

Algorithms for GIS

csci3225

Laura Toma

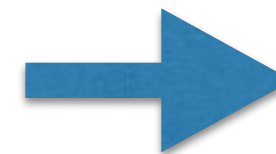
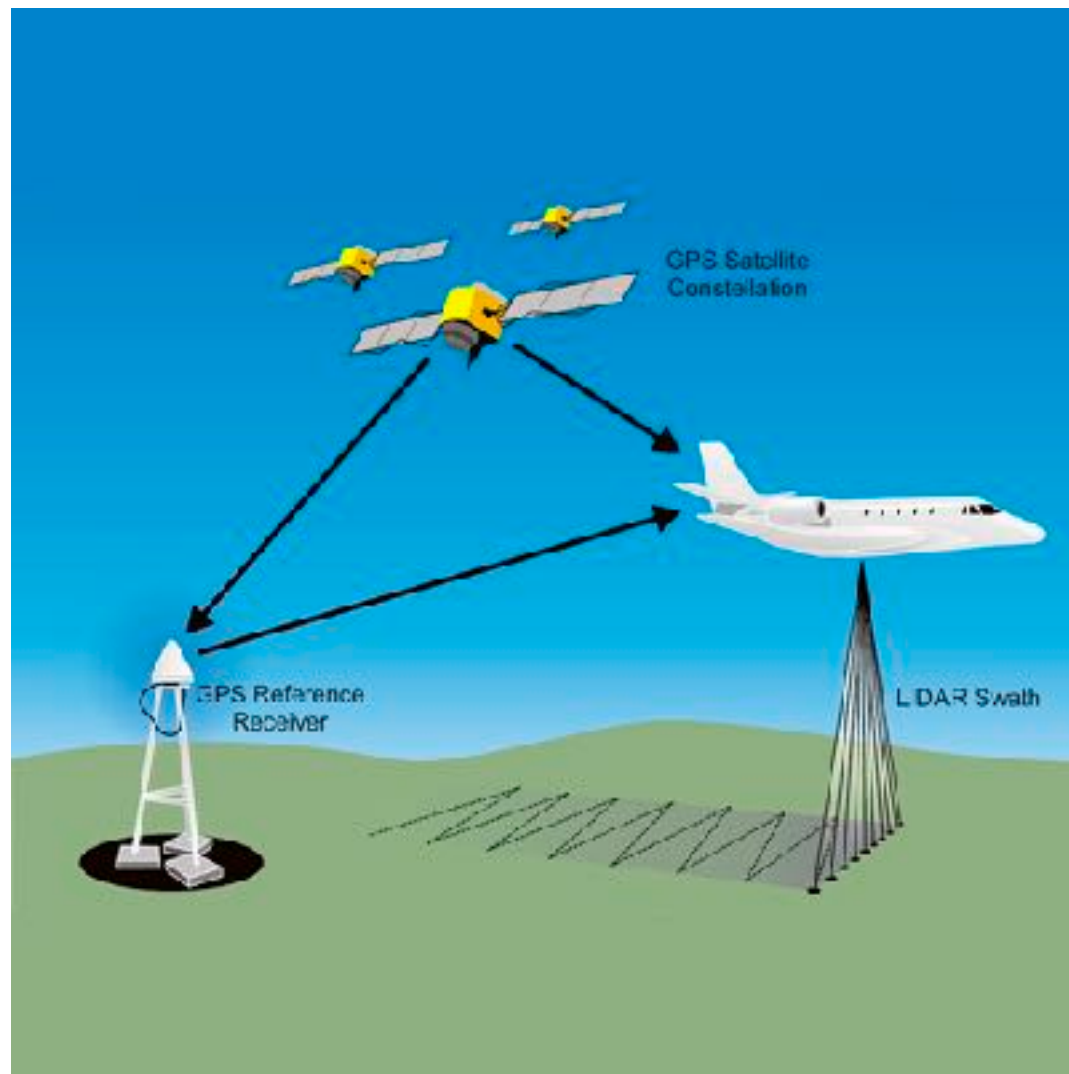
Bowdoin College

LiDAR data in GIS

LiDAR (Light Detection and Ranging)

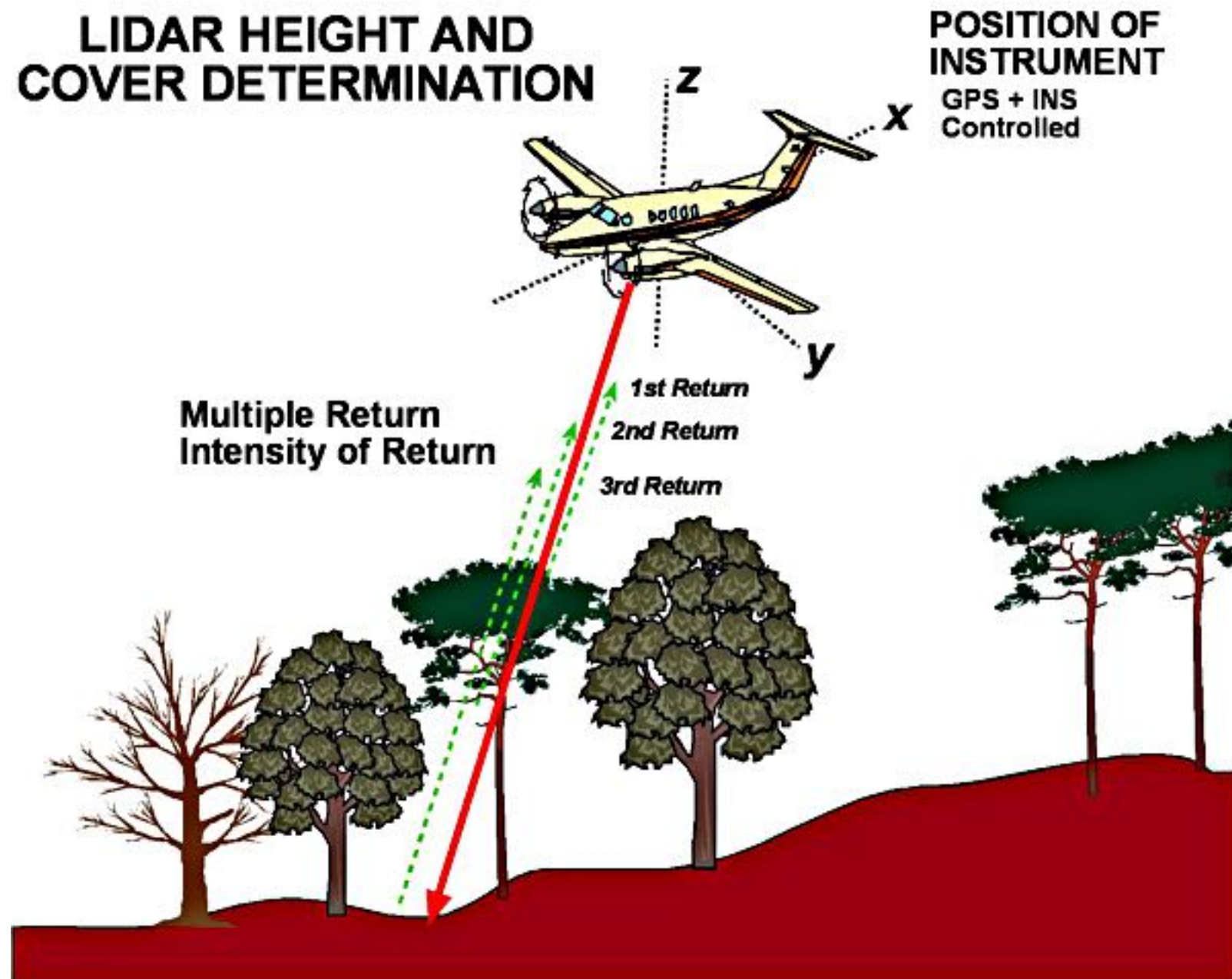
Each point records:

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



LiDAR point cloud: $\{ (x,y,z, \dots) \}$

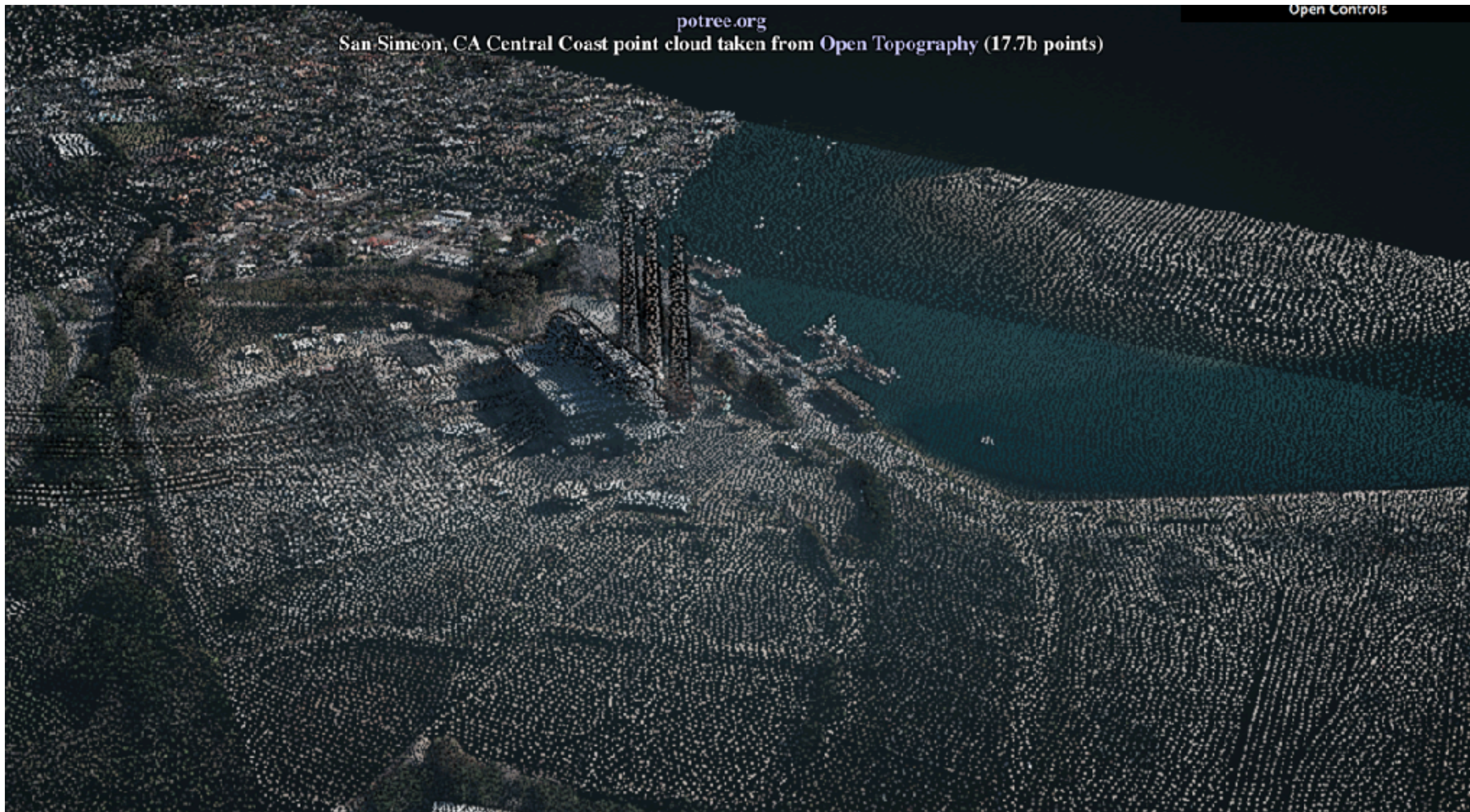
First return, last return



potree.org

Open Controls

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



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

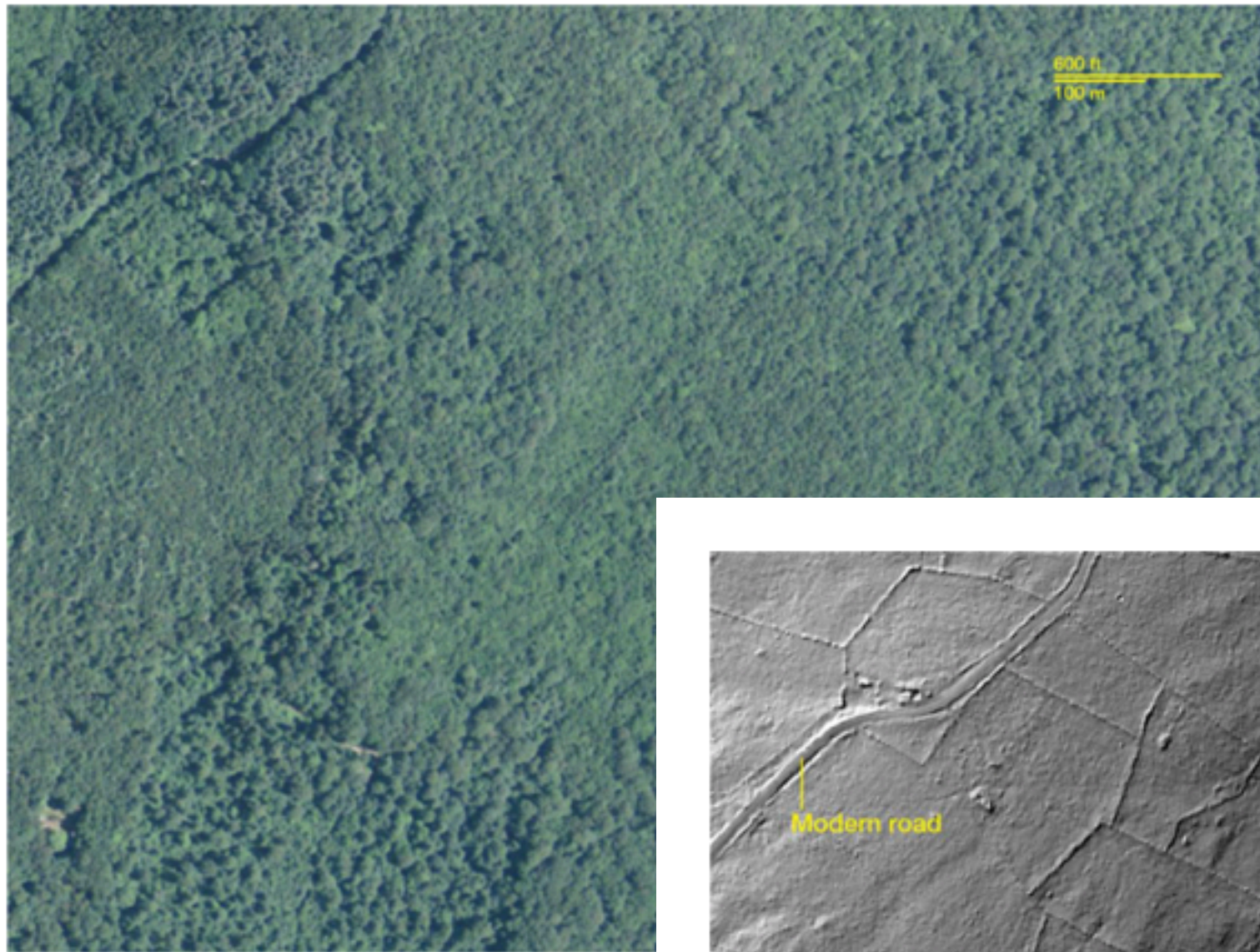
<http://news.nationalgeographic.com/news/2014/01/140103-new-england-archaeology-lidar-science.html>

"Lost" New England Revealed by High-Tech Archaeology

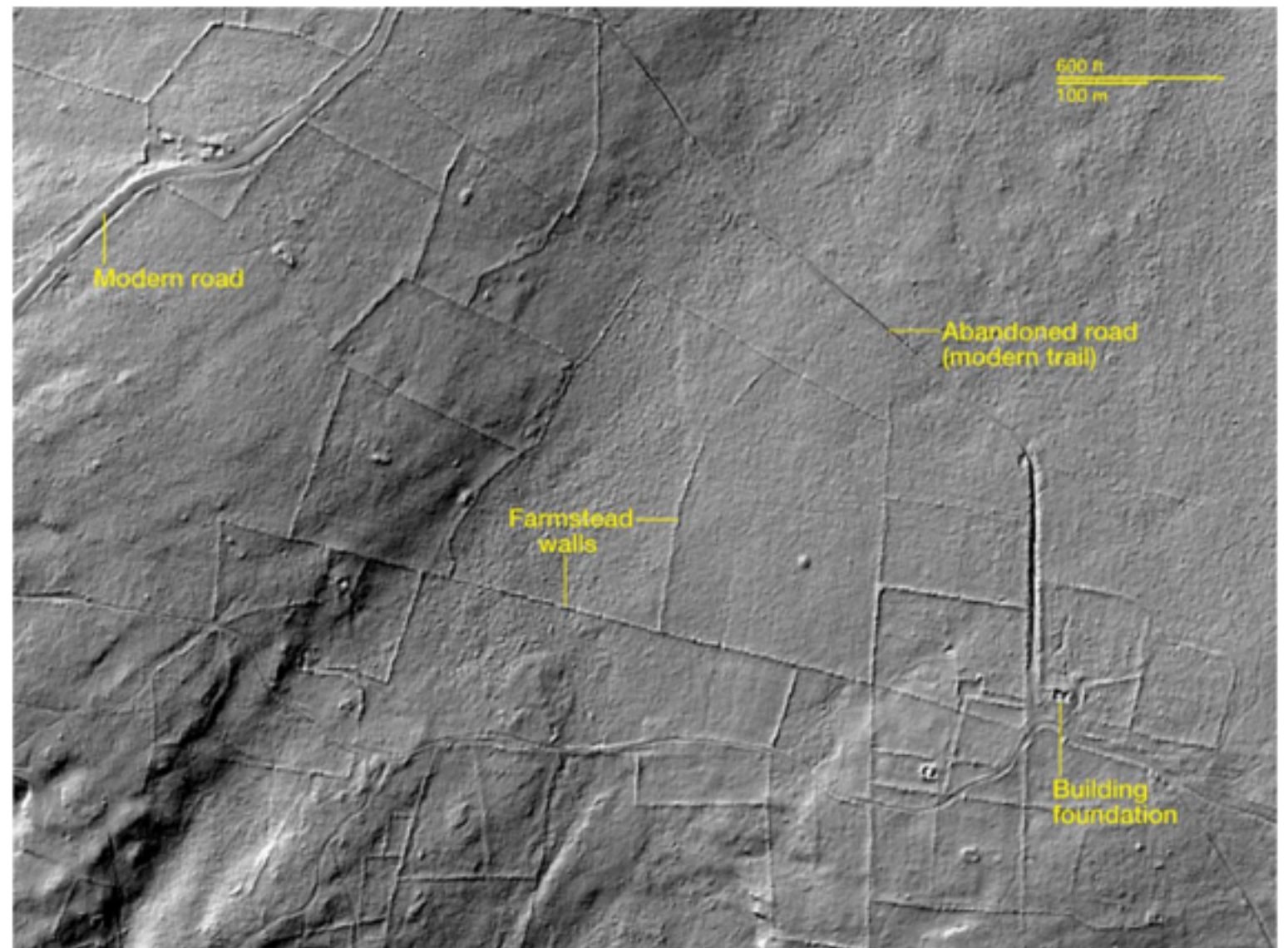
By **Dan Vergano**, [National Geographic](#)

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.



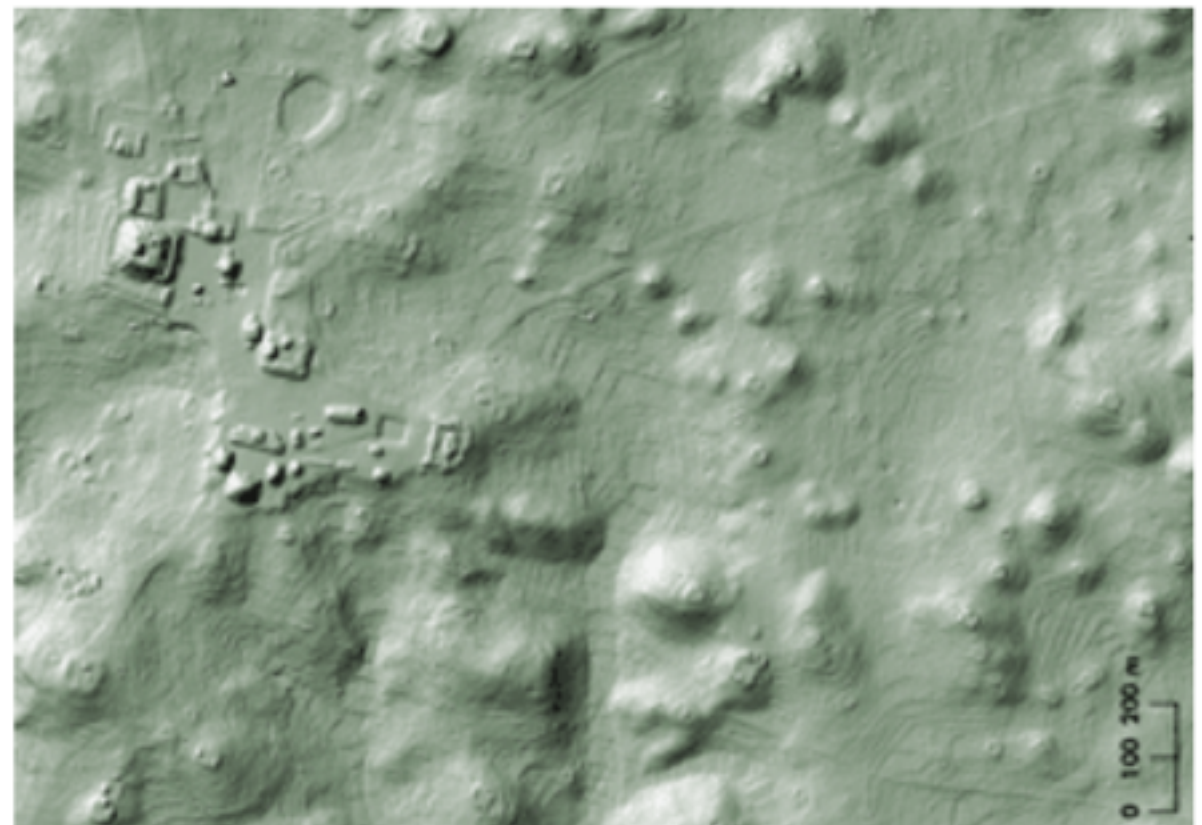
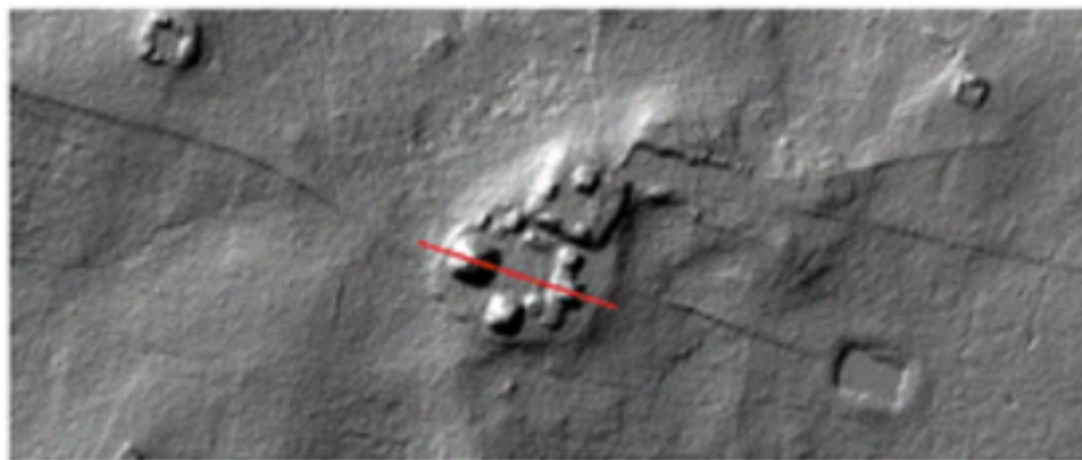
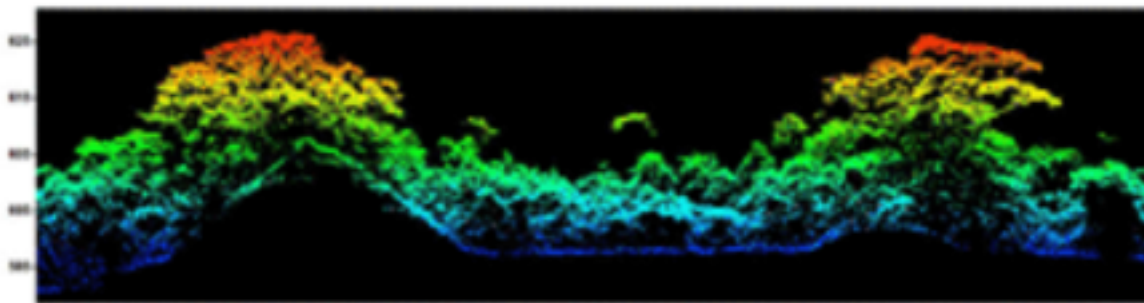
Katharine Johnson, William Oimet,
U. Connecticut

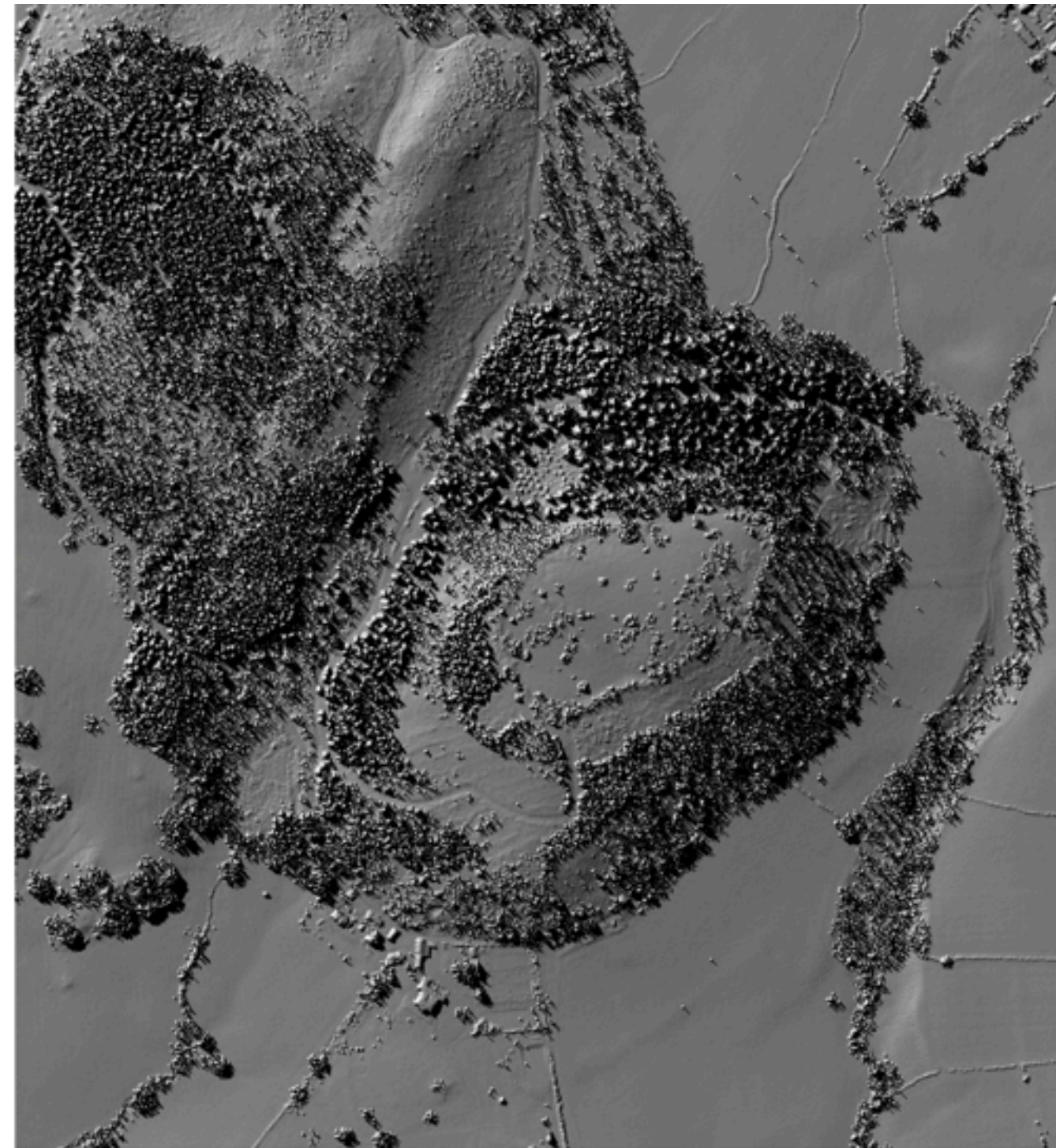


stone walls, building foundations,
old roads and dams

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



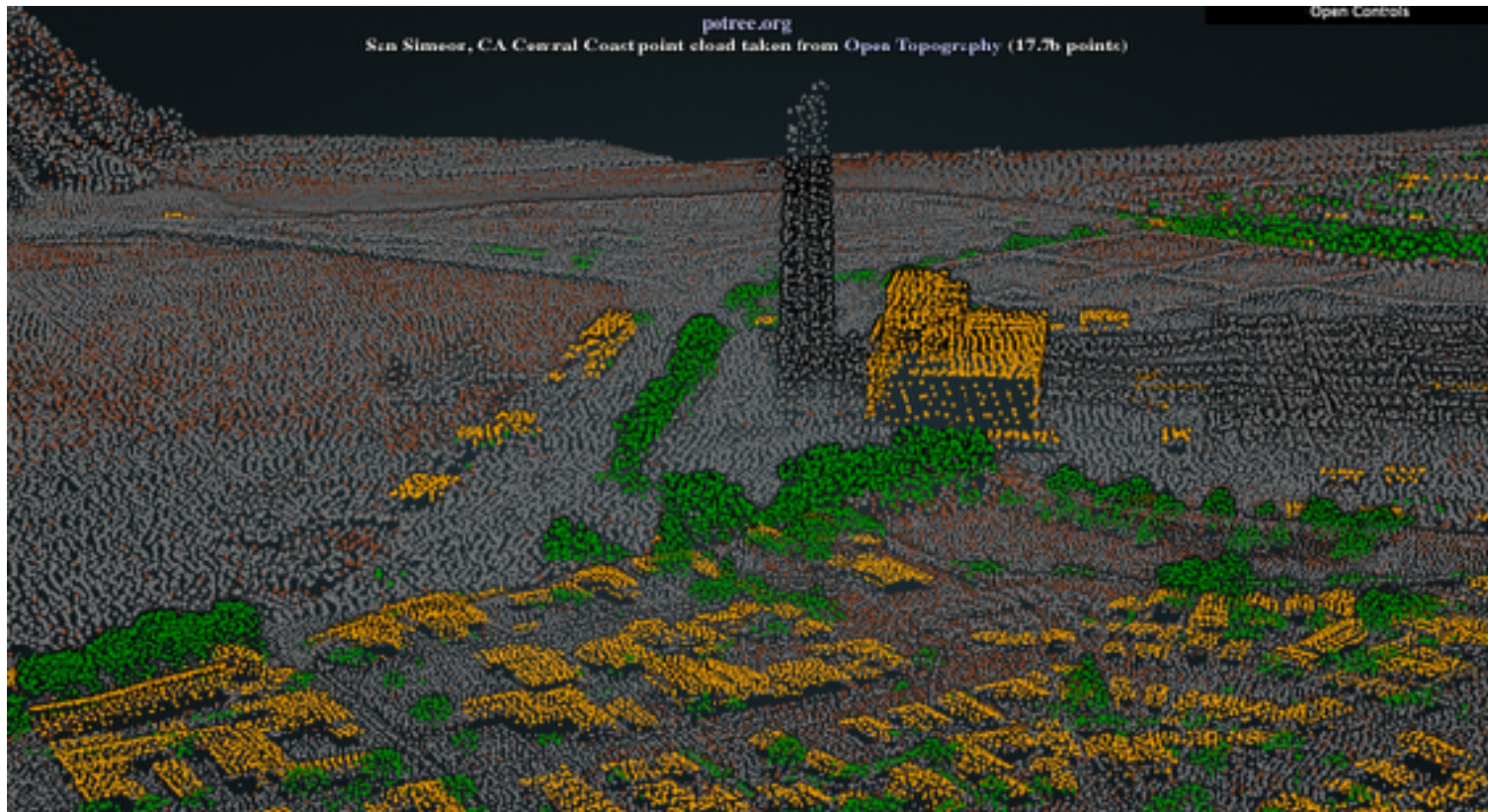


An example of first return data (above), and bare earth data (below) for a fort site in Shropshire. Note how LiDAR pulses that have penetrated the tree canopy and vegetation cover to reach the ground can be used to produce a terrain model of the ground surface, effectively 'removing' the trees. Using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

An Introduction to LiDAR for Archaeology

Working with LiDAR data in GIS

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

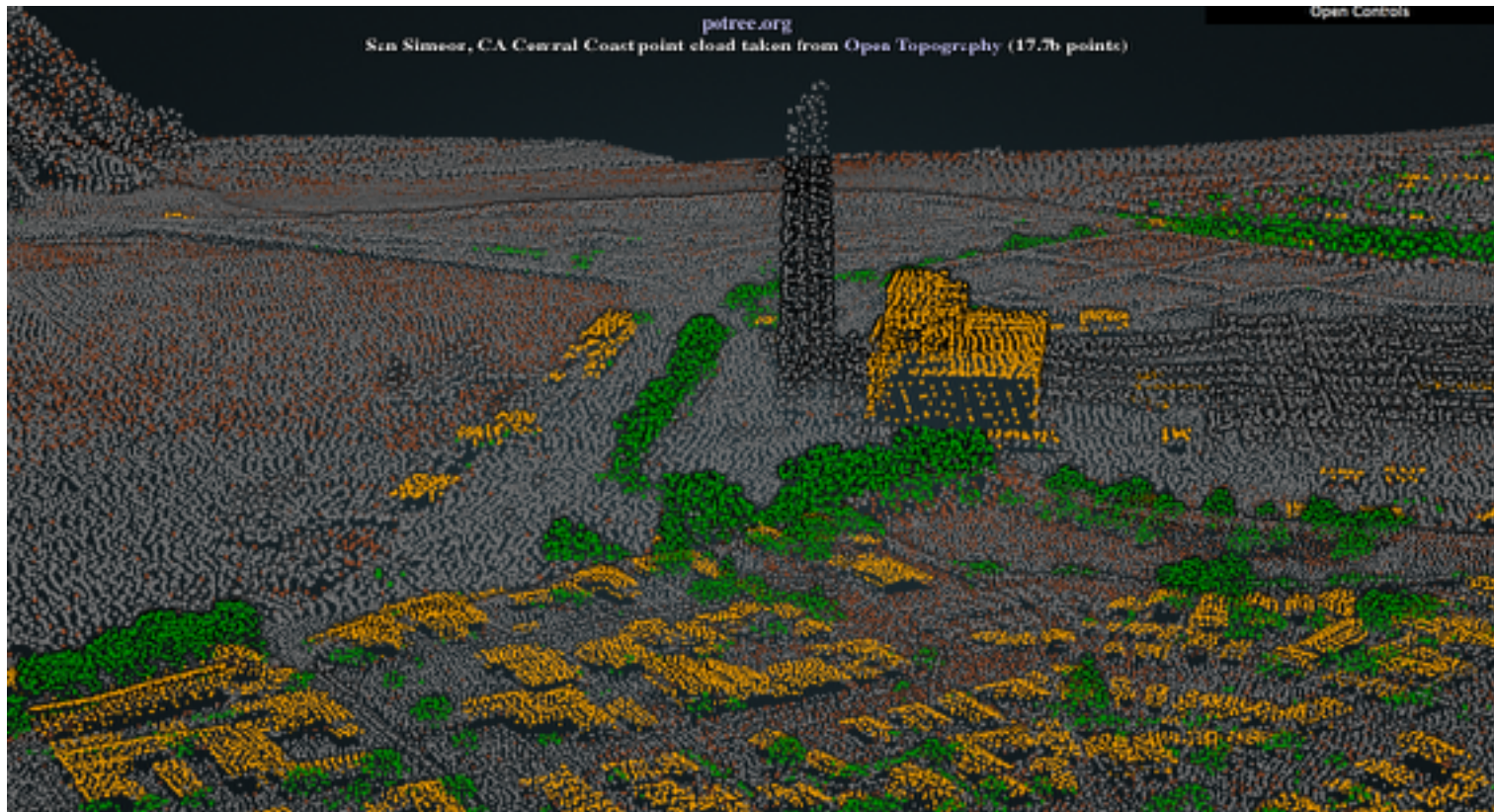


Classification Value and Meaning

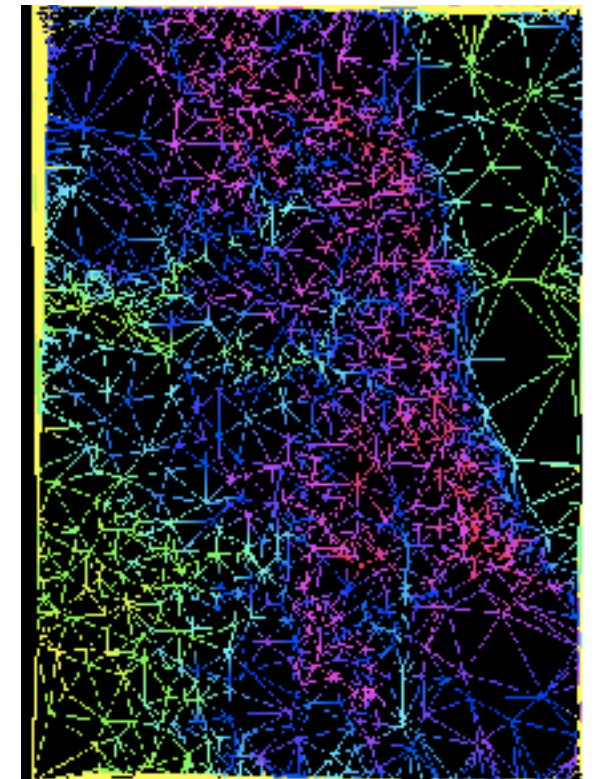
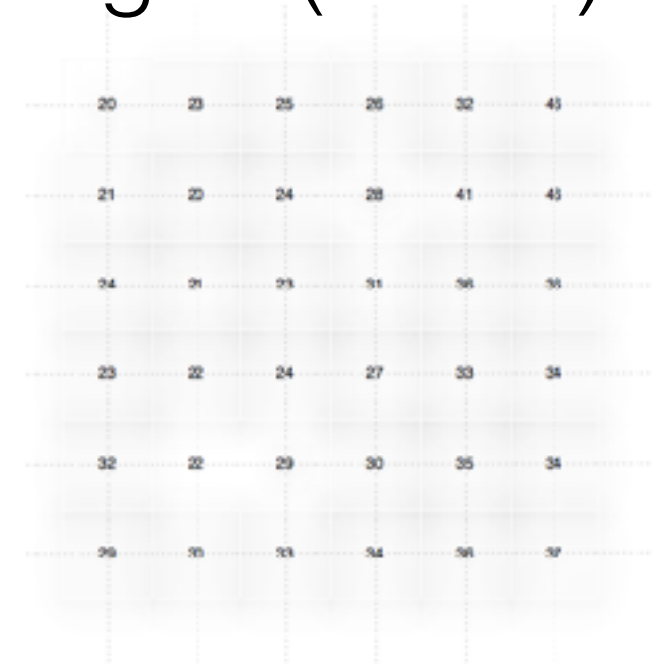
0	Created, never classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	Reserved for ASPRS Definition
11	Reserved for ASPRS Definition
12	Overlap Points
13-31	Reserved for ASPRS Definition

Working with LiDAR data in GIS

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



grid (raster)



TIN

Challenges

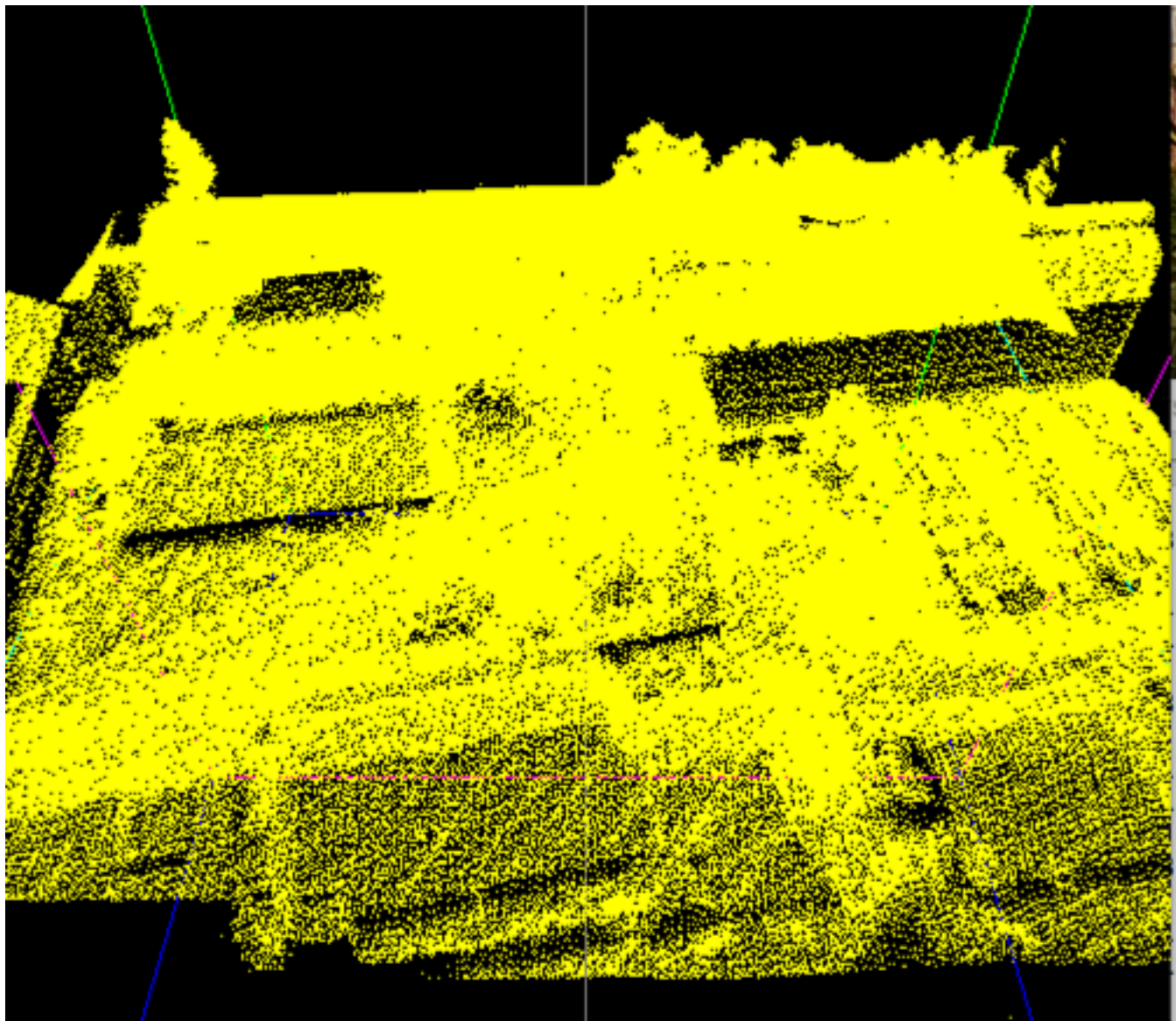
- **Huge!**
- Storage issues
- Need algorithms
- Need efficient algorithms
 - CPU efficient
 - IO-efficient (streaming)
 - cache-efficient
 - parallel

Next: Brainstorming

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

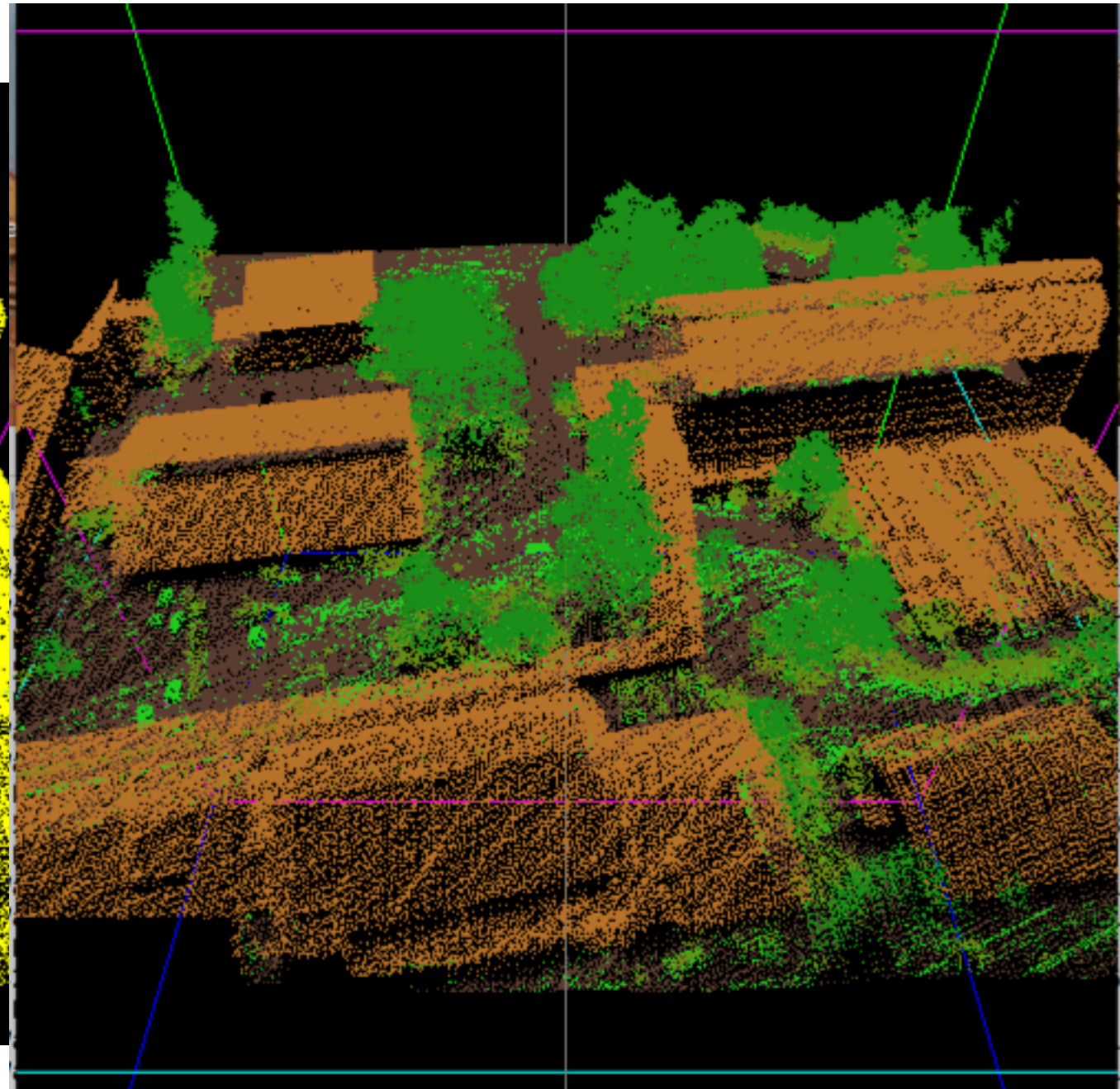
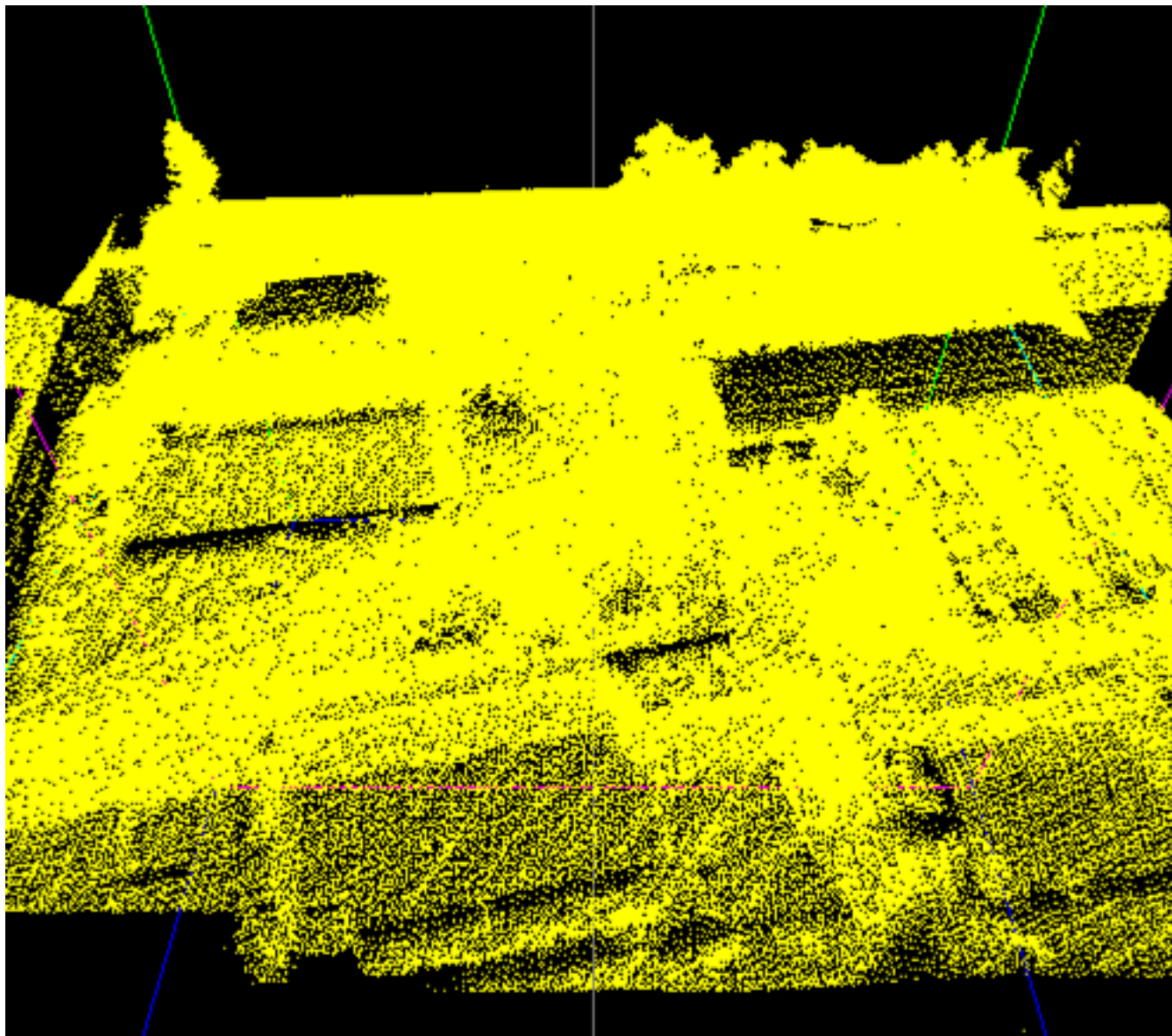
Classification

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



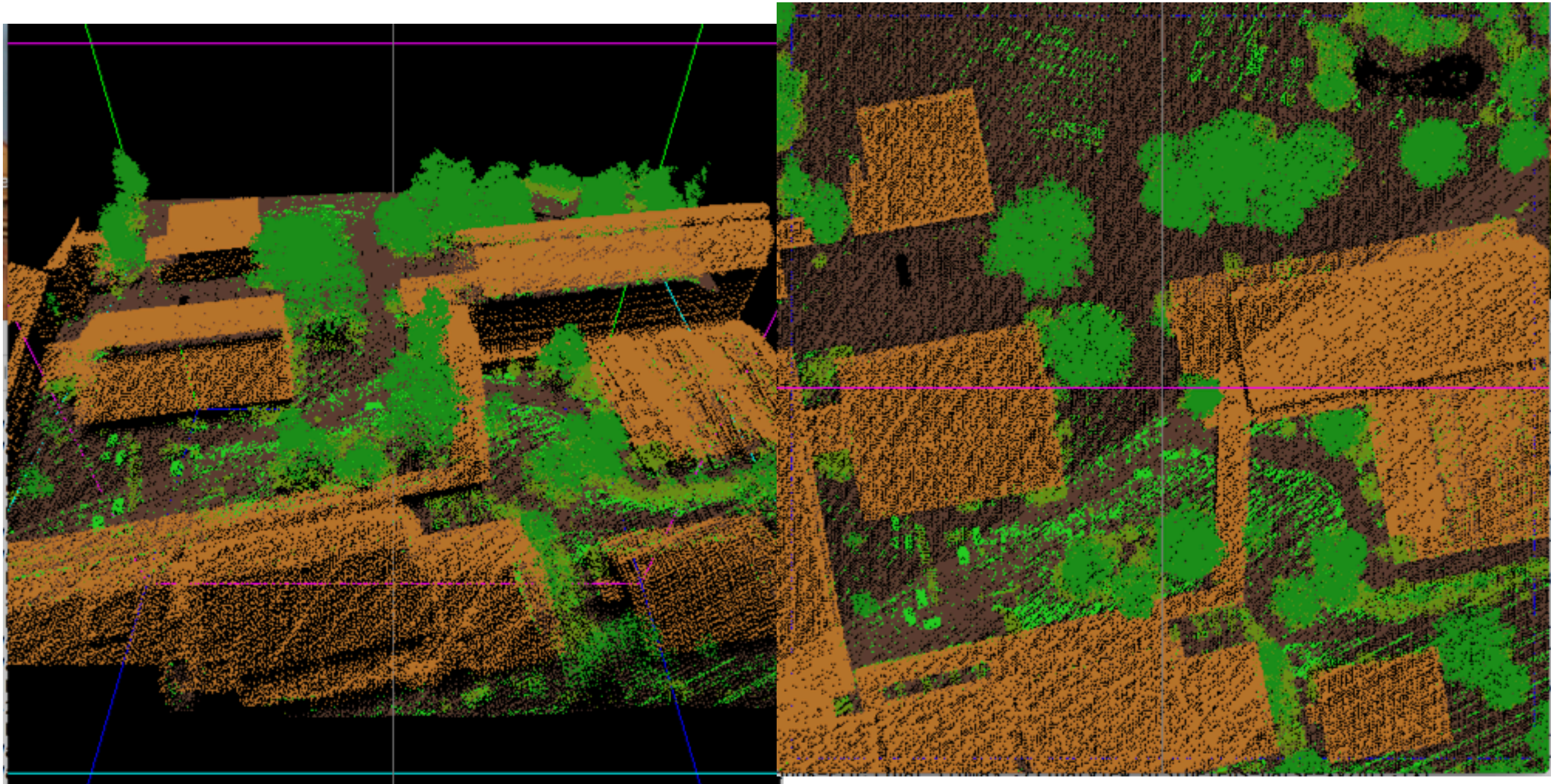
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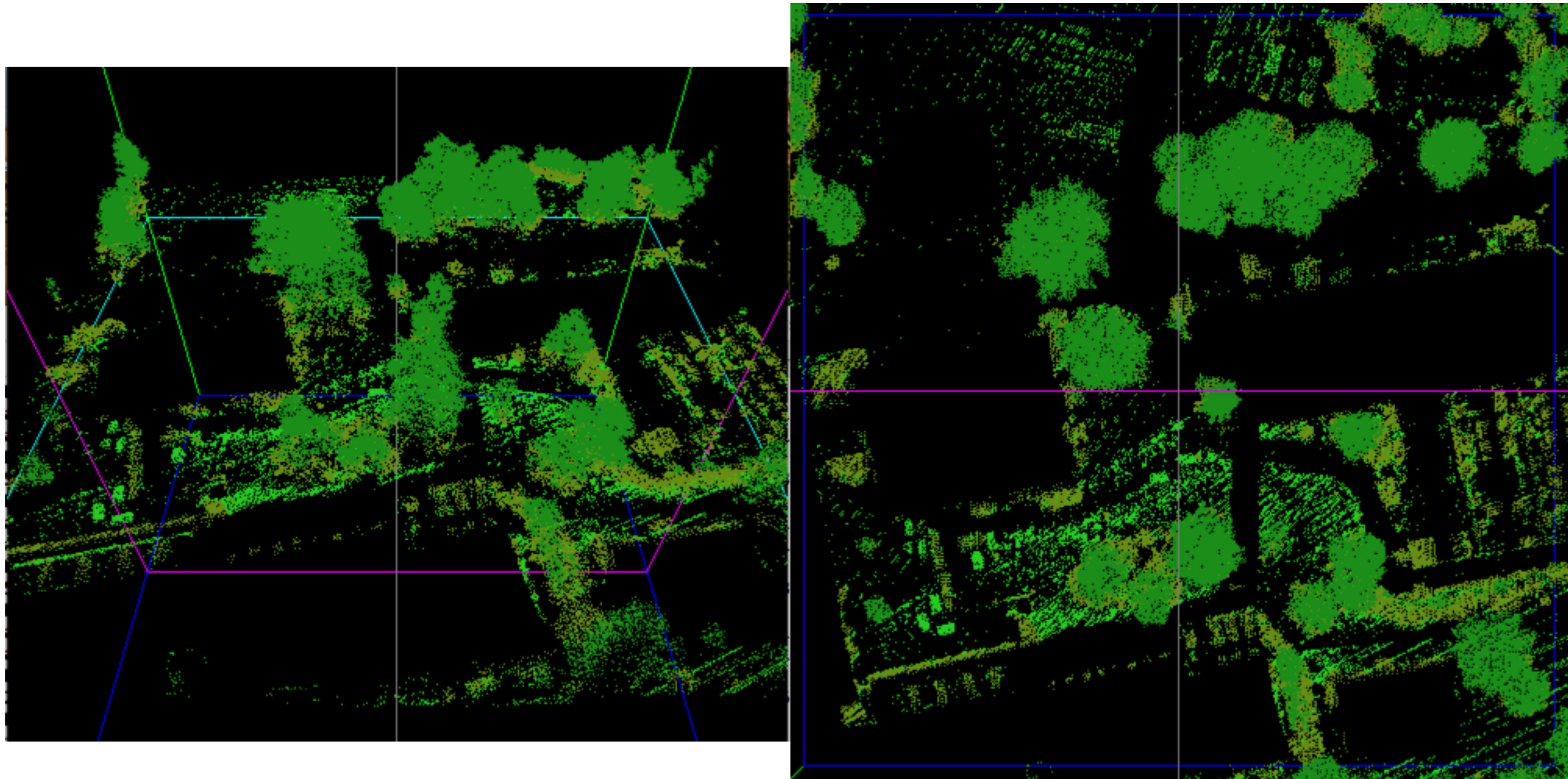
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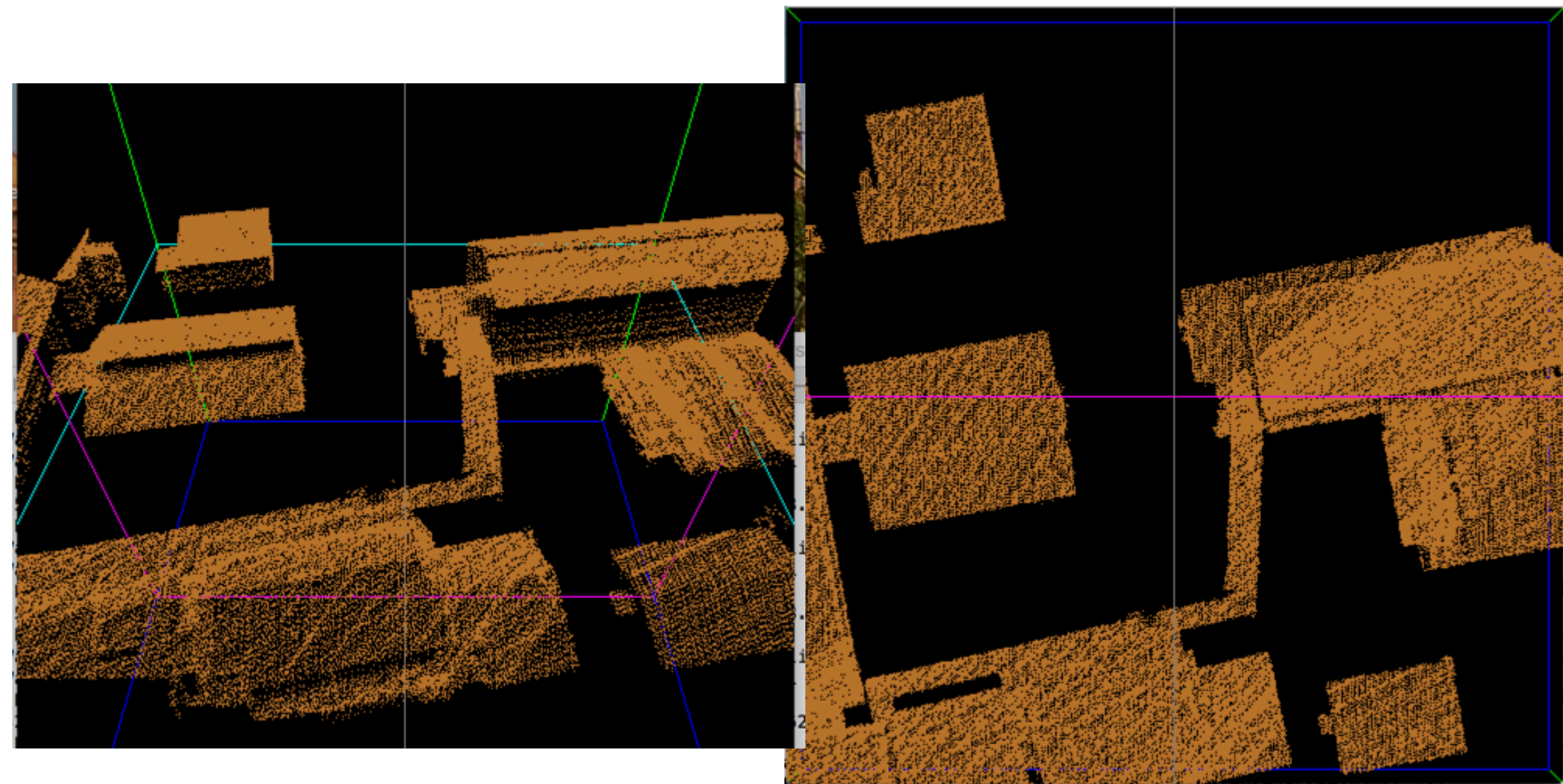


Automatic extraction of vegetation

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

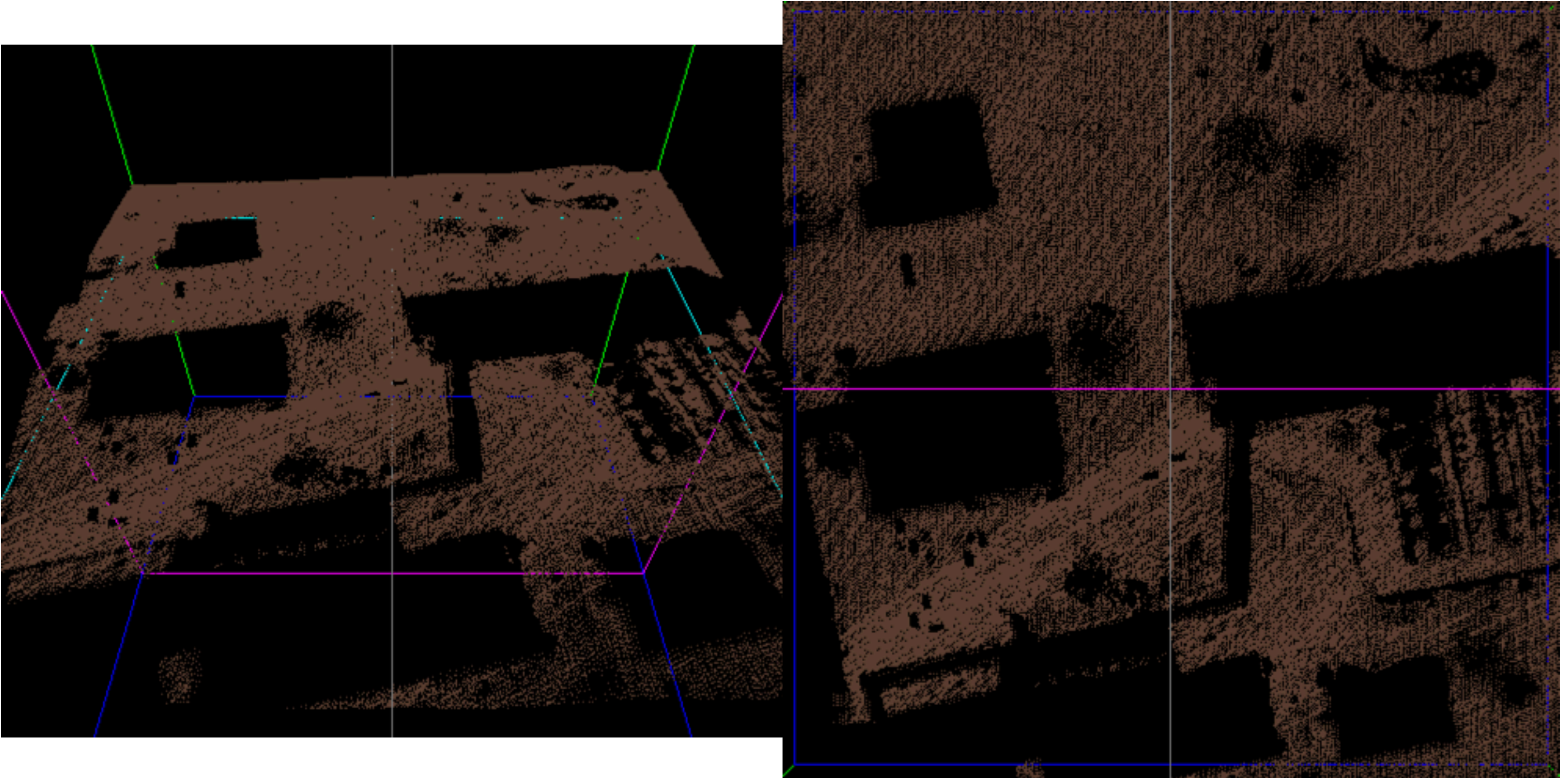


Automatic building delineation



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)

Individual tree shape modeling for canopy delineation ...

<https://www.spiedigitallibrary.org/conference-proceedings-of-spie/...>

In this paper a method for individual tree shape modeling and canopy coverage delineation is provided for high density airborne LIDAR data. Three basic 3-D canopy

[PDF] [extraction of tree crowns and heights using lidar](#)

<web.pdx.edu/~jduh/courses/geog493f12/Projects/SwamerHouser.pdf>

36,800,000 Results Any time extraction of tree crowns and heights using lidar ... o US Forest Service program to analyze LIDAR data and derive canopy ... watershed delineation ...

[PDF] [AUTOMATIC BUILDING FEATURE EXTRACTION ..](#)

<www.asprs.org/a/publications/proceedings/fall2006/0019.pdf>

Rapid Tree Canopy Delineation from Aerial LiDAR » ... MAPPS/ASPRS 2006 Fall Conference November 6 – 10, 2006 * San Antonio, Texas www.ayresgeospatial.com/2016/01/28/rapid-tree-canopy-delineation...

AUTOMATIC BUILDING FEATURE EXTRACTION USING LIDAR ... Rapid Tree Canopy Delineation from Aerial LiDAR ... are the most common products derived from LIDAR data, ... on Rapid Tree Canopy Delineation from Aerial ...

[PDF] [Automatic Building Extraction From LiDAR data](#)

graphics.usc.edu/cgit/publications/papers/CP_2.pdf

Automatic Building Extraction From LiDAR data Charalambos Poullis, Suya You, UI www.cis.rit.edu/DocumentLibrary/admin/uploads/CIS000233.pdf

Neumann Computer Graphics and Immersive Technologies Lab ... Canopy Segmentation using Airborne LiDAR Senior Project: ... The airborne LiDAR data for this site was ... differences in RGB breaks with a canopy would allow for ...

[PDF] [Automated Building Extraction and Reconstruction](#)

Authors: Ashley Miller · Jan Van Aardt · Bob Kremers · Paul Romanczyk · Ches:.. www.grc.missouri.edu/icrestprojarchive/NASA/FeatureExtraction...

Affiliation: Rochester Institute of Technology 1 Automated Building Extraction and Reconstruction from LIDAR Data Abstract Building information is extremely important for many applications such as urban

[PDF] [LiDAR mapping of canopy gaps in continuous cover .](#)

https://www.researchgate.net/profile/Tim_Malthus/publication...

[PDF] [AUTOMATIC BUILDING EXTRACTION FROM LIDAR ..](#) little explicit consideration has been given to delineation of canopy gaps from LIDAR data. The assumption that mapping canopy gaps using LIDAR is straightforward ...

www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-3/25/...

AUTOMATIC BUILDING EXTRACTION FROM LIDAR DATA COVERING COMPLEX URBAN SCENES Mohammad Awrangjeb a,, Guojun Lu a ...

Authors: Mohammad Awrangjeb · Guojun Lu · Clive S Fraser

Affiliation: Federation University Australia · Isle of Man Department of Transport

About: Segmentation · Lidar · Extraction · Building · Point cloud · Plane

[PDF] [Building Extraction from LIDAR Data - lidar.com.br](#)

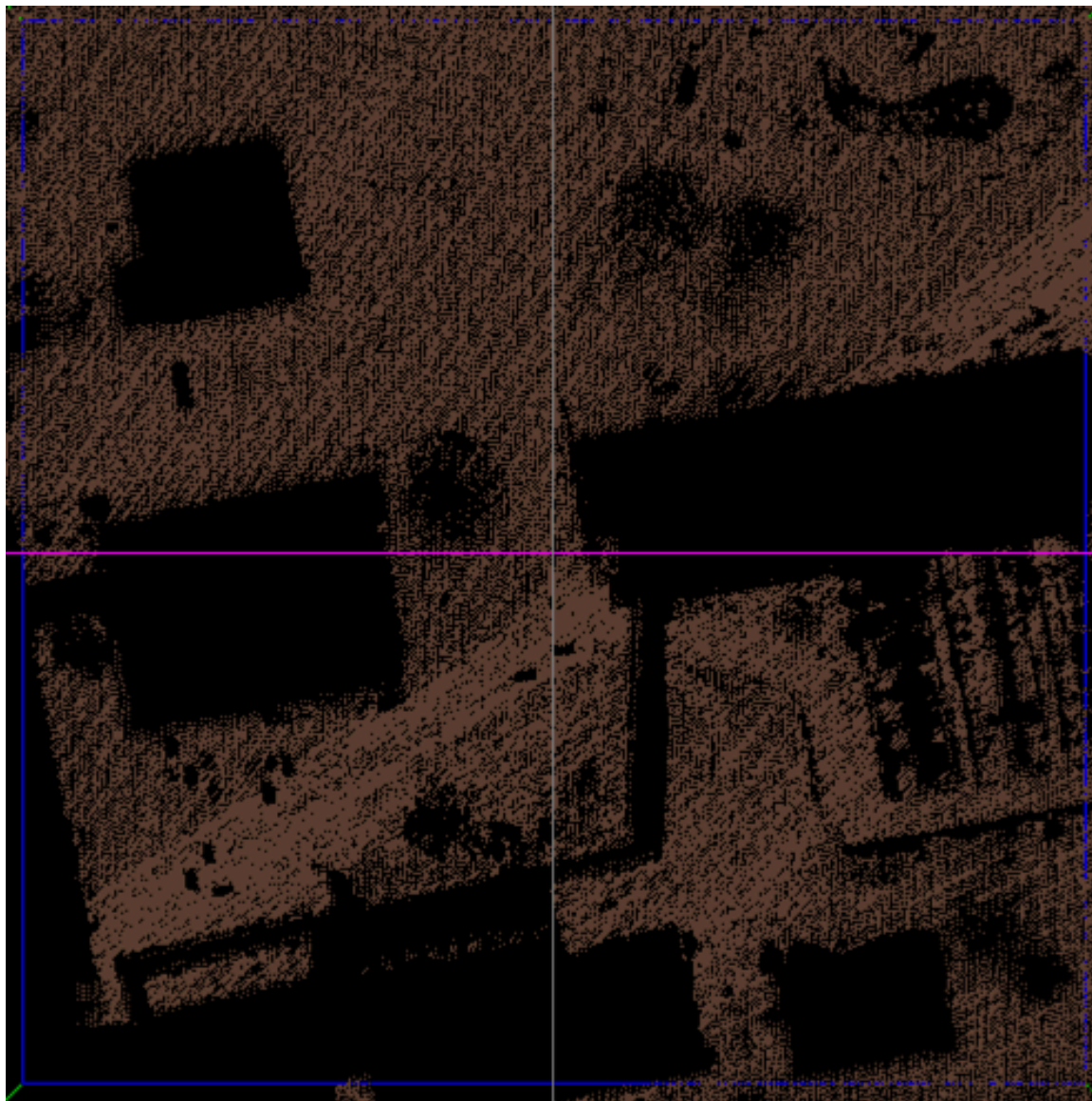
www.lidar.com.br/arquivos/BuildingExtraction.pdf

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

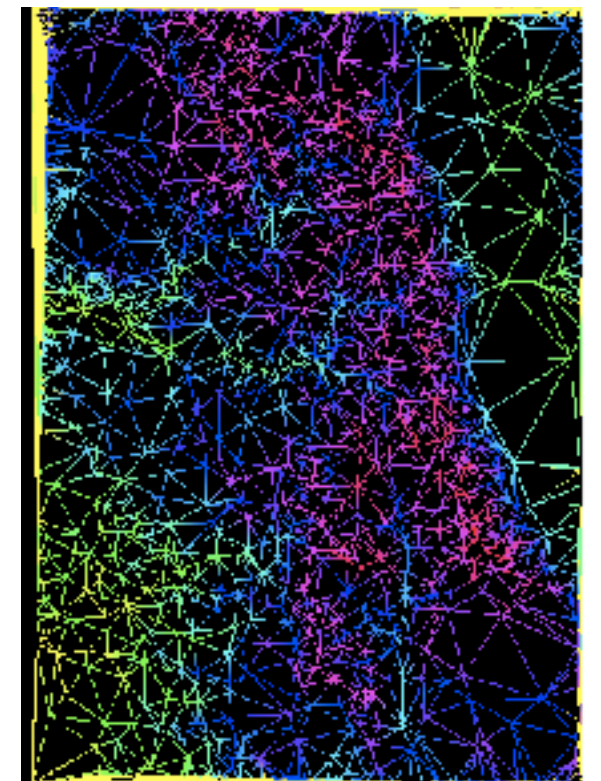
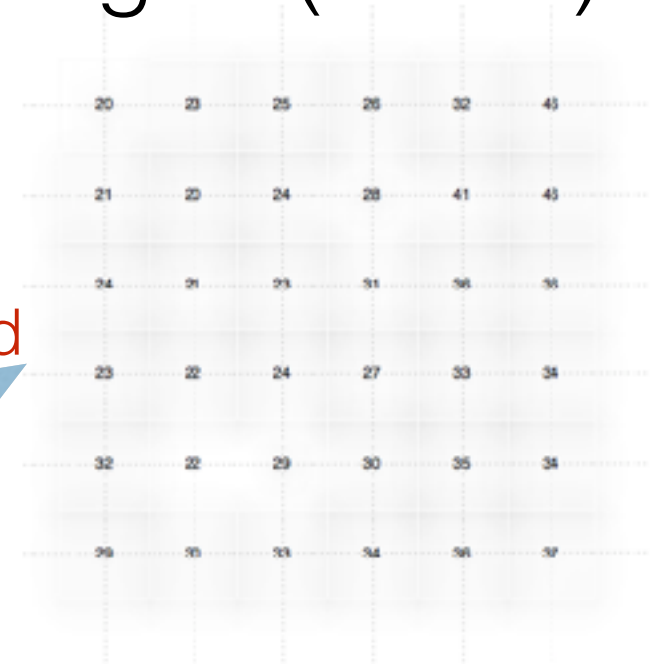
- Start with a classified point cloud



point cloud to grid

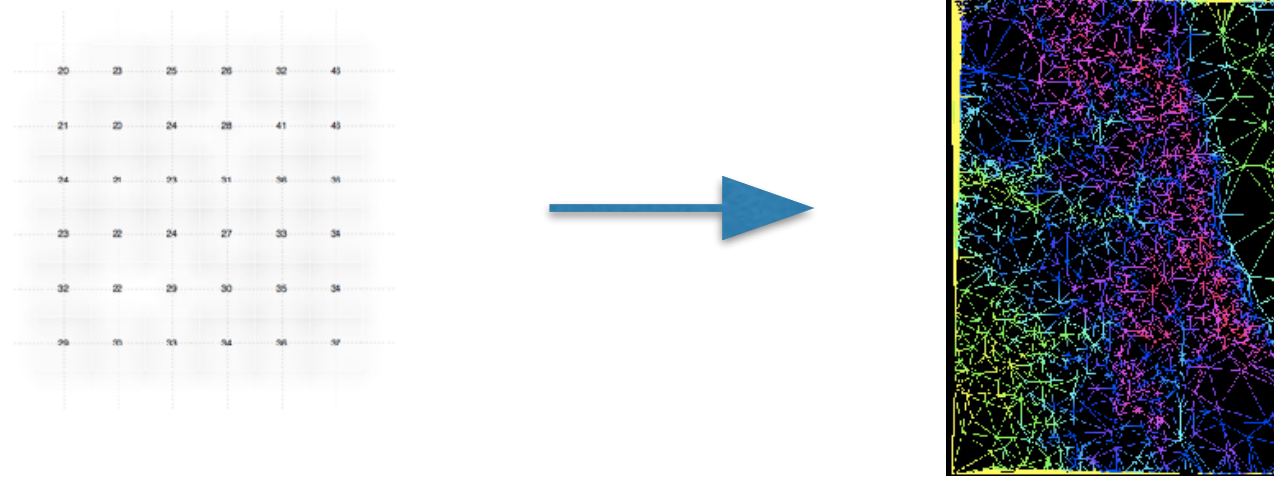
point cloud to TIN

grid (raster)



TIN

Point-cloud-to-TIN



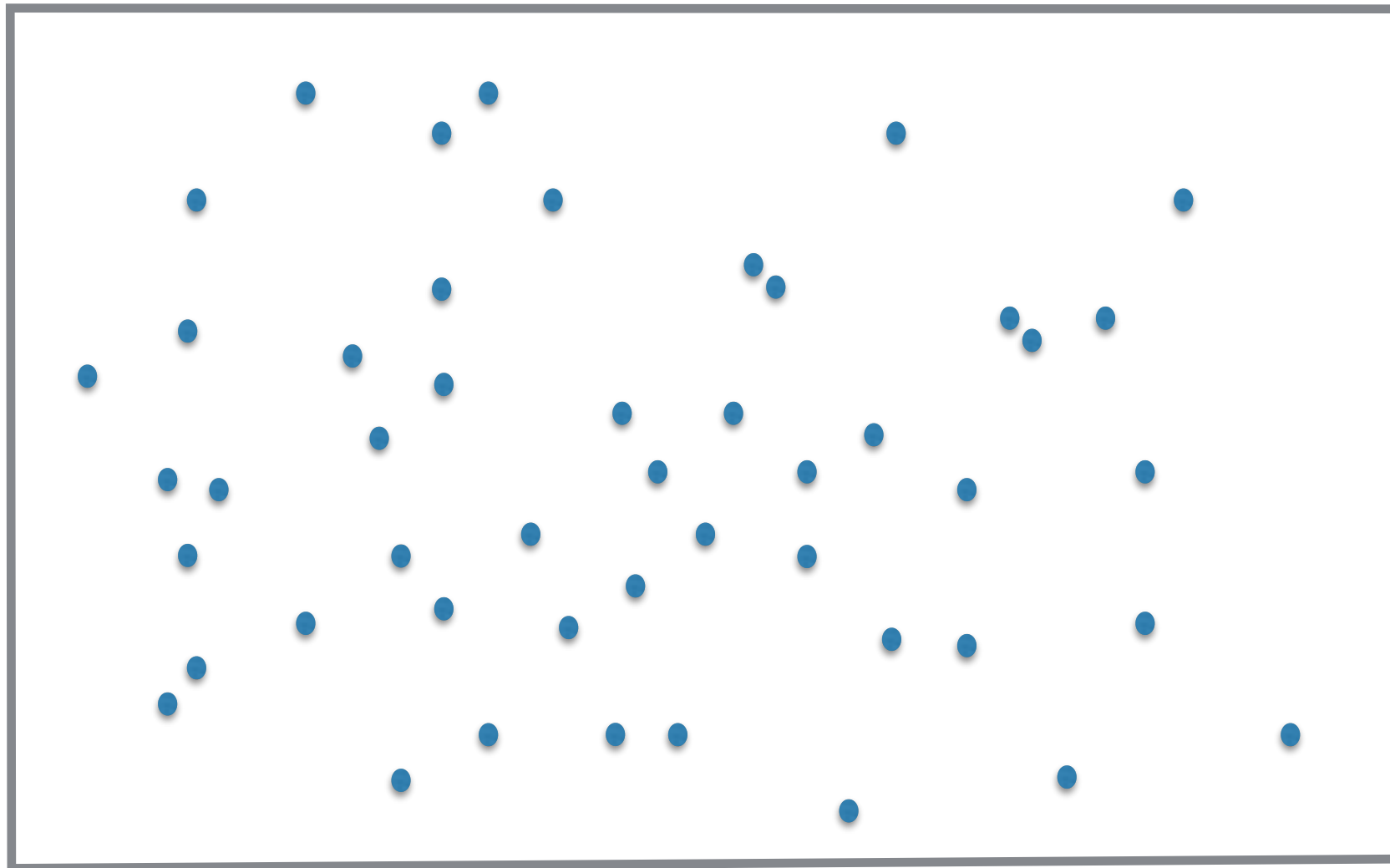
Algorithm:

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

What needs to change?

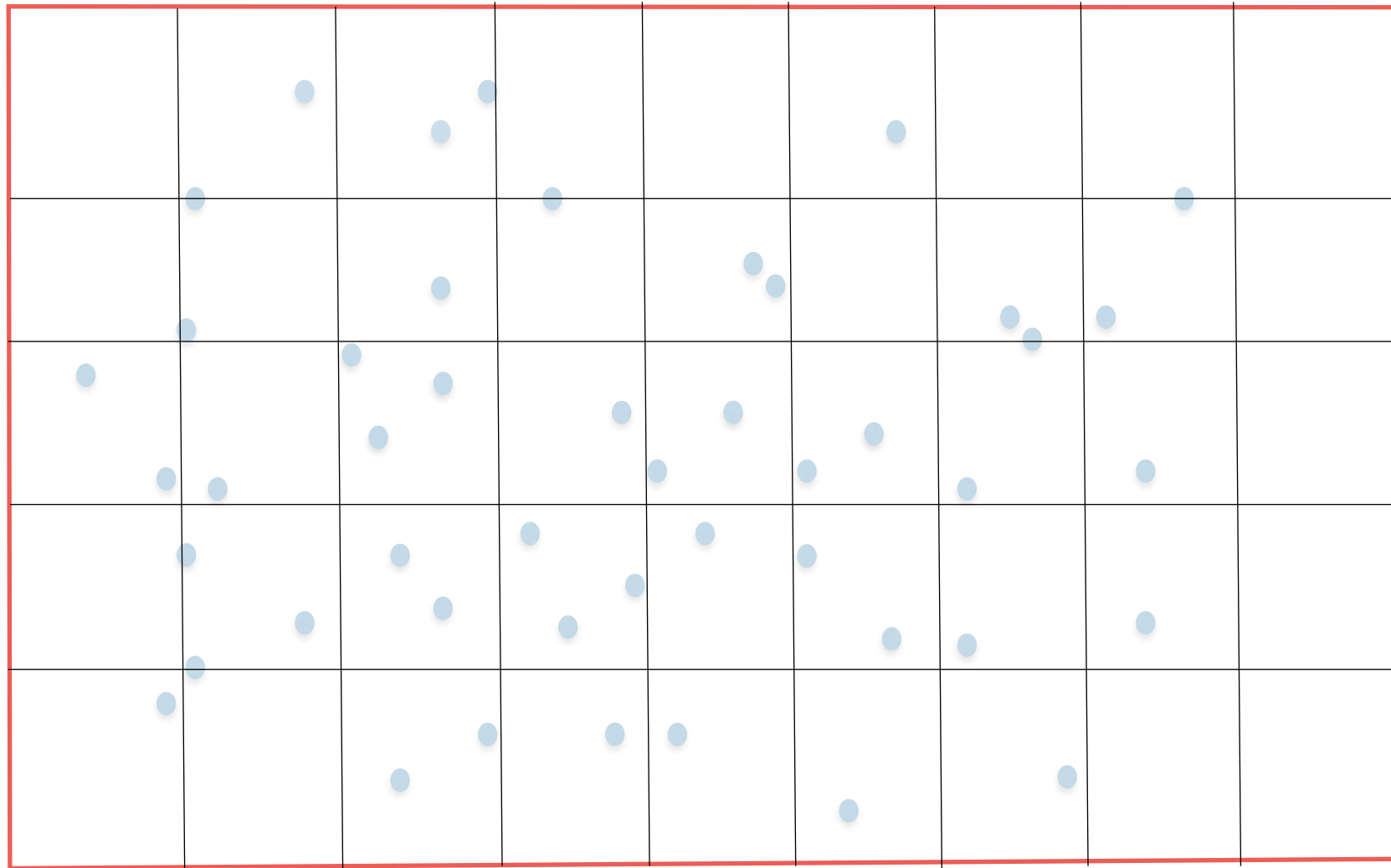
Point-cloud-to-grid

Given a point-cloud P (that represents a surface) and a desired grid spacing, compute a grid that represents $\text{surf}(P)$.



Point-cloud-to-grid

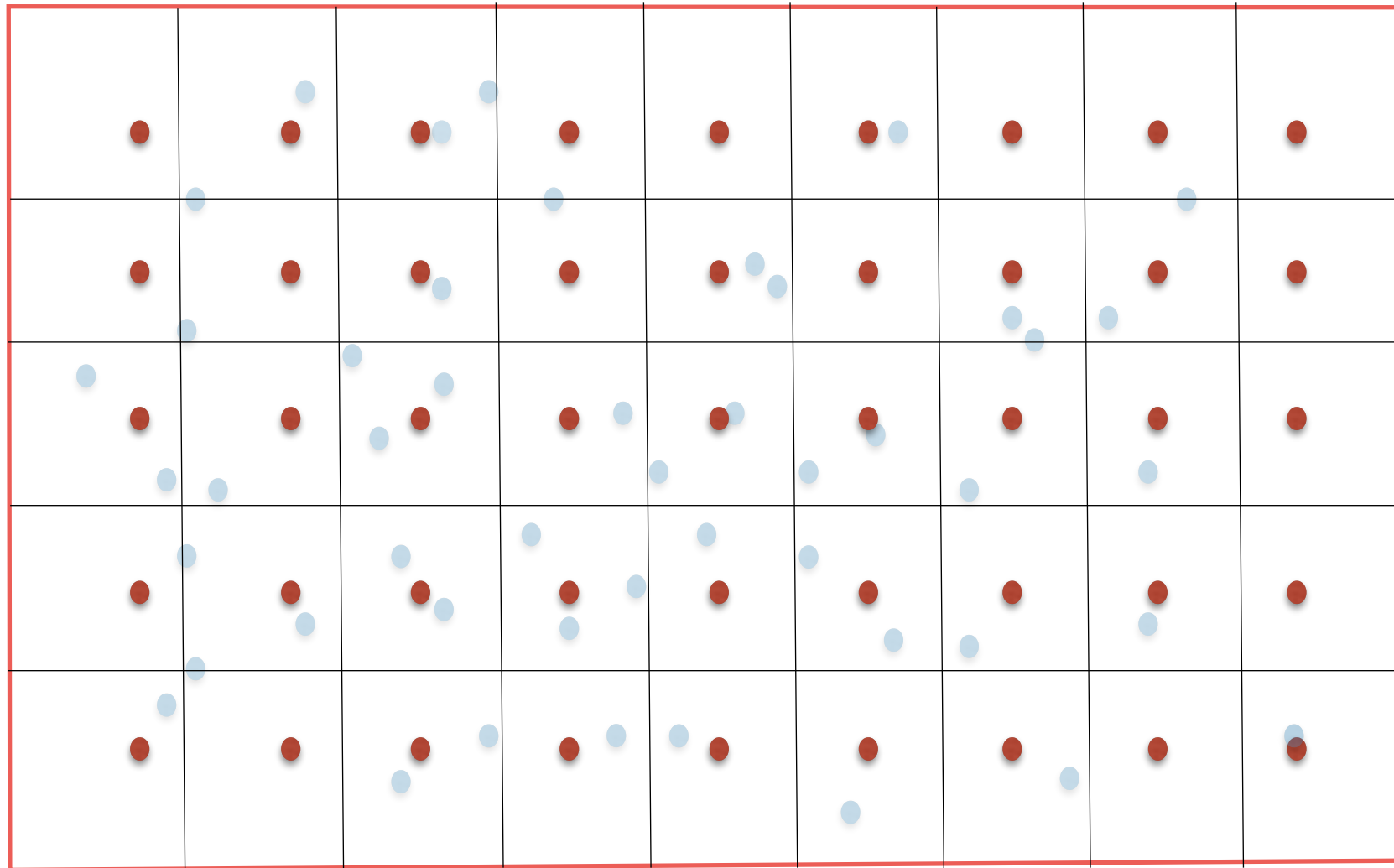
Given a point-cloud P (that represents a surface) and a desired grid spacing, compute a grid that represents $\text{surf}(P)$.



How to choose the grid spacing?
Pros? Cons?

Point-cloud-to-grid

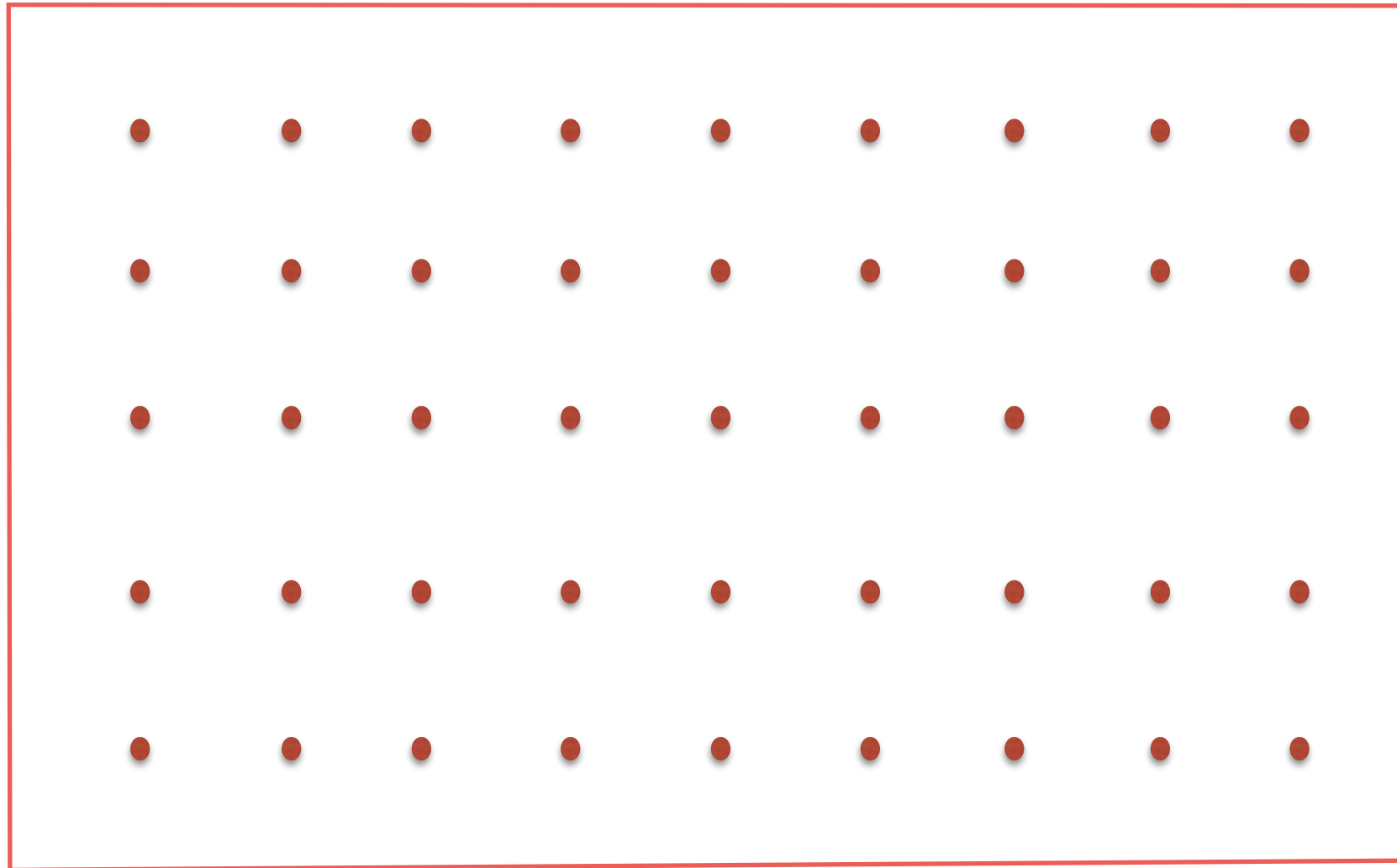
Given a point-cloud P (that represents a surface) and a desired grid spacing, compute a grid that represents $\text{surf}(P)$.



How to choose the grid spacing?
Pros? Cons?

Point-cloud-to-grid

Given a point-cloud P (that represents a surface) and a desired grid spacing, compute a grid that represents $\text{surf}(P)$.



Ground points to grid

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

