INVESTIGATING APPLICATIONS OF MACHINE LEARNING IN CONSTRUCTION COMPLIANCE SYSTEMS

Alan Wang

Background

Australian Financial Review:

"85% of residences in new buildings have experienced structural issues"

Opal Tower

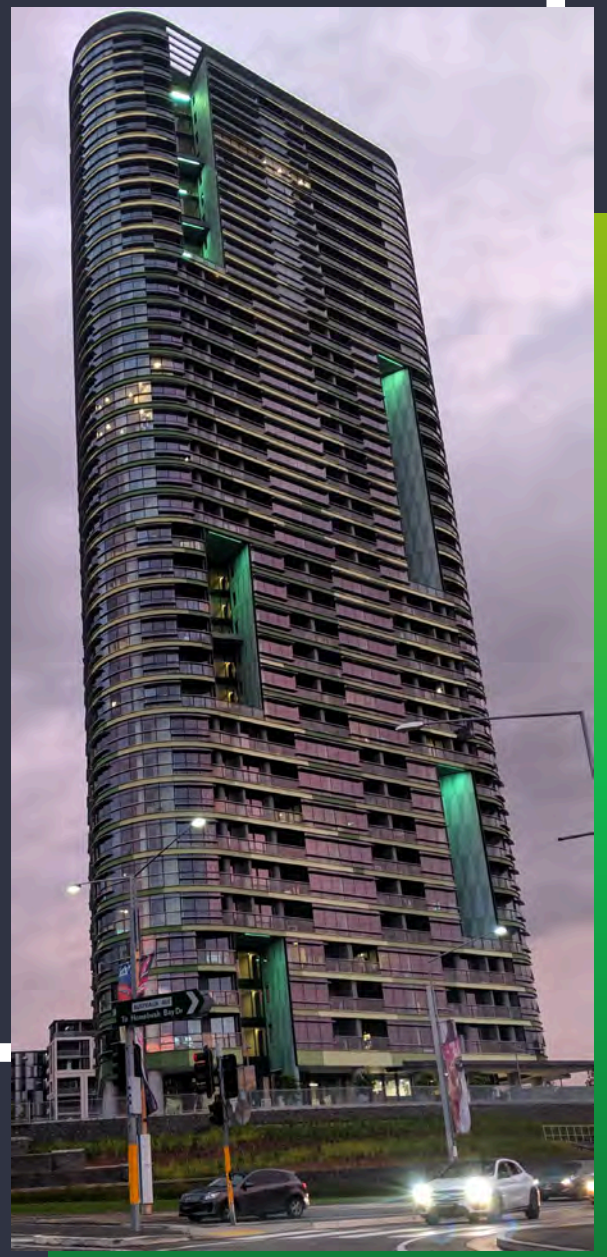
Bunn Street

Bowman Street

Stawell Street

Chelsea Towers

Mascot Towers



Opal Tower

NSW Planning Opal Tower investigation report:

"Cause for structural failure were the horizontal support beams, which were not compliant and lacked proper grouting. Additional issues were underlined such as poor-quality construction materials, issues with foundations, poor quality workmanship or errors during construction and flaws or errors in the design of the structural systems."

BUILDING INSPECTIONS

Manual in person approach:

- Visual inspection
- Manual measurement
- Expensive and slow process
- Not all parts of a building can be examined.

BUILDING INSPECTION

3D Scanning

- Computerised point clouds
- Computed measurements
- Fast and efficient process
- Progress can be archived
- Inspection can be performed off site
- All areas of building can be captured using UAV.

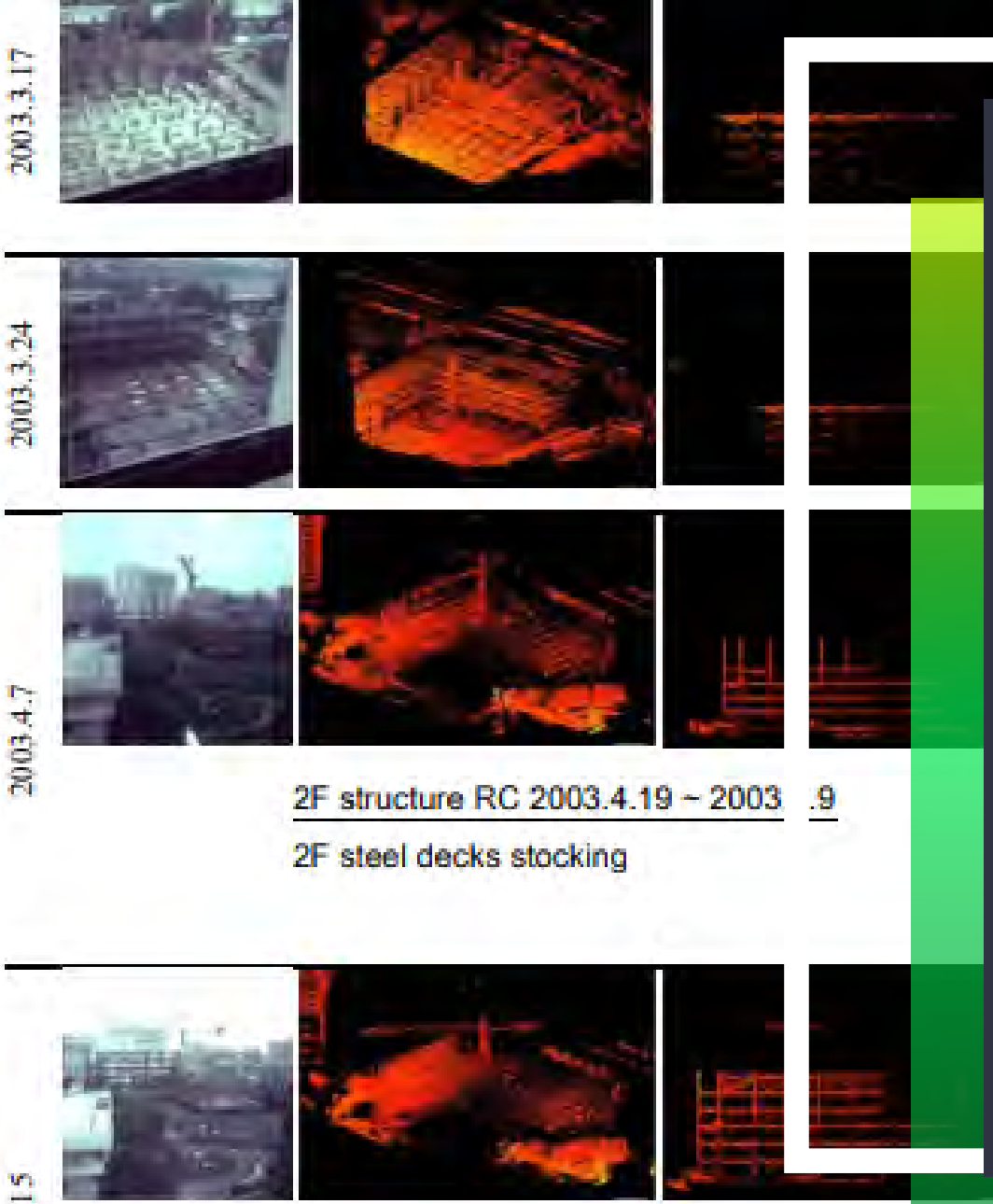
Alan Wang

LIDAR

- Point clouds generated from reflections and angles projected from a laser
- Alternatives: Radar, Ultrasound, LED Mapping
- Captures generic point clouds.
- Colour can be mapped with external software.

Problems with LIDAR

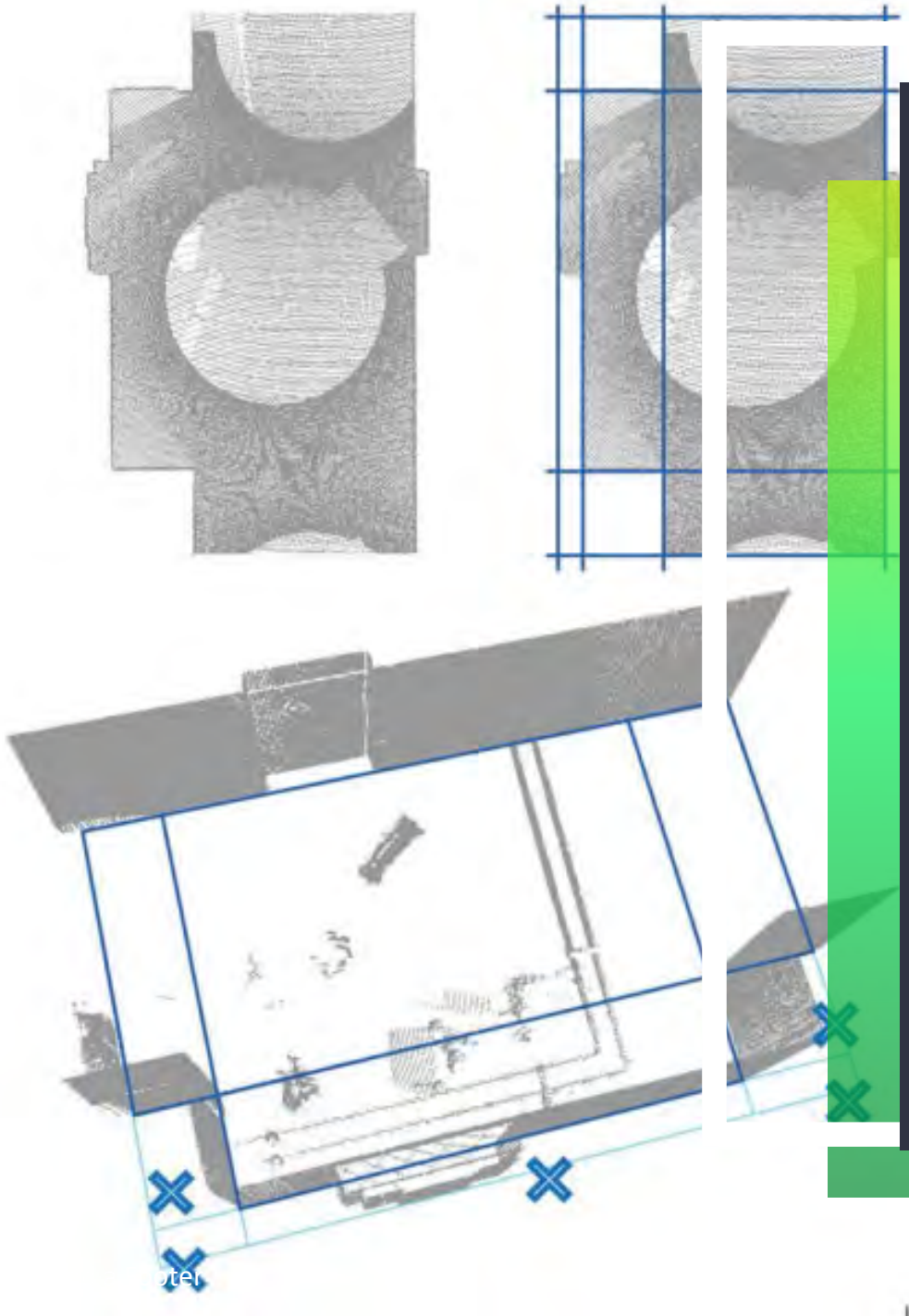
- Points only have a location, no other data.
- Measurements and examinations are still made manually.
- Does not serve to assist compliance.
- Output is DATA not INFORMATION



EXISTING CASE STUDY

A 3D Point-Cloud-Based Verification of As-built Construction Progress

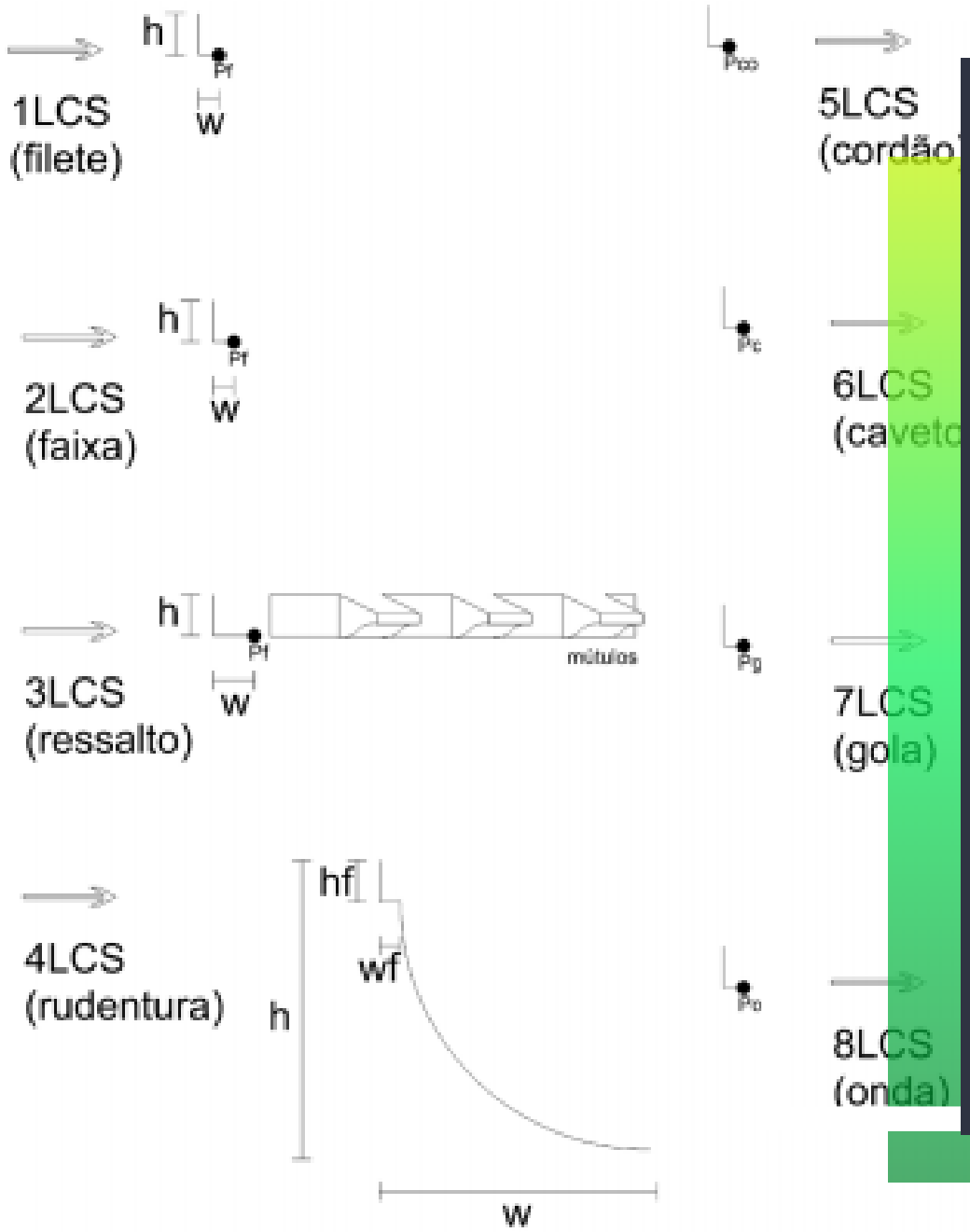
- Lidar Scans taken for the verification of construction progress.]
- At least two scans from different times are taken to compare the differences between the two.
- Boolean intersection of 3D point cloud zones reveals the construction progress.



EXISTING CASE STUDY

Automated 3D Reconstruction of Interiors from Point Clouds

- 3D Point clouds from lidar scans are put through sweeping algorithms to align similar vectors.
- Horizontal + vertical + rotational alignment.
- Lines are drawn from similar vectors and a floor plan is generated
- Does not identify individual features of a room, only the floorplan.



PREVIOUS CASE STUDY

From Point Cloud to Shape Grammar to Grammatical Transformations

- Based on the definition of 'Shape Grammar' by Stiny and Gipps.
- New Shape grammar is extracted from 3D Point Clouds.
- Not a fully automatic workflow, parts are manually selected, and shape grammar is generated.

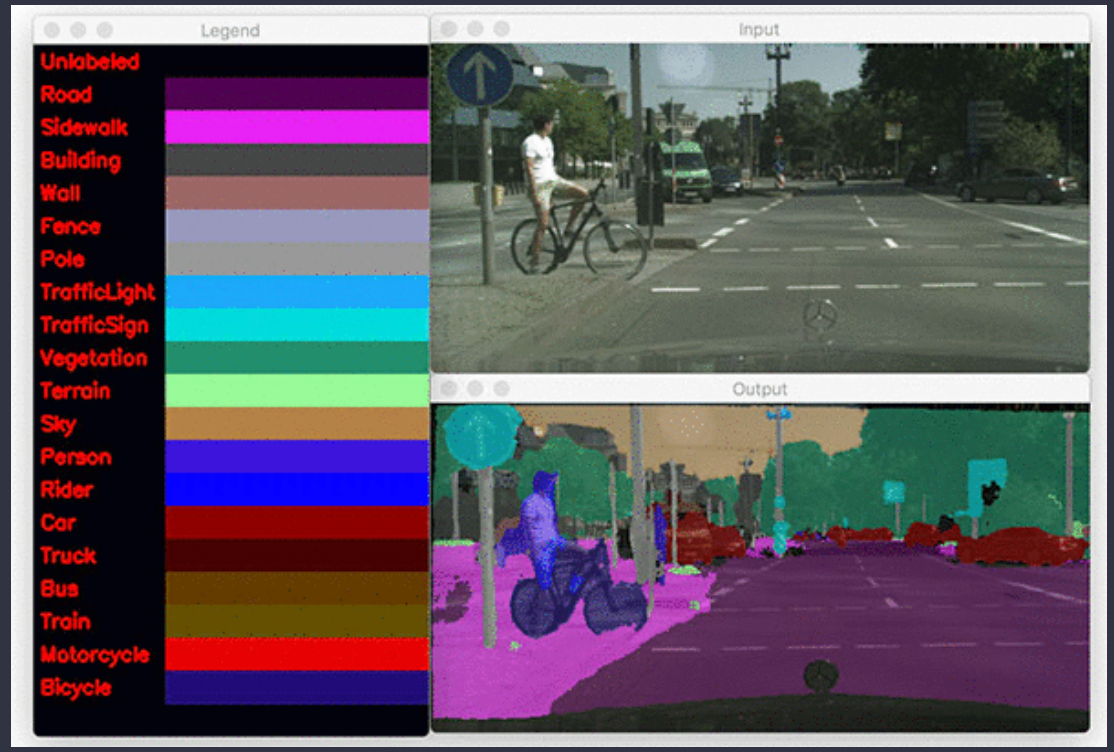
MACHINE LEARNING PREPARATION

MACHINE LEARNING

Proposed Method

- Can learn patterns based on training data
- Processes information faster than humans.
- Can separate data into different categories.
- Easily scalable and highly customizable
- Semantic segmentation separates in object classifications.
- Most practical way of processing large sets of data such as a point cloud.

Problem: Requires an extensive amount of research for the neural network structure.



MACHINE LEARNING?

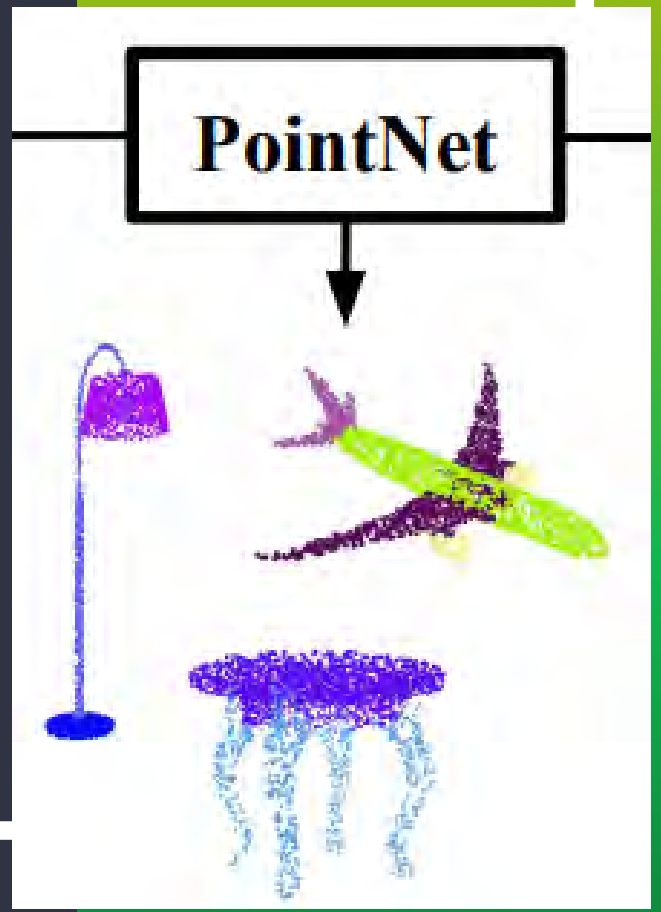
How does a machine learn?

- A neural network is based on neurons.
- Connections and pattern recognition.
- Similar to teaching children, they only learn what we show them.

Alan Wang

Pointnet

- Research project by Stanford University.
- Created the ‘Pointnet Architecture’
- Utilises Tensorflow (Python Library)



Pointnet Architecture

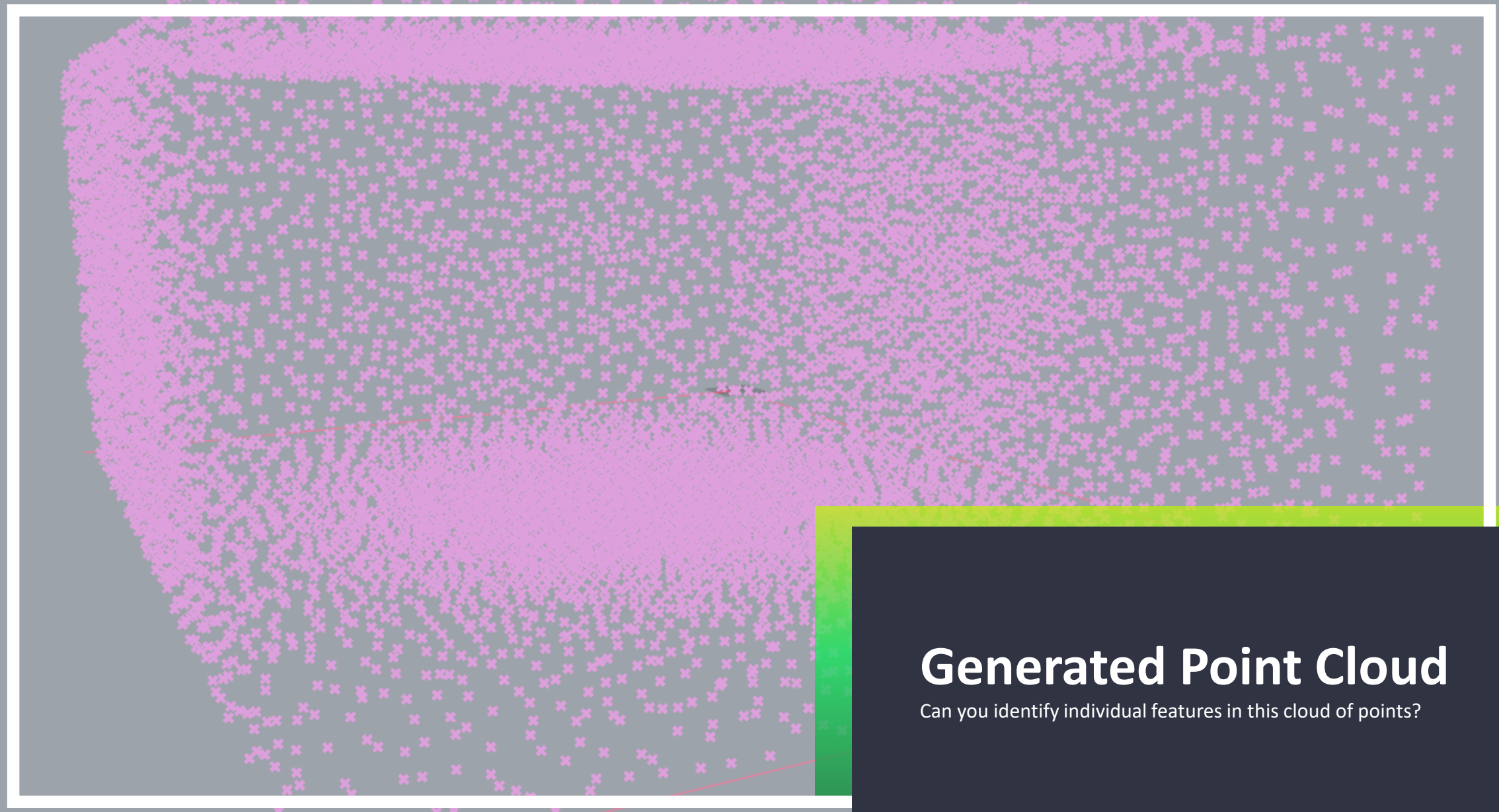
- Works from unordered list of points (point cloud has no reference)
- Identifies ‘Local’ features based on point proximity.
- Identifies ‘Global’ features based on point context
- Machine learning layers already setup for point clouds.

TRAINING THE NEURAL NETWORK

Problem

- The problem with machine learning is that it requires lots of data.
- A neural network can only learn from what it is fed.
- Manually classifying a point cloud will take hours and not yield a high range of different geometries.

Solution: Artificially generate the data



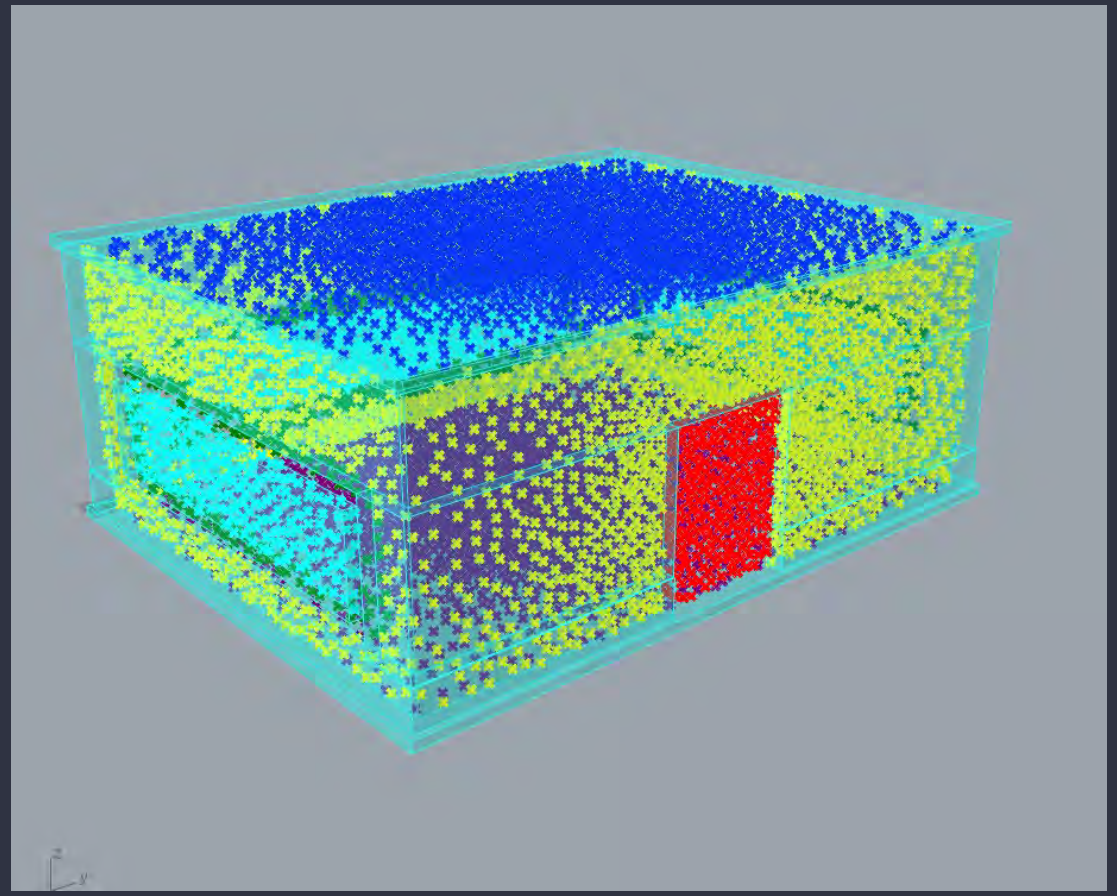
Generated Point Cloud

Can you identify individual features in this cloud of points?

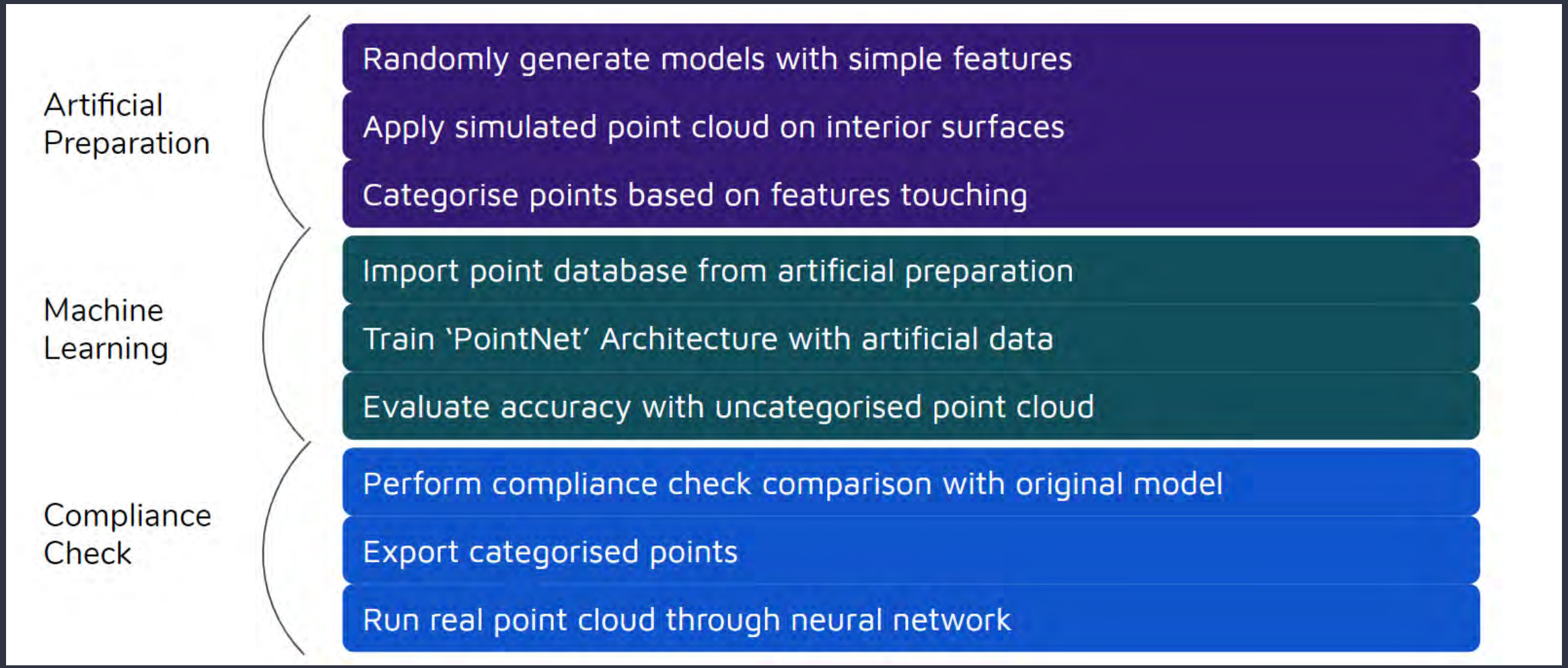
TRAINING THE NEURAL NETWORK

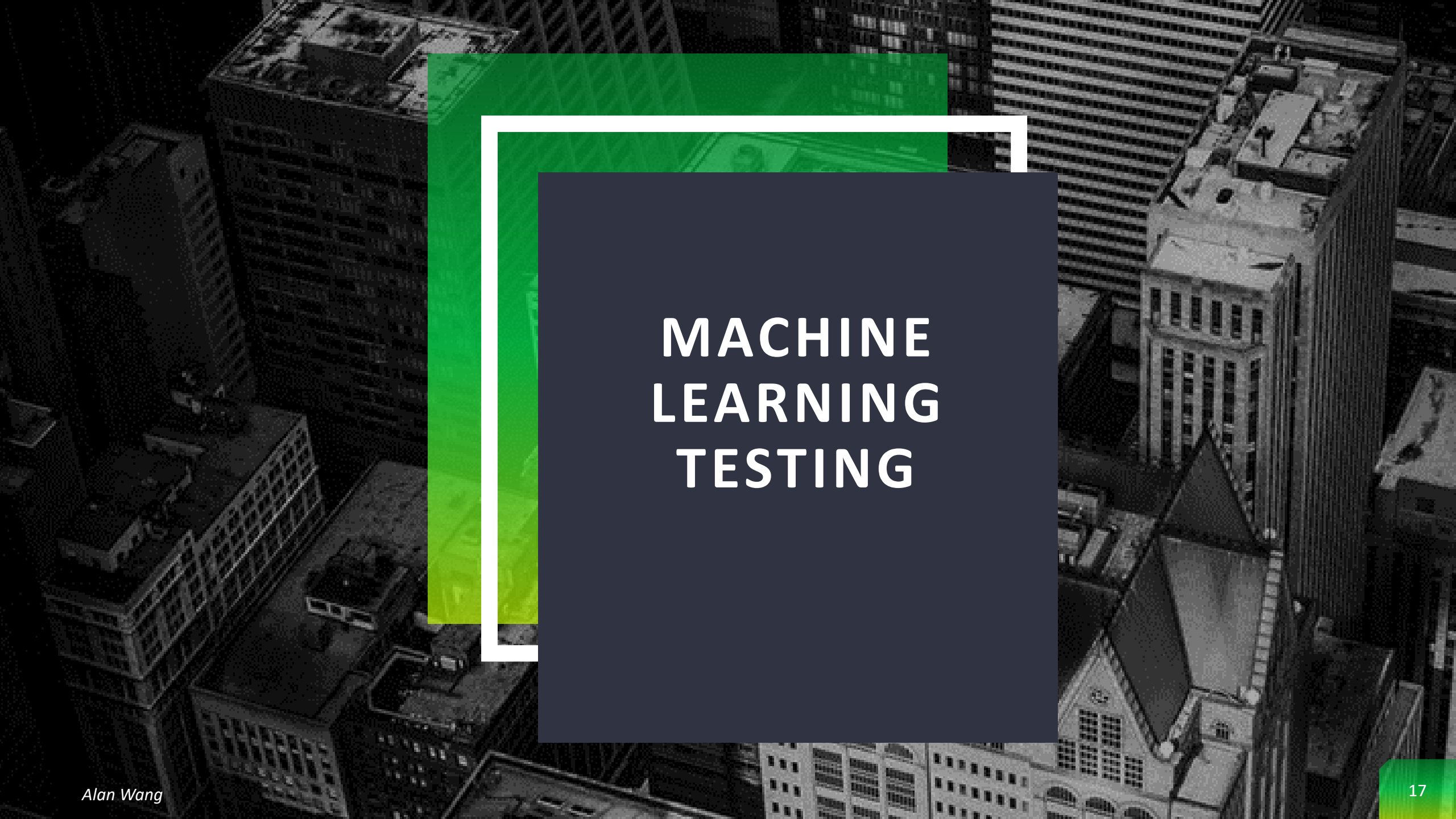
Solution

- Artificially feed data for neural network to recognise features.
- Randomized buildings with basic features (Door, walls, window frames, roof.)
- Apply interior points spread throughout model.
- Log points based on collided geometry.

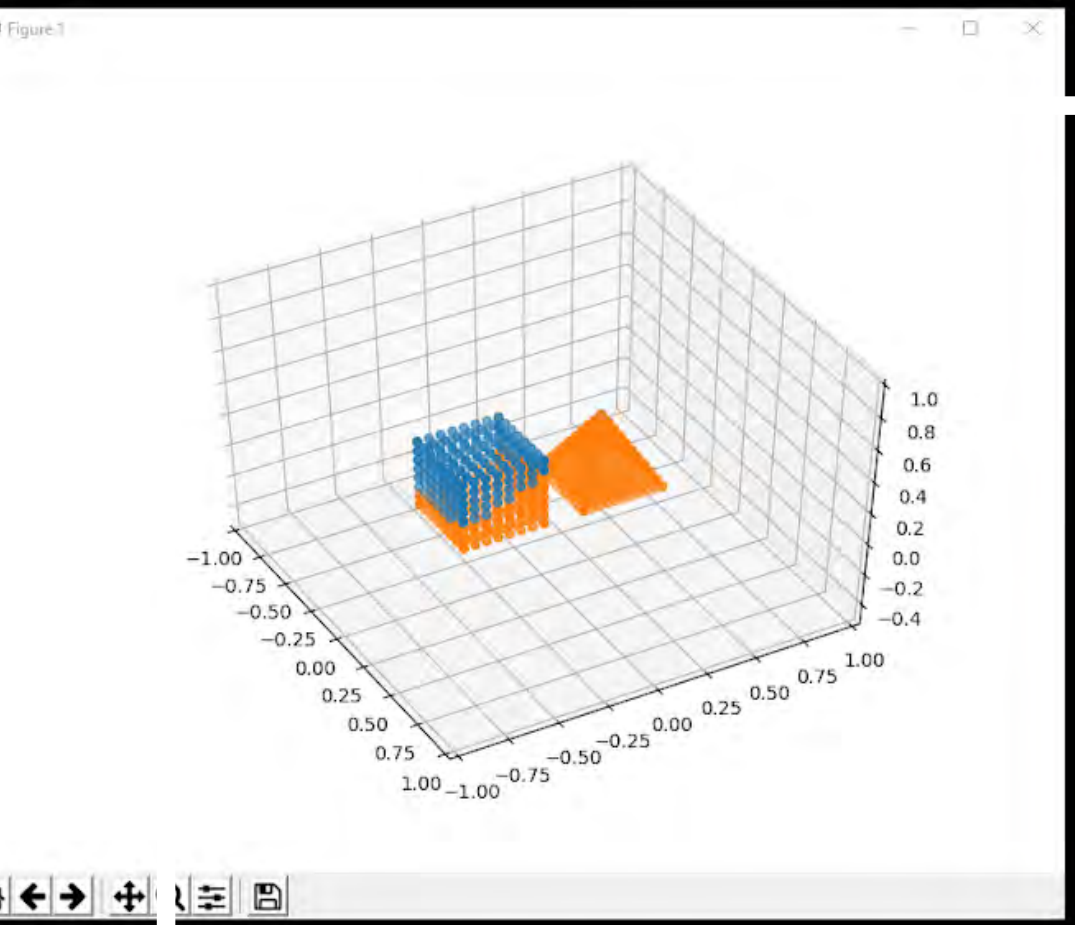


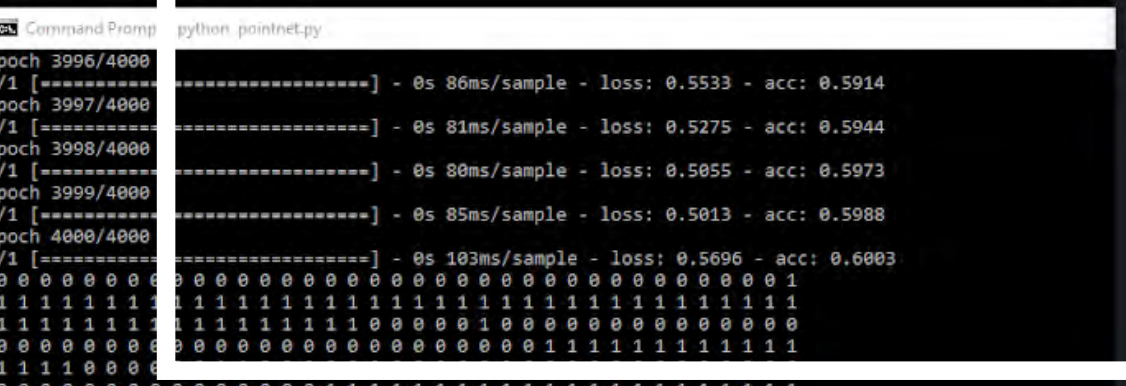
METHOD

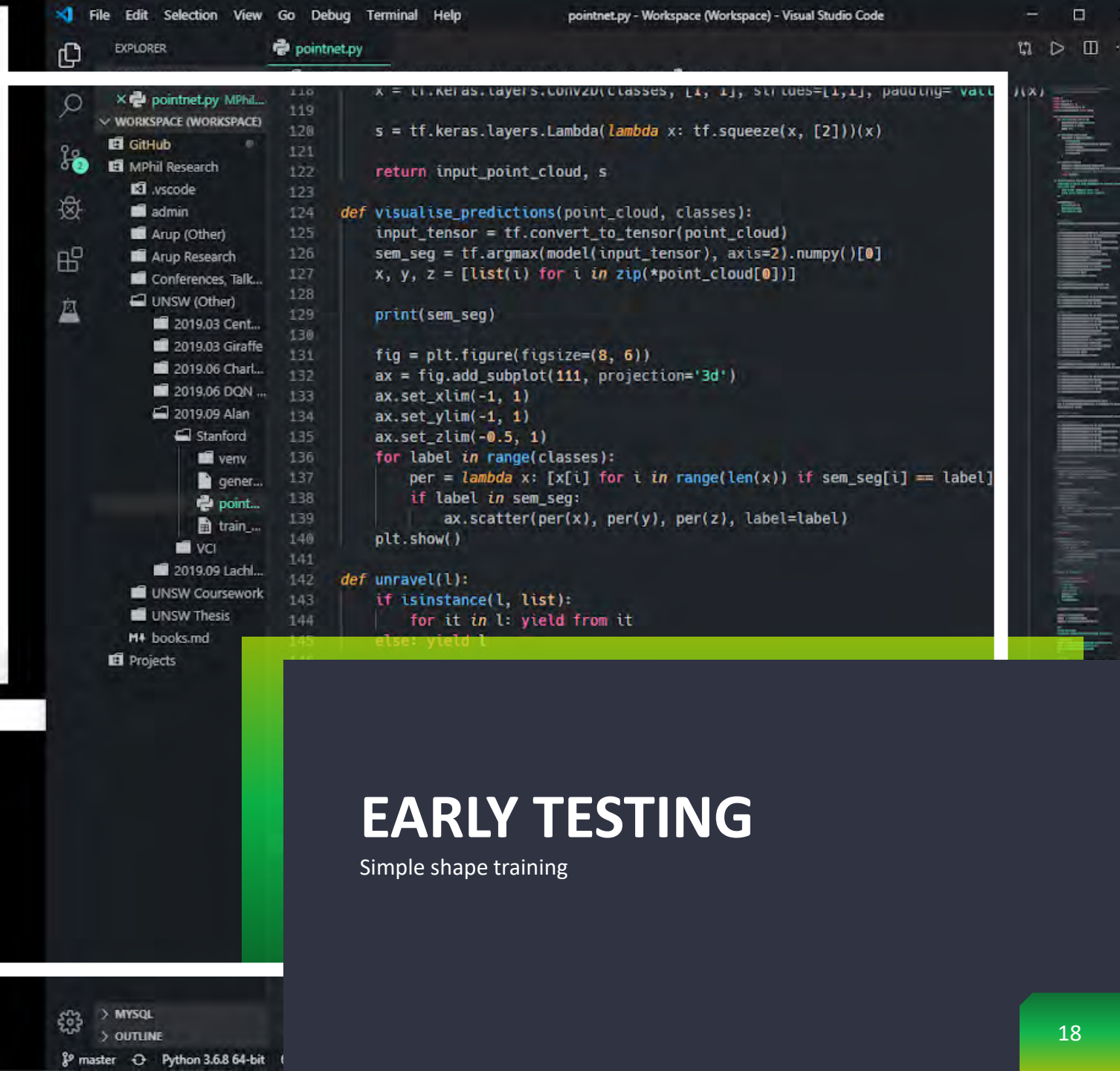

Artificial Preparation
Randomly generate models with simple features
Apply simulated point cloud on interior surfaces
Categorise points based on features touching
Machine Learning
Import point database from artificial preparation
Train 'PointNet' Architecture with artificial data
Evaluate accuracy with uncategorised point cloud
Compliance Check
Perform compliance check comparison with original model
Export categorised points
Run real point cloud through neural network



MACHINE LEARNING TESTING

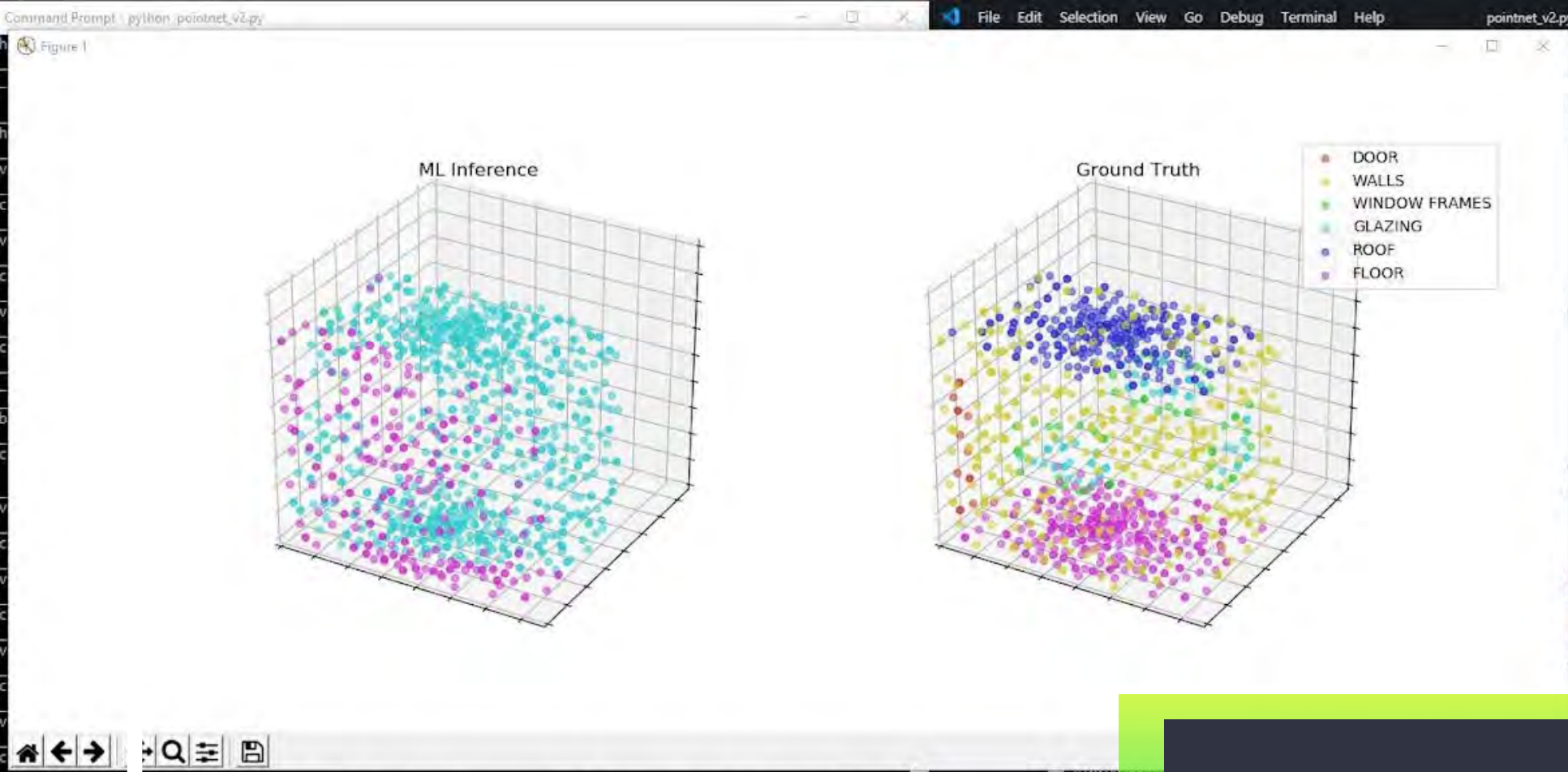


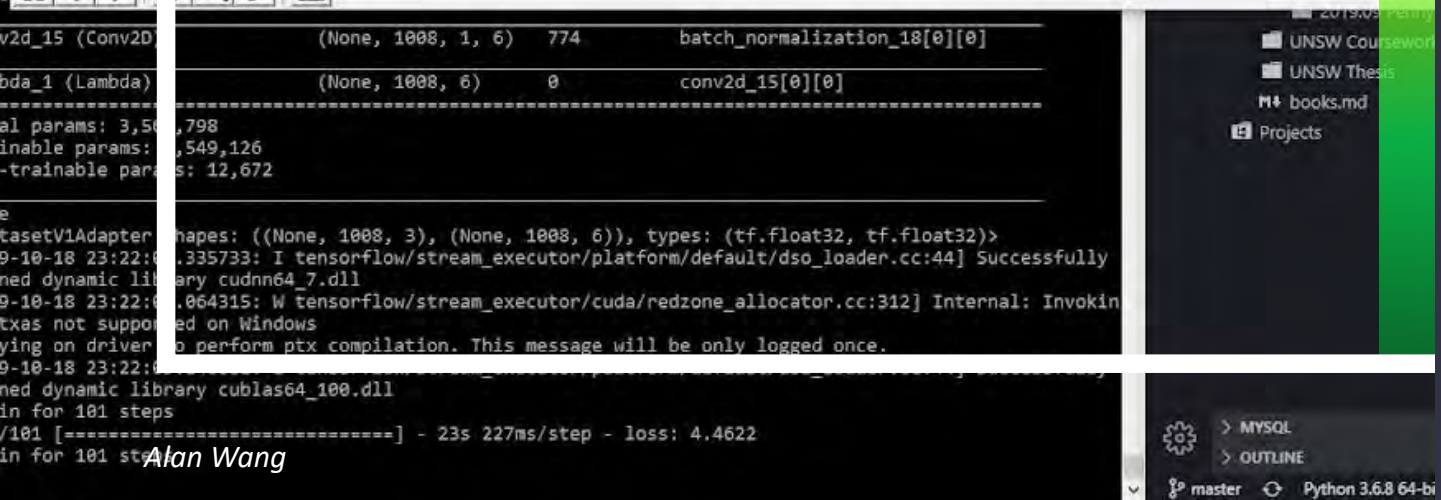




EARLY TESTING

Simple shape training

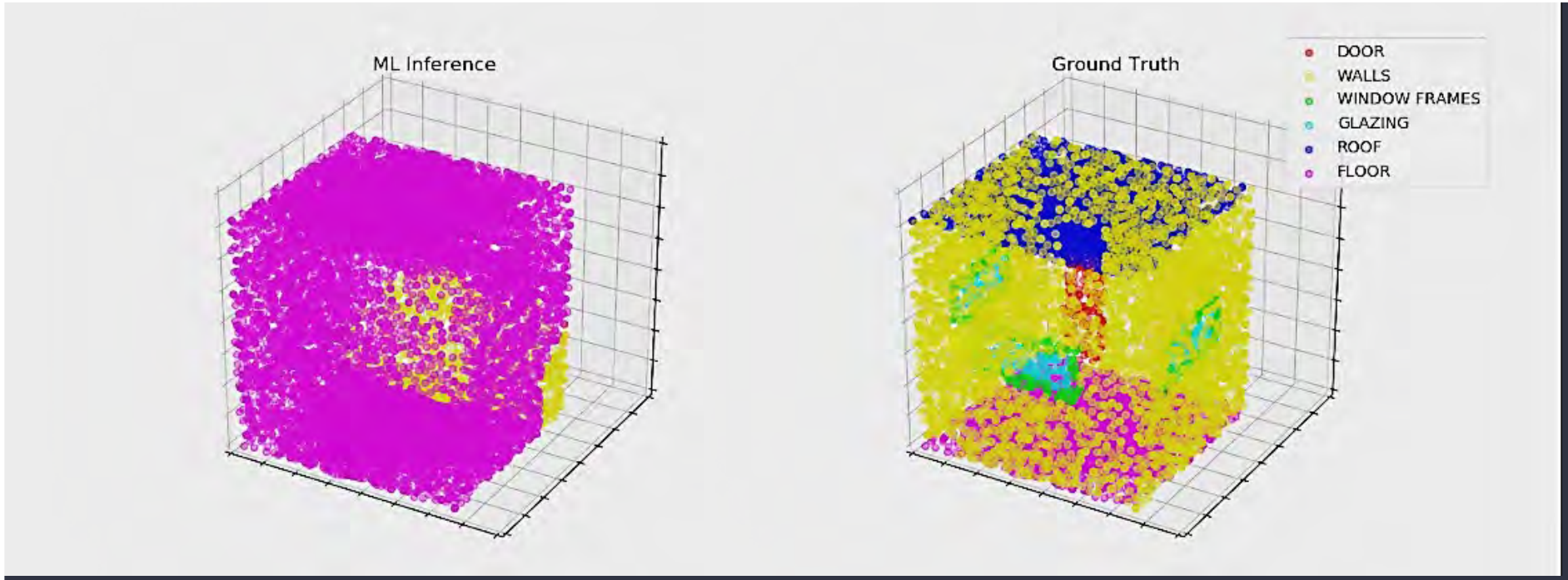




EARLY TESTING

Room points generated and trained

Alan Wang



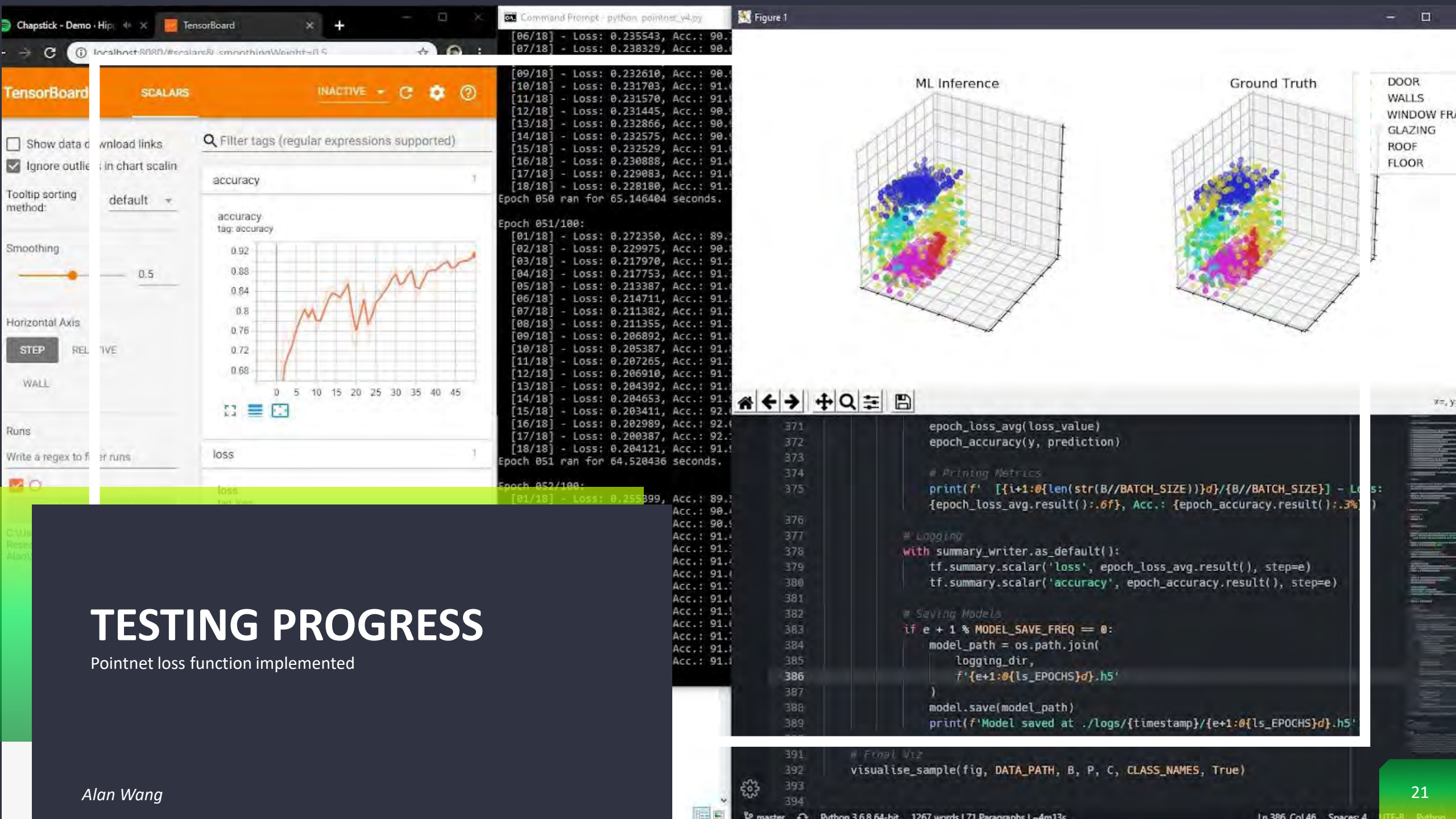
EARLY TESTING

Tested with 10 000 points

TESTING PROGRESS

Pointnet loss function implemented

Alan Wang



TESTING ACCURACY

5 0 0 R o o m s @ 1 0 K P o i n t s

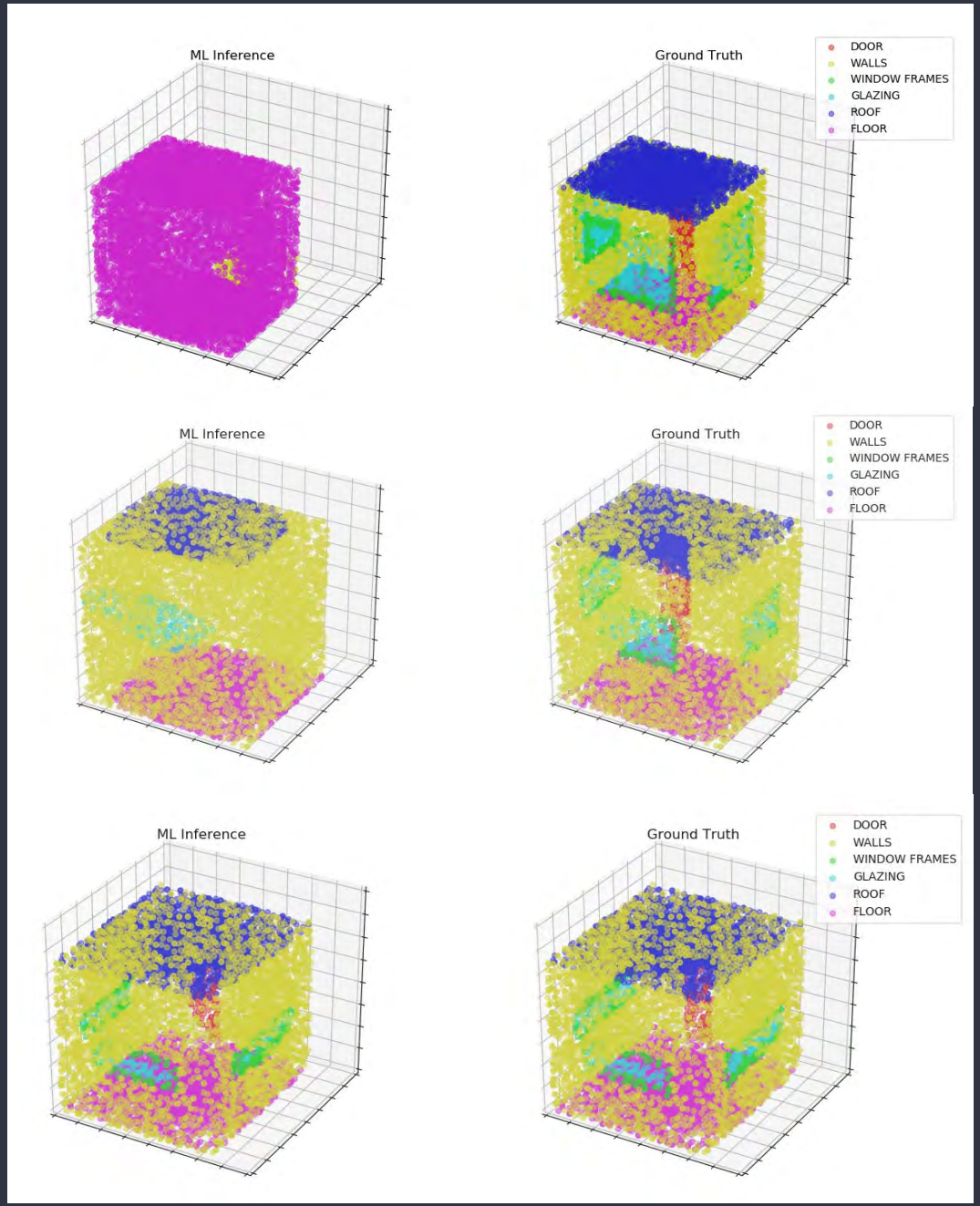
Epoch 0: 29% Accuracy

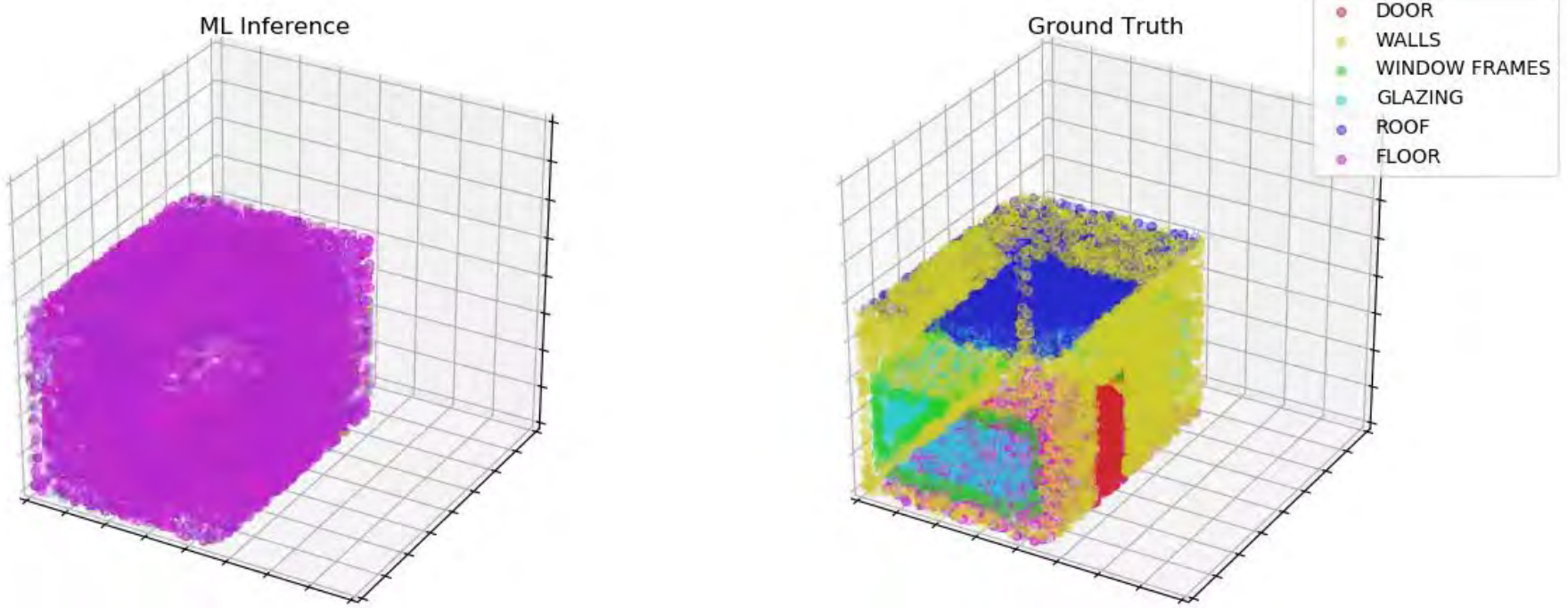
Epoch 1: 84% Accuracy

Epoch 2: 90% Accuracy

…

Epoch 8: 95% Accuracy

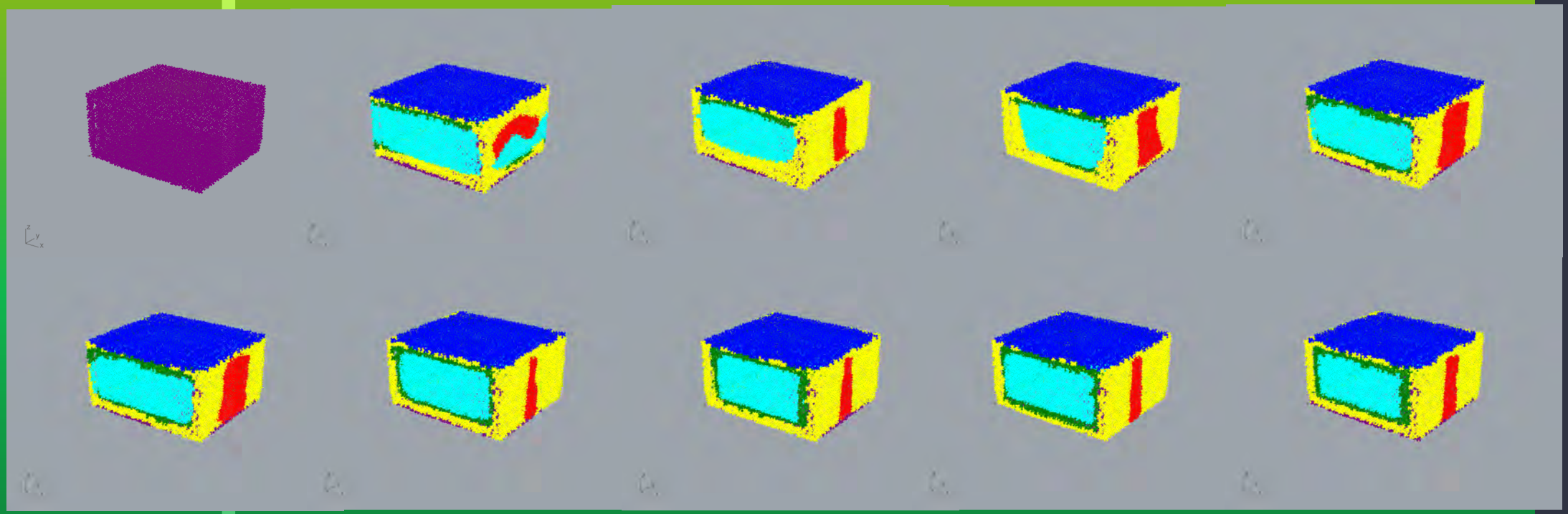




TRAINING

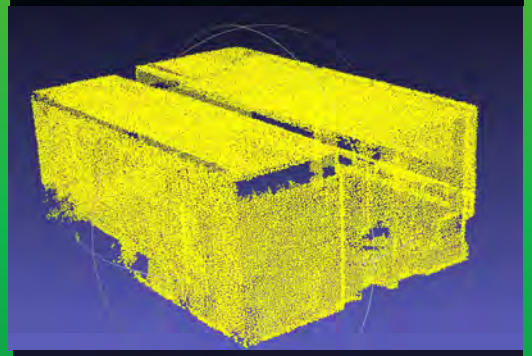
Video

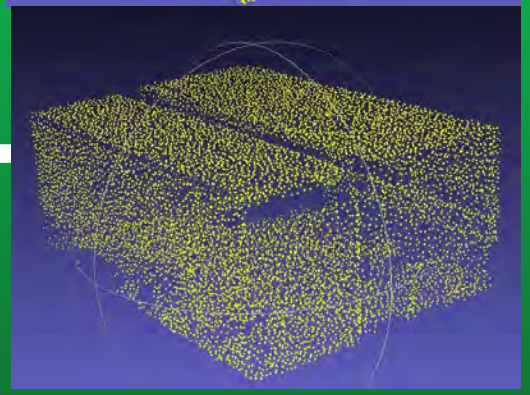
INFERENCE PER EPOCH



Collecting Point Cloud

- 3D Point cloud was collected with a ZebRevo RT handheld scanner.
- Scan performed on classroom
- Initial point cloud had over 23 million points.
- No RGB mapping performed





Cleaning Point Cloud

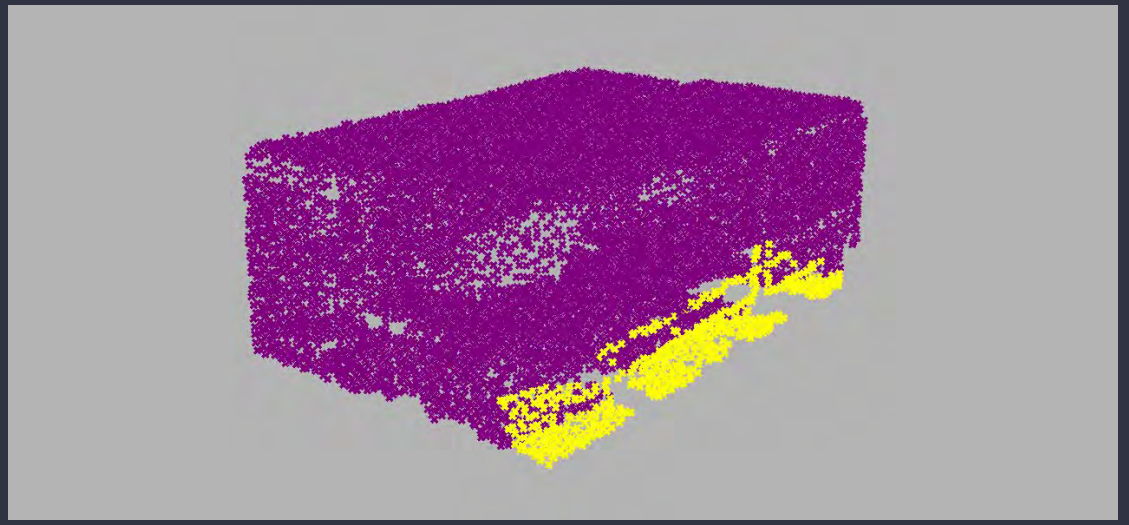
- Reduced point cloud and removed noise.
- Removed interior items as neural network was not trained.
- Reduced further to 10 000 points.

TESTING POINT CLOUD

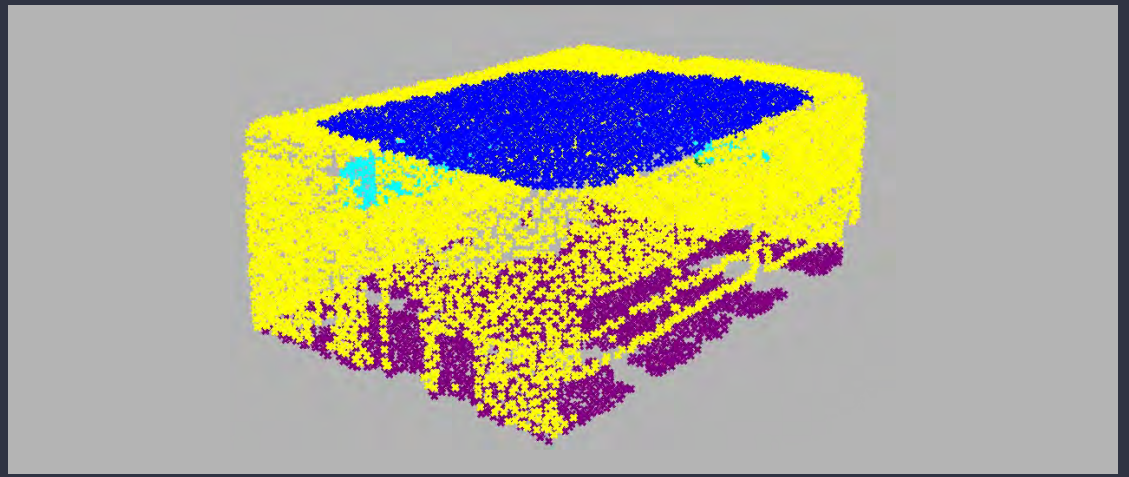
REAL WORLD TEST

- Initial prediction is random.
- Trained prediction is shown after one epoch.
- Can not measure accuracy as no original geometry to be compared with.
- Roof, floor and walls correctly identified.
- Further epochs show overfitting and place doors and glazing randomly on points.

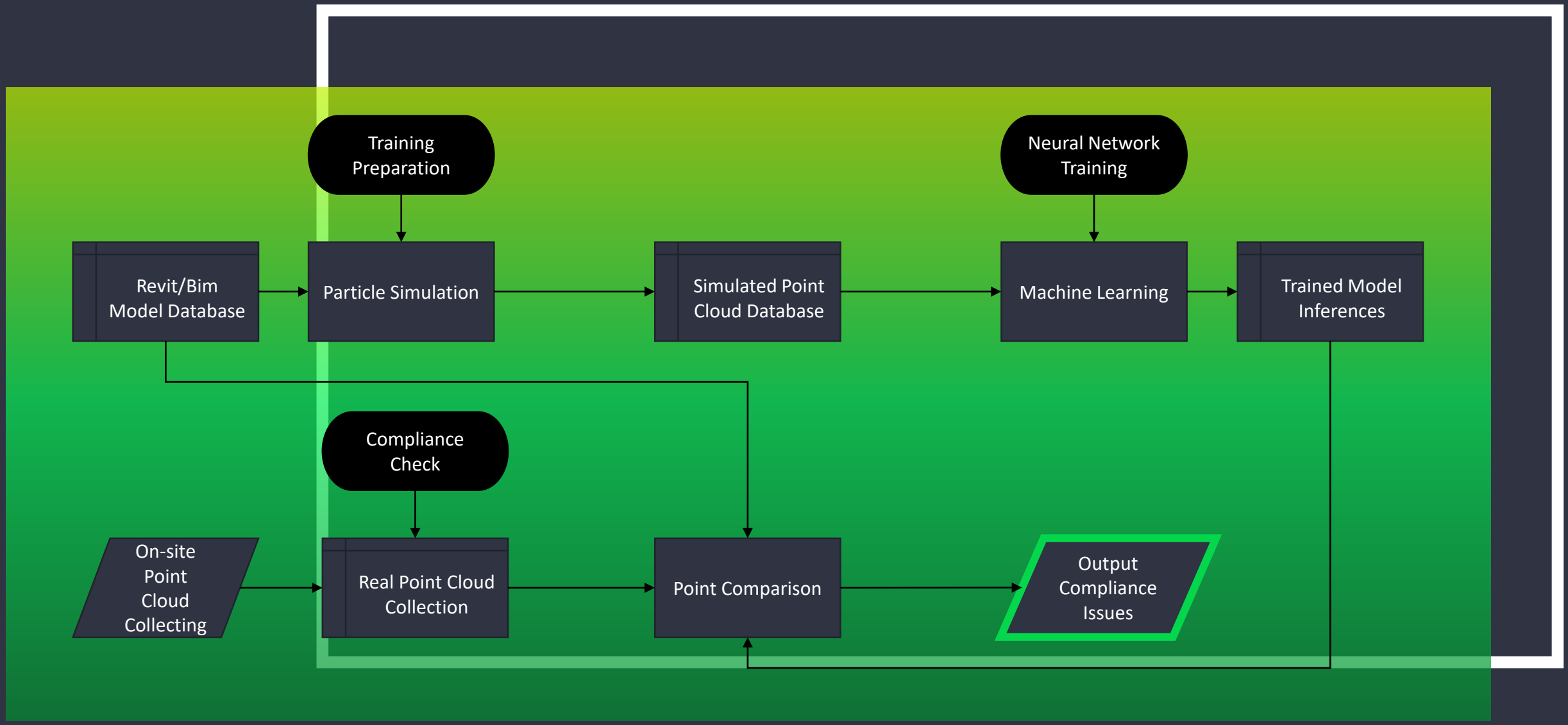
Initial Prediction



Trained Prediction



EXAMPLE IMPLEMENTATION



Evaluation

- Training a neural network is an extremely feasible solution to compliance checking.
- Provided that there is enough range in data, accuracy can be extremely high.
- This solution can be developed into a completely automated pipeline.

Limitations

- Dataset needs to include noise and imperfections.
- Heavily dependent on computational power.
- Neural network architecture must be developed correctly before any training is performed.
- Compliance checking techniques must be refined.