Algorithms for GIS
csci3225

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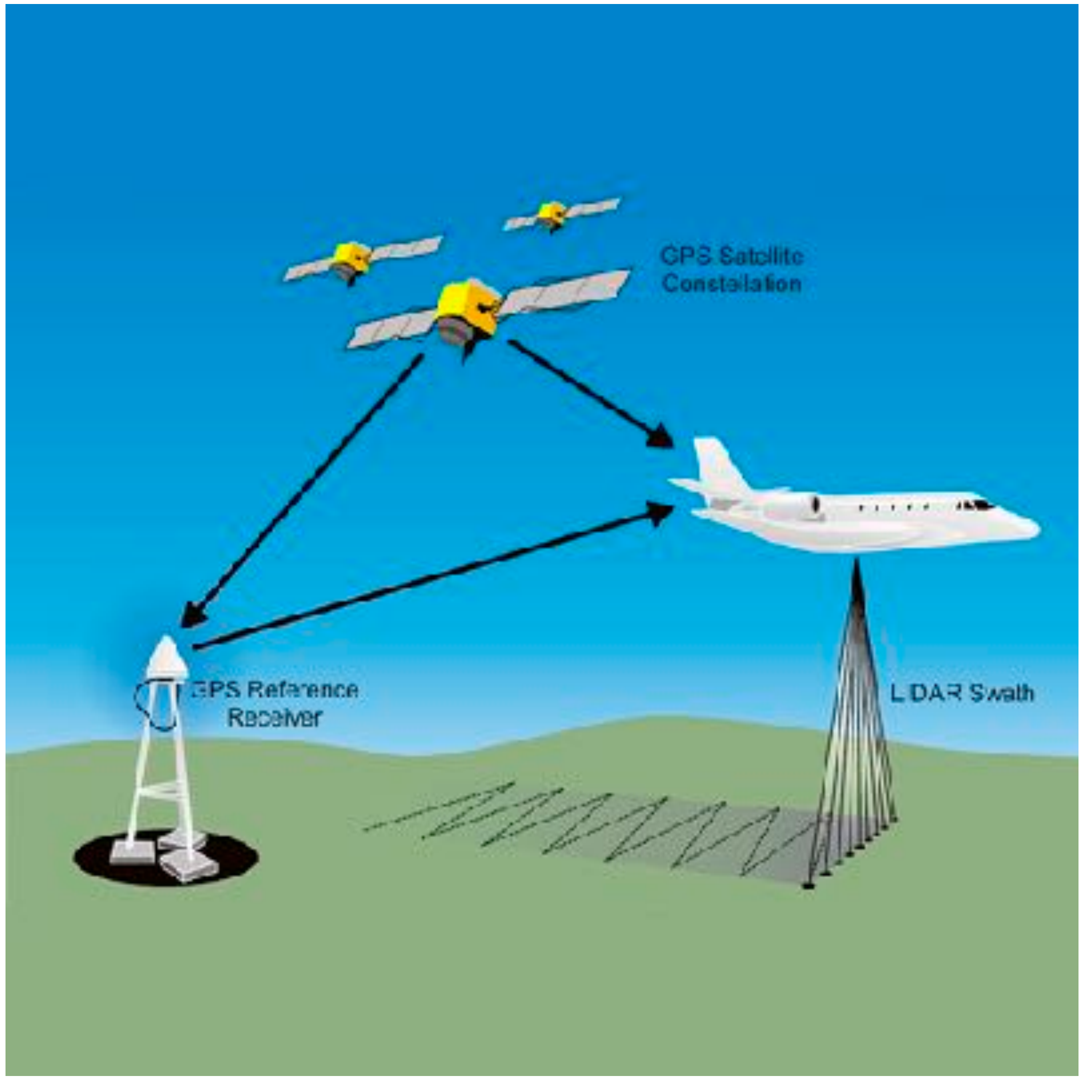
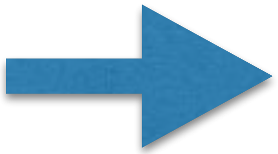
LiDAR data in GIS

LiDAR (Light Detection and Ranging)



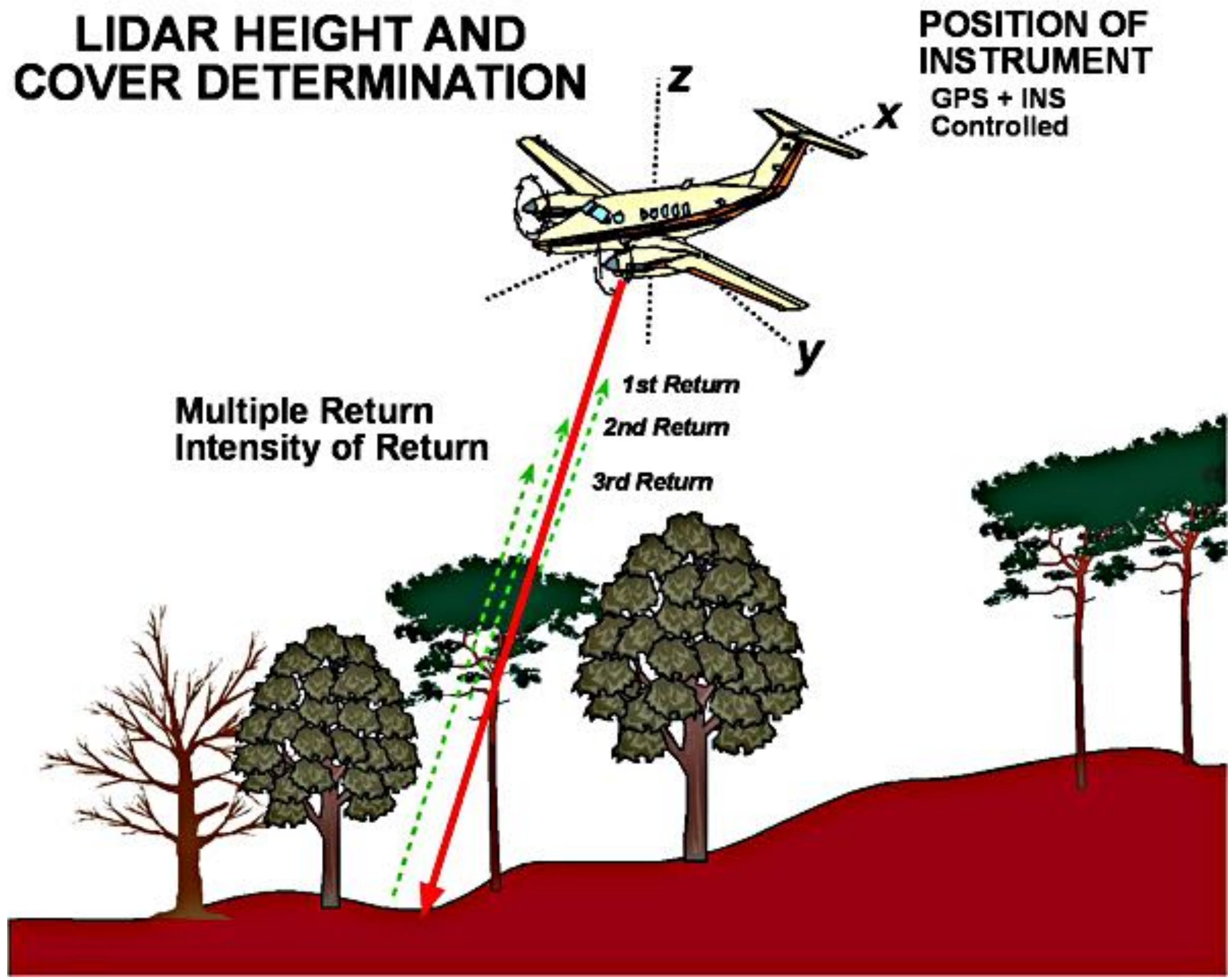
Each point records:

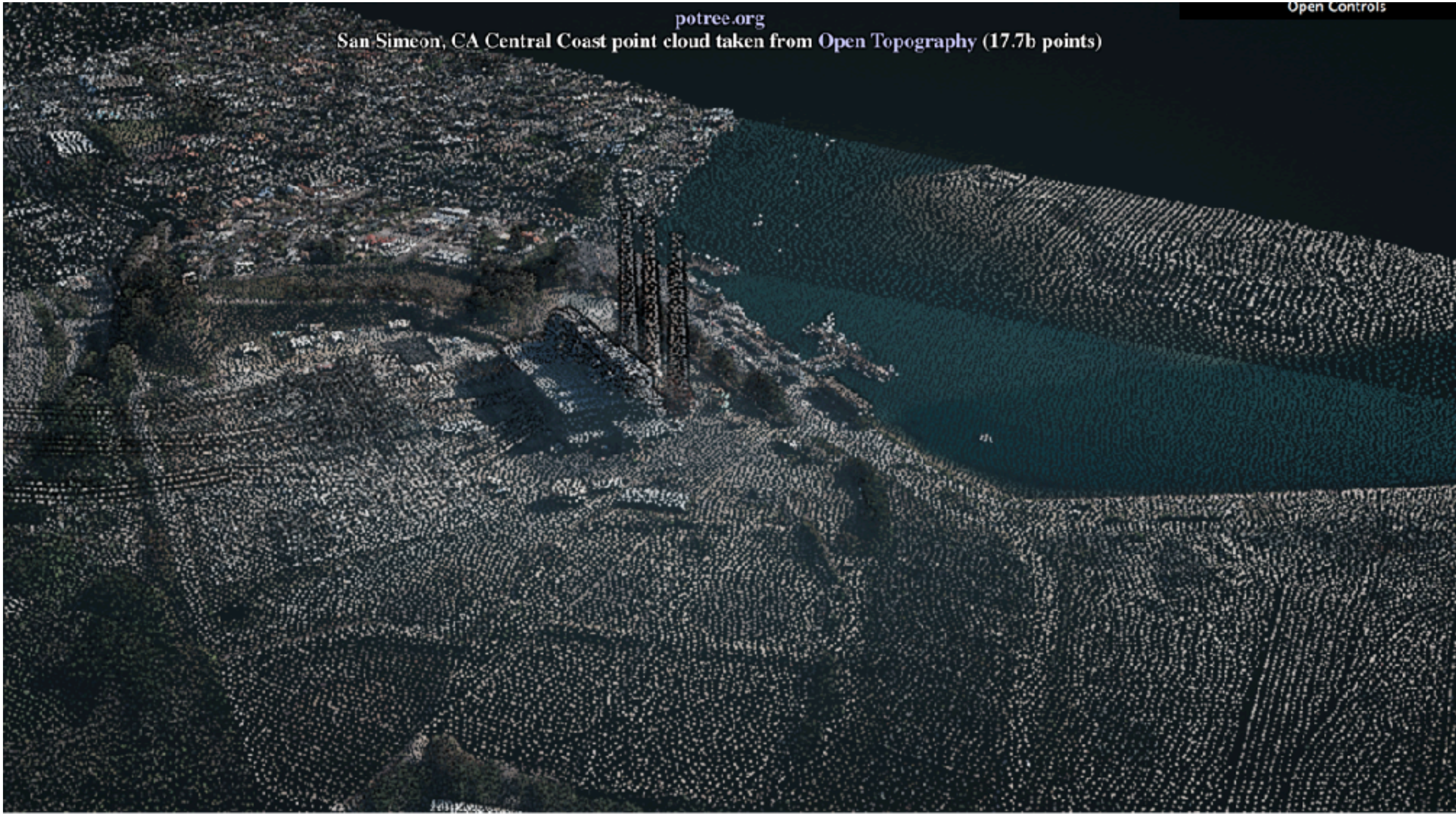
- **its geographic location x,y**
- **its height z**
- the number of returns in its pulse
- its return number
- intensity
- RGB
- ..



LiDAR point cloud: { (x,y,z. …) }

First return, last return




potree.org
San Simeon, CA Central Coast point cloud taken from Open Topography (17.7b points)
Open Controls

LiDAR web visualizers

http://potree.org

http://plas.io

LiDAR has many uses

- GIS, LiDAR data used to get digital terrain models (grids)
- Medicine: models of tumors
- Robotics: sense and classify environment
- Self driving cars: avoid obstacles
- Archaeology

AV use LiDAR
to construct maps and avoid obstacles

LiDAR has .5m horizontal resolution

and .2m vertical accuracy

NATIONAL GEOGRAPHIC

http://news.nationalgeographic.com/news/2014/01/140103-new-england-archaeology-lidar-science.html

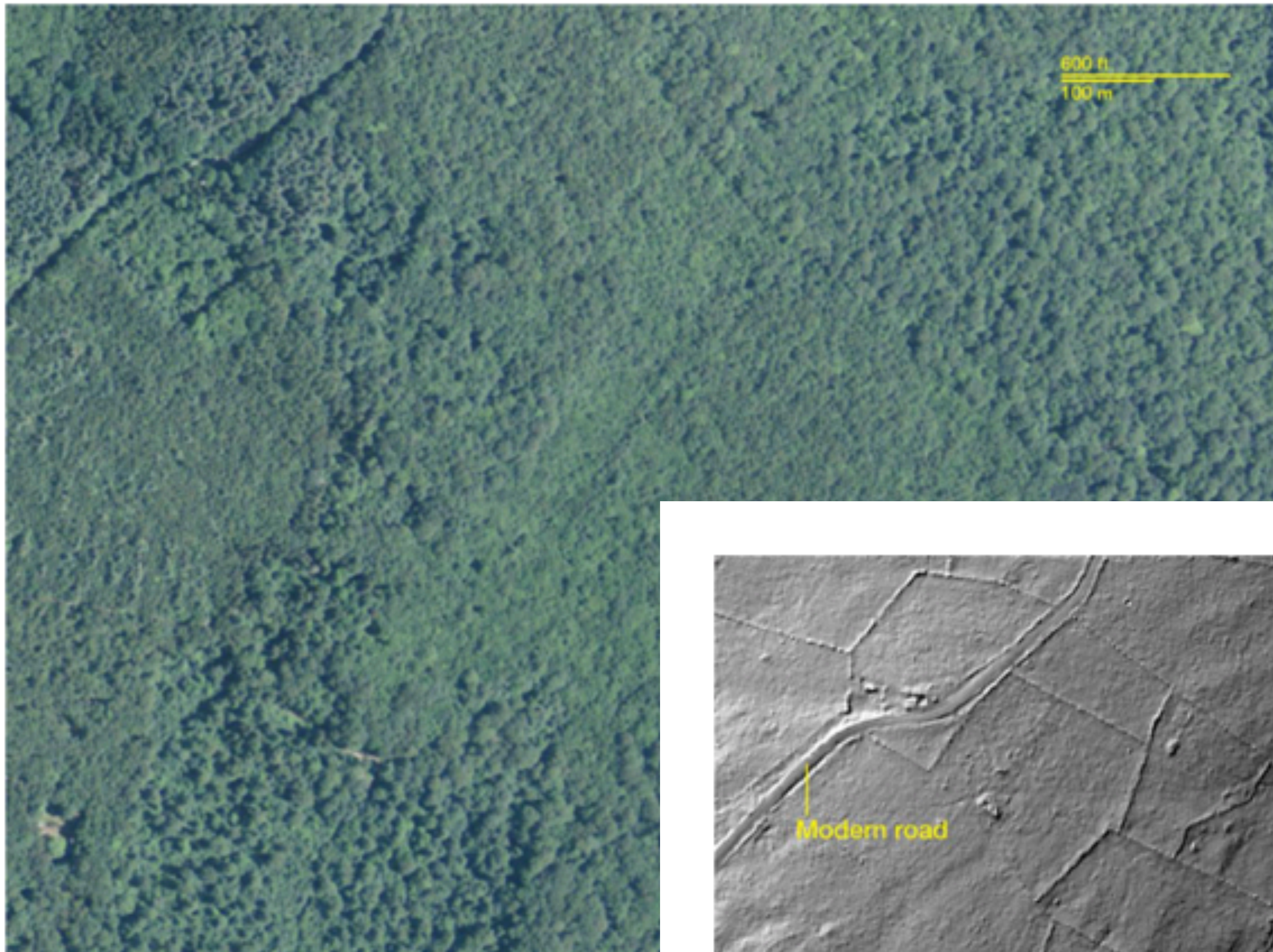
"Lost" New England Revealed by High-Tech Archaeology

By **Dan Vergano**, National Geographic

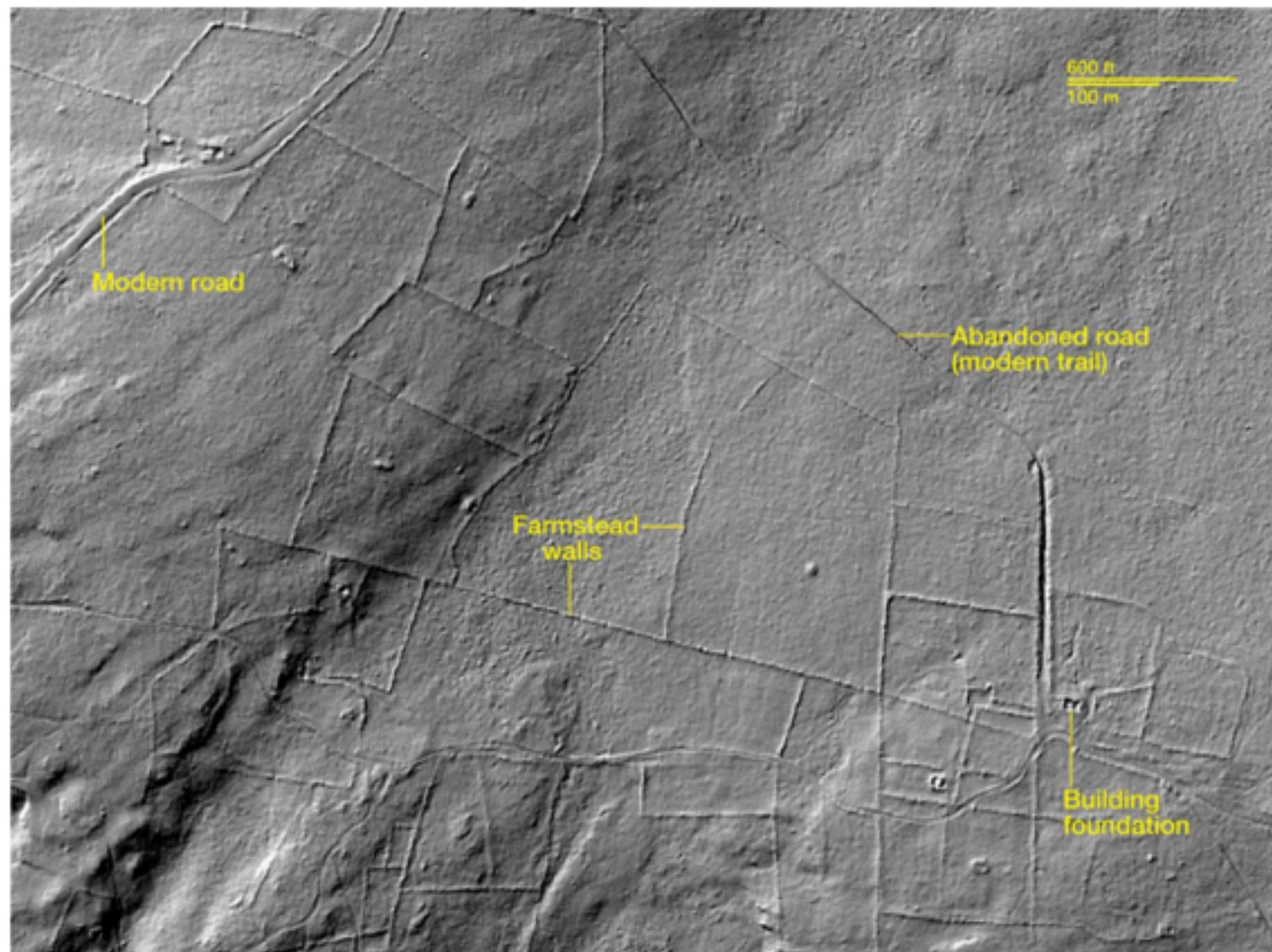
PUBLISHED JANUARY 3, 2014

This "lost" New England of the colonial era has started to emerge, thanks to archaeologists piercing the forests with the latest in high-tech scanners, called light detection and ranging (LiDAR). In the images above, LiDAR reveals farm walls, roads and homesteads hidden within Connecticut's Pachaug State Forest. Dating to the 18th Century, the farmsteads were abandoned in the 1950's.

https://news.nationalgeographic.com/news/2014/01/140103-new-england-archaeology-lidar-science/



Katharine Johnson, William Oimet, U. Connecticut

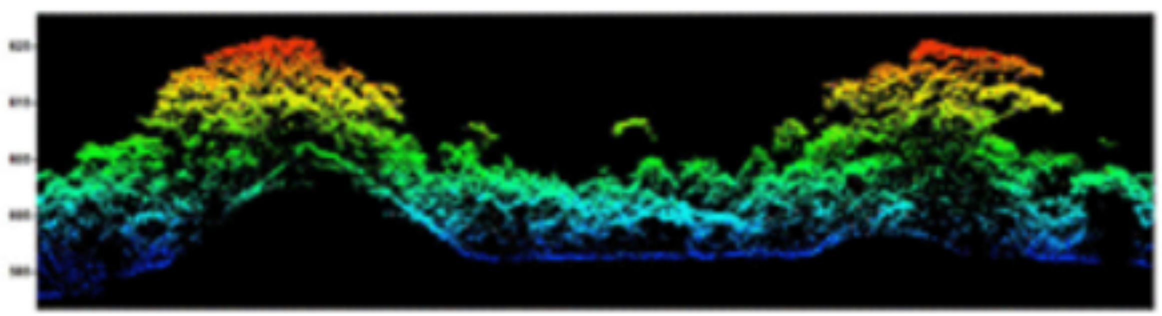


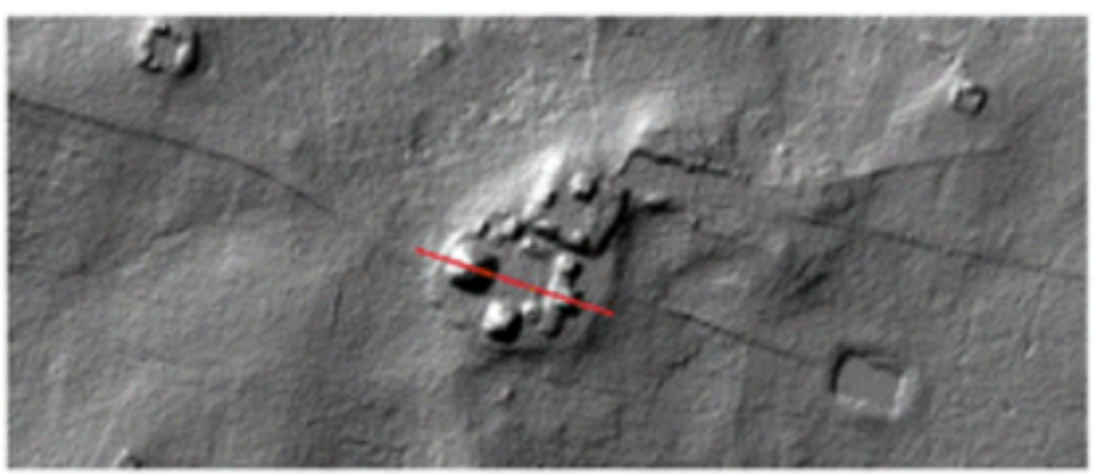
stone walls, building foundations, old roads and dams

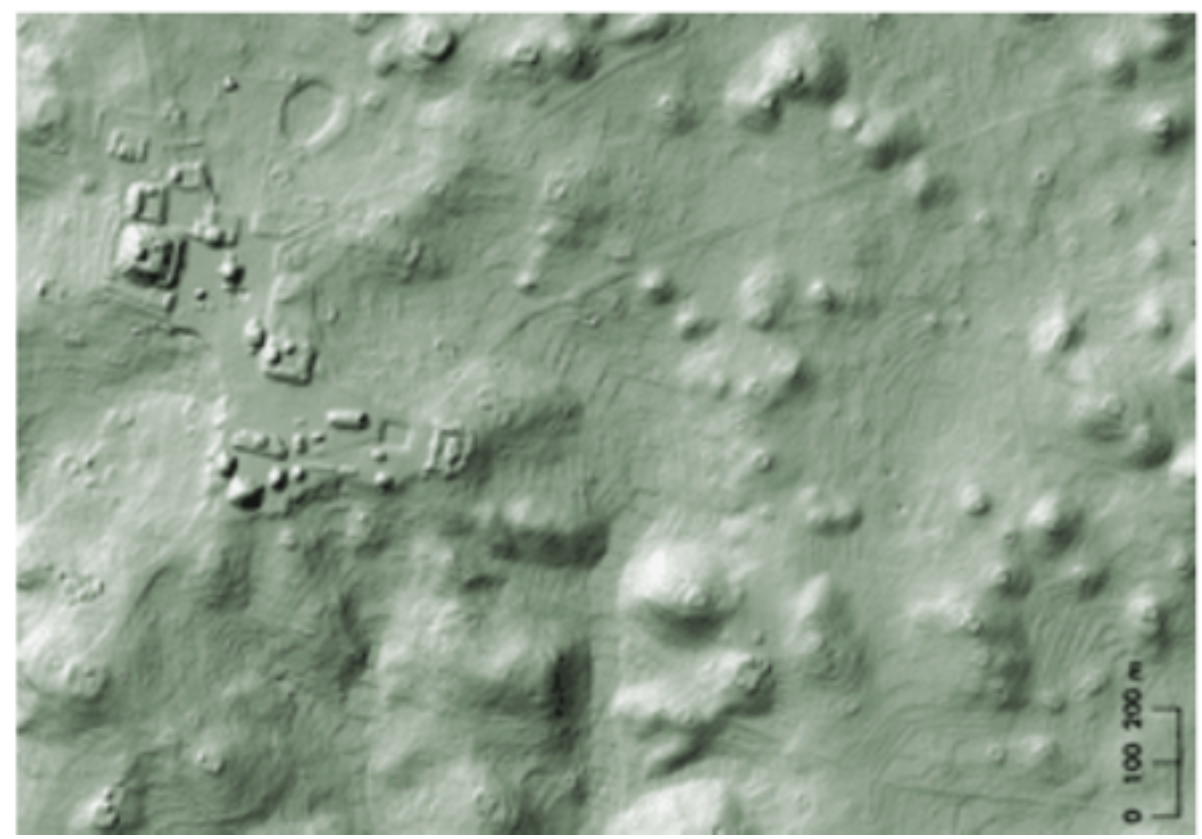
http://www.archaeology.org/
ARCHAEOLOGY Archive
(http://www.archaeology.org/)
A publication of the Archaeological Institute of America

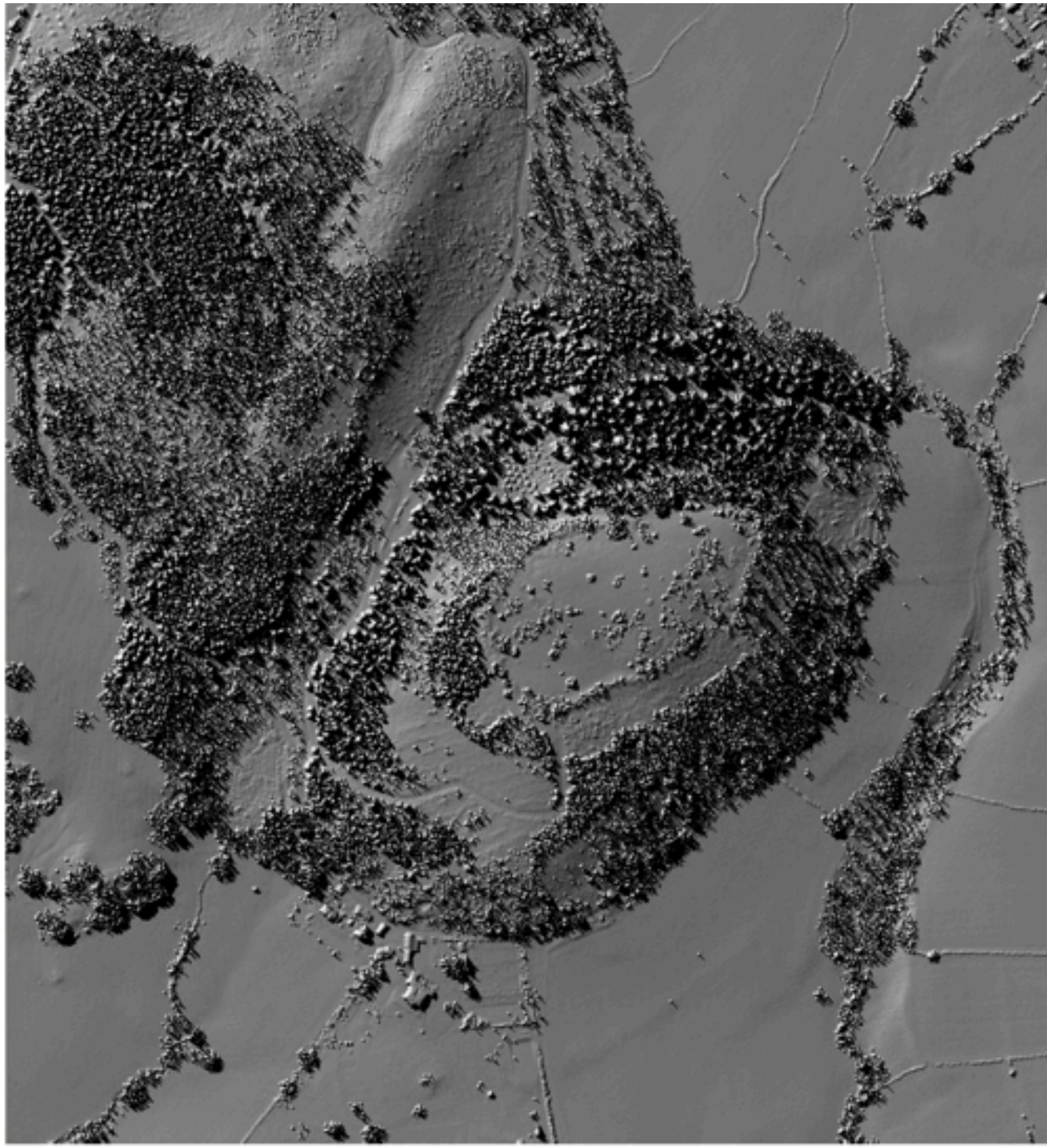
The Maya site of Caracol in Belize

- Maya sites are hard to see even when their location are known, because of the overgrowth of the jungle
- Caracol has been excavated for 25 years
- LiDAR reveals the hidden features under the forest









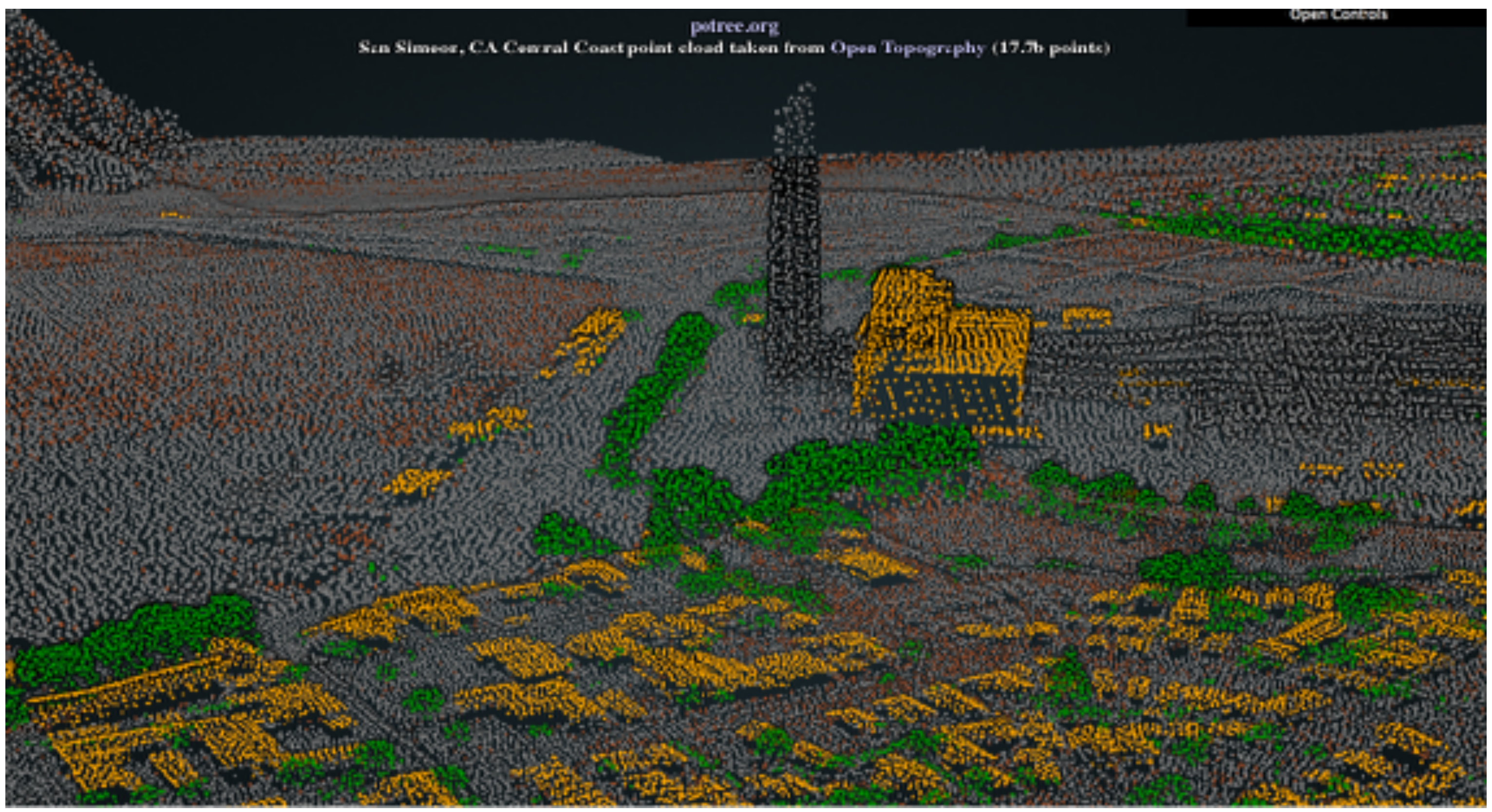
An example of first return data (above), and bare earth data (below) for a fort site in Shropshire. Note how LiDAR pulses that have penetrated the tree canopy and vegetation cover to reach the ground can be used to produce a terrain model of the ground surface, effectively 'removing' the trees. Using this method, the rampart and ditches of two later prehistoric enclosures are revealed.

An Introduction to LiDAR for Archaeology

AOC Archaeology Group

Working with LiDAR data in GIS

- Classify it (ground, buildings, vegetation, noise)

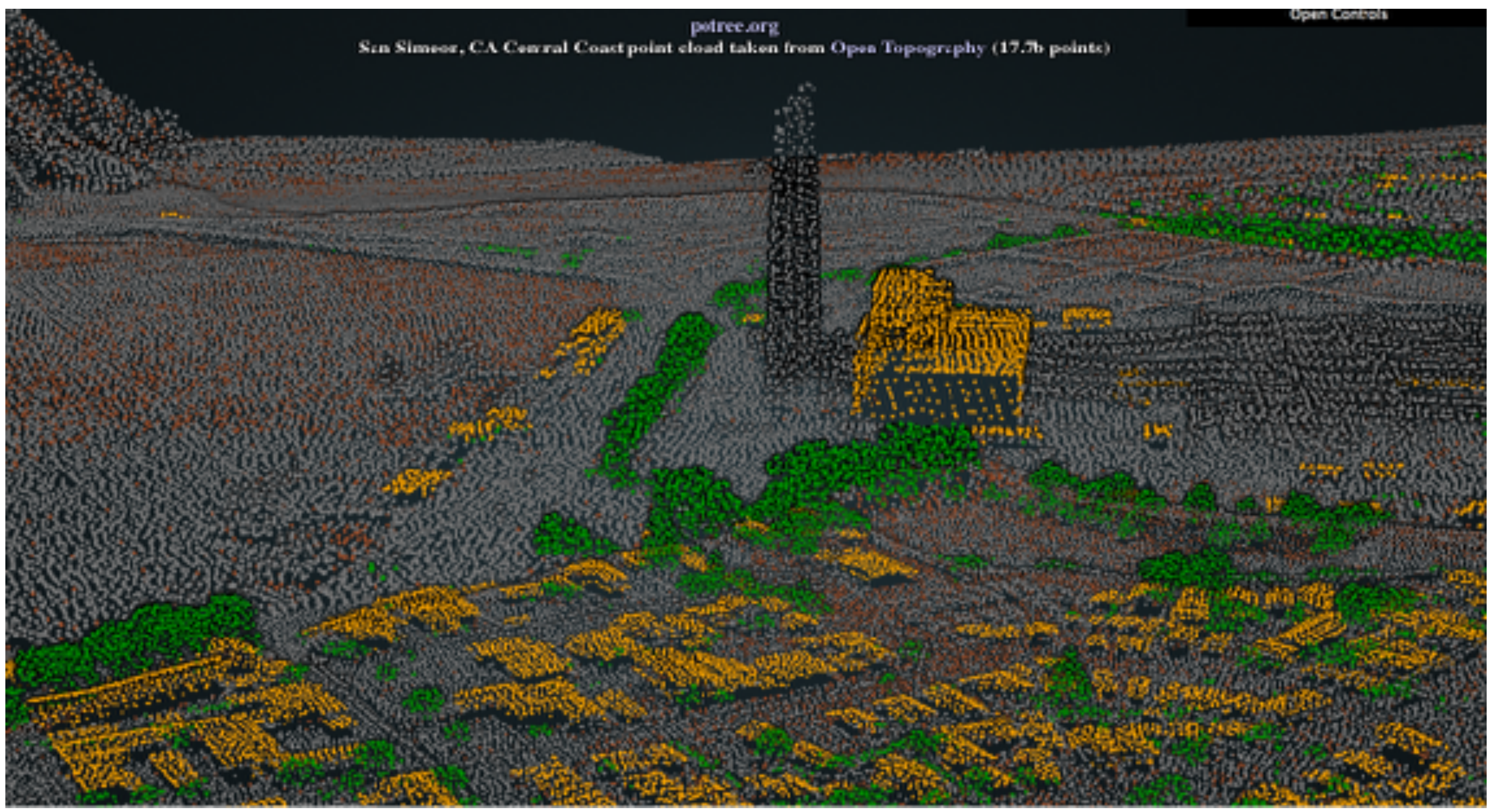


Classification Value and Meaning

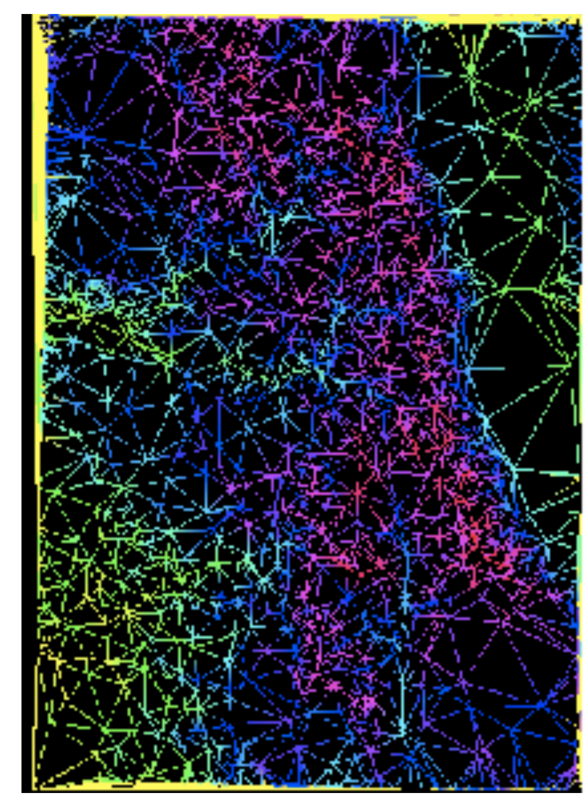
0 Created, never classified
1 Unclassified
2 Ground
3 Low Vegetation
4 Medium Vegetation
5 High Vegetation
6 Building
7 Low Point (noise)
8 Model Key-point (mass point)
9 Water
10 Reserved for ASPRS Definition
11 Reserved for ASPRS Definition
12 Overlap Points
13-31 Reserved for ASPRS Definition

Working with LiDAR data in GIS

- Classify it (ground, buildings, vegetation, noise, ..)
- Ground points => high resolution ground model



grid (raster)



TIN

Challenges

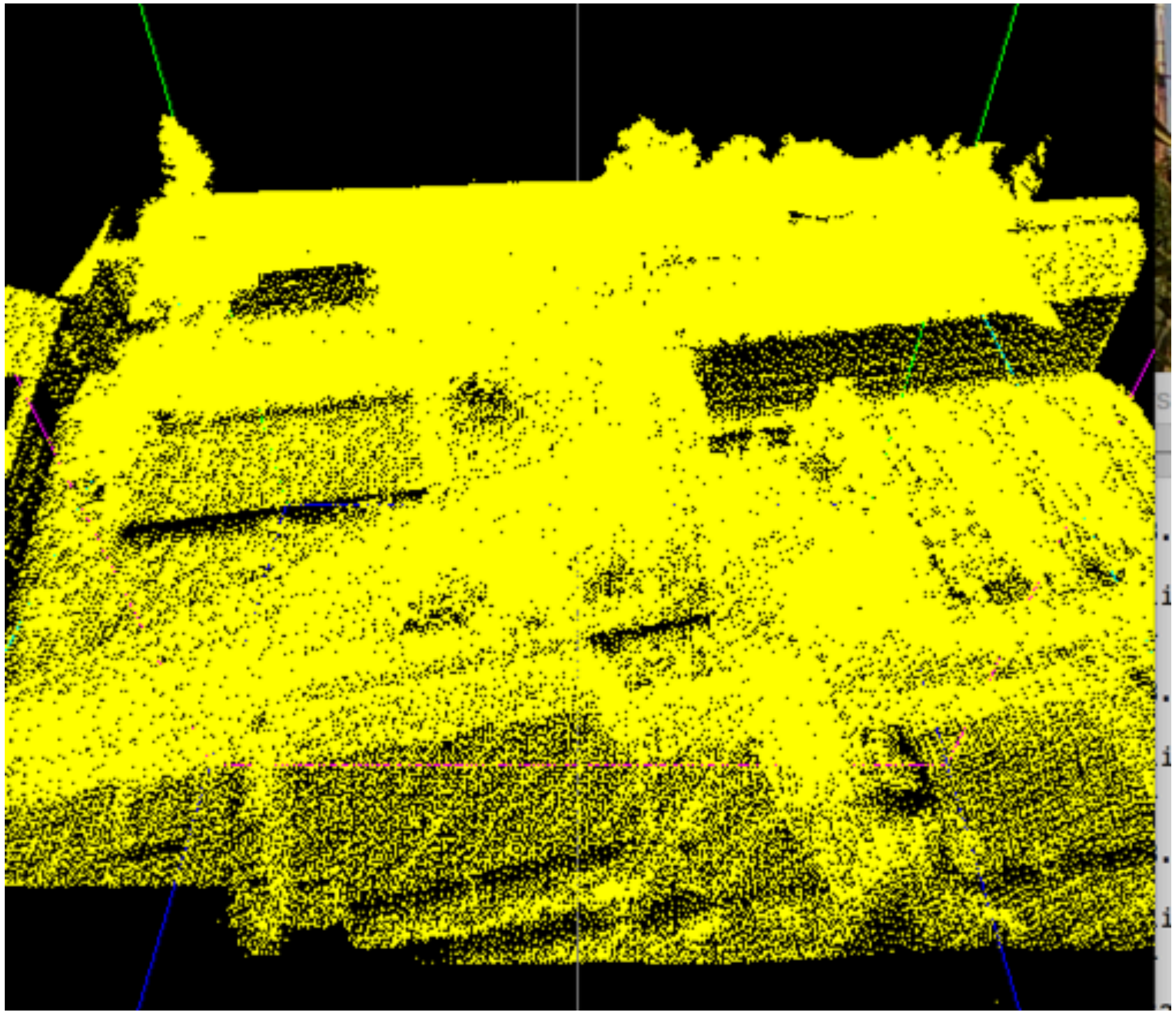
- **Huge!**
- Storage issues
- Need algorithms
- Need efficient algorithms
    - CPU efficient
    - IO-efficient (streaming)
    - cache-efficient
    - parallel

Next: Brainstorming

- Classifying LiDAR data (ground, vegetation, buildings)
- From point cloud to grid or TIN

Classification

Given a point-cloud P, label each point as one of {ground, vegetation, building, other}



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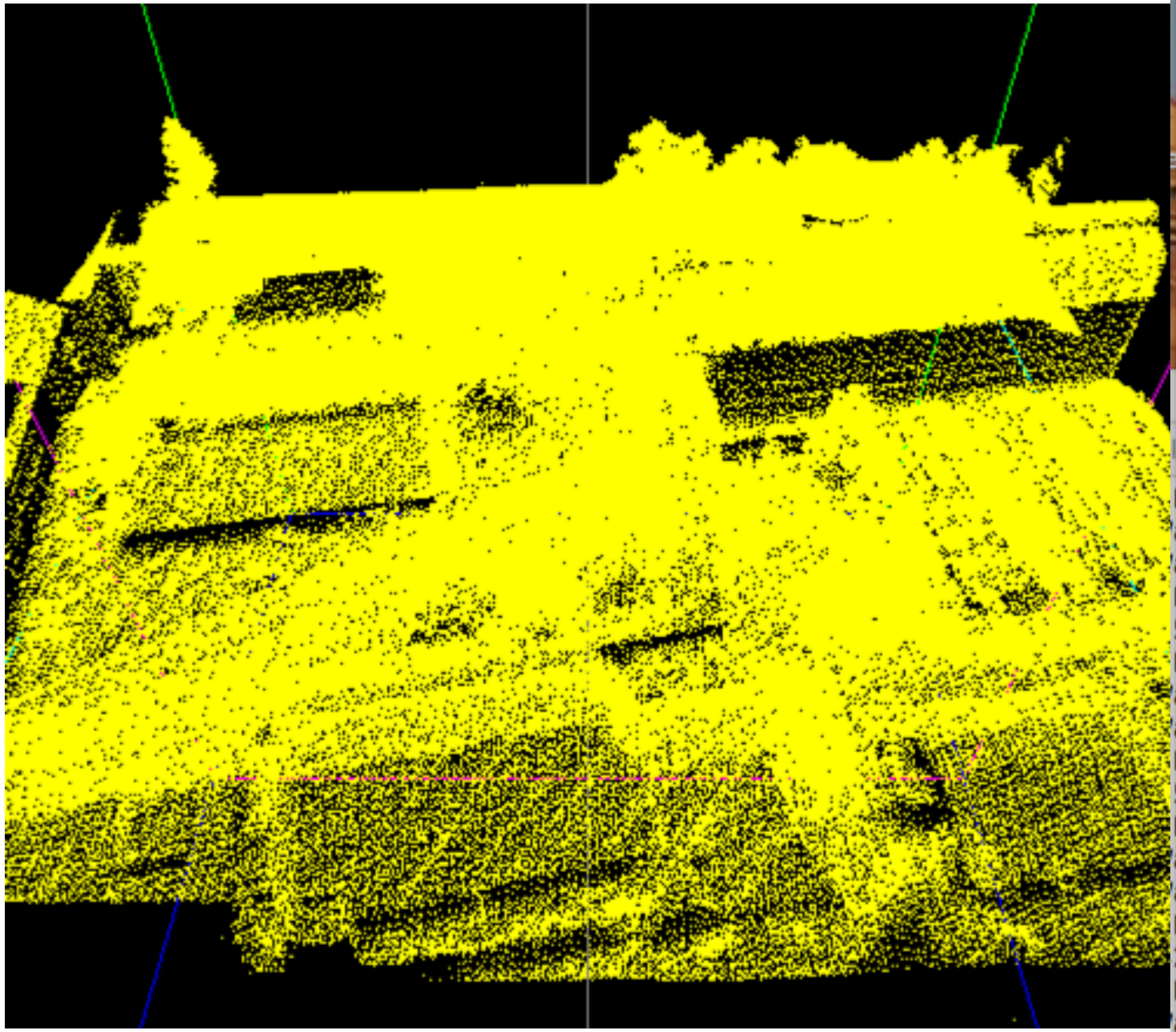

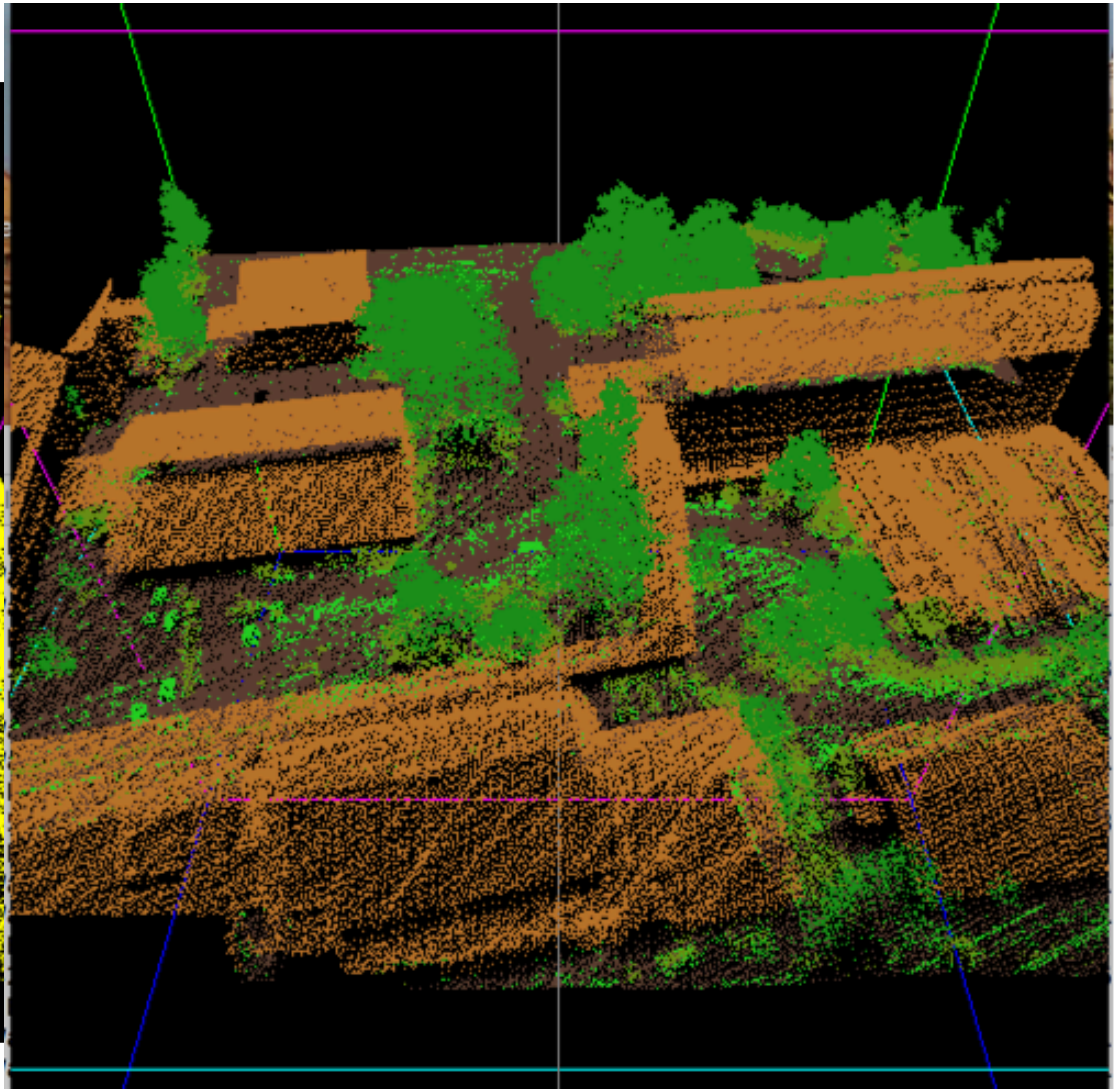

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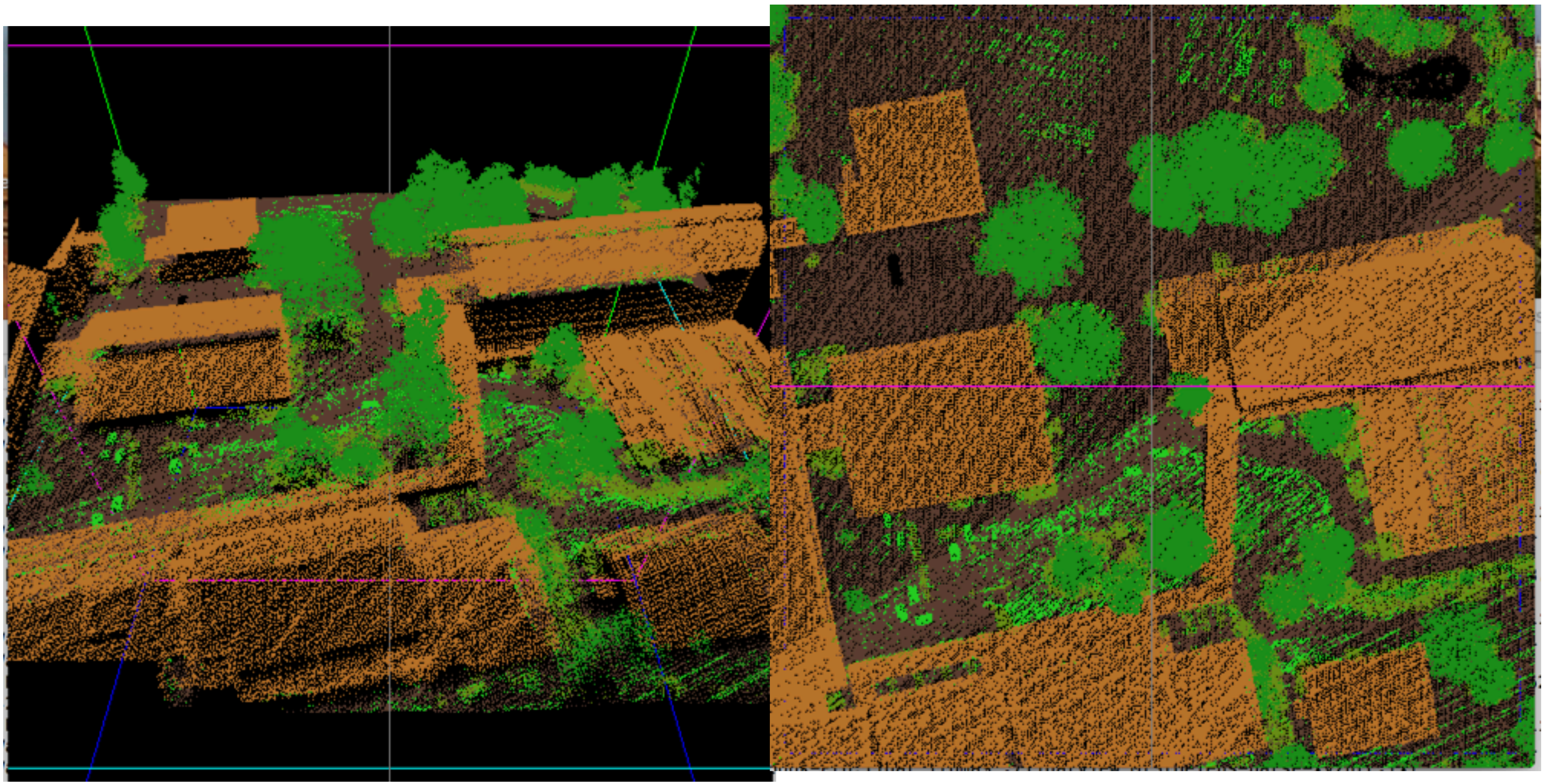
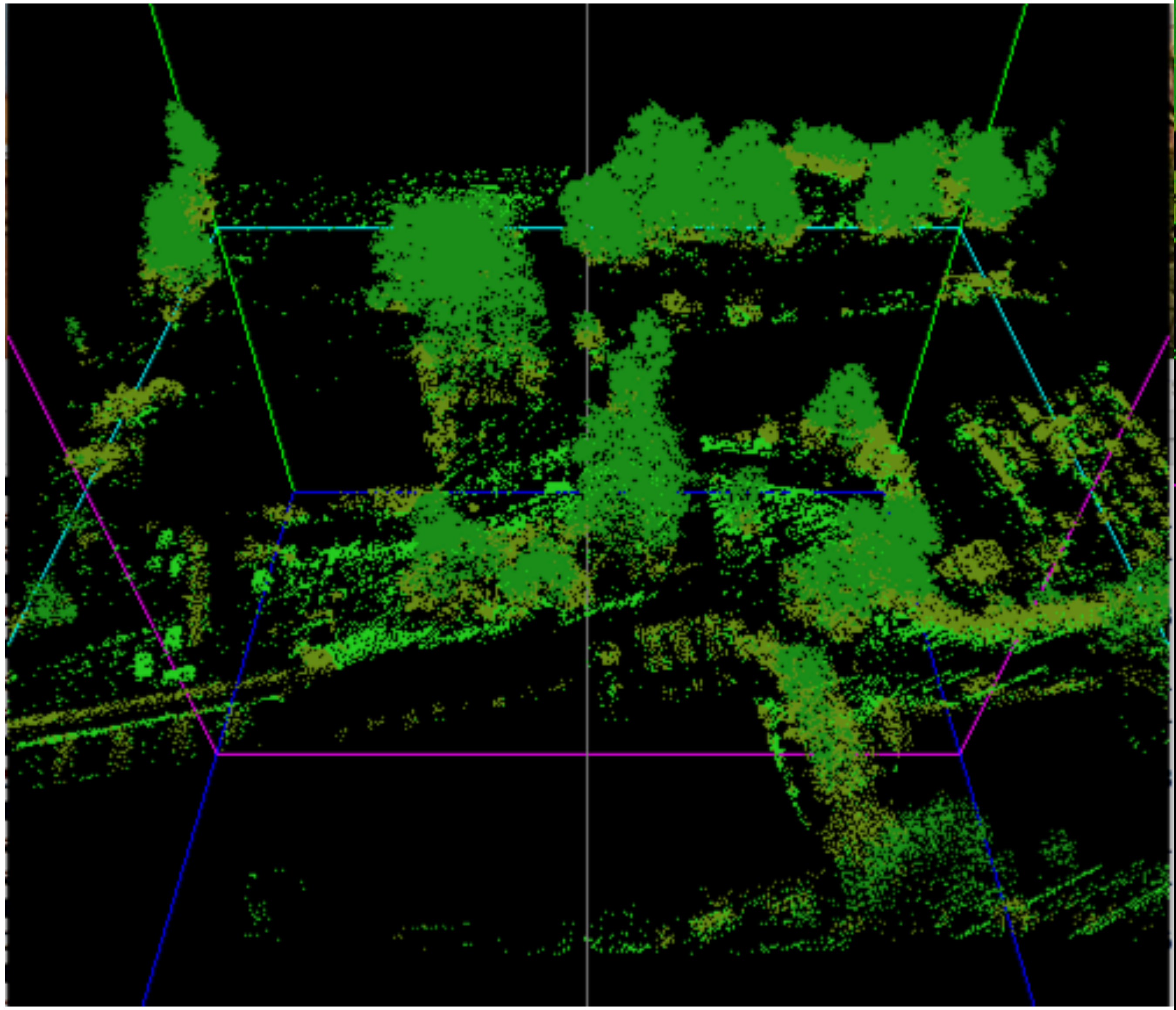
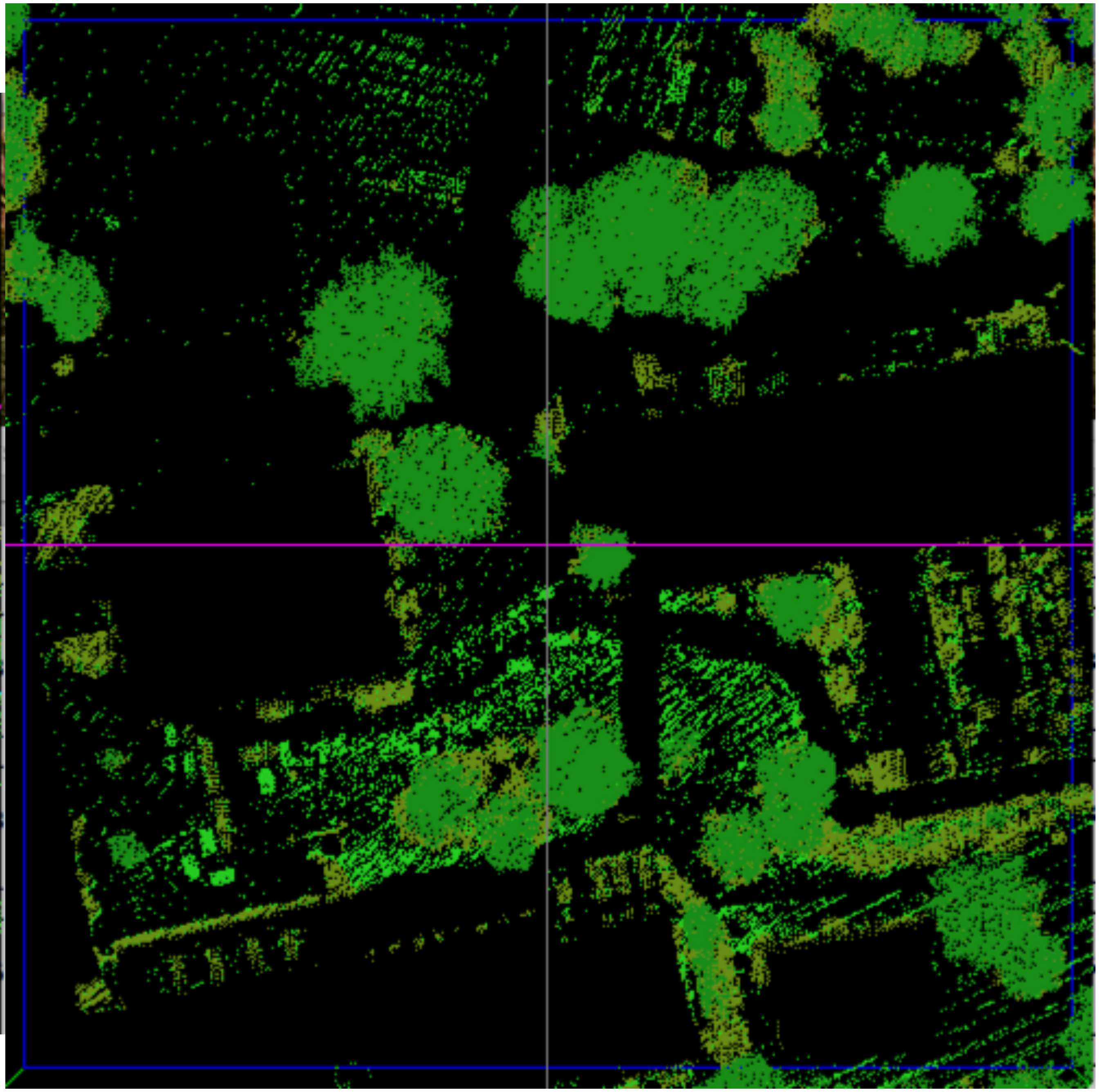


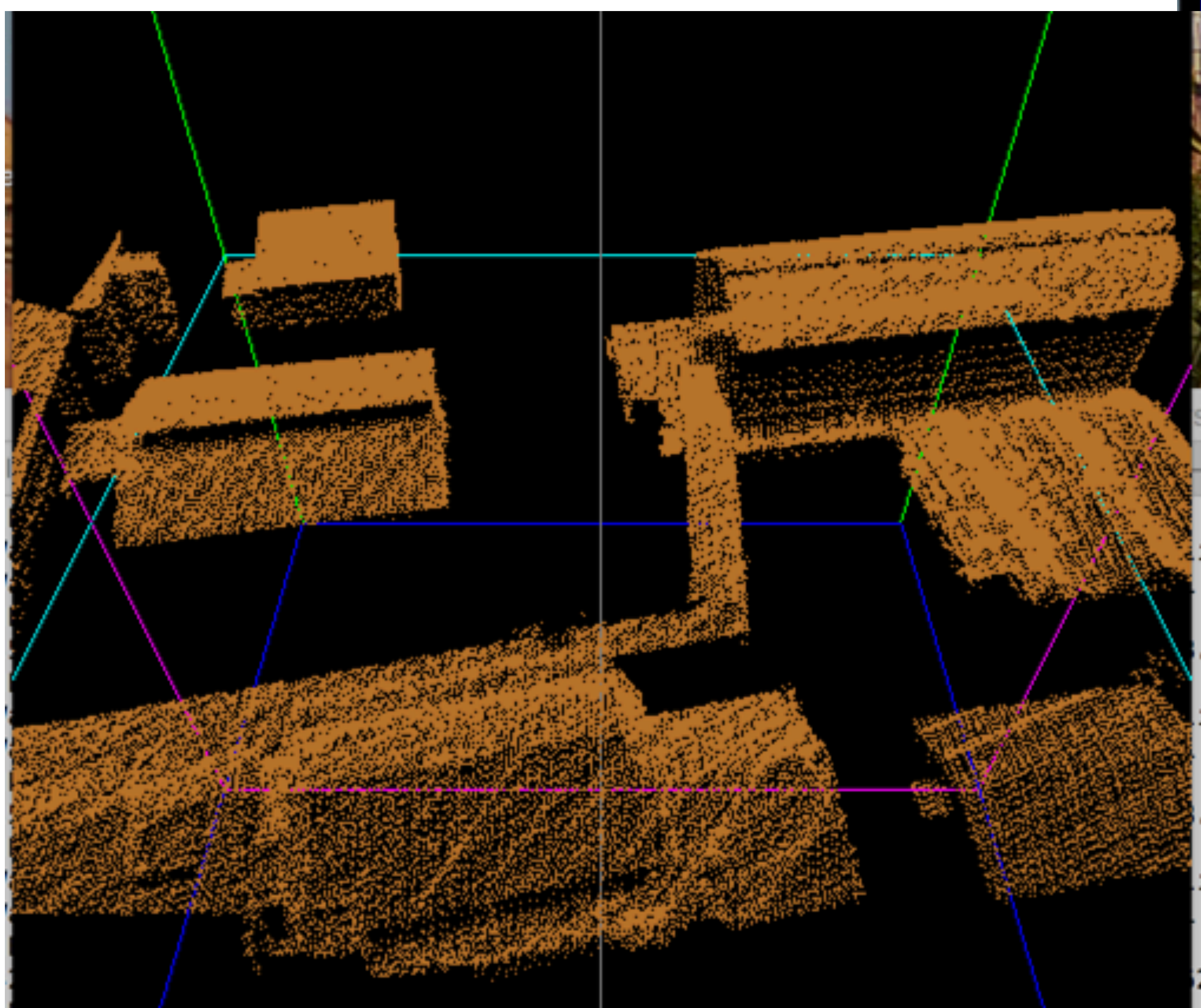
Automatic extraction of vegetation

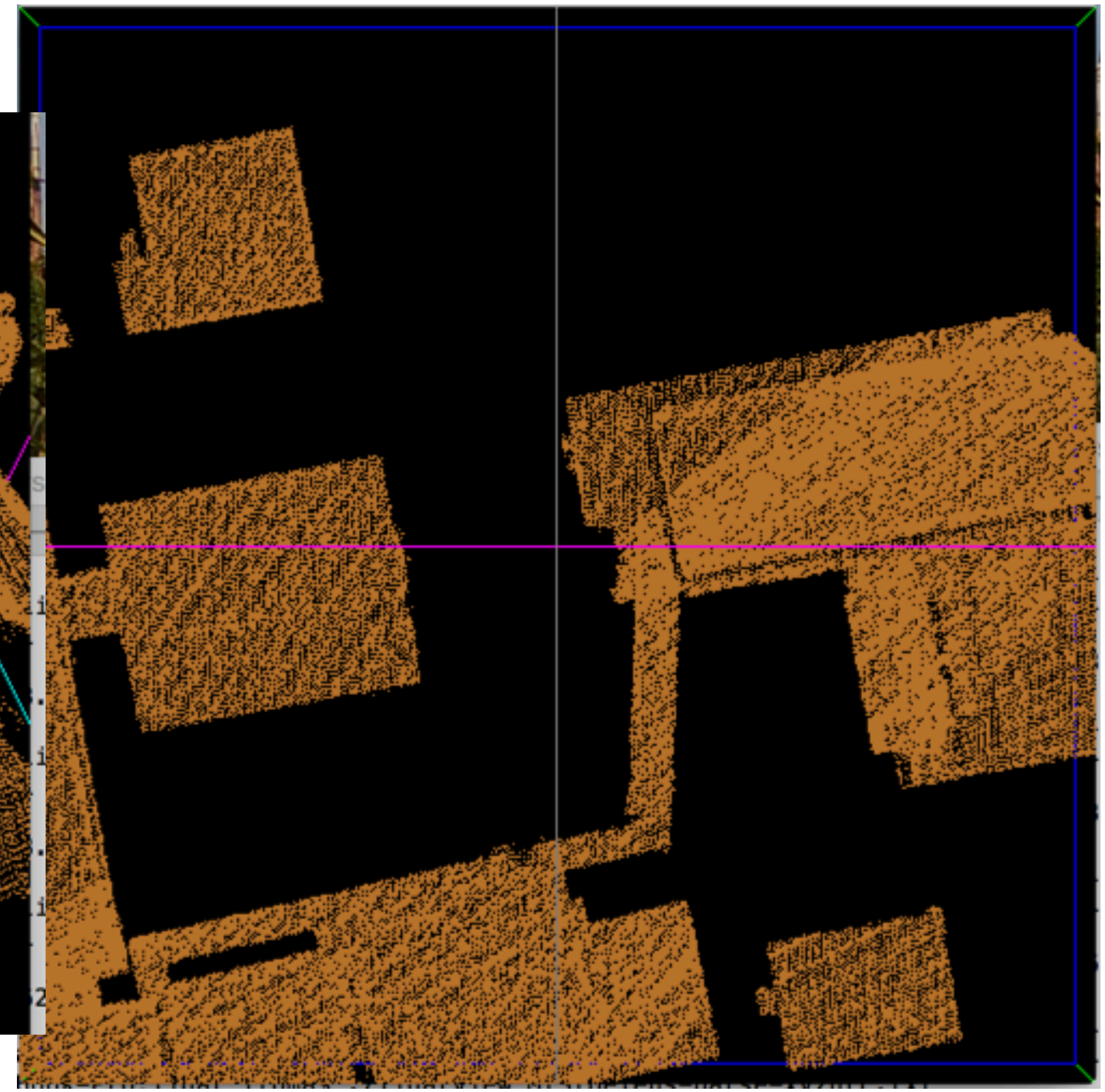
Can be used to extract species, estimate biomass, forest age and health, asses fire damage, etc





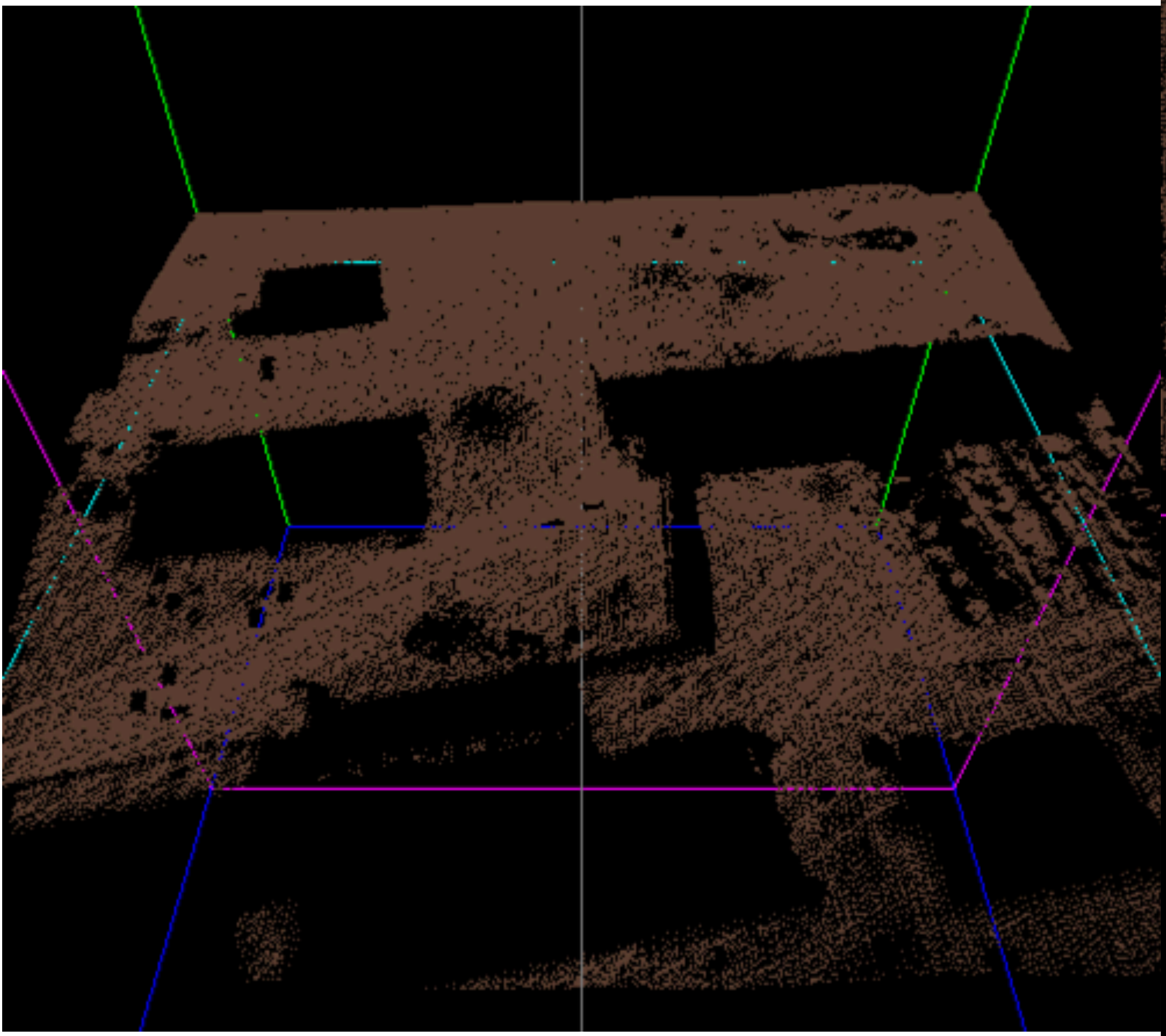
Automatic building delineation

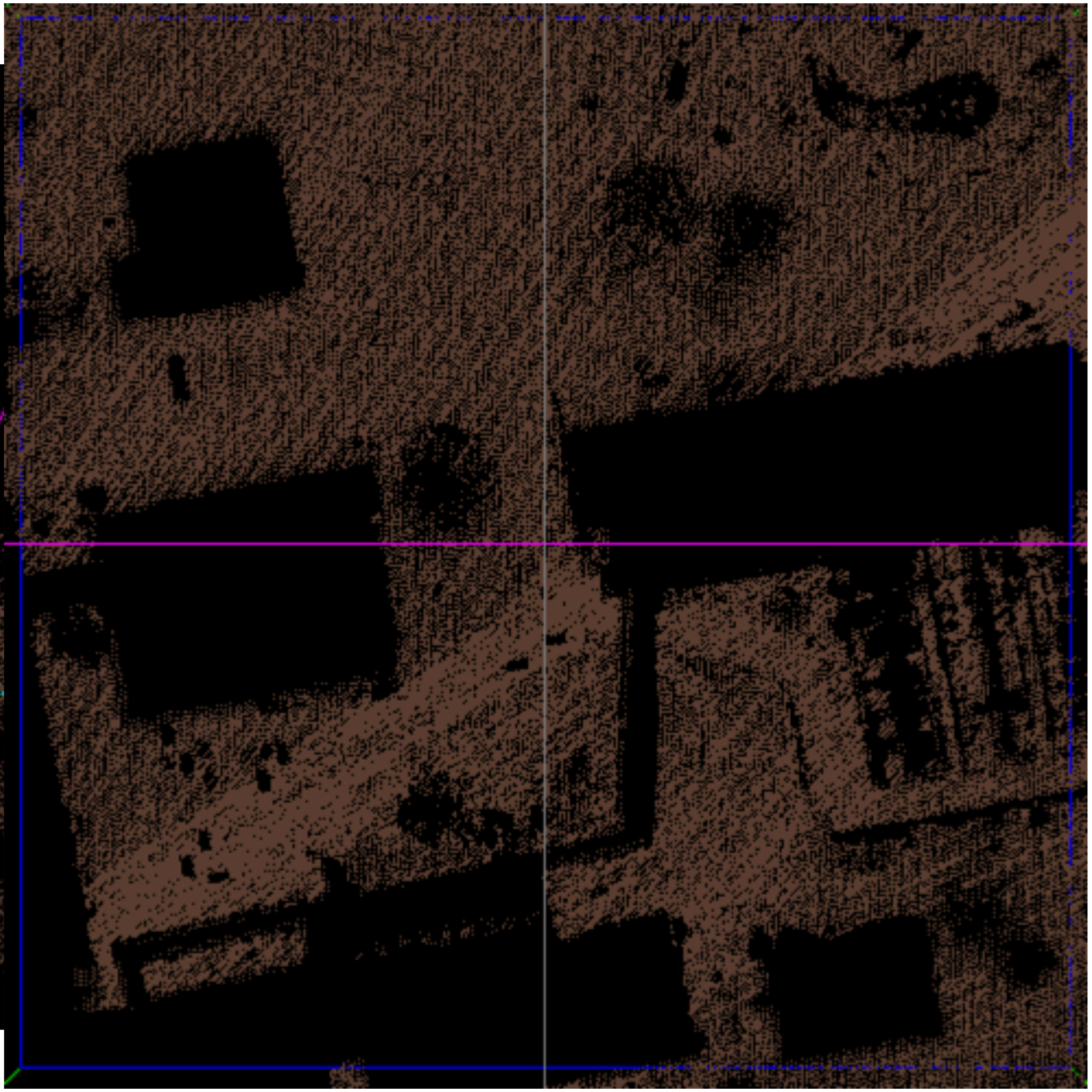




Finding the ground

Gives high-resolution ground models to be used in terrain modeling

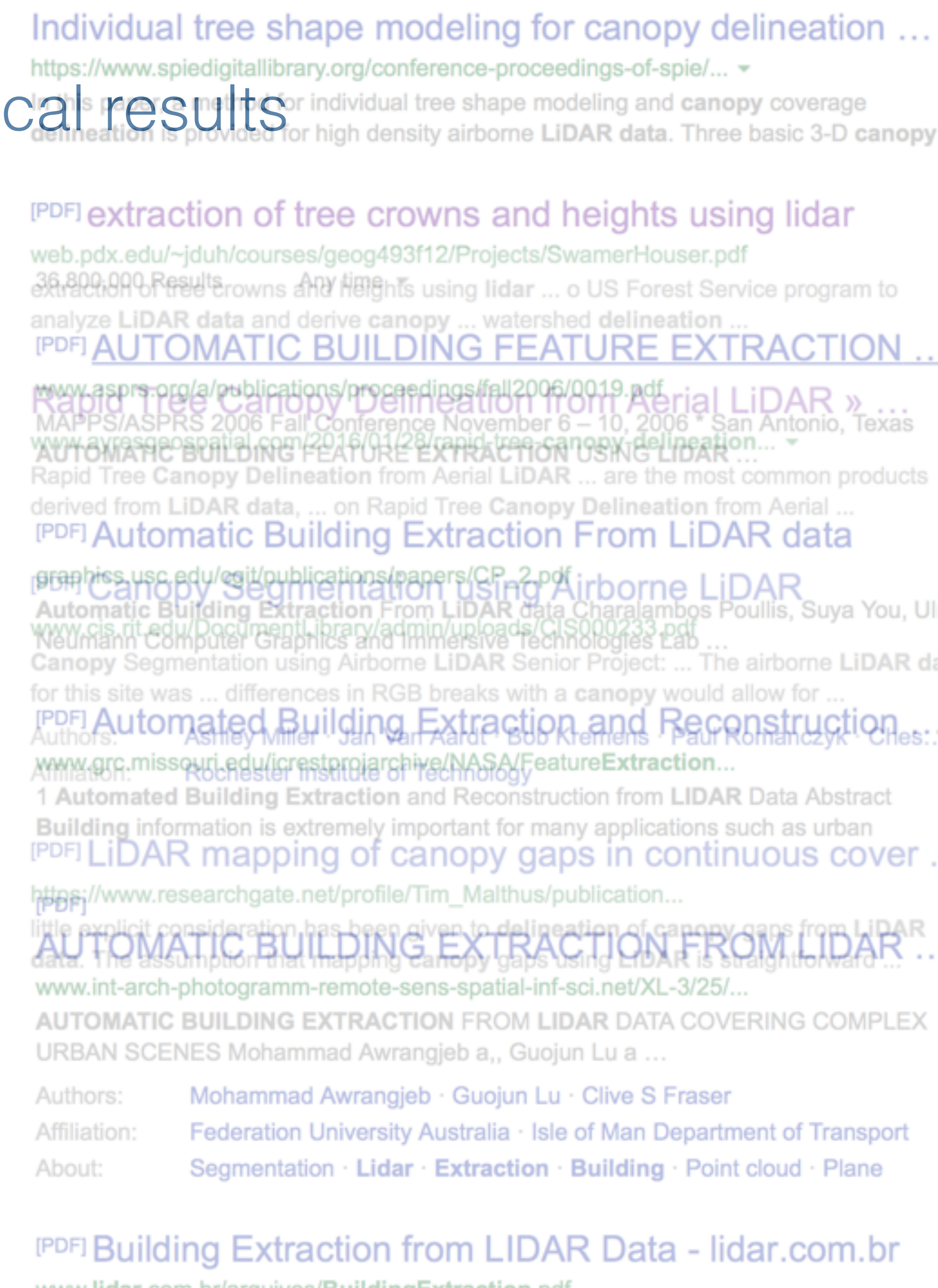




Classification: lots of empirical results

Some ideas

- height filters (e.g. building are taller than 10ft)
- smoothness assumptions (e.g. roof tops are almost flat)
- shape assumptions
- detect abrupt changes
    - boundary of buildings and trees have abrupt changes
- use filters to remove noise but keep features
    - erosion: set each p as p = min of its neighborhood
    - dilation: set each p as p = max of its neighborhood
    - erosion + dilation (rounds)

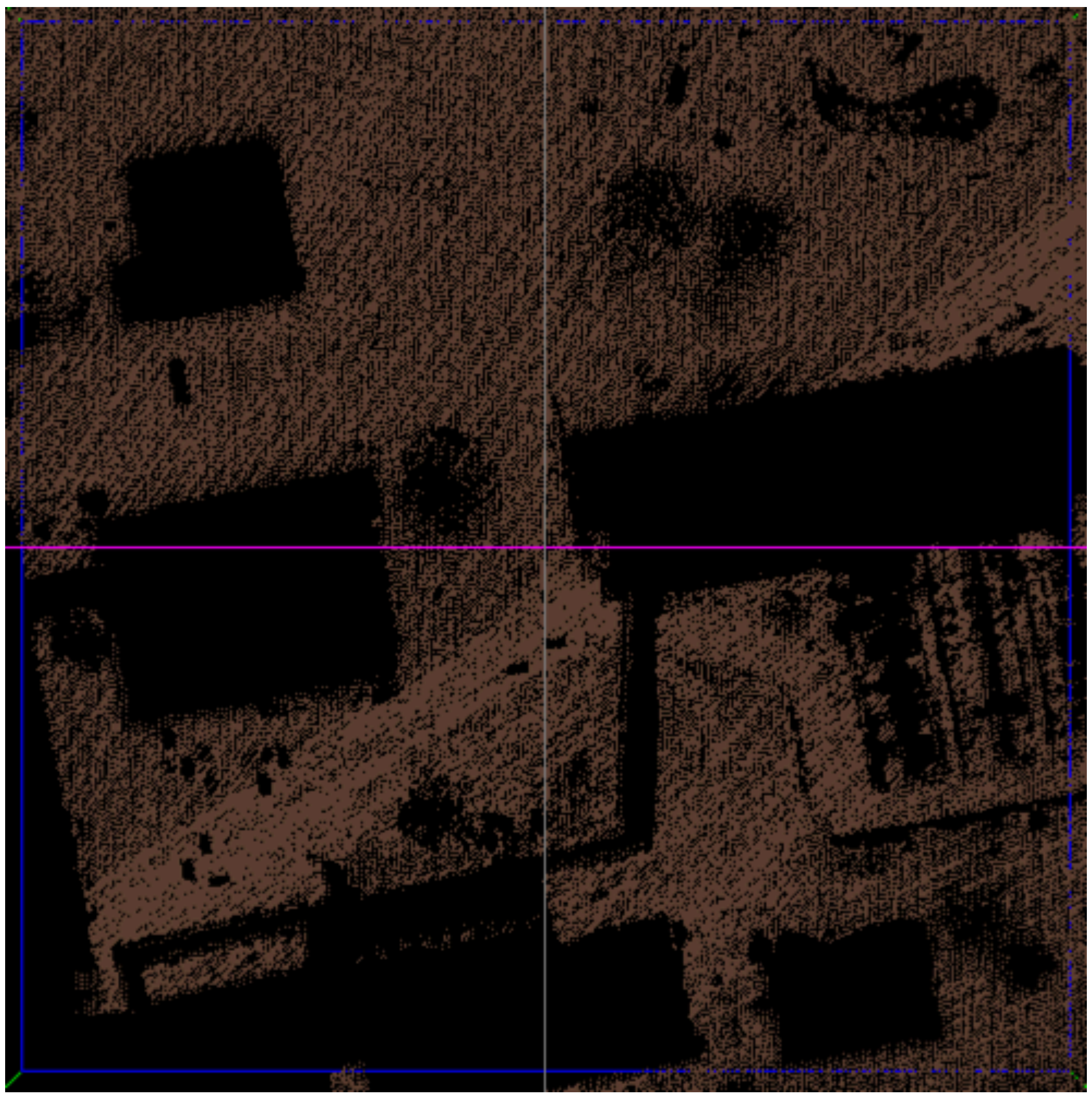


Classification

- The points with >1 returns are mostly the vegetation (and noise)
- Last returns: ground + roof tops + vegetation noise
- To find the ground, start from last returns, and traverse the points aiming to discard what does not look like ground
  - steep variations in height are most likely not ground
  - you'll need to estimate either slope or height difference at a point, so you'll need to be able to find neighbors
  - start the search from a point of minimum elevation, because that must be ground

From point cloud to TIN or grid

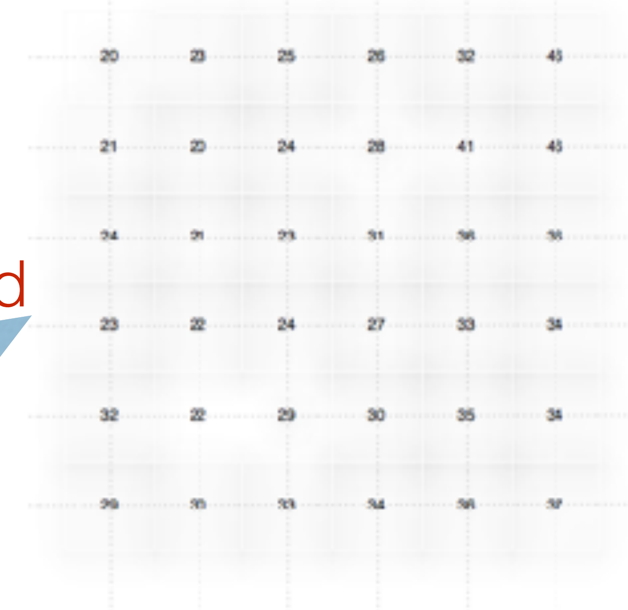
- Start with a classified point cloud

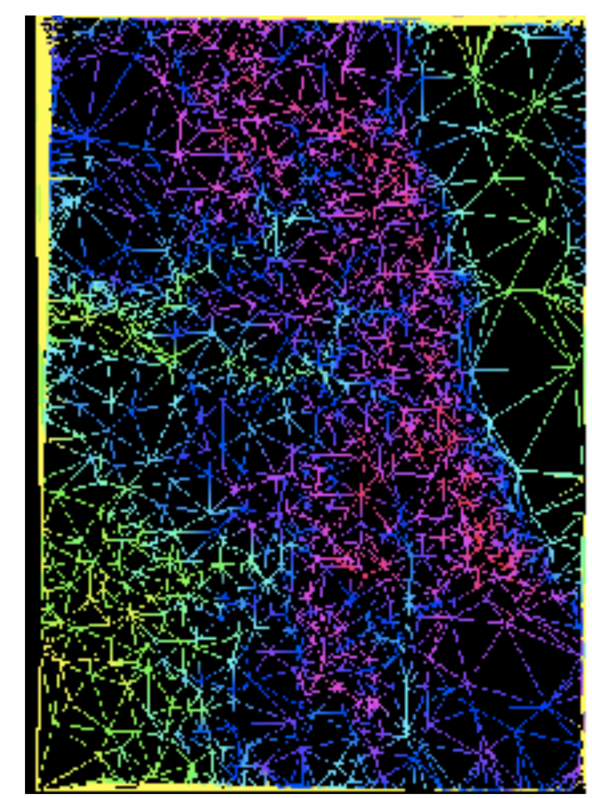


point cloud to grid

point cloud to TIN

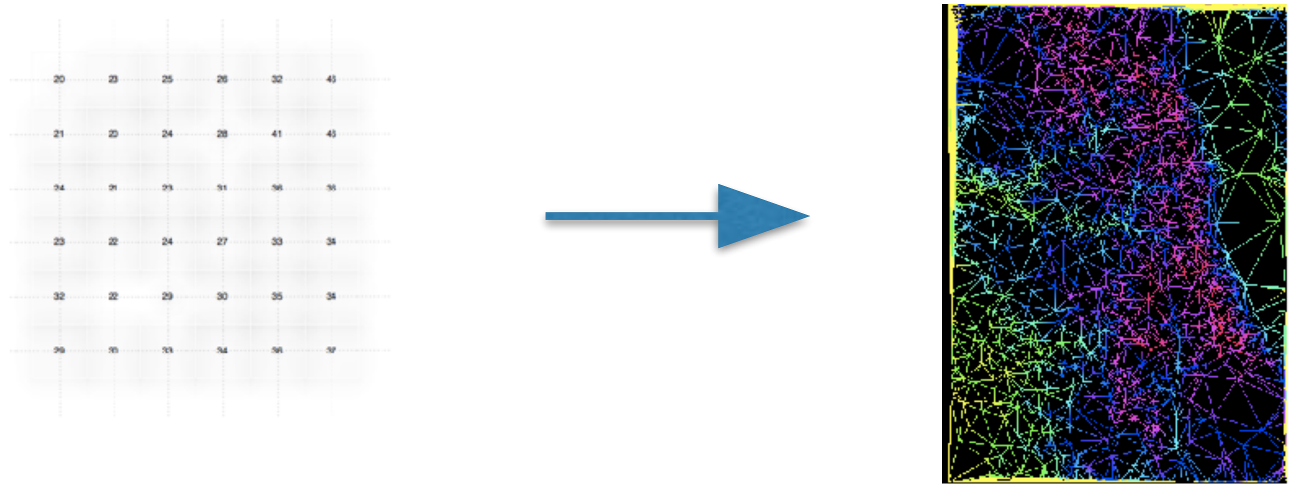
grid (raster)





TIN

Point-cloud-to-TIN



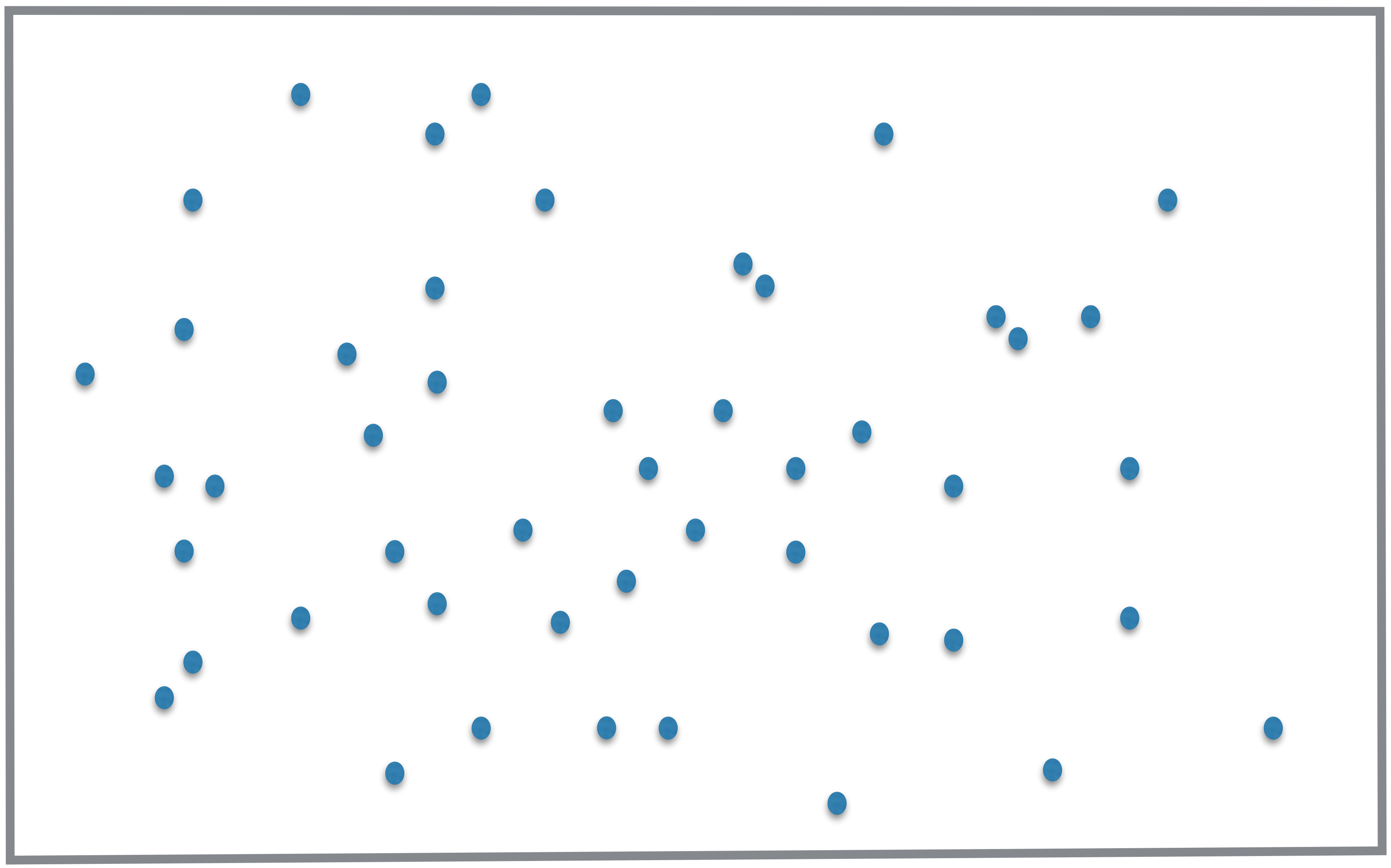
Algorithm:

- P = {all grid points}, P’ = {4 corner points}
- Initialize TIN to two triangles with corners as vertices
- while not DONE() do
    - for each point p in P, compute error(p)
    - select point p with largest error(p)
    - insert p in P’, delete p from P, and update TIN(P’)

What needs to change?

Point-cloud-to-grid

Given a point-cloud P (that represents a surface) and a desired grid spacing, compute a grid that represents surf (P).



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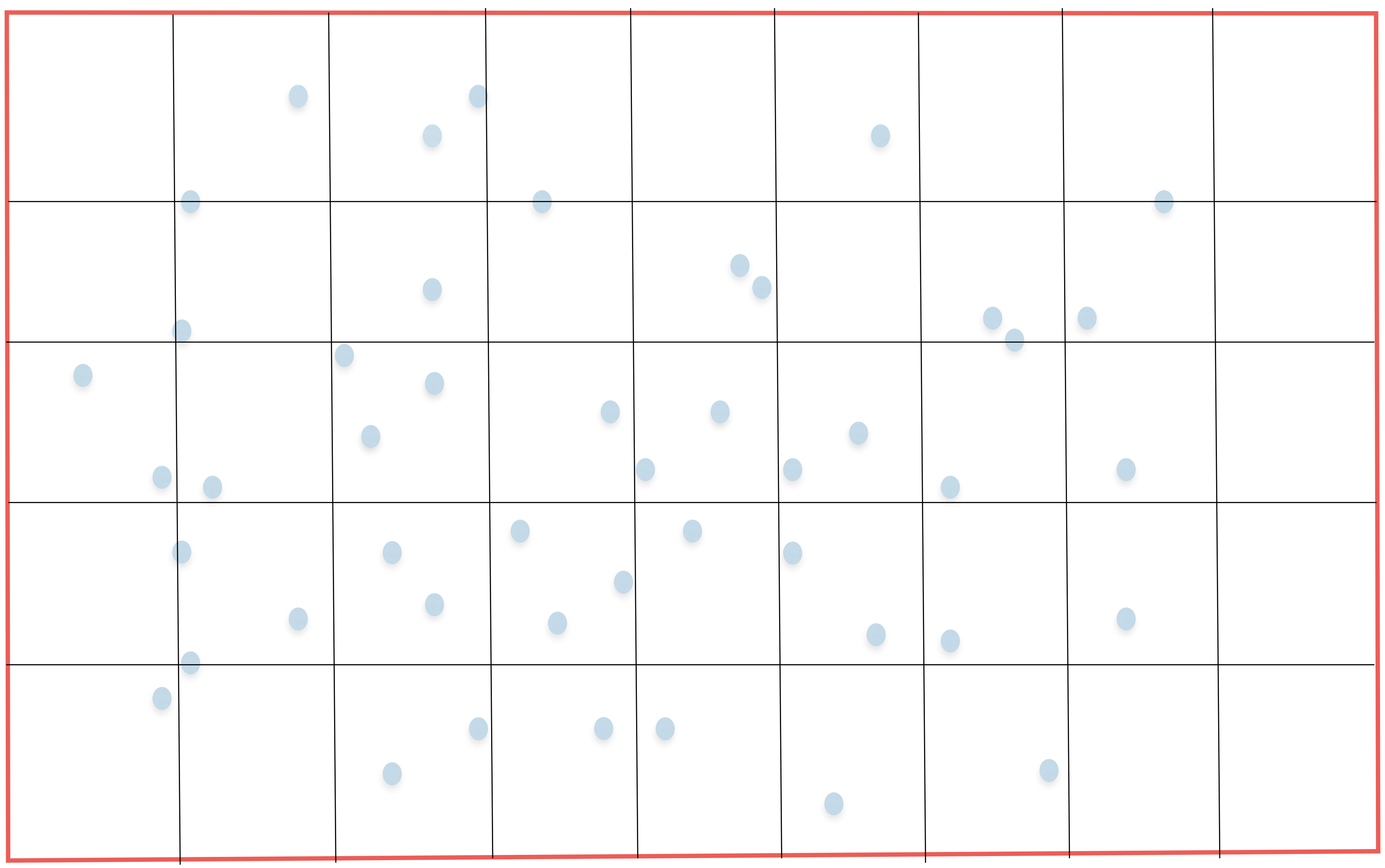

How to chose the grid spacing?
Pros? Cons?

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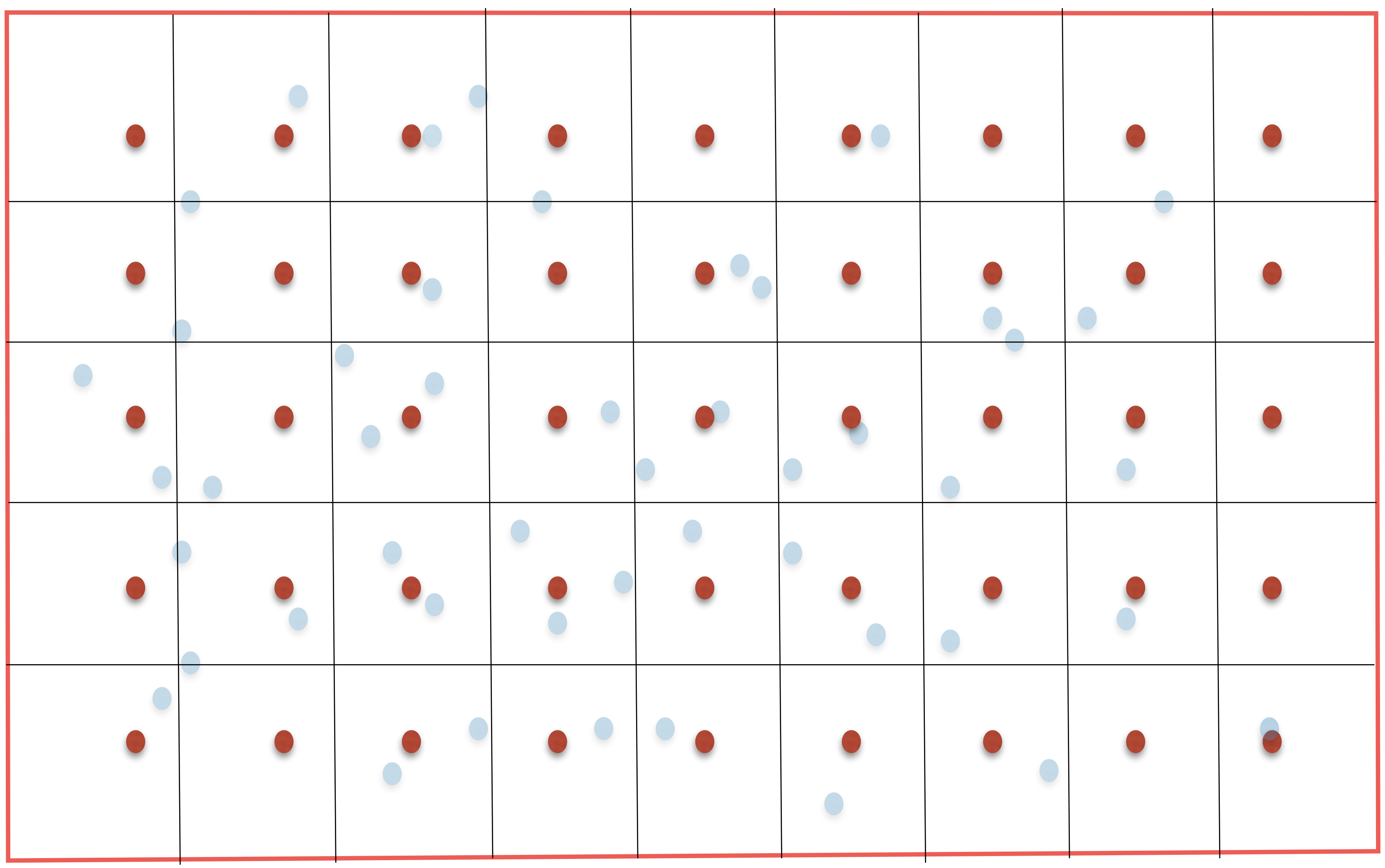

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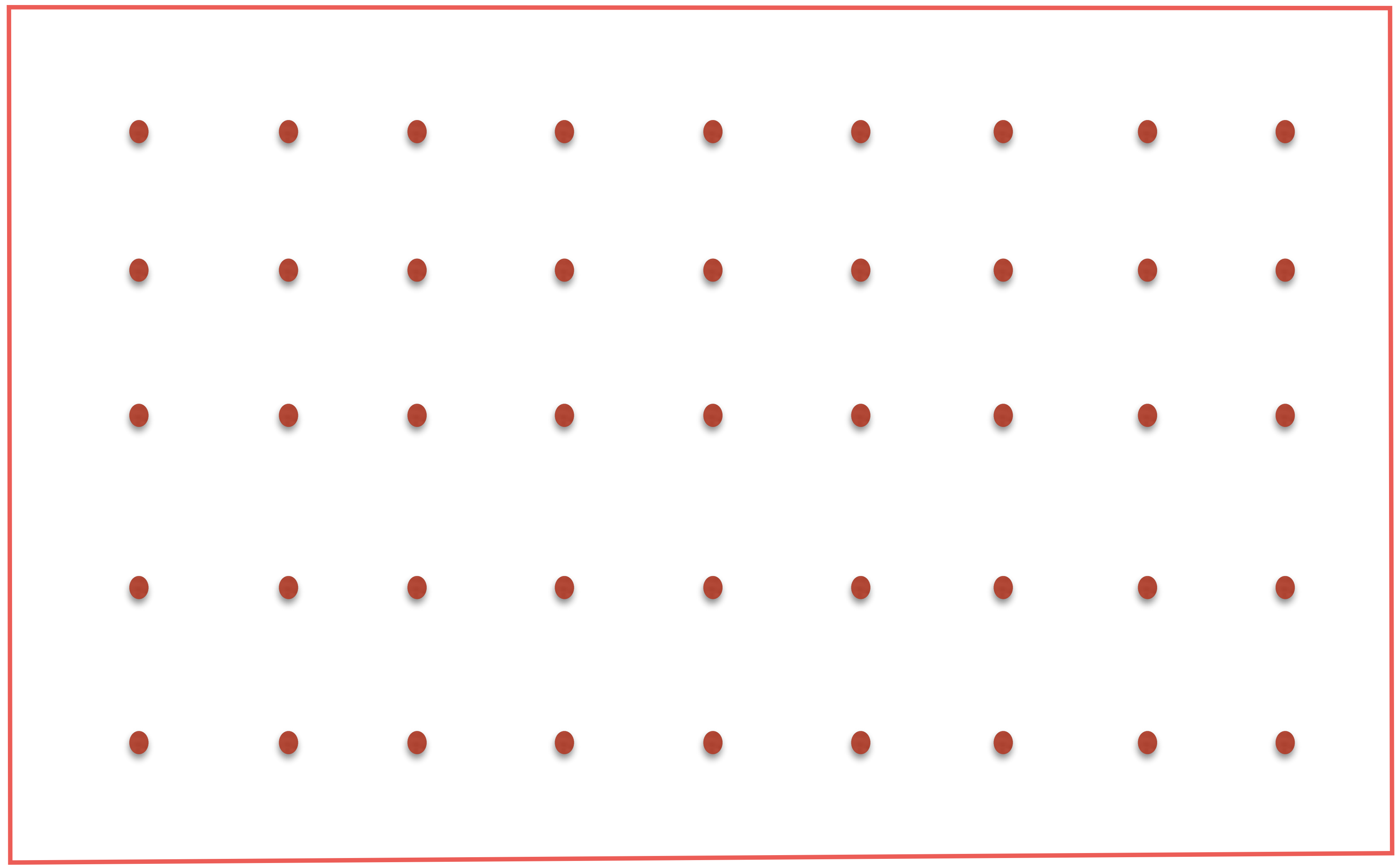

Ground points to grid

Given a point-cloud P that represents the ground points and a desired grid spacing, compute a grid that represents surf (P).