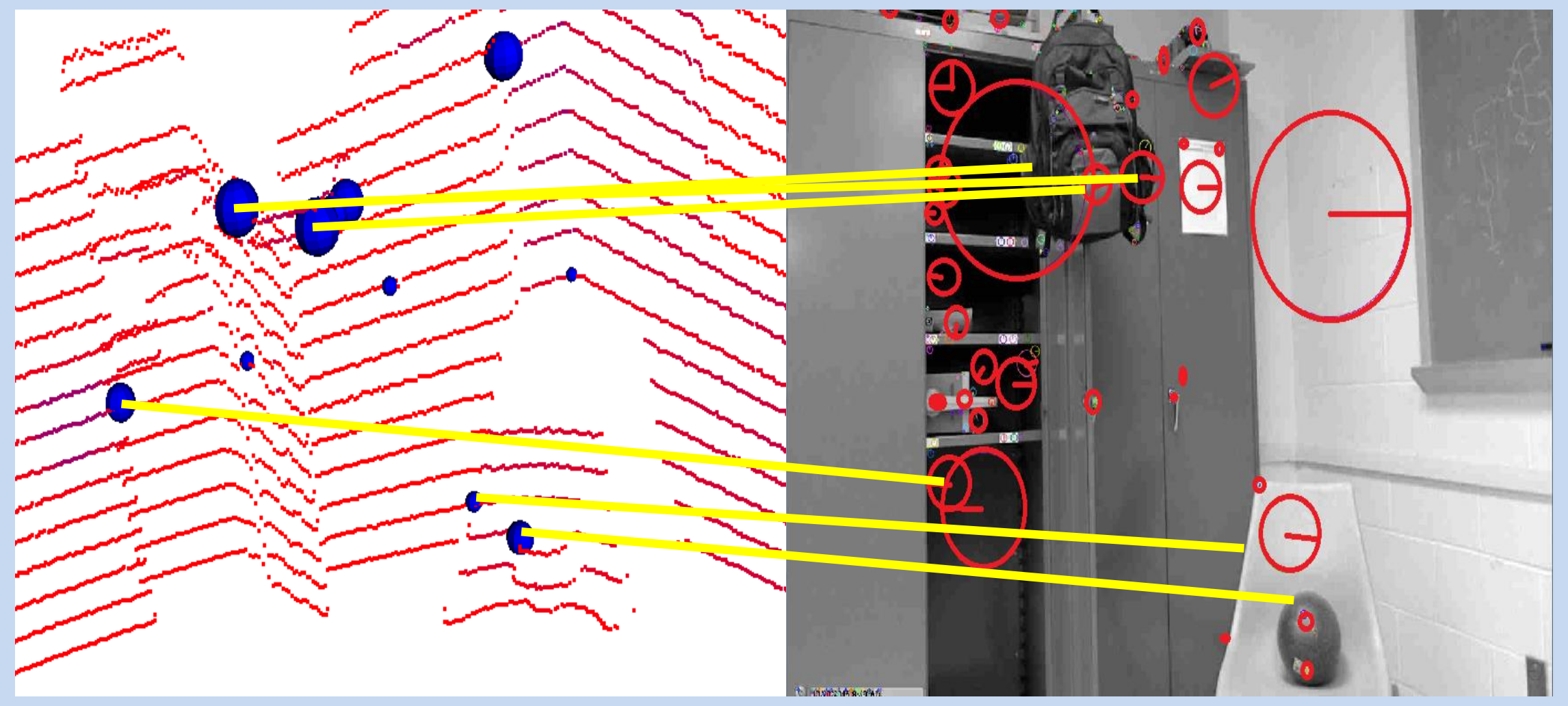
Register range image with camera image

Two angle inputs set the range of interest for each cycle of 360° collected. Each cycle is called a "frame."

As lidar data enters the system it is organized and stored in a frame object to later be registered with a matching camera image.

Object Detection

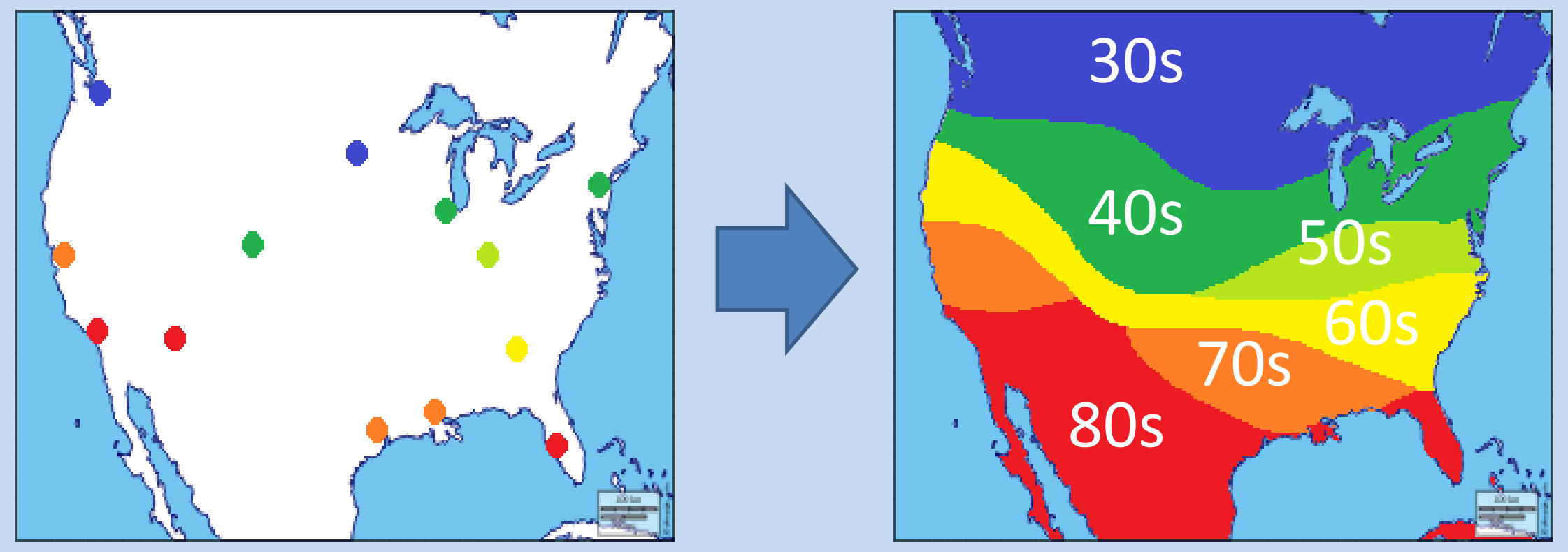
To identify objects for matching lidar to camera data, the scale invariant feature transform (SIFT) [2] is used. Keypoints are determined either by differences in distance or contrast in nearby points.



Demonstration of matching lidar keypoints to image keypoints using SIFT

Filling Data Gaps

Due to the uneven distribution of lidar data, many "holes" of unknown distances exist between known points. To fill these holes, Barnes' interpolation method [1] is applied to two dimensions of lidar data.



Unevenly distributed data interpolated over full image

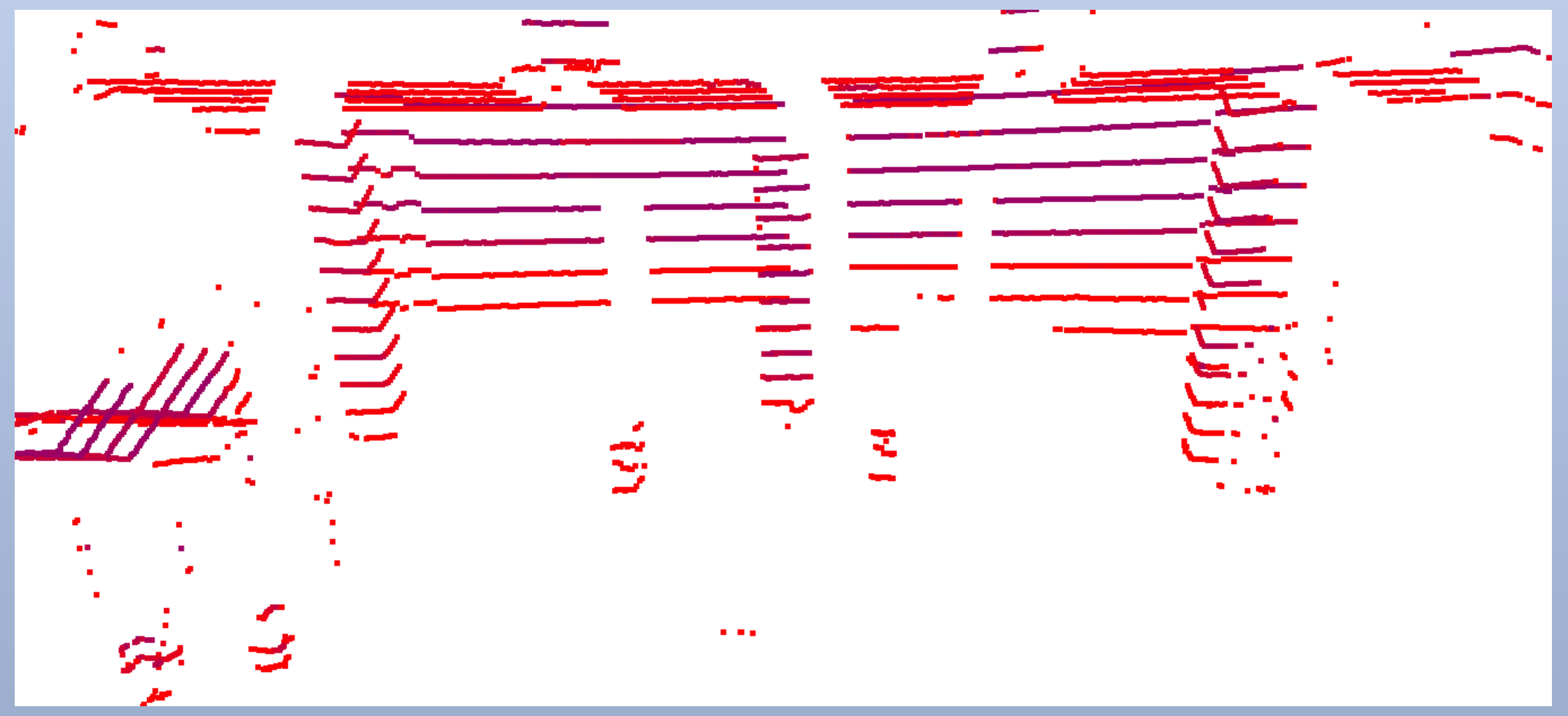
Distance value in grid: $g(x,y) = \frac{\sum_{j=0}^{M} \eta(r_j) f_j}{\sum_{j=0}^{M} \eta(r_j)}$,

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.

III. Results

Renaissance Coliseum (RC) set-up



Coliseum lidar data

Barnes Interpolation with colored thresholds

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