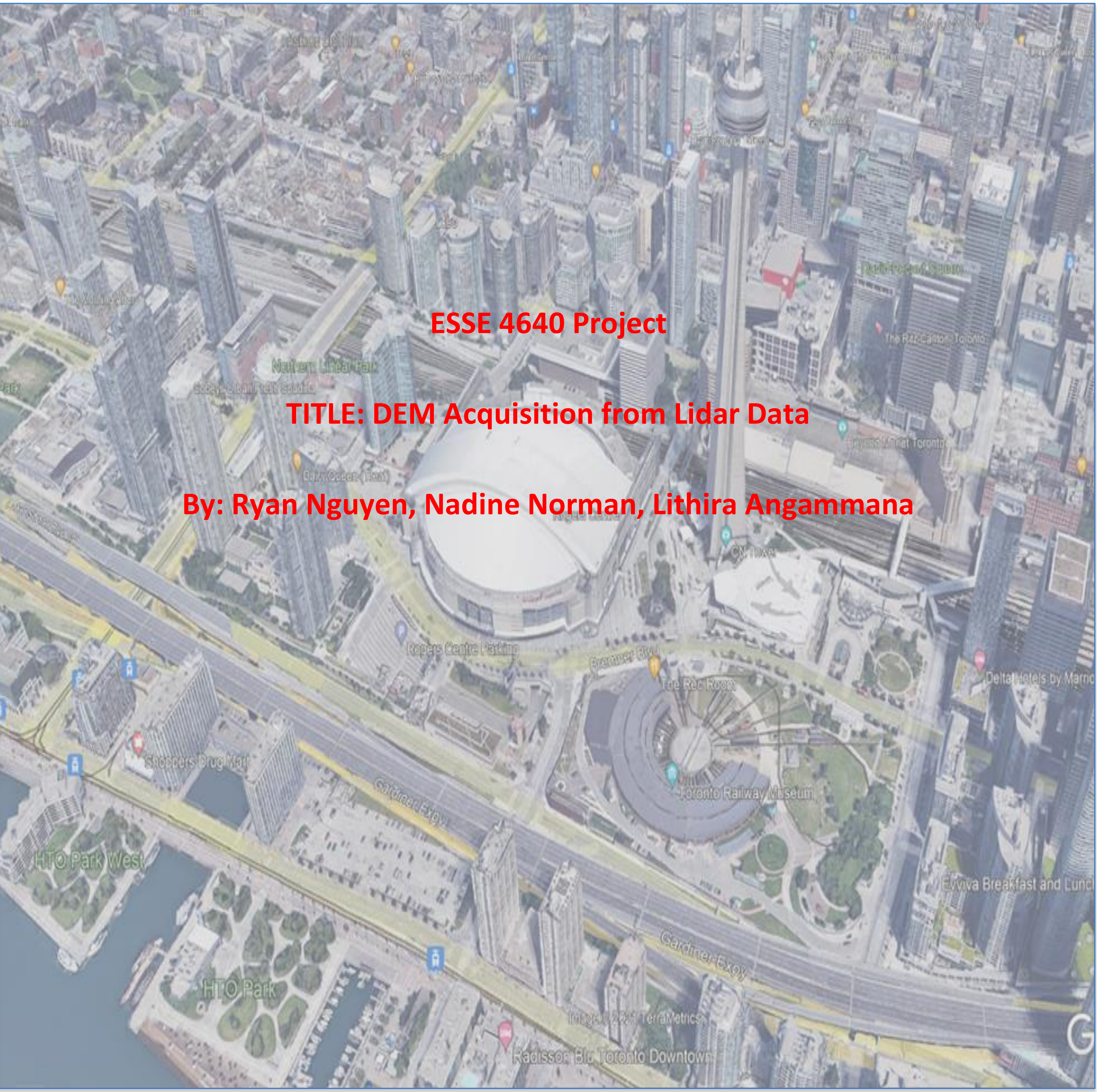

ESSE 4640 Project

TITLE: DEM Acquisition from Lidar Data

By: Ryan Nguyen, Nadine Norman, Lithira Angammana

Table of Contents

Division of Labor

NADINE- Report Methodology and structure, NRCAN DEM retrieval, ArcGIS Processing (Raster, DEM and 3D slope analysis)

LITHIRA- Executive Summary, Introduction and Scope

RYAN – Study area and data description, compiled video presentation, methodology, provided images of model through MATLAB, ArcGIS, and CloudCompare.

EXECUTIVE SUMMARY

The project explains how to reconstruct a 3D model using the mapping techniques we learned over the course of the semester. The area chosen was the downtown area near the Rogers Centre and the CN tower. The area was already mapped, and the data was given to us, and we had to use a 3D modeling software called CloudCompare to construct everything.

The initial scope will describe what the applications of indoor and outdoor mapping are and the effects of LIDAR technology on today's society. It will also explain the objectives and steps that should be followed if we were to scan and generate a 3D model of an area in real life instead of taking already collected data. Our problem statement and objectives will go further into details about the requirements that need to be done in this project. Our considerations and methodology behind choosing an area in Toronto will also be explained further. The tools used for the project such as where and how we got our data and the process of creating a 3D model with all the data given of the point clouds. The different types of data files and how it is used for the project will be explored as well. For the software, the algorithms and how they work using mathematical principles will be explained. In the final section, the 3D model will be shown with an analysis of how accurate it is compared to the real world image of the area.

INTRODUCTION AND SCOPE

3D modeling has become widespread in use with technology from the geomatics field such as LIDAR. Processing power for newly developed technology has very accurate sensors and this results in a creation of services that rely on indoor and outdoor mapping. LIDAR is an exception because it is very expensive to rent LIDAR equipment, surveying crews, and other external costs that factor into it. If we were to use a struct sensor with a tablet, we can scan any area we want, preferably an area inside a building, and reconstruct the 3D model using the CloudCompare software. CloudCompare will allow us to align and register each of the scans done and create a more clearer and complete 3D view. The texturization and colourization part can also be done in CloudCompare. CloudCompare uses photogrammetric techniques when taking the orthoimages and colorizing the point clouds. To validate the final model, we can compare real life orthoimages of the area chosen and compare the accuracy of the 3D scans by measuring certain distances.

OBJECTIVES

The objective of this Project is to reconstruct a DEM file from a given Lidar Data set. To complete this task we shall be making use of some point interpolation methods introduced in the ESSE 4640 course.

STUDY AREA AND DATA DESCRIPTION

The study area we decided to conduct our 3D reconstruction is at the downtown core, it encompasses the Rogers Center and CN Tower. We chose this location because almost all buildings in the entertainment district are popular and very unique. We wanted to focus more on the CN Tower and Rogers Centre but there is also the Scotia Bank arena, Union Station, and the Toronto Railway Museum. We thought it would be exciting to see a model of one of the former world's tallest free-standing structures and capture the Rogers Center Dome. However, this later affected the results when it came to the DEM reconstruction.

The data was provided by York University Library, the area of interest was first selected from an ArcGIS Map called "Index map of LiDAR data of Toronto produced by Airborne Imaging". Information regarding the selected tiles 6295_48330 and 6230_48330 were then requested through the GAIA website.

Requested Information:

- Point Cloud LiDAR Data in .las format
- Digital Terrain Model (1-meter Grids) of Bare Earth and Full Feature in XYZ ASCII Format
- Hillside Images, Bare Earth, and Full Feature in GeoTIFF Format
- 50 cm, 1m, and 5m Contours of the Bare Earth.

Received Data:

- The LiDAR data in .las format of tiles 6295_48330 and 6300_48330
- 50 cm contours in .shp, .dbf, .prj, and .shx files of tiles 6295_48330 and 6300_48330
- The XYZ coordinates of the DTM model in 1m grids of Bare Earth and Full Feature
- 1m hillside images of the Bare Earth and Full Feature in .tiff format

The .las (laser) files contain LiDAR data taken from the study area. It was assumed that the data was recorded using an airborne LiDAR system as it may not be possible to record the data points of very tall buildings without being airborne. It is possible that the altitude of the UAV wasn't as high as the CN Tower because it cuts off right above the observation deck.

We only used the shapefiles for the 50cm contours, since shapefiles store data of location, shape, and attributes of geographic features [1]. Contours are typically used in topographic maps to illustrate points of equal elevation which is the height above the mean sea level [2].

The .tif (geotiff or tagged image format) is a special type of image file that contains additional information about the map projection and registration in addition to the raster image [3]. We received two .tif files for the Bare Earth and Full Feature. Full Feature displays what the surface looks like including the buildings and infrastructure. Our Bare Earth file, however, is not a depiction of the DEM model of our study area.

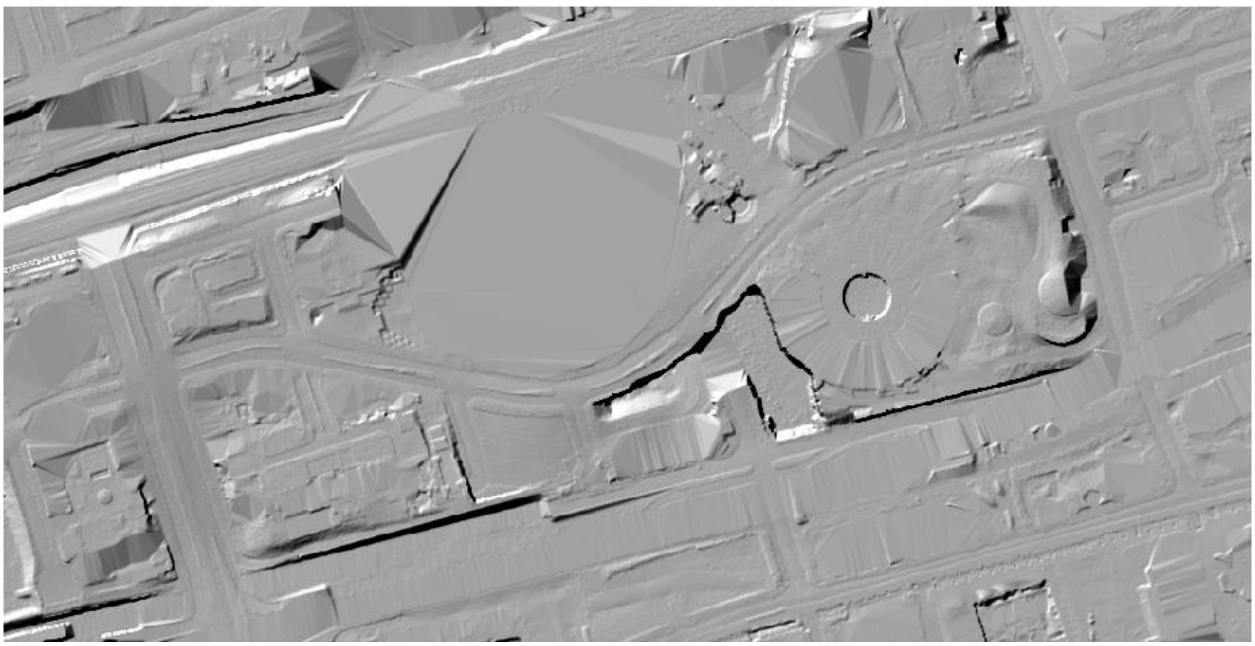

Fig 1: Image of the Bare earth .tif file provided

In the figure above, we can see the shadows of existing buildings. Hence, this tif file was ignored and the LiDAR Data was processed to produce a DEM.
The .xyz files can be opened using notepad and contains the UTM coordinates of the lidar points in XYZ format. There are also two files for this to include the UTM coordinates of the Bare Earth and Full Feature collected points.

METHODOLOGY

.las DATA REPRESENTATION IN MATLAB

Firstly, the .las file was converted into a pcd file (point cloud data) using CloudCompare. The .las files were then imported and saved as .pcd files into separate folders.

The visuals of the 3D data on cloud compare were quite grainy. So, MATLAB was used to get a better visualization of the area of interest. To do so, first install the automated driving toolbox for MATLAB. To use this toolbox, enter in the command window: *groundTruthLabeler*. Then click **open → add signals** and change the source type to **point cloud sequence**.

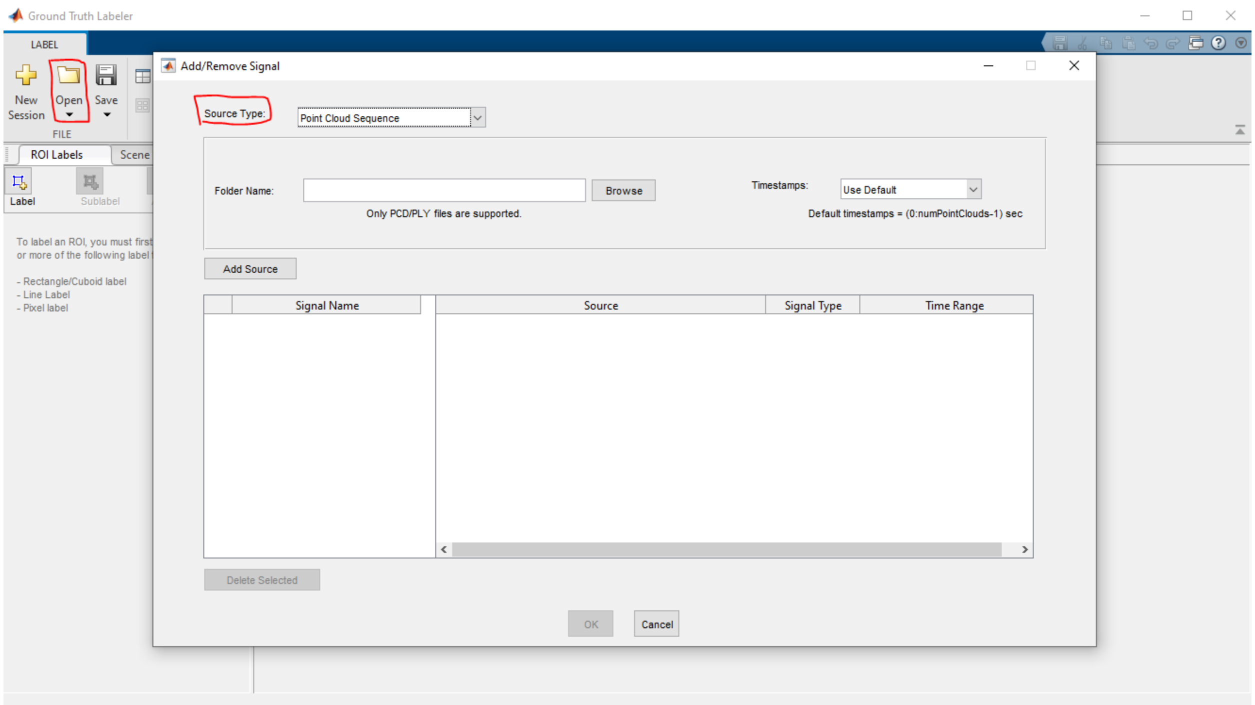

Fig 2 : Image showing the MATLAB Process

Browse to the folder that has the saved .pcd file and click **add source** and **ok.** This was done for the other .pcd file as well and it will produce the LiDAR data collected for our study area.

.las DATA REPRESENTATION IN ArcGIS

Filtering for ground points and surface points

The LiDAR data was loaded onto ArcGIS along with the 50cm contour shapefiles and the Full Feature .tif files. To filter out the surface points, leaving only the ground points, the LAS filter was used, and ground points selected. However, with the removal of the surface points, there were blank spaces in the new file so we had to use other filtering methods and point interpolation methods to produce the final DEM results.

Las to raster à using ground points

The filtered LiDAR data that only had the ground points was then converted to a raster file using the ***LAS Dataset to Raster*** tool. The interpolation type used was the triangulation method, this helped fill in the blank spaces in the filtered LiDAR data. The raster file was then filtered to remove any noise from the data, this was done using a Gaussian 5 by 5 filter which is a low pass filter.

To interpolate the missing points in the data when creating the DEM, a raster file was required which would provide the elevation data that is then used to estimate the missing points. This is the reason why the LiDAR data was first converted to a raster file since a point interpolation method is used in this conversion process. Using other raster files provided (like the full feature or bare earth) resulted in a weird looking DEM.

Using the ***Interpolate from Point Cloud*** toolbox, with the filtered data as the *input LAS file* and the filtered raster data as the *input fill DEM,* a DTM/DEM was created. The interpolation method used was TIN Linear Interpolation.

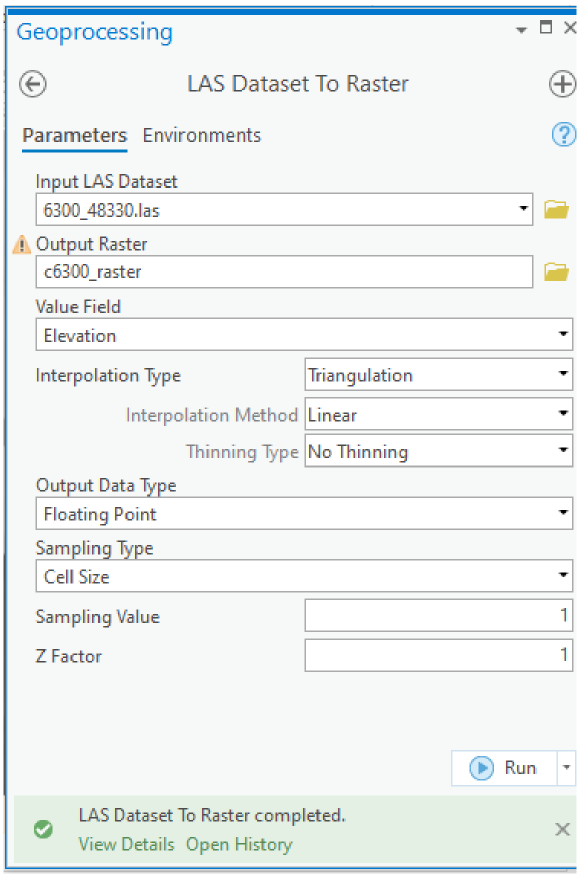

Fig 3: Image of LiDAR to Raster Process

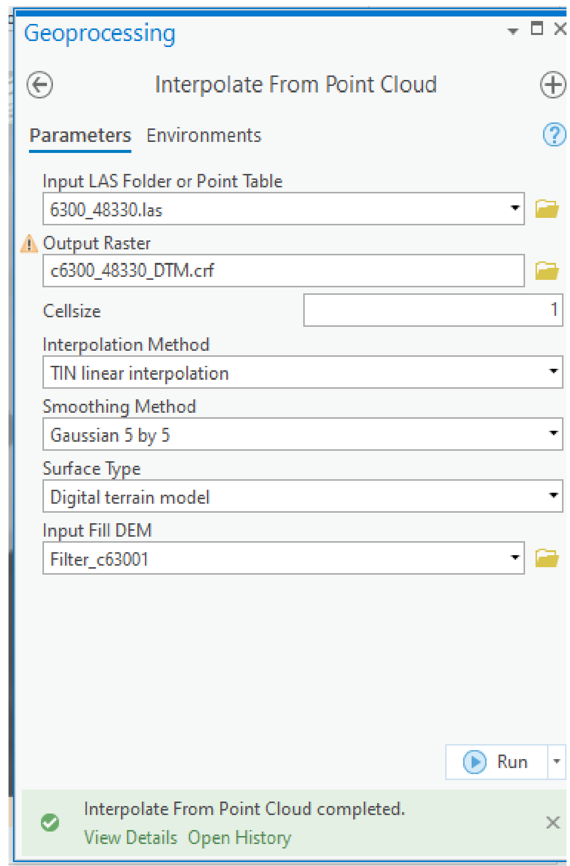

Fig 4: Image of the point interpolation process to produce the DEM.

RESULTS AND ANALYSIS

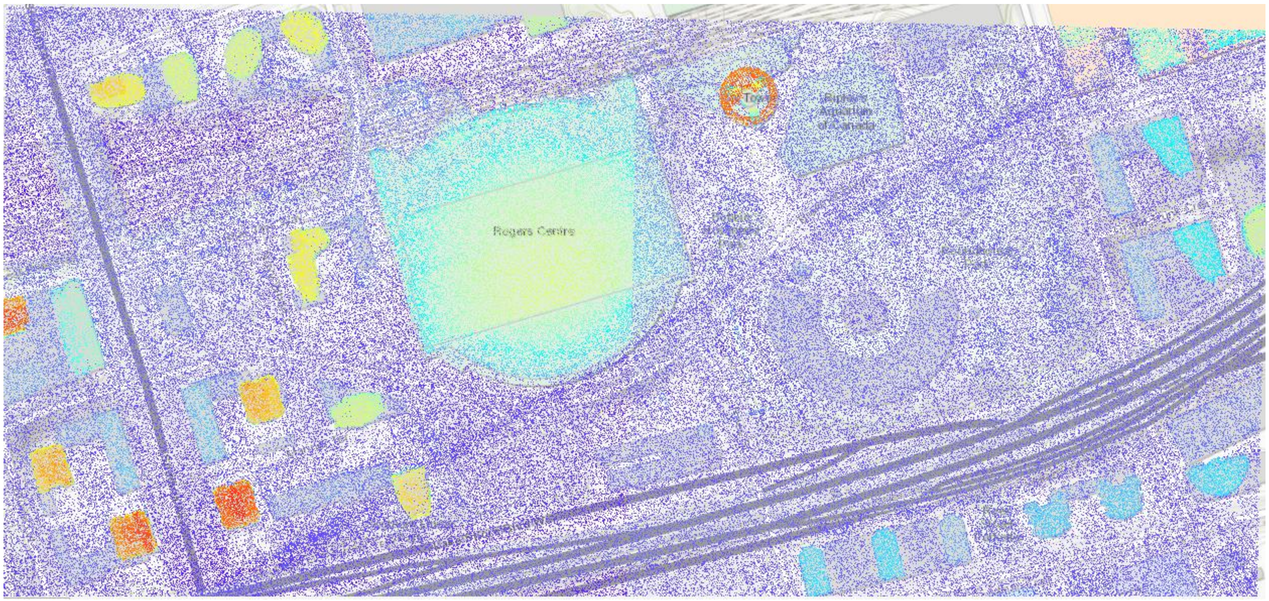

Fig 5: Image of the complete LiDAR Data

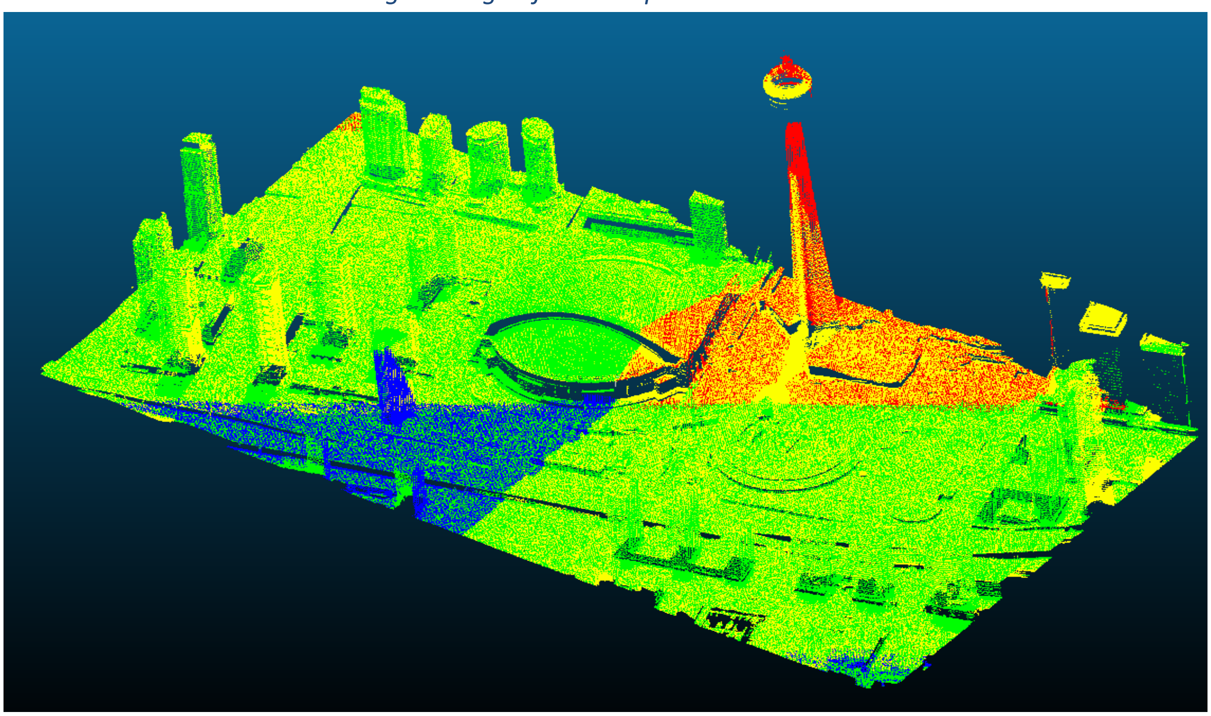

Fig 6: Image of the 3D visual of the LiDAR Data using the CloudCompare software

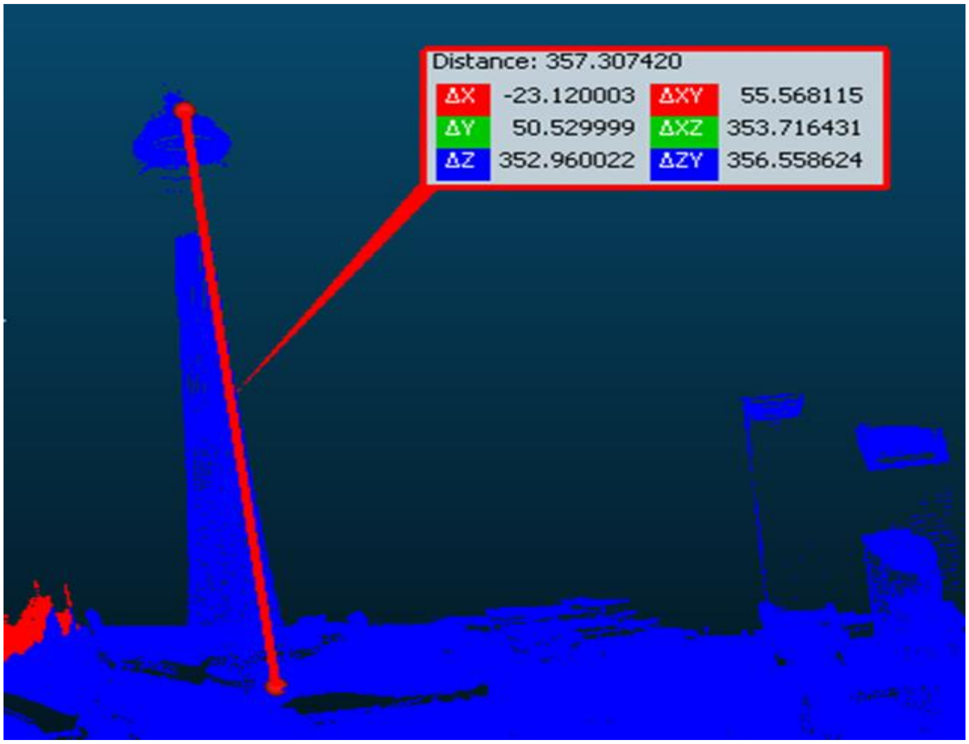

Fig 6b: checking the CN Tower height

The height of the CN tower is ~500m, we believe this could be an accurate representation of the CN tower due to the LiDAR data being cutoff above the observation deck.

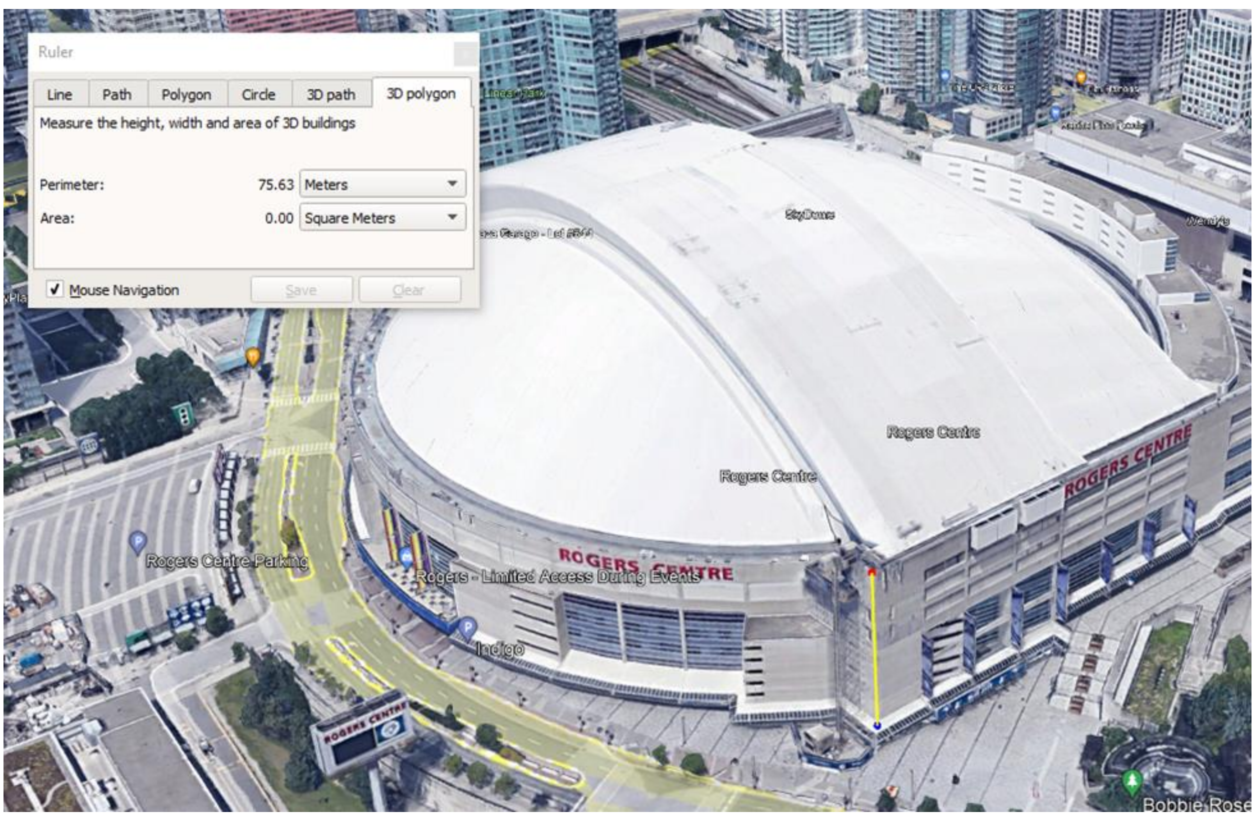

Fig 6c: Height of Rogers Center in Google Earth Pro

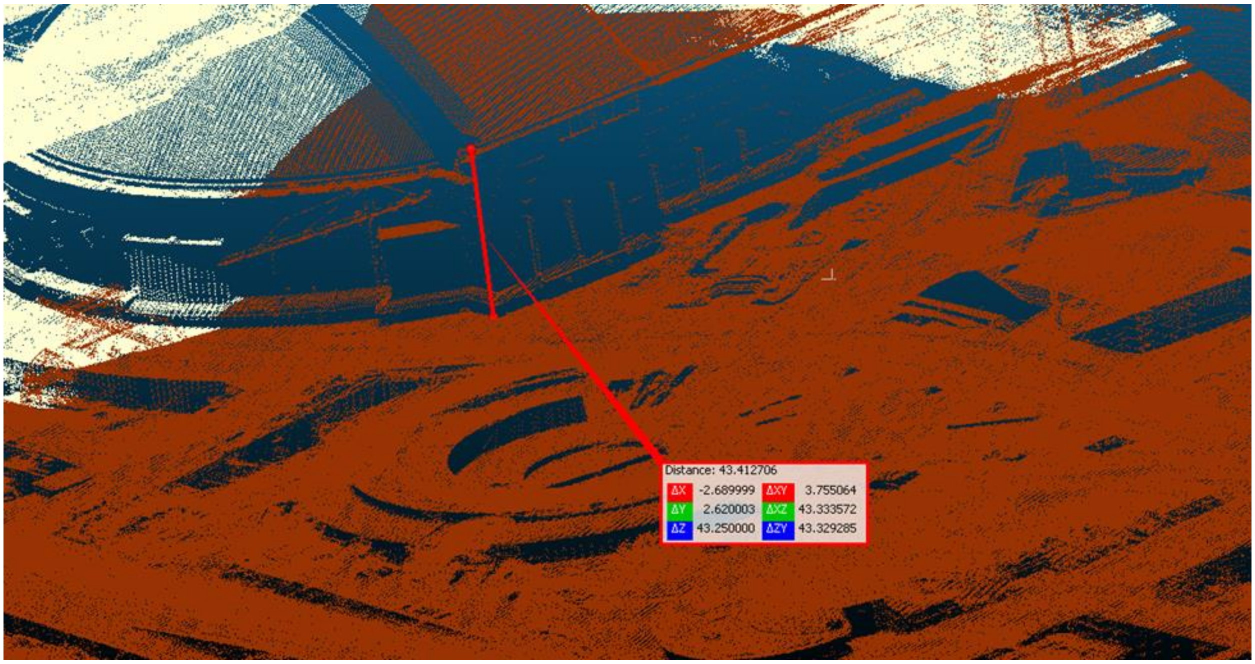

Fig 6c: Height of Rogers Center in CloudCompare

The height of the Rogers Centre is a misrepresentation as depicted in both images. It seems in CloudCompare that the height is half of what it actually is when compared to Google Earth Pro.

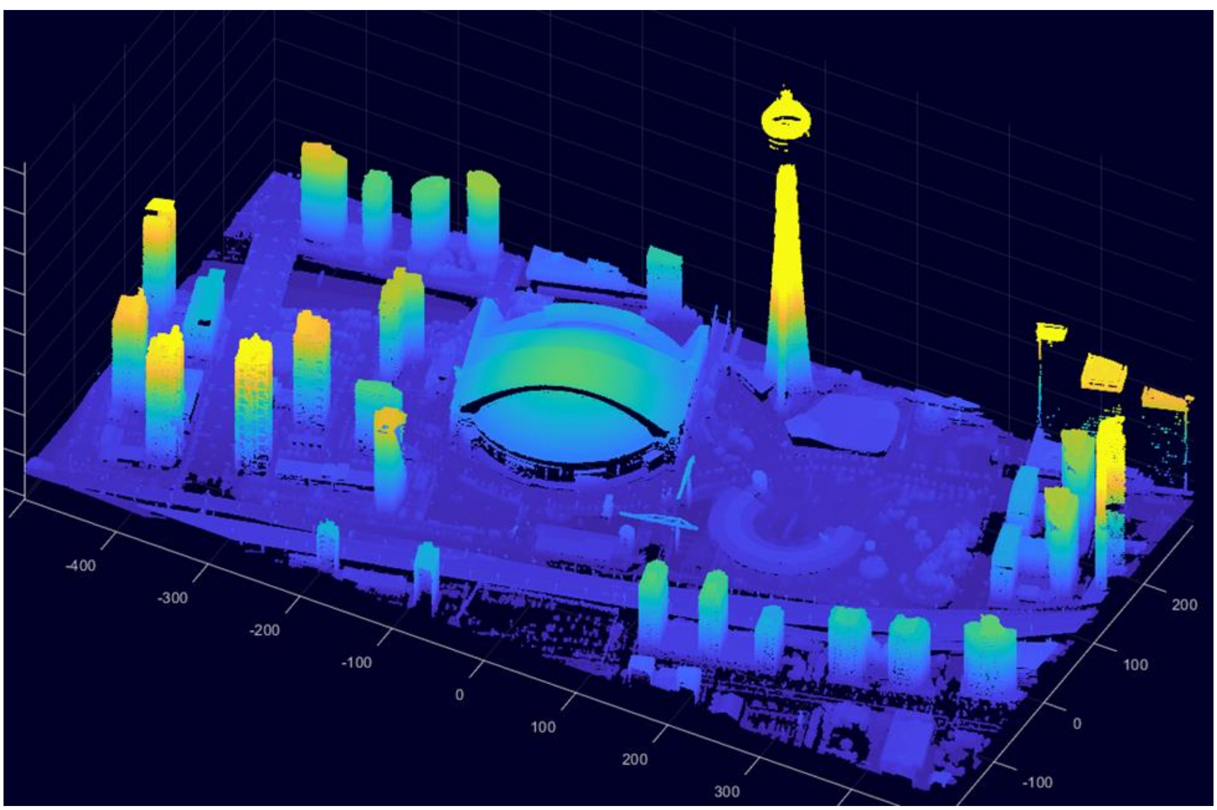

Fig 7: Image of the 3D visual of the LiDAR Data using the MATLAB software

Comparing figure 6 and 7 it is obvious as to why the MATLAB Visualization was preferred over the CloudCompare visual.

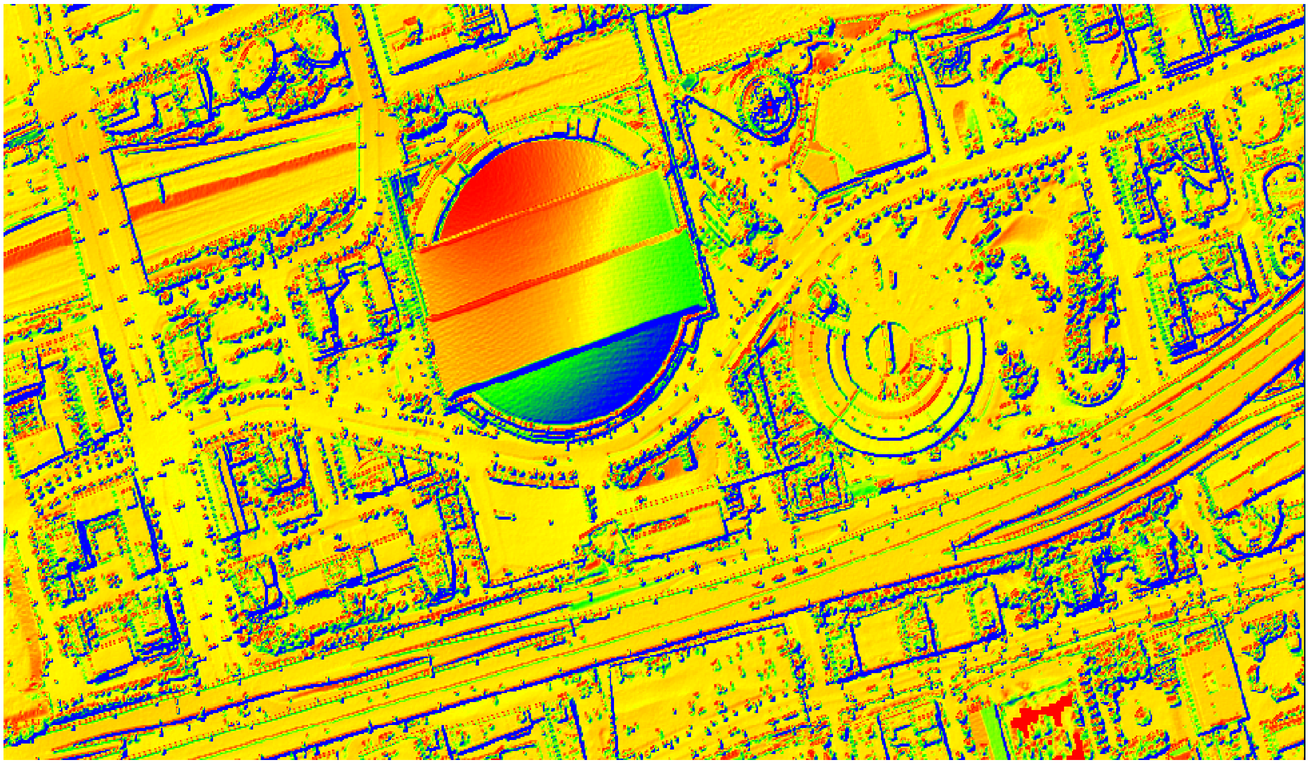

Fig 8: Image of the DSM data

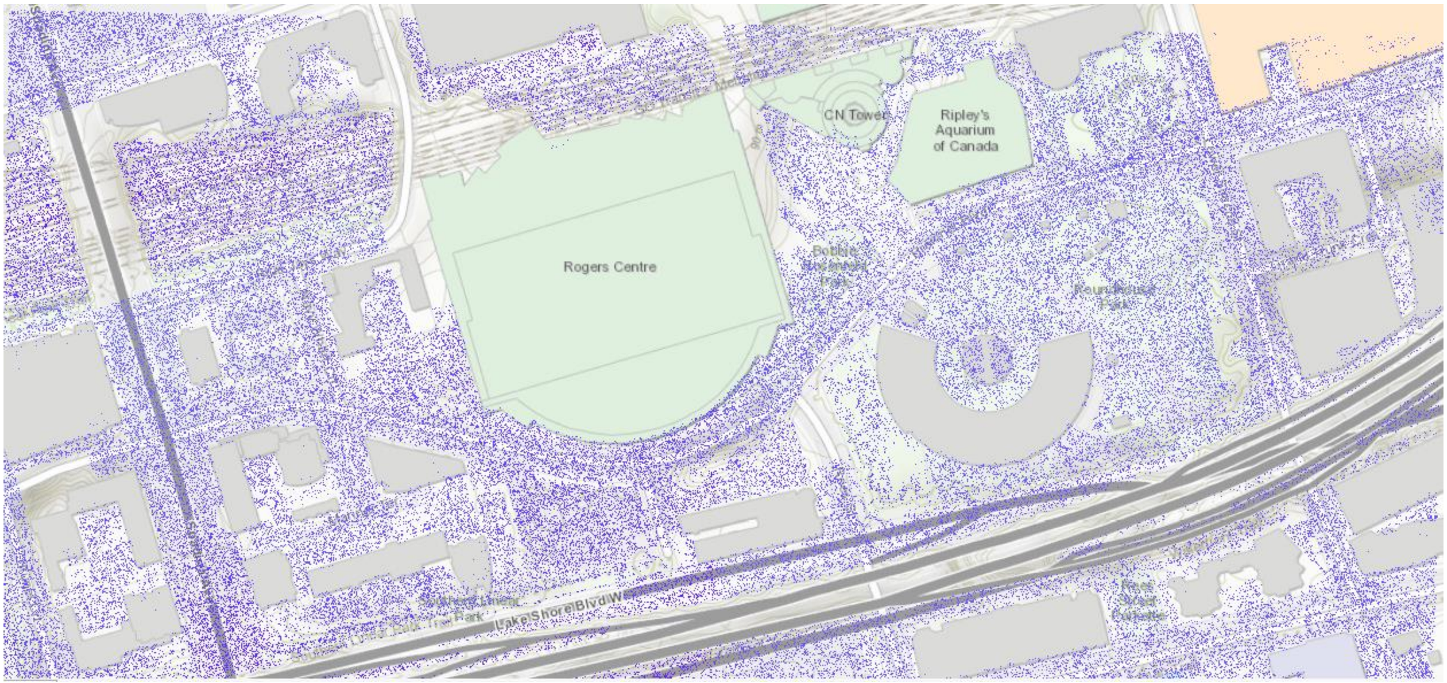

Fig 9: Image of LiDAR Data with only ground points

As seen in figure 9, we had a lot of empty gaps to fill in, therefore the LiDAR Data had to be converted to a rater first to interpolate those missing points.

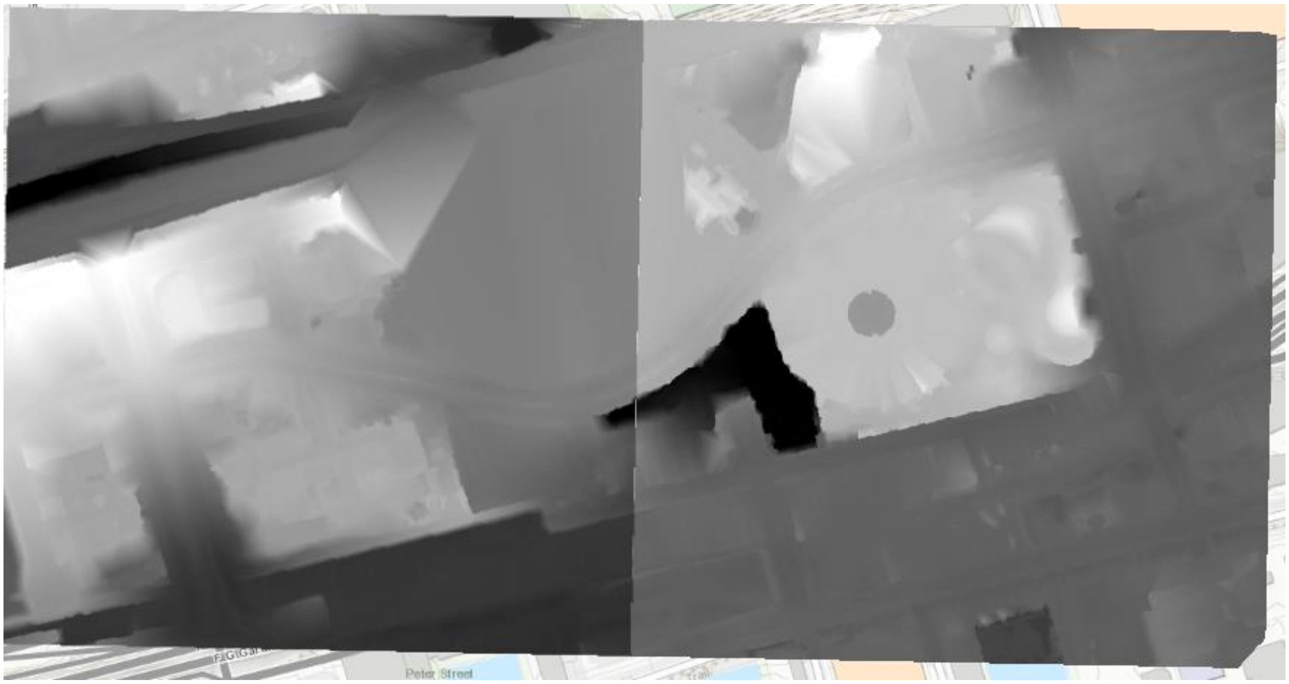

Fig 10: Raster Imagery of the filtered LiDAR Data

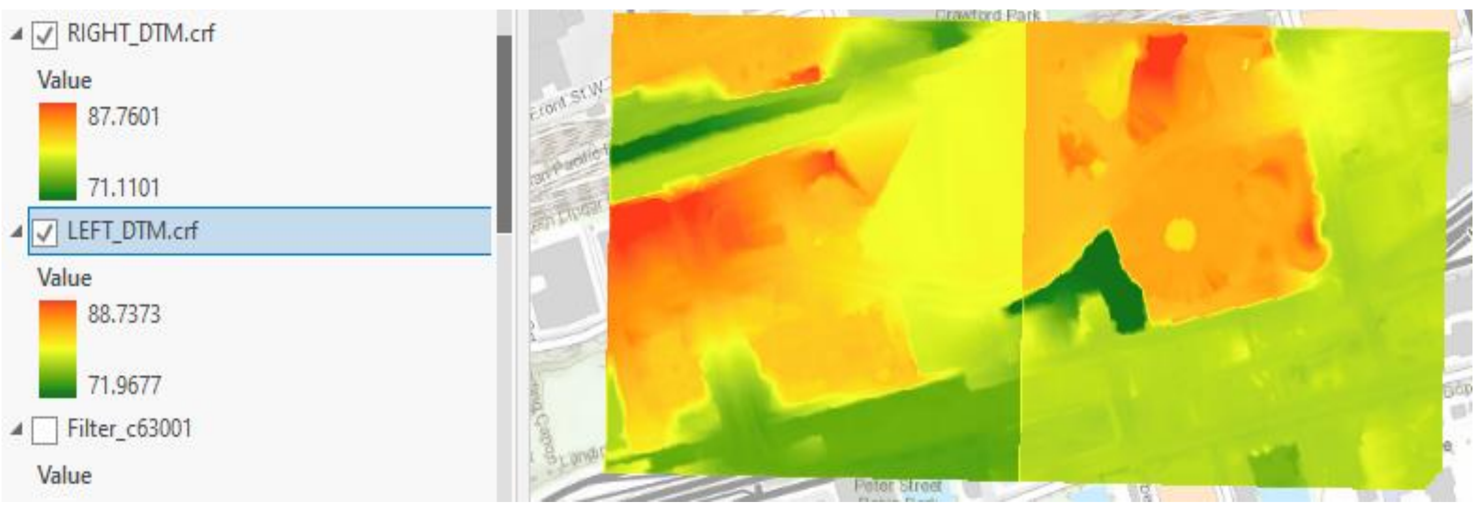

Fig 11: Image of the Interpolated DEM

Since two tiles were combined, there is a slight deviation in the color scheme between the left and right DEM's. The distinct line in the center represents the end of one tile and the beginning of another. Just because the interpolation and filtering methods make use of neighboring points and the statistical variability of the whole Data, we see a slight difference. To get rid of this issue, various attempts were made to combine the .las files into one at the earlier stages of processing, however, this proved futile since the merged data could not be saved in a separate folder.

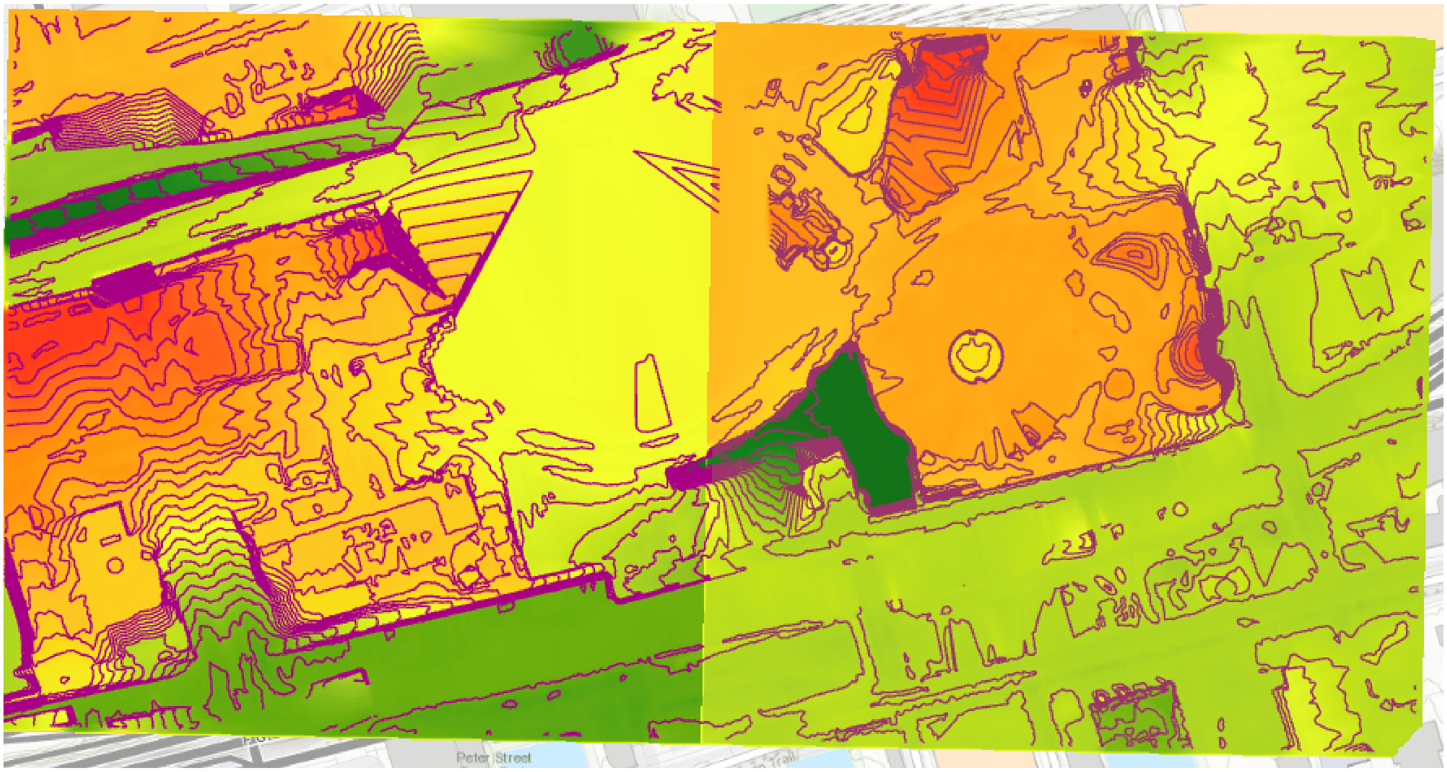

Fig 13: Image of the Interpolated DEM and provided Contours

Fig 14: Slope Analysis of the Area

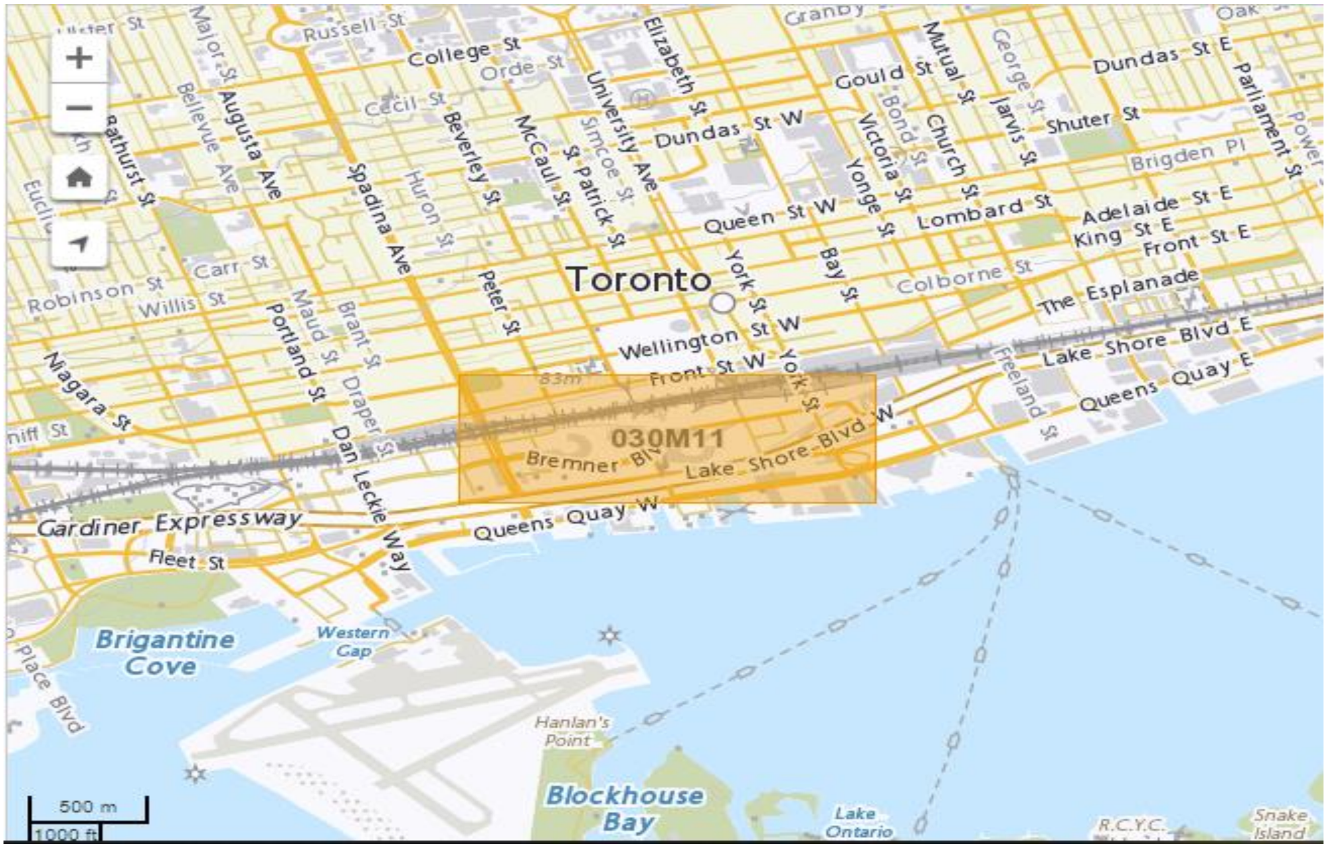

Fig 14: Area selected for NRCAN DEM Retrieval

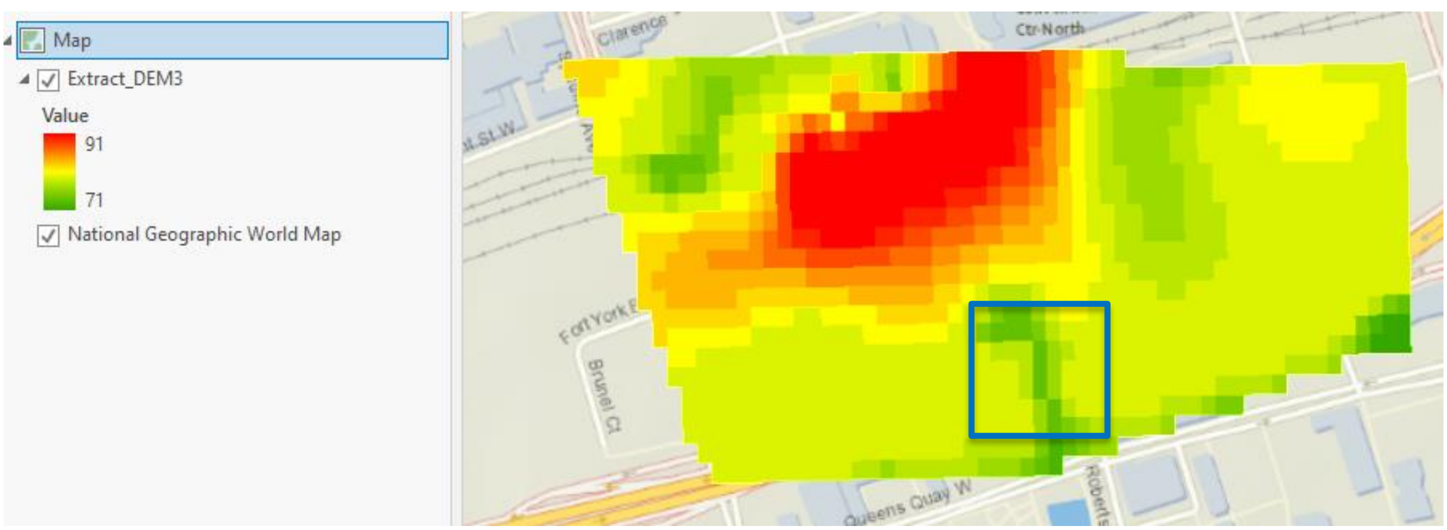

Fig 15: DEM from NRCAN

Figure 15 is quite blurry due to the bad resolution, unfortunately we couldn't get this DEM and our contours in the same projection using ArcGIS, the visuals was always off. The resolution is also quite bad in this imagery; however, we do see some similarities especially in the cliff area highlighted by the blue square. Though our DEM is quite similar, we still have slight imprints of the surface features, we can tell where the railway tracks are and the rogers center. It is quite a good estimation though considering that we started in an urban area.

CONCLUSION

Results were as expected based on what was learnt in class. Filtering and Point Interpolation methods were very handy when it came to producing acceptable results. The DEM may not be as accurate since there were huge gaps in the ground point data that had to be interpolated which can introduce errors since it had to undergo a lot of processing. Comparing the data to what we got from NRCAN, our results are not that bad of the area. It is quite difficult to retrieve DEM from LiDAR of an already established Urban area as this leads to a lot of post processing of the area. Even with all the post processing we could still see slight imprints of the removed surface features. However, we were still able to present a general representation of the elevation of the area.

REFERENCES

[1] Shapefiles. (n.d.). Retrieved November 29, 2021, from https://doc.arcgis.com/en/arcgis-online/reference/shapefiles.htm

[2] TOPOGRAPHIC MAPS: The basics. (n.d.). Retrieved from https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/topo101/pdf/mapping_basics_e.pdf

[3] GEOTIFF. (n.d.). Retrieved November 29, 2021, from https://www.usna.edu/Users/oceano/pguth/md_help/html/tbme9v52.htm

[4] https://www.arcgis.com/home/webmap/viewer.html?webmap=9bea49bf653b4e28a10c21f833e38b1e&extent=-79.8195,43.5133,-78.933,43.9202

[5] http://gaia.library.yorku.ca/

[6] Topographic Information (nrcan.gc.ca)