Investigation into surface roughness characterization using LiDAR and cameras

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① INTRODUCTION

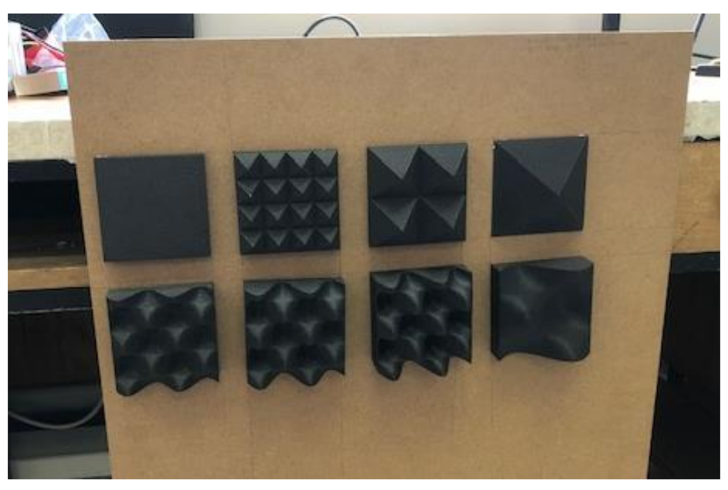
This project investigates the use of LiDAR and camera technology for the purpose of characterization of surface roughness. The application of this research is to eventually be used to characterize sea ice in the Marginal Ice Zone near Antarctica. This would assist in understanding the dynamics of the sea ice due to the effect surface roughness has on the drift of sea ice. These surface roughness parameters include: arithmetic mean, RMS mean, kurtosis and skewness.

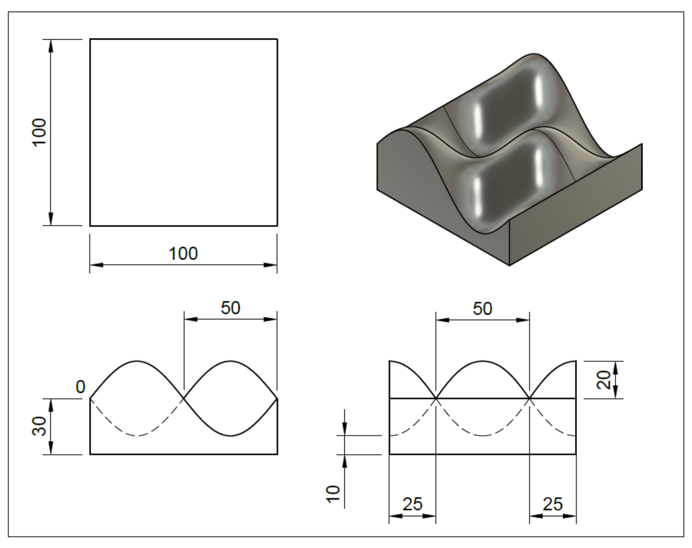
② METHODOLOGY

Initially, an analysis into the literature relating to this field was done. LiDAR scans were then taken of surfaces with known surface roughness and constant reflectivity using the Velodyne VLP-16 attached to the Clearpath Husky UGV. This involves the design of the surfaces, the capturing of the data, the design of the data processing pipeline as well as partial processing of the pipeline in MATLAB.

③ SURFACE DESIGN

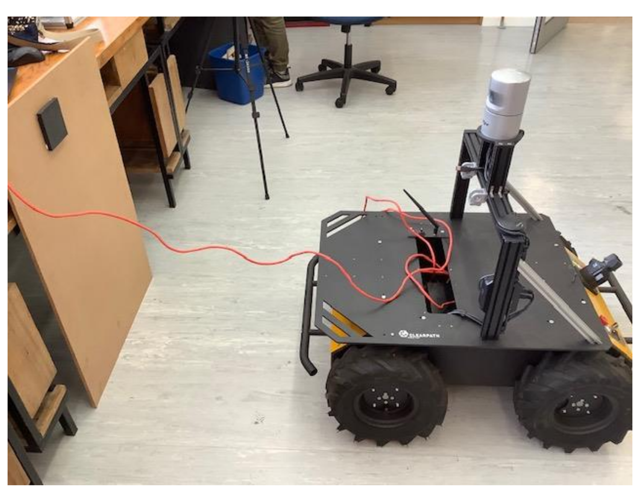
A series of 100mm x 100mm surface tiles were designed in Fusion360 (right image) and then 3D printed using the Prusa MINI(left image). Since the VLP-16 has an accuracy of only 30mm, the shapes are larger than ice roughness heights. These tiles are then mounted onto a piece of hardboard which acts as ground truth.





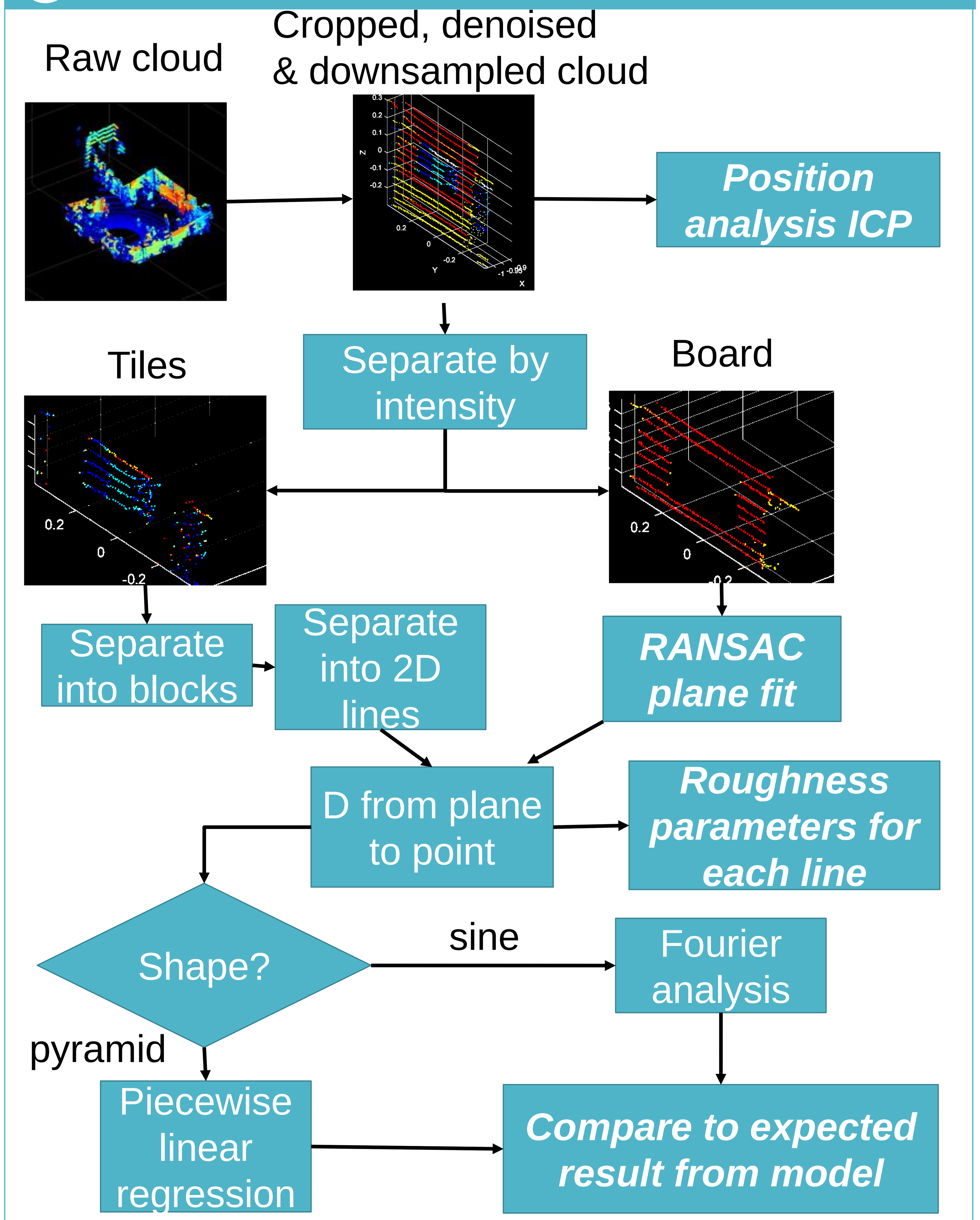
④ LIDAR EXPERIMENTS

A series of scans were taken varying the distance away from the board, the angle of the Husky in relation to the board as well as the movement of the board in the y-direction (left/right). Each scan was recorded in the form of a rosbag file which contained point cloud LiDAR data as well as data from the Husky's camera.



GitHub repository containing all code, data collected and a PDF copy of the full report

⑤ DATA PROCESSING PIPELINE



⑥ RESULTS

ICP Positional analysis

With a variation in the x-direction, the algorithm predicted the measured distances. Although the expected y-translation was zero, the measured translation was between 4mm and 12mm. This is very small and hence negligible. The z-translation showed a linear relationship due to the limitation of the board are measured as the x-distance decreases.

RANSAC Plane fitting

This is a robust form of linear regression. The average plane error of the scans analysed was between 0.53cm and 1.73cm which is consistent with the manufacturer accuracy of 3cm.

⑦ CONCLUSIONS & FUTURE WORK

The scans that performed best were those measured less than 1m away from the board. The ICP analysis proved to be in line with the physical tape measurements. The RANSAC plane fitting provided a good fit, but this can be improved by using a smaller area. A large dataset was collected but only the variations in the x-direction were analyzed. Greater analysis can be done on the y-direction movements, the angled scans as well as merging the camera data with the LiDAR data. Considering only a portion of the pipeline was demonstrated in MATLAB, the code can also be expanded and improved to exclude any manual filtering.