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Constructing Digital Elevation Models from Lake Michigan Dune Imagery

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INTRODUCTION

Lake Michigan dune complexes evolve as winds and waves erode the sand, causing major topographic changes over time. Digital Terrain Maps (DTMs) are a great way to analyze these topographic changes. A DTM, as shown schematically in Figure 2, is a map of the bare ground surface of the dune which excludes ground obstructions such as trees and bushes. The traditional method for creating these DTMs has two steps:

1. Classify each point in the point cloud as either ground or non-ground.
2. Interpolate between the points classified as ground.

This technique generally works well for point clouds that have been constructed from LIDAR. However, since our point clouds are created from aerial drone imagery rather than from LIDAR, the results using this technique have been unsatisfactory.

In this project we have begun developing a new approach to create DTMs, which uses an artificial neural network (ANN) to classify the ground elevation of small 1-meter by 1-meter tiles within the drone imagery. This neural network is given the elevation of the points within the tile. Initial testing shows potential for this being a successful method.

SITE

The primary location for this research is the parabolic dune and surrounding area at Green Mountain Beach. At this dune system, there is a variety of ground cover and terrain. The trough in the center is bare sand with some steep slopes, while other portions have thick dune grass or bushes and trees.

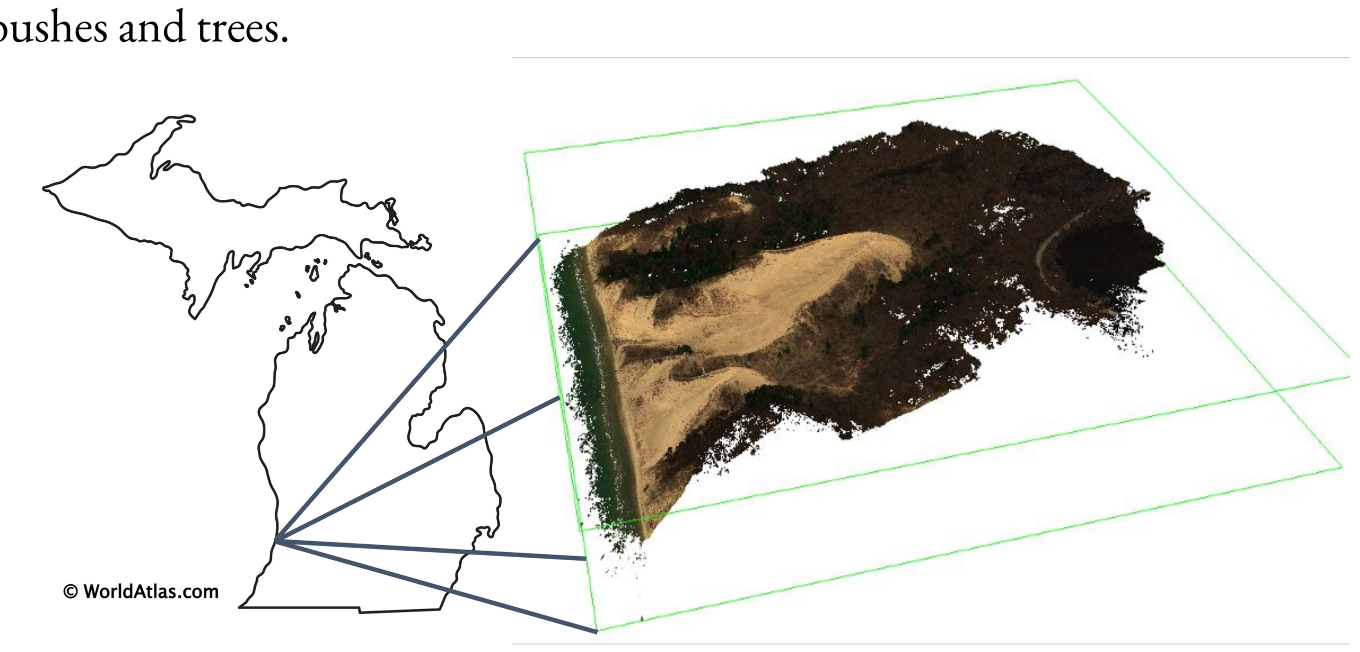

Figure 1: Green Mountain Beach, and a point cloud of the dune area.

DATA

Using drones, the Hope College Dune Group collected hundreds of images of the sand dune complex at Green Mountain Beach. By looking at the perspective variation of points between drone images, the elevation of those points was found using the software Agisoft Metashape. With this process, a point cloud was created–a data type that, in our case, contains hundreds of thousands of points. Each of these points contains positional information (x, y, and z) as well as spectral information (R, G, B, and NIR). One of these point clouds is shown above in Figure 1.

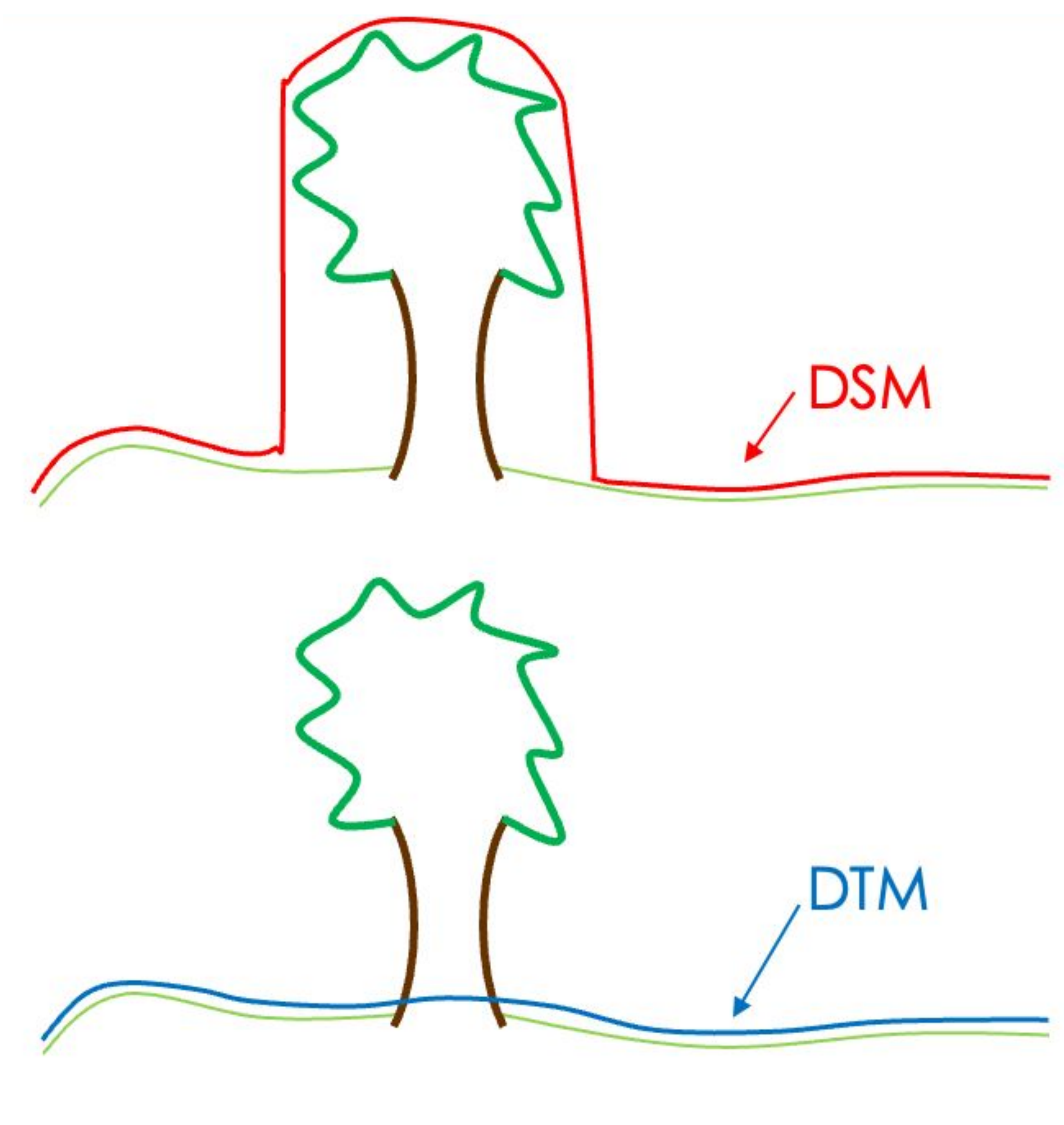

Figure 2: Illustration of a Digital Surface Model (DSM) and a DTM.

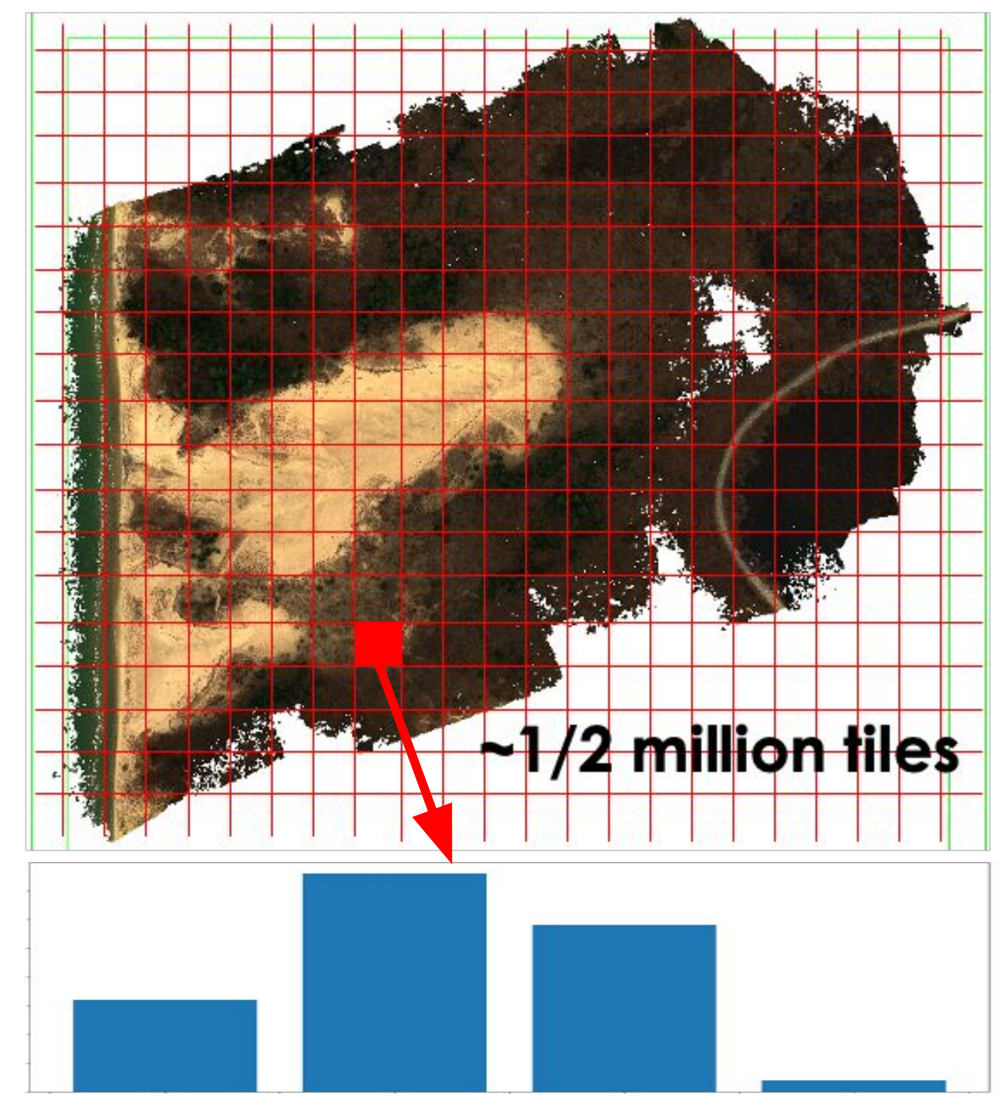

Figure 3: The point cloud is first tiled into 1mx1m tiles. Histograms are then created for the elevations of the points in each tile.

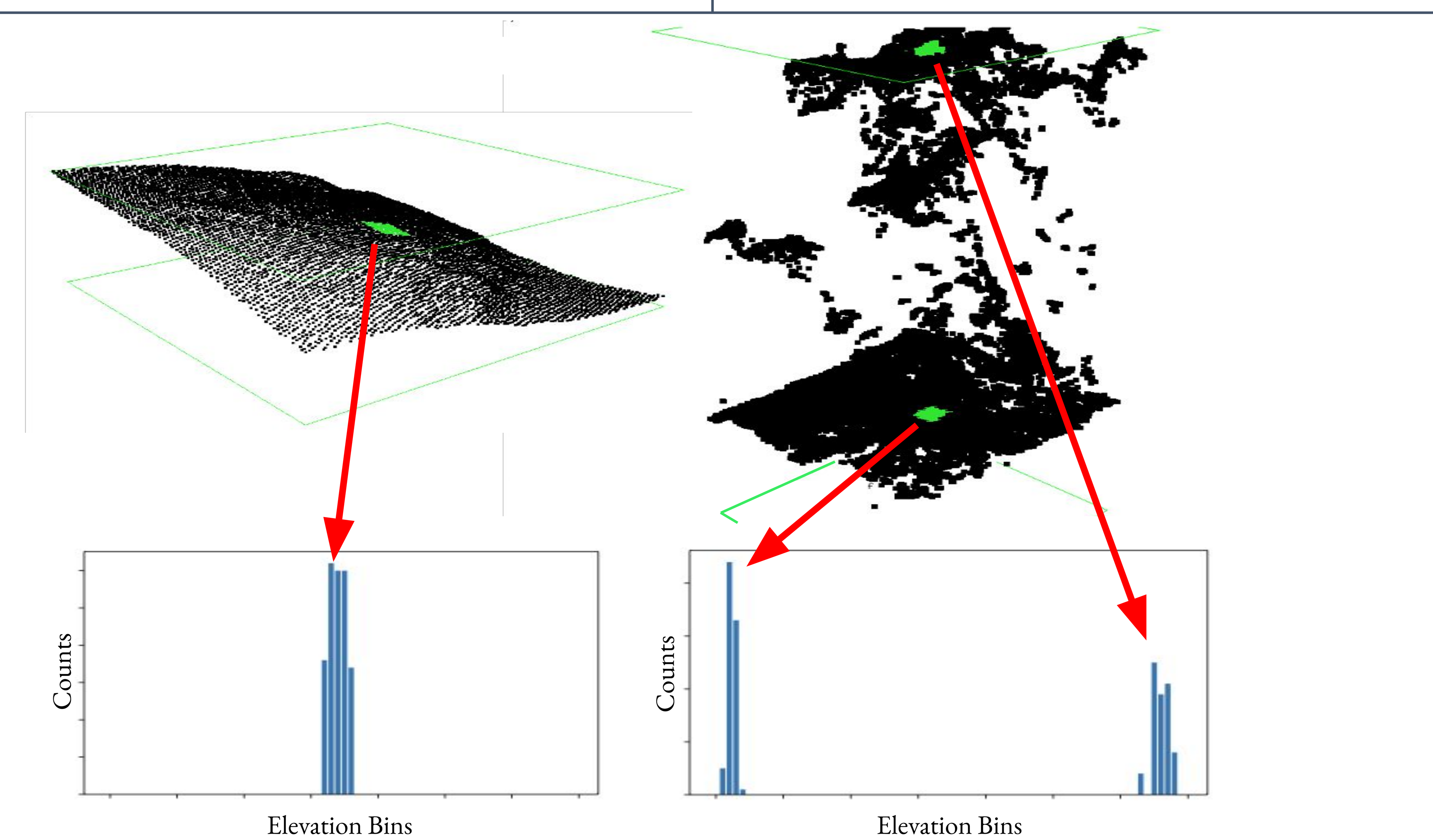

Figure 4: Examples of the points within the 1mx1m tiles. The green points are the points within the 1mx1m tile, and the black points are the surrounding points to give context. Approximate histograms for these locations are shown below the sample point clouds.

ACKNOWLEDGMENTS

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METHODS

In the method we have developed, the main steps for the process are:

1. The entire point cloud is tiled into 1mx1m tiles as shown in the upper portion of Figure 3.
2. For each tile, the elevation of all points within that tile is compiled into a histogram. This is shown schematically Figure 4.
3. This histogram is written as a vector and then standardized.
4. The result is then an input for a binary classification ANN which predicts if there any ground points within that tile.
5. For the tiles with ground points, the vector is then used as an input to a regression ANN predicting the ground elevation in the tile.
6. The elevation of tiles classified without ground points can be determined later by interpolating between nearby tiles.

One of the most important considerations in this method is the construction of the input vectors. Every element in these vectors represents a bin in the histogram of 0.2 meters. We standardized the vectors by shifting the entries to ensure the mean elevation was at the middle of the vector. We kept track of the shifts to account for them later. Additionally, we provided a second histogram vector representing the elevation of the points in the surrounding area (Figure 4) to give the ANN additional context.

To construct a train and test set, coordinate locations were randomly sampled from strategic areas within the point cloud. For each of these locations, a representative ground point was found and selected manually in order to classify the ground elevation of the tile at that location. From this classified set, 70% of the locations were used for training while the remaining 30% were used for testing.

RESULTS

The model has 90% classification accuracy for the binary classification, and mean absolute error for the regression problem of 1.5 m.

	best accuracy/mean absolute error
Binary Classification ANN	90%
Regression ANN	1.5 m

CONCLUSIONS AND FUTURE WORK

- We began developing a novel technique for creating DTMs using neural networks and the elevation of all point in the point cloud
- Initial testing shows strengths of this method over traditional methods
- The process has to be refined, tuned, and streamlined in order to improve the accuracy and workflow organization
- More attention needs to be devoted to ensuring that a representative sample is being used when training the model
- On-site ground truthing needs to be performed