



2022

Developing Object Detection for Autonomous Obstacle Avoidance

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Anjanee Nikhila | Mingxing He | Aidan Corral

Mentors: Navid Sabbaghi | SMC Business Analytics
Brian Boogaard, Nelson.Brown |NASA



Aerial LiDAR Applications in AS Conflict Detection

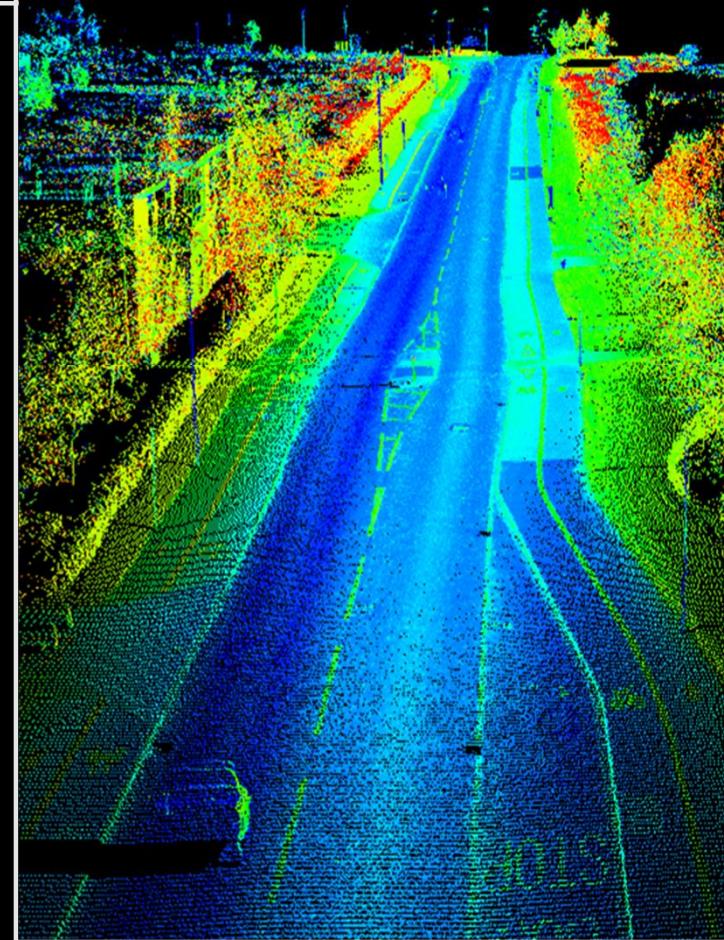
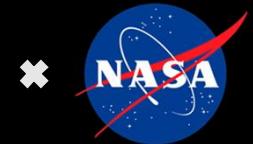


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Brian Boogaard | TTP Coordinator, NASA
Nelson Brown | Project Chief Engineer, NASA

Saint Mary's College of California MSBA Practicum |
NASA

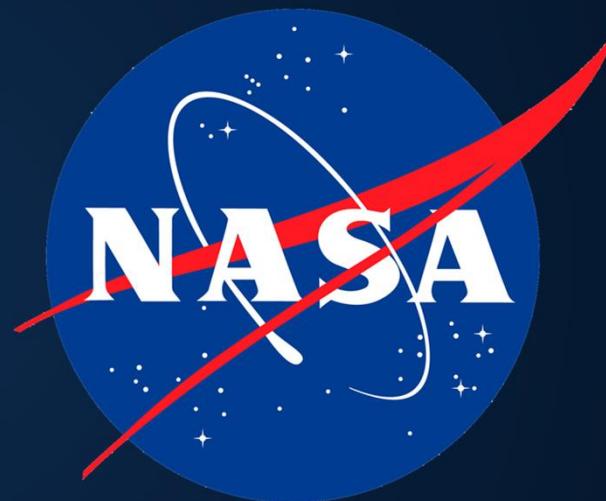
LIDAR BASED OBSTACLE DETECTION IN UAS SYSTEMS



Saint Mary's College MSBA Practicum | NASA



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»»» Meet the Team



Ming xing He Melanie



Graduated from Jiangtan university with a B.A. in Art design. Current Master program in Business Analytics at Saint Mary's College of California. A dog person, hiking often.

Paul Turek



Graduated from SDSU with a B.A. in Economics. He works at S&B as an account manager and in his free time likes to play golf and go snowboarding at Lake Tahoe.

Marc Goulart

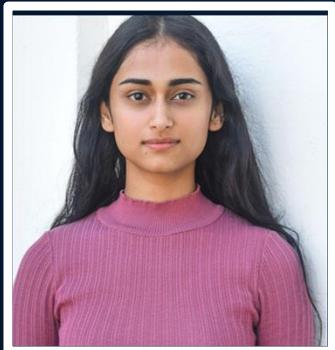


Currently enrolled in the Business Analytics Master's Program at Saint Mary's College of California. 2021 Saint Mary's undergraduate graduate, earning a B.S. in Business Administration.

»»» Meet the Team



Anjanee Nikhila



Currently pursuing Master's in Business Analytics at Saint Mary's College of California. Earned Bachelor's degree in Business Management & Accountancy at University of Mumbai. Free time dedicated to singing and art.

Aidan Corral



Current MSBA student and recent 2022 undergrad graduate in mathematics and computer science both at Saint Mary's College of California. Currently works as a market research analyst at Deep North. Likes to workout, mix martial arts, and play basketball.

David Rovner



I am a Federal Law Enforcement Officer with 22 years of federal service. I am pursuing my MS in Business Analytics to change careers. I am a U.S. Army Veteran. I graduated from Cal Poly San Luis Obispo with a B.S. in Industrial Technology. In my free time, I enjoy traveling, going to concerts, hiking, going to the beach, going on random adventures, and riding my Harley. ⁶



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Introduction

Background

Problem Statement

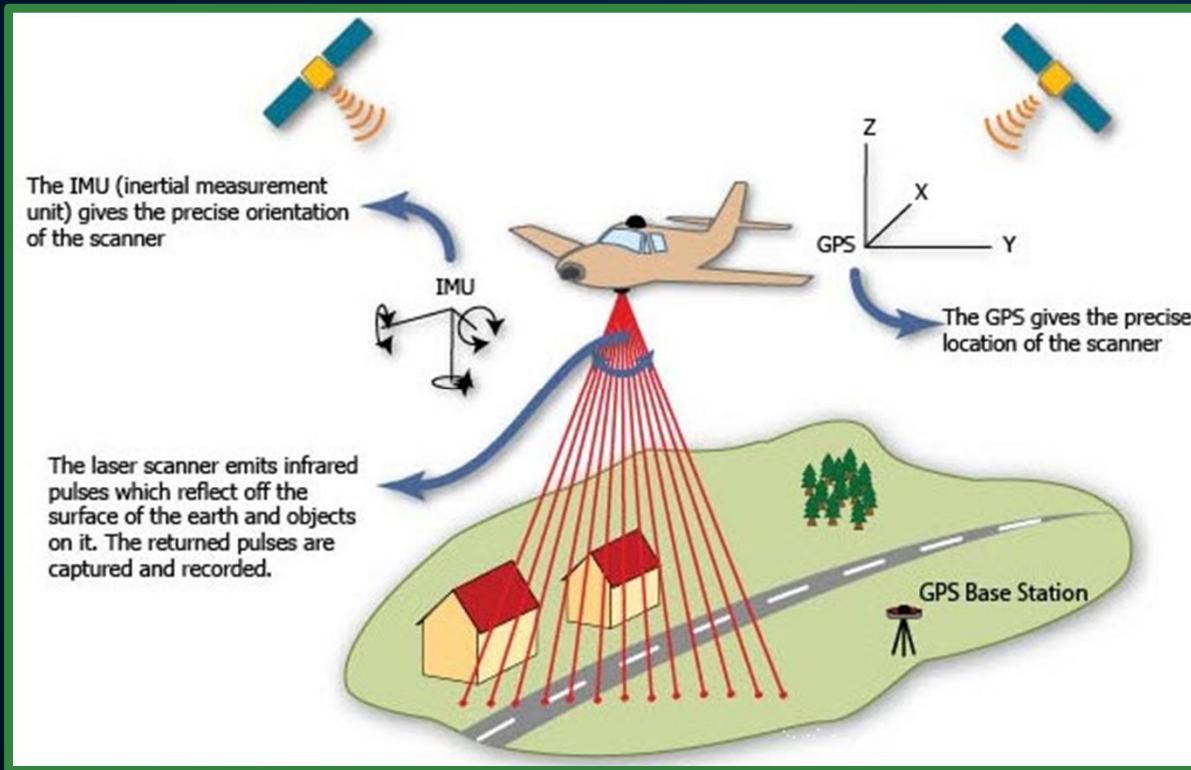
Project Goals



»» Background: What is LiDAR?



LiDAR: Light Detection and Ranging



Mapping professionals to examine both natural and manmade environments with accuracy, precision, and flexibility.



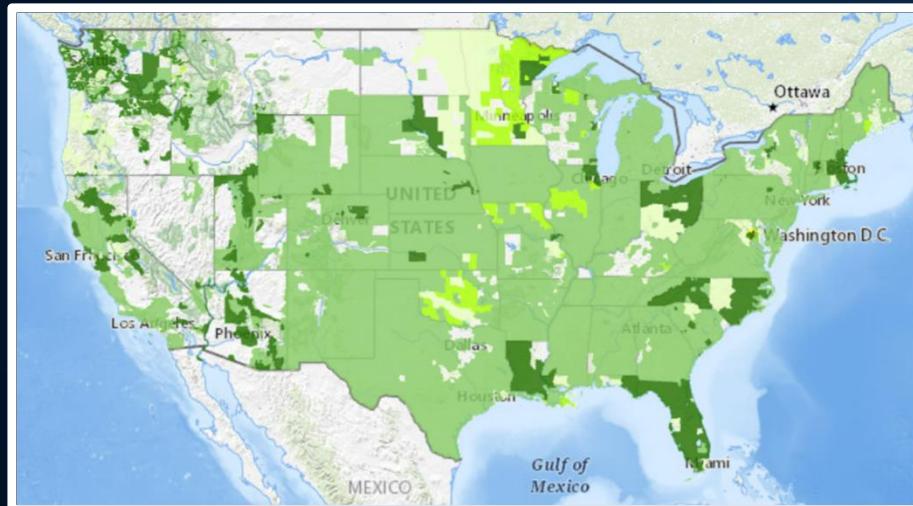
Light pulses are sent out, reflected off objects, and received for interpretation, mainly to measure distance.

»» Background: LiDAR Datasets

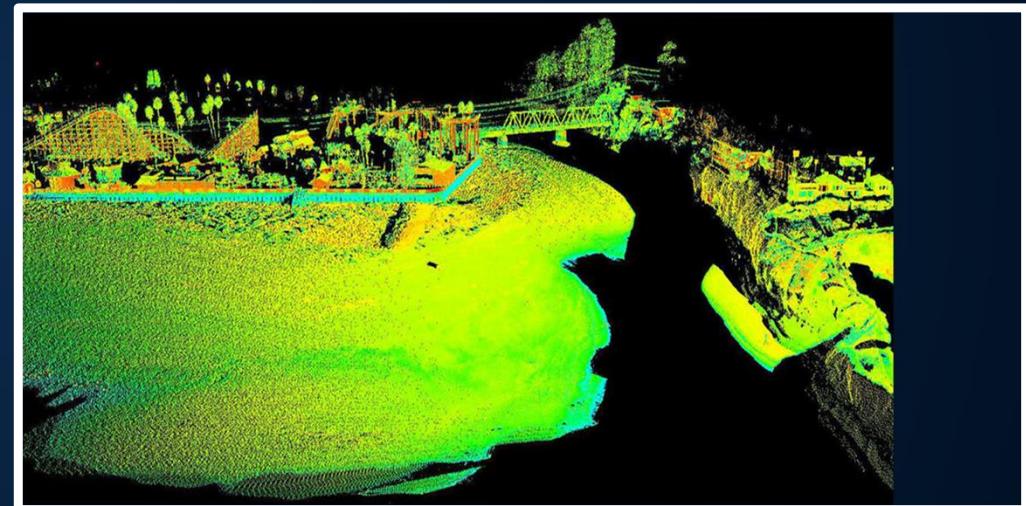


LiDAR: Light Detection and Ranging

- LiDAR datasets are abundant and updated regularly



Visualization of U.S. topography surveyed by aerial LiDAR by SGS.



Point clouds are sets of points that describe an object or surface. Each point contains an ample amount of data that can be integrated with other data sources or used to create 3D models.

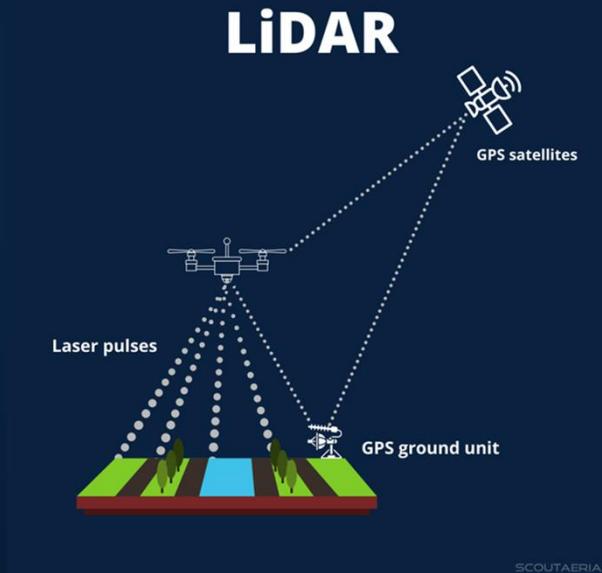
»» Background: Drone Autonomy



?hy ?ntegrate ?iDAR in Drone technology?

?nable drones to use as much information as possible to avoid collisions with static and dynamic obstacles

Collision avoidance systems are crucial for enabling autonomous operations for unmanned vehicles of all kinds. These systems take in data from various onboard sensors, as well as data from external sources, and calculate the best manoeuvres for the vehicle to make in order to avoid hitting an obstacle or hazard.



More advanced systems may use artificial intelligence and computer vision to perform detection and classification of objects picked up by the sensors.

»» Background: NASA TTP Goals



Task

- ? Use available datasets captured from to increase the capabilities of object detection and avoidance systems
- ? Develop an algorithm that can be used to identify obstacles in areas that have been surveyed by aerial LiDAR.

? why?

- ? Commercial drones are becoming increasingly more popular
- ? These drones are relatively small, and the hardware that is onboard the craft must be sparse to minimize weight

How:

- ? Using publicly available LiDAR datasets, create a geodatabase of tall obstacles in urban environments that are hazardous to drones and other aerial vehicles flying at low altitudes.
- ? Minimize the size of the obstacle database so that it can be stored onboard drones, depending on the flight path.

»» ? hat's happening now

A2Z Drone Delivery Winch is Defining the Way Packages Drop to Your Doorstep

Posted By: Miriam McNabb on: October 03, 2022



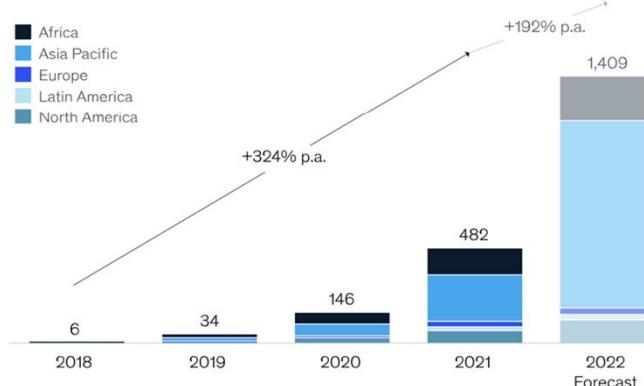
The A2Z drone delivery winch and drone platform are drone delivery tools designed to keep the drone at a distance from the home, eliminating noise and many safety concerns, while delivering a package gently and accurately to the doorstep.



The last few years have been seen a dramatic change in the drone industry. COVID absolutely gave this industry a huge push.

Commercial drone deliveries are expected to increase.

Commercial drone deliveries, Thousands



Note: Number of deliveries represents number of parcels delivered, not total number of items within the parcels.
source: McKinsey Drone Delivery Tracker and Forecast



Amazon's new delivery drone scheduled start deliveries in Rockeford, California and College Station, Texas by the end of 2022.

zipline



32,967,042

miles flown



464,839

commercial deliveries



4,480,991

products delivered



25 Million

serviceable customers

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HOME · NEWS

Oops! Drone delivery crash knocks out power for thousands



By Trevor Mogg
October 2, 2022

SHARE

Google sister company Wing has been making steady progress with tests involving its delivery drone in Australia, but a recent accident highlights some of the challenges facing such pilot projects as they attempt to go mainstream.

The mishap occurred when a Wing drone on its way to deliver a food order to a customer in Logan City, Brisbane, crashed into an 11,000-volt power line. The collision caused a small fire as the drone fried on the wire before falling to the ground, leading to the disruption of electricity supplies to around 2,300 homes and businesses.

<https://dronedj.com/2022/03/25/amazon-delivery-drone-crash-oregon/>

<https://www.digitltrends.com/news/drone-delivery-crash-knocks-out-power-for-thousands/>



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M?t?r ?a??re a??d ?ra?hed t? the ?r??d?

Amazon delivery drone crash sparked acres-wide fire in Oregon: FAA

Ishveena Singh - Mar. 25th 2022 11:45 am PT [@IshveenaSingh](#)

DRONE DELIVERY AMAZON



Comments [f](#) [t](#) [p](#) [in](#) [g](#)

Amazon's drone delivery program is again under the scanner with a new *Business Insider* report highlighting how an experimental Prime Air drone set several acres of a wheat farm ablaze when it crashed in eastern Oregon during a test flight last summer.

According to a June 2021 FAA report accessed by the publication, an Amazon delivery drone prototype (model MK27) was flying at an altitude of 160 feet before it encountered motor failure and crashed to the ground.



»» Object Detection Background



01

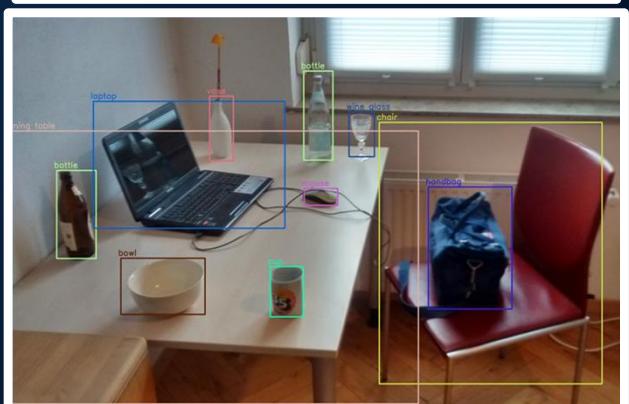
What is object detection?

A software that identifies and locates objects within an image or video.

02

Uses?

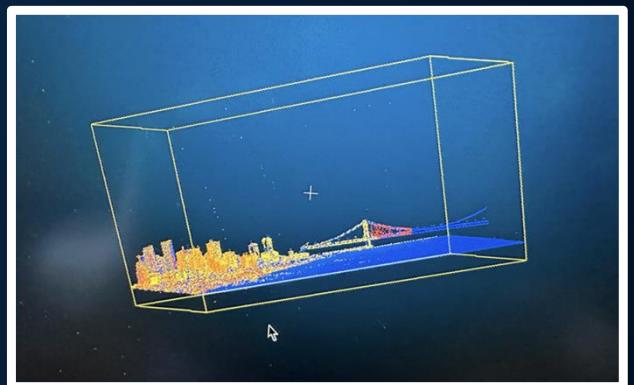
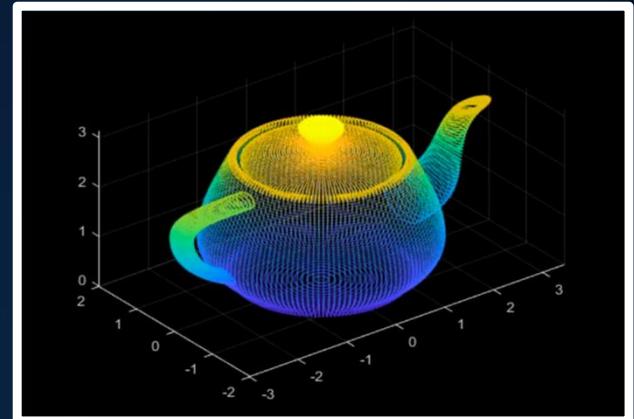
Image annotation, vehicle counting, activity recognition, face detection, face recognition, video object co-segmentation.



»» ? What is a Point Cloud?



- ? A point cloud is an extremely large bundle of points that are specifically put together to take a geographical area, terrain, building or feature and plot them in to a 3d space.



»» The Intense Details of a Point Cloud



01



02



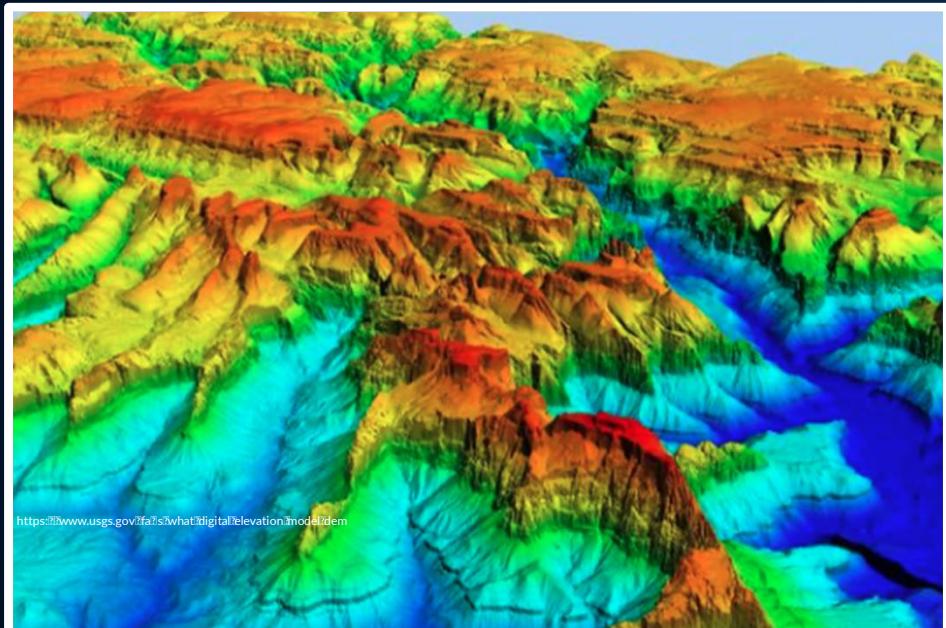
03



04



»» D?M ?Digital ?levation Model?



- A representation of the bare earth topographic surface of the Earth? excluding trees, buildings, and any other surface objects.?
- Using a D?M raster, we can predict the elevation of areas of non-ground points.

02.

Tools and Libraries



>>> T???



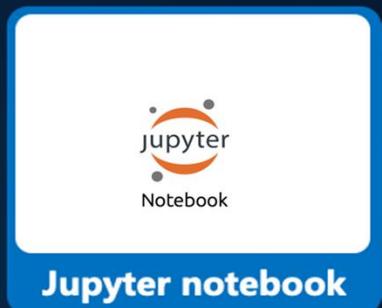
Python + Colab



CloudCompare



ArcGIS Pro



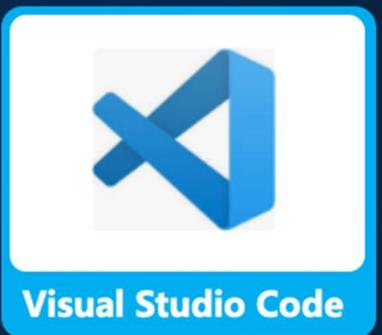
Jupyter notebook



WSL 2



R Studio



Visual Studio Code



JavaScript



Mamba



Pip Python package



Mambaforge



Docker



»» ArcGIS Pro



01

A full-featured professional desktop GIS application from Esri.

02

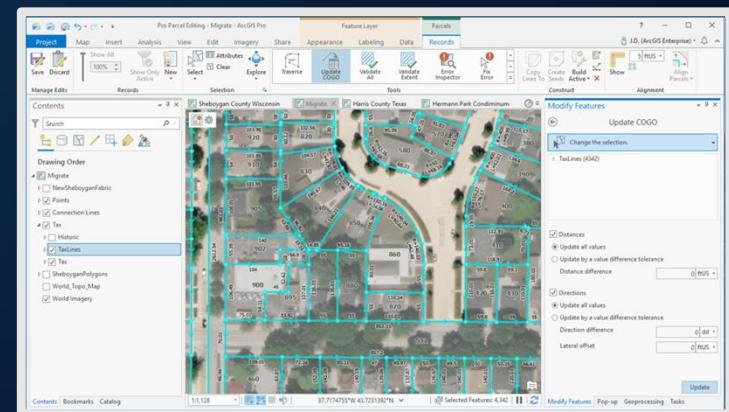
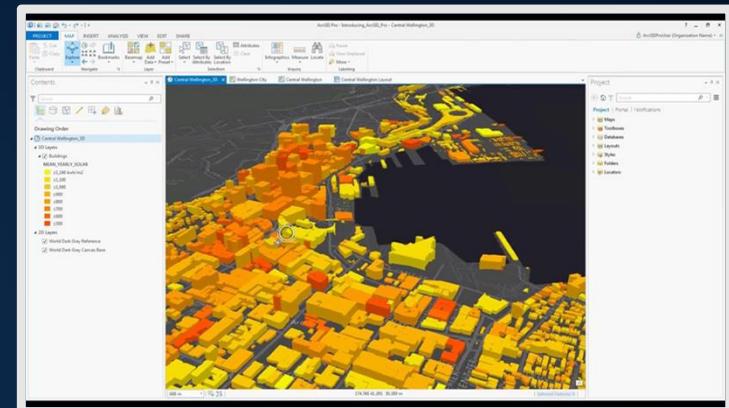
Stores spatial data.

03

Explores, visualizes, and analyzes data

04

Create 2D maps and 3D scenes.



01

Open?D

Supports rapid development of software that deals with ?D data.

02

???

An airborne ?iDAR filtering method which is based on cloth simulation.

03

laspy

Python library for reading, modifying and creating ?AS ?iDAR files

04

PDA?

C?C library for translating and manipulating point cloud data.

05

Matplotlib

Static, animated, and interactive visuali?ations in Python

06

GDA?

translator library for raster and vector geospatial data formats

07

Others

numpy, pandas.

O ?.

Data ?xploration

Object?Detection Project Data
Object?Detection Project ?ourney

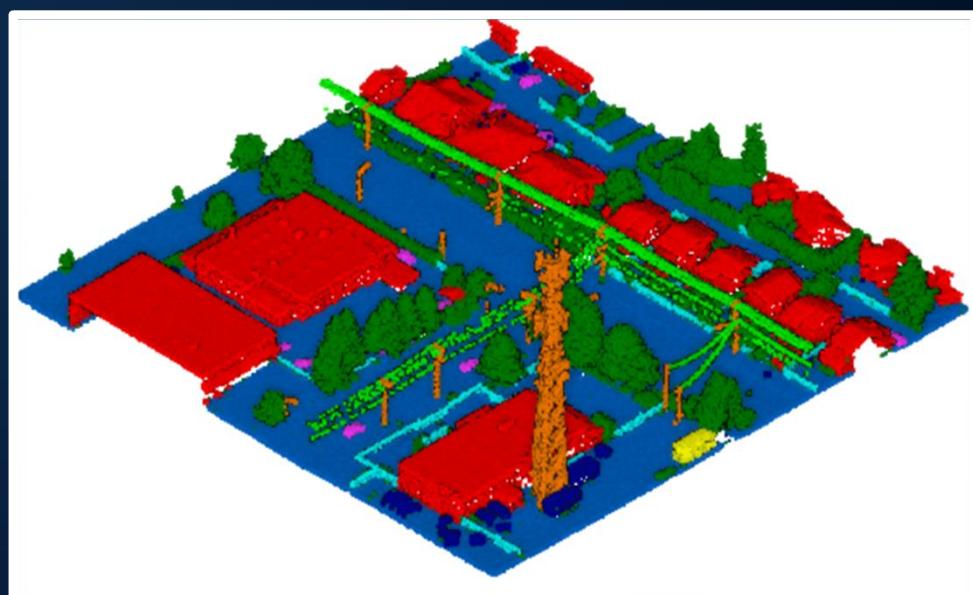


»» Object Detection Project Data



SGS Aerial LiDAR

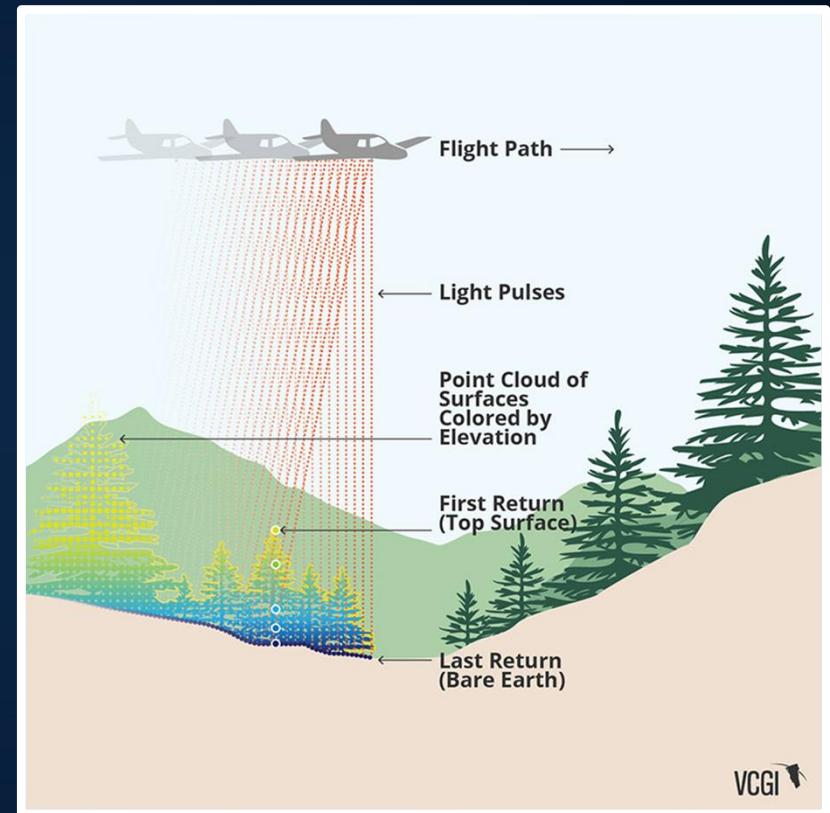
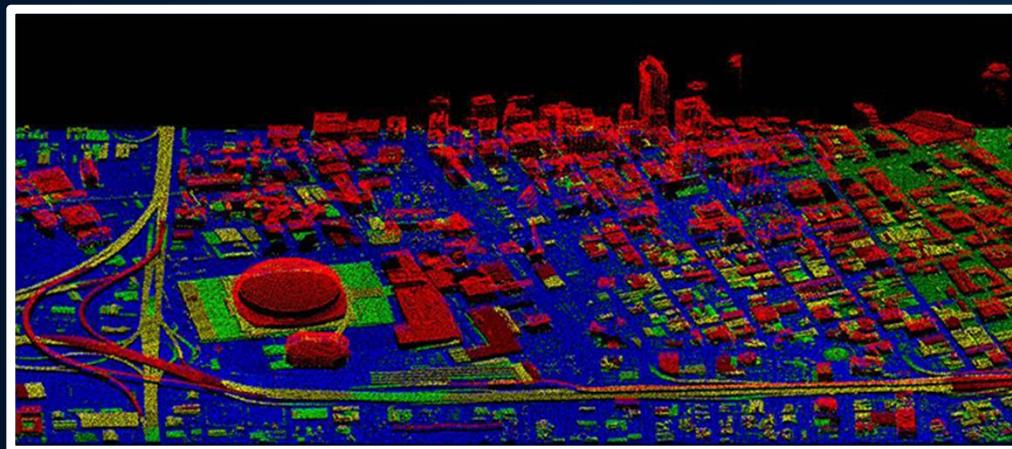
DAVIS Semantic Segmentation Dataset



»» SGS Aerial LiDAR



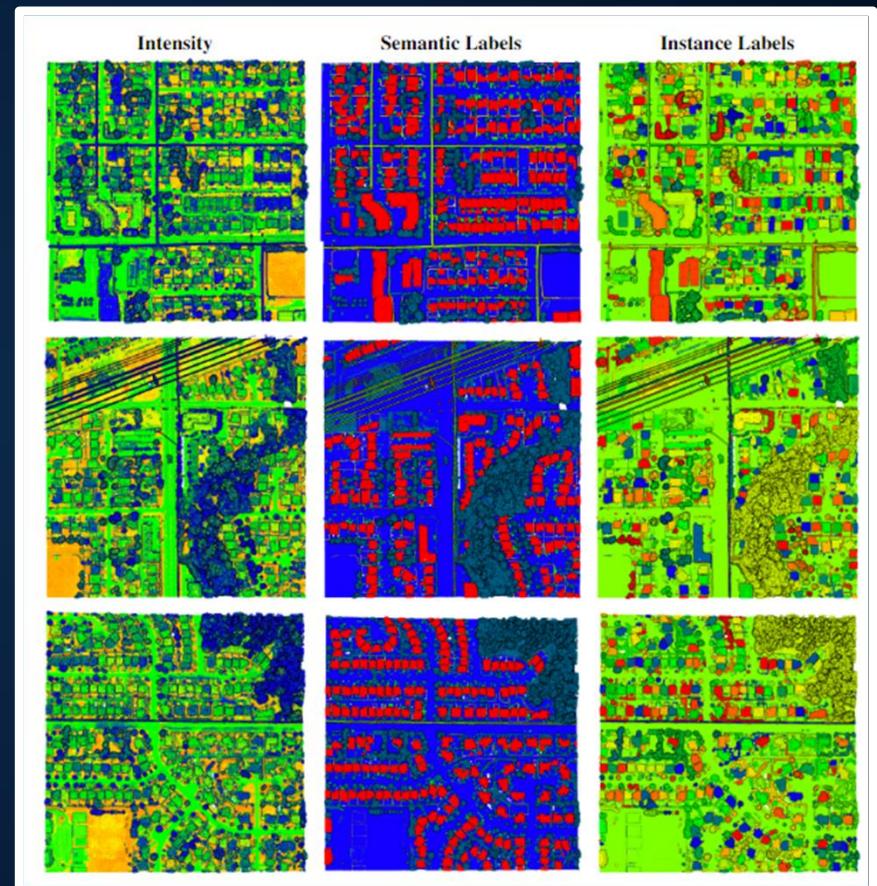
- ? This is free public data accessible to anyone.
- ? Captures a large scale of land, obstacles, roofs and tall vegetation.
- ? Aircraft emits and captures light pulses.
- ? Point Cloud surfaces colored by elevation.
- ? First return is the top surface. Last is the bare earth.



» DA??S Semantic Segmentation Dataset



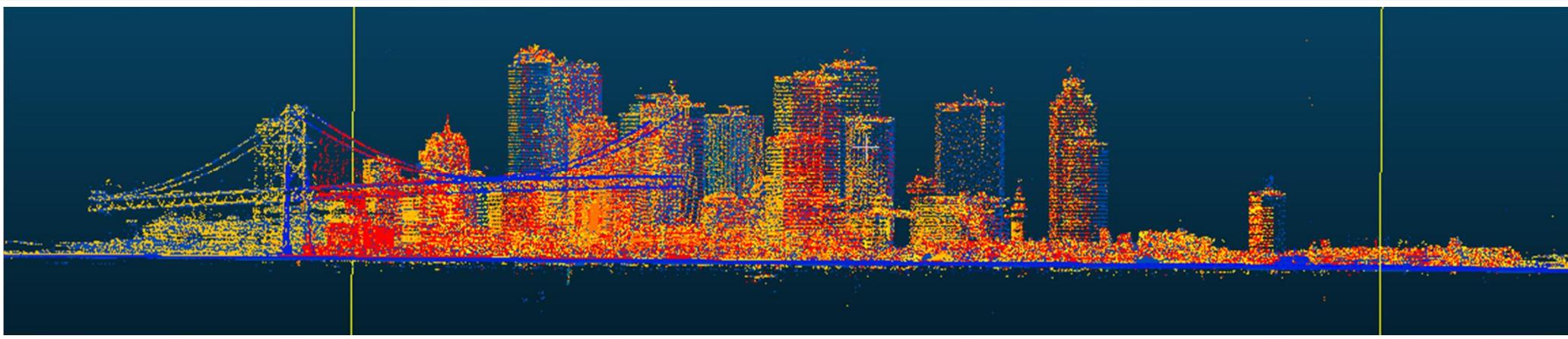
- Source: University of Dayton
- Initial data set: 20 km² area.
Final data set: 20 tiles of 0.2 km² each
- Scene Types: Urban, Suburban, Rural, and Commercial.
- Object Categories : Ground (blue), Vegetation (dark green), Cars (pink), Trucks (yellow), Power Lines (light green), Fences (light blue), Poles (orange), and Buildings (red)



»» Cloud Compare



• Mat? ? a? aer? data?et ? the ?a? ?ra? ?me a?d ?a? ?rd?e
M? data ?t? th? ???

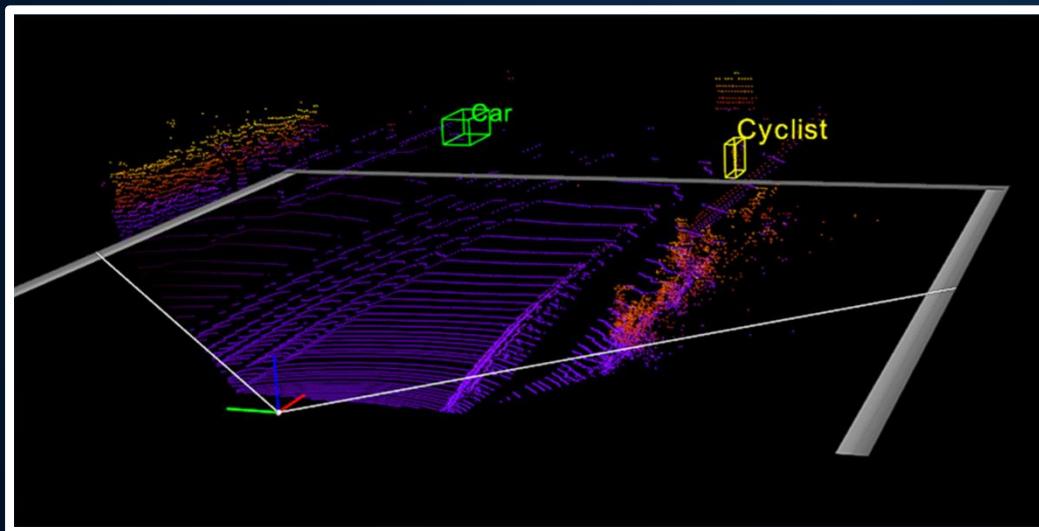


Source: SGS Lidar Point Cloud PCARRA CA GoldenGate 2000 00 2020 02 2022 AS

»» Object Detection Project Journey



- ② We found that current object detection algorithms on 2D point clouds was too time consuming
- ② Tested object detection deep learning algorithms on jpeg images and high density 3D LiDAR point clouds.

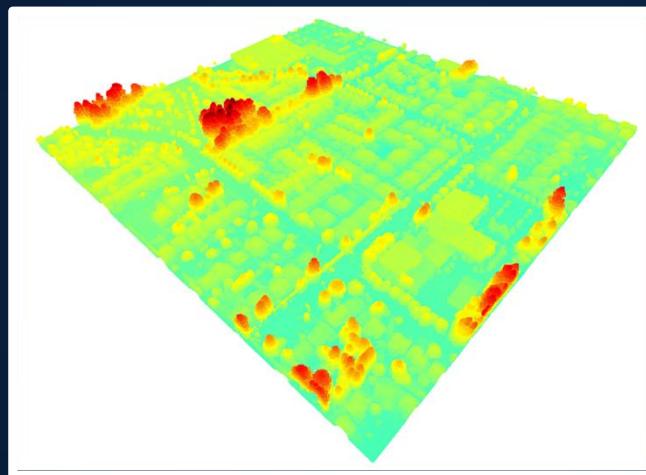


»» Object Detection Project Journey



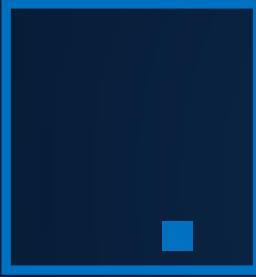
Next

We then took the LiDAR data and extracted into a 3D point cloud.



Through downsampling, we then voxelized the data structure which is a store of geometric information in a continuous domain into a rasterized image.

0



Approaches





Many ground filtering algorithms have been proposed, but are mathematically complex or separated ground and non-ground measurements by removing non-ground points from LiDAR datasets

Problems:

- ①. The performance of these algorithms changes according to the topographic features of the area
- 2. The filtering results are usually unreliable in complex cityscapes and very steep areas.
- ②. Models oftentimes fail to effectively model terrain with steep slopes and large variability because they are based on the assumption that the terrain is a smooth surface

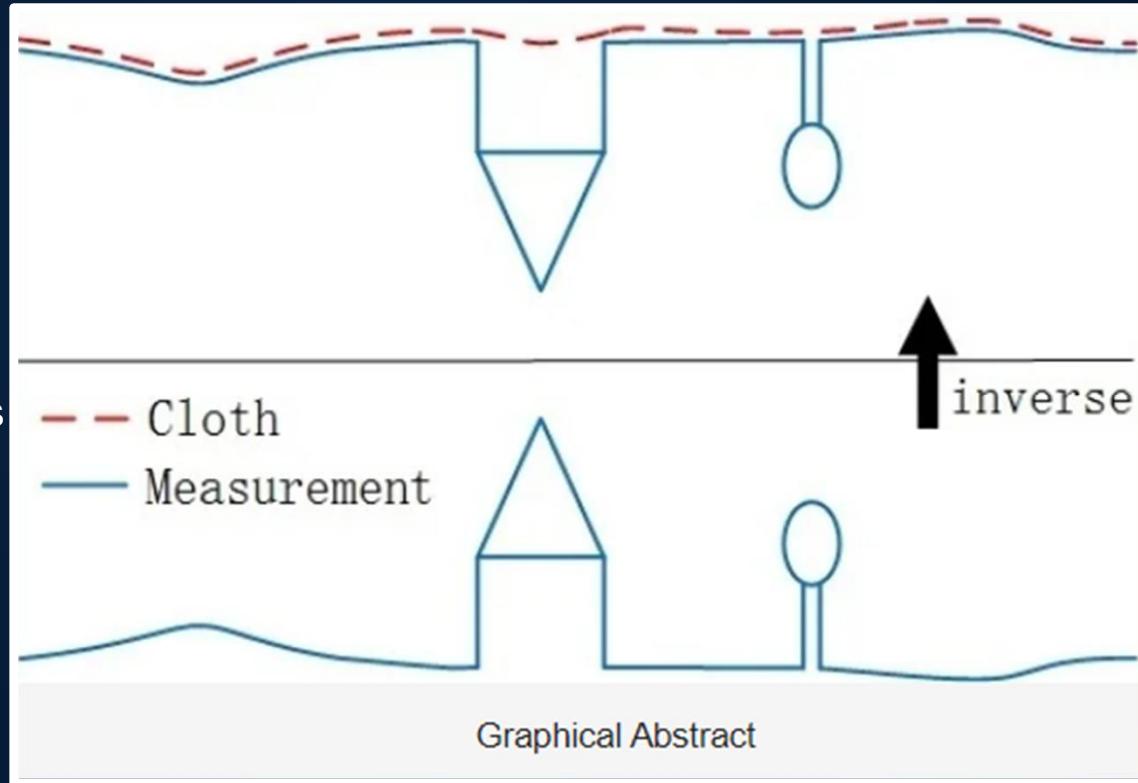
»» LiDAR Data Filtering: Cloth Simulation



Cloth simulation filters the ground points by simulating a physical process that a virtual cloth drops down to an inverted (upside-down) point cloud.

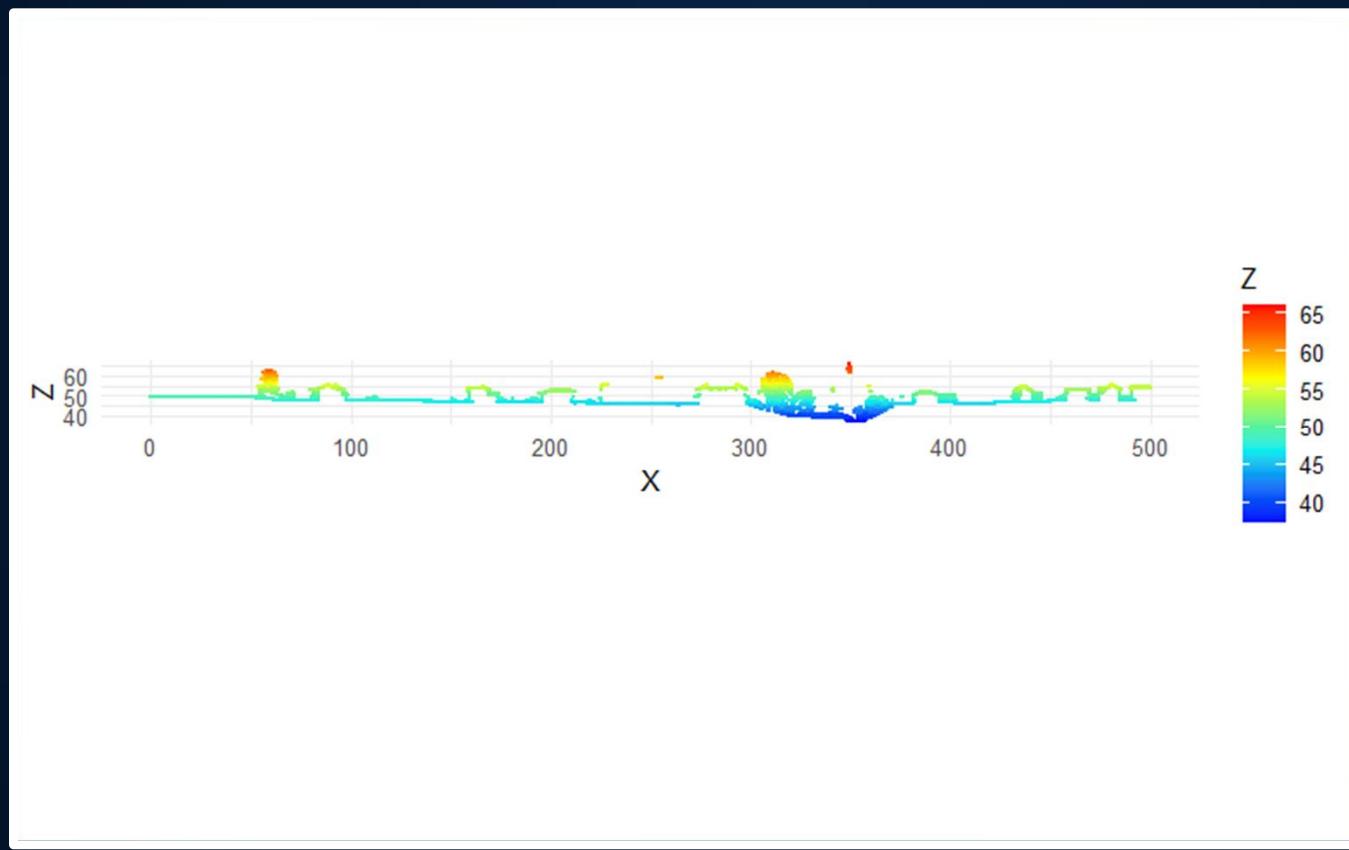
Advantages:

1. Few parameters are used in the proposed algorithm, and these parameters are easy to understand and set
1. The proposed algorithm can be applied to various landscapes without determining elaborate filtering parameters
1. This method works on raw LiDAR data



»» LiDAR Data Filtering in r

LiDAR technology has brought the possibility to separate the vegetation from the ground return (when it is visible) even under the canopy.

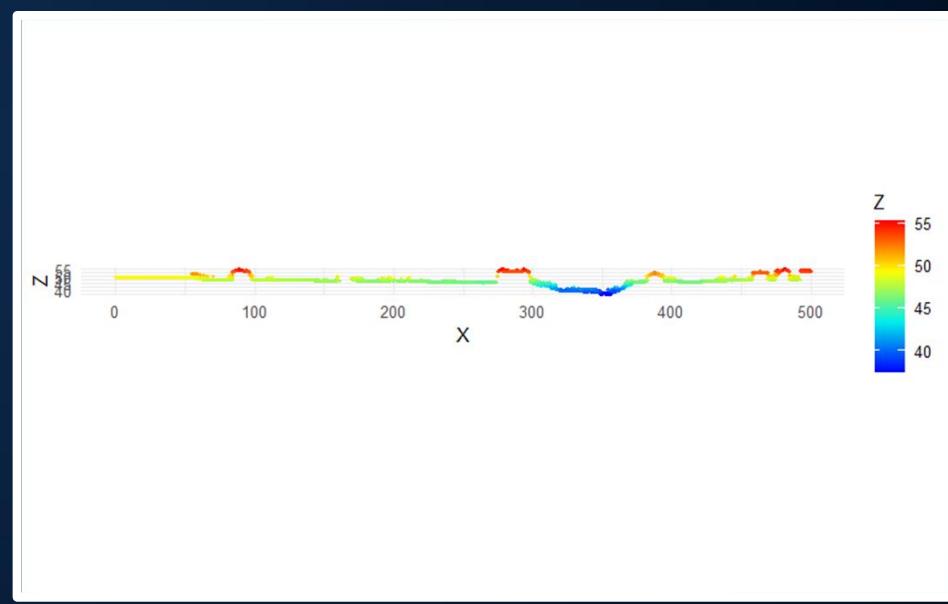


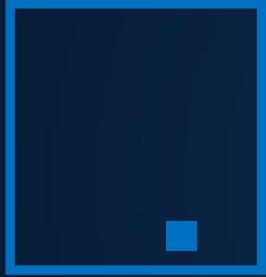
»» LiDAR Data Filtering: Classification in r

Once we can differentiate ground points from vegetation and buildings, we can measure the height along the z-axis by subtracting the height of the ground level from the height of the obstacle.



Alternatively, we can view a cross section of just the ground level:



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Data Preprocessing

CSF pipeline to determine ground points & base elevation.

Point Segmentation/K Means Clustering

Automate finding the optimal amount of clusters within a .las dataset.

Find the radius of each cluster using the max distance from each cluster centroid.

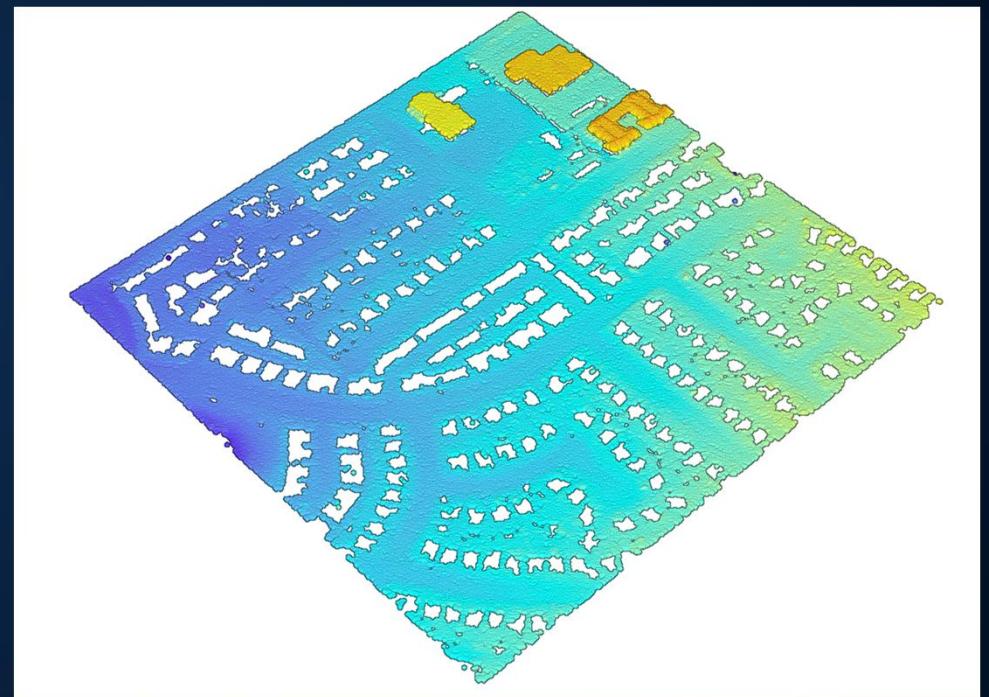
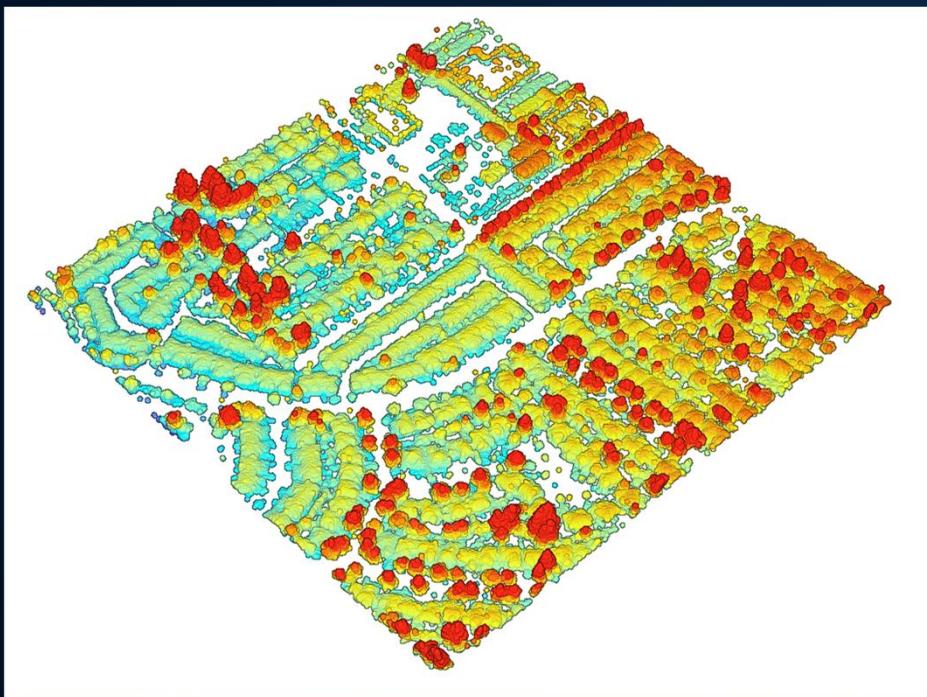
Store obstacles in an accessible database

Save results to a .csv file.

» LiDAR Data Filtering: Cloth Simulation



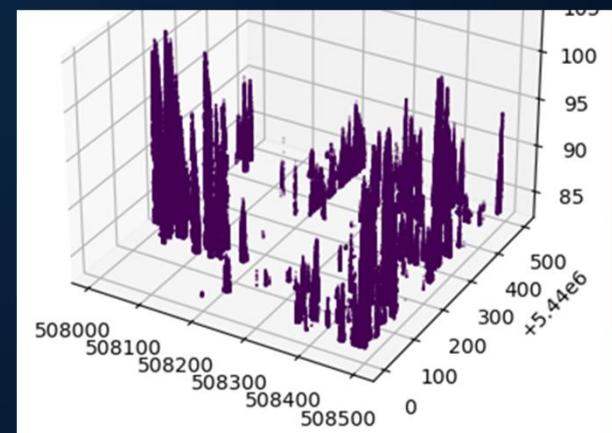
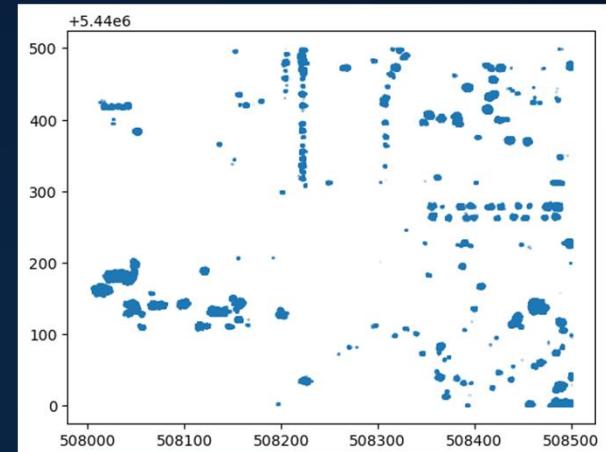
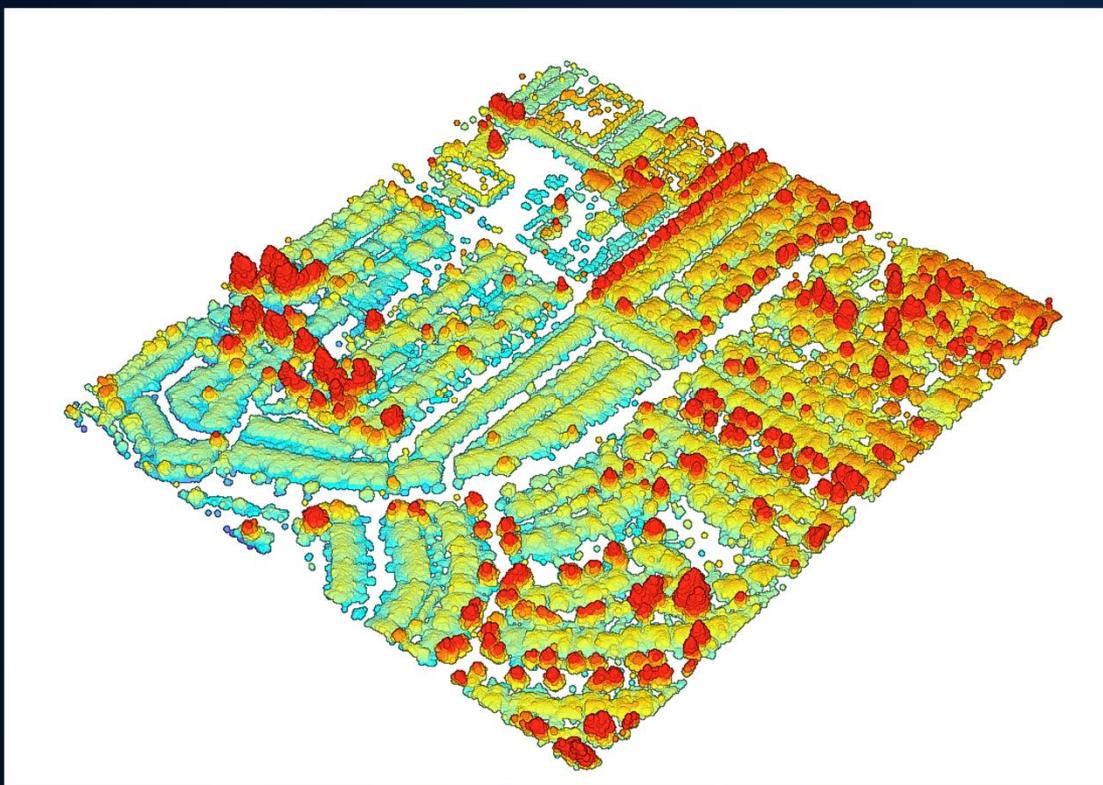
Experimental results yield an average total error of 4.58%, which is comparable with most of the state-of-the-art filtering algorithms



»» LiDAR Data Filtering: Creating a Threshold



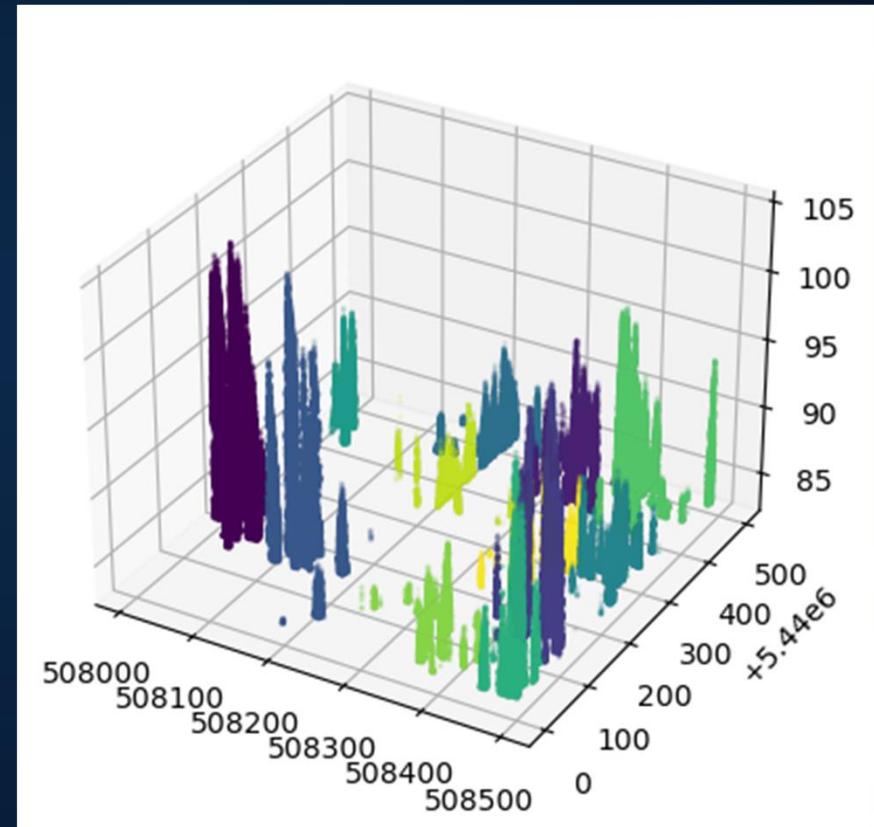
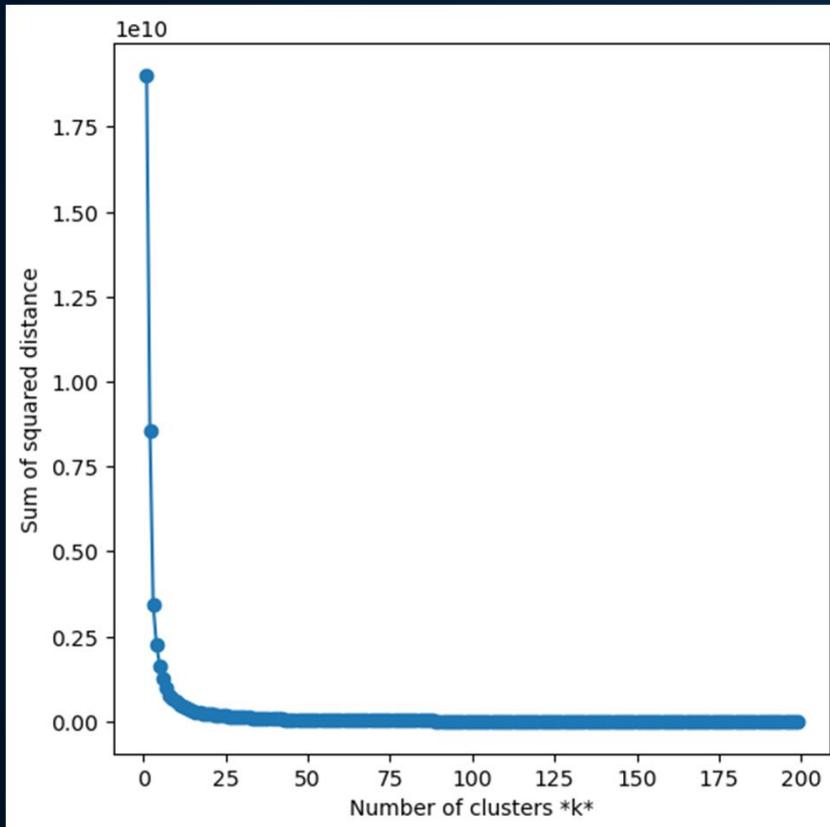
Filtering out points in the point cloud that are < 30 feet.



»» Radar Data Filtering: K Means Clustering



Finding an optimal cluster value



»» Radar Data Filtering: Exporting Results



Saving the output to a .csv

location	radius	max_height
0 [5.08037541e+05 5.44016355e+06 9.01013927e+01]	59.63149	103.54
1 [5.08439834e+05 5.44026785e+06 8.55030107e+01]	153.1537	91.53
2 [5.08465506e+05 5.44002334e+06 8.70261367e+01]	109.1026	101.06
3 [5.08411187e+05 5.44042115e+06 8.74543431e+01]	111.6253	98.72
4 [5.08247479e+05 5.44044102e+06 8.51570238e+01]	150.571	91.66
5 [5.08039568e+05 5.44040782e+06 8.63504955e+01]	130.5881	94.02
6 [5.08143561e+05 5.44013160e+06 8.90390878e+01]	154.6615	104.2
7 [5.08450901e+05 5.44012774e+06 8.88527533e+01]	154.9142	101.43



Future Research Recommendations



Automate the process of creating accurate classification models with the cloth method, and using thresholds to create clusters of tall objects and exporting the data into a SQL database.

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Efficiently downsample the point cloud without loss for small/thin objects like power lines.

For irregular shapes, apply more complex methods to fit the shapes of clusters into polygons, and find the vertices of the objects (maybe CNN / pytorch / C / DA / tensorflow)

Use voxelization to efficiently loop through point clouds with CNNs, take voxel heights and use for step 2.

Algorithms to scrape LiDAR data and apply findings to add to obstacle database.



Questions?
Thanks for Listening!