Pre-rupture datasets?

April 19, 2022

What type of datasets where used?

SRTM: Nura, Wasatch, San Andreas, NZ

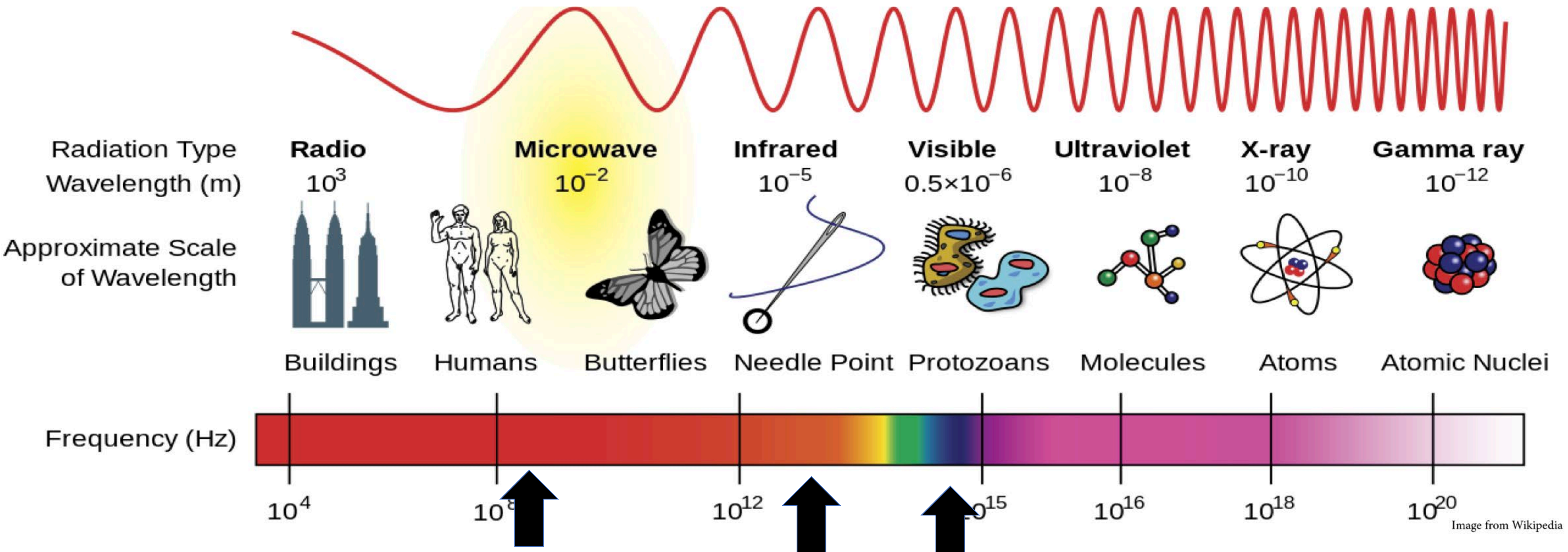
Lidar: Napa, EMC, Wasatch, Wasatch, San Andreas, NZ,

Structure from Motion: Borah Peak, Denali, San Andreas

Stereophotogrammetry: Ridgecrest

Challenge: For pre-rupture mapping, we need a dataset before the earthquake. This requires the foresight for where to collect the data, funding to collect it, and clever processing often for older datasets.

Remote Sensing Datasets



SRTM: 5.6 cm

Visible- Imagery, SfM & stereo topography

Lidar – mostly near infrared 900-1500 nm

Shuttle Radar Topography Mission

Near global topography: 56S to 60 N

Flown Feb 2000

Initially released 90 m topography; Late 2015 released 30 m topography

Radar system (C band – 5.6 cm wavelength)

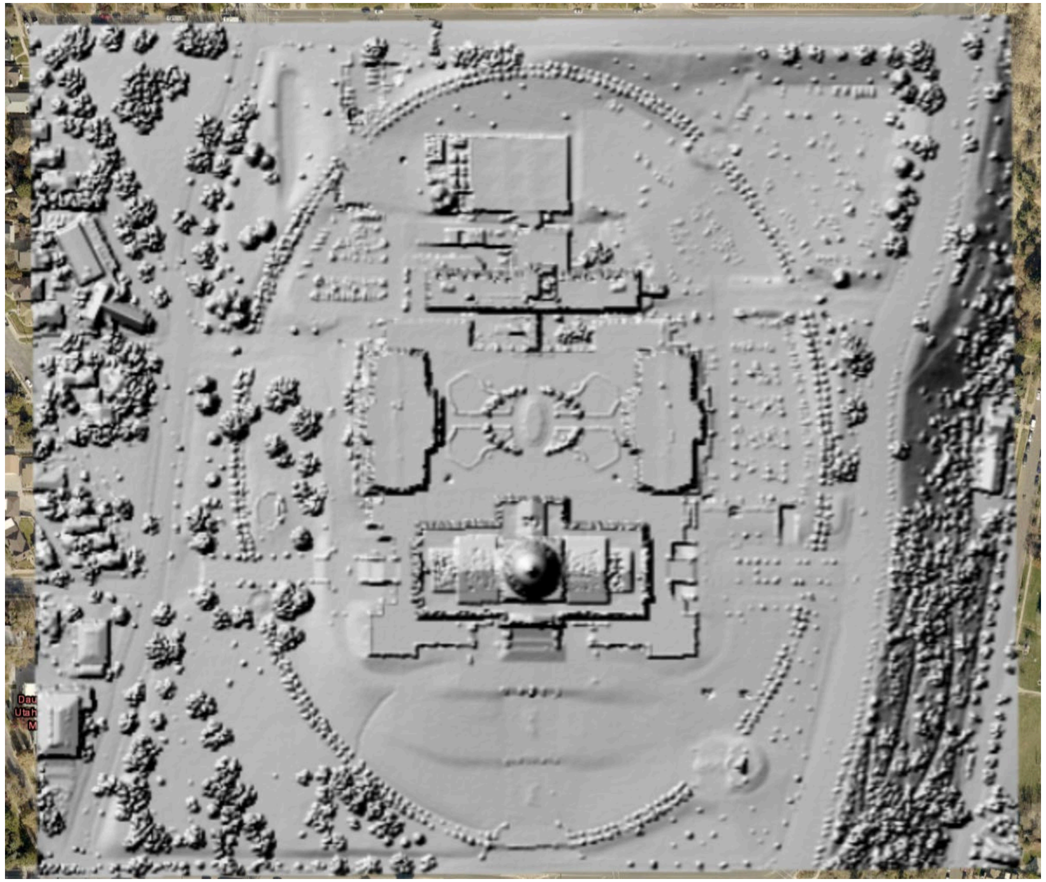
Single Pass Interferometry: Space Shuttle Endeavor had two antennas - one on the shuttle's payload and the other on a 60 m mast

Topography from interferometry: Compare two radar images taken at at the same time looking at different angles

Double pass interferometry does not work: Changes in atmospheric & ionospheric properties and errors in the location of the satellite/ shuttle produce significant noise.

Lidar topography

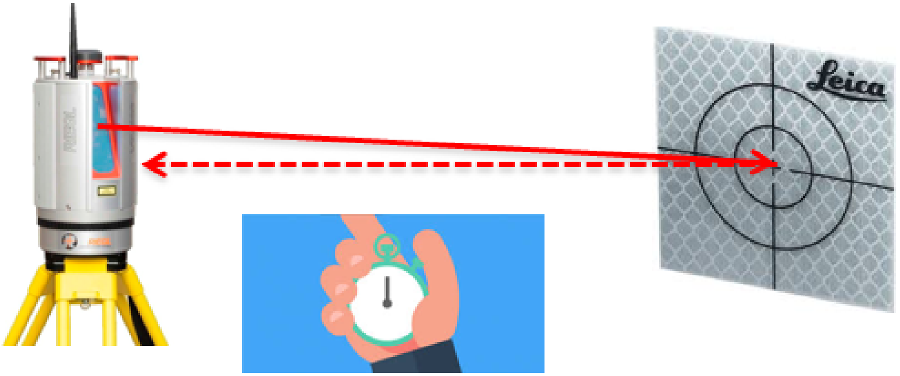
https://ot-process2.sdsc.edu/potree/index.html?r=%22https://ot-process2.sdsc.edu/appEntwineEPTService1650382647382-1881281358/pc1650382636593%22



Time of flight

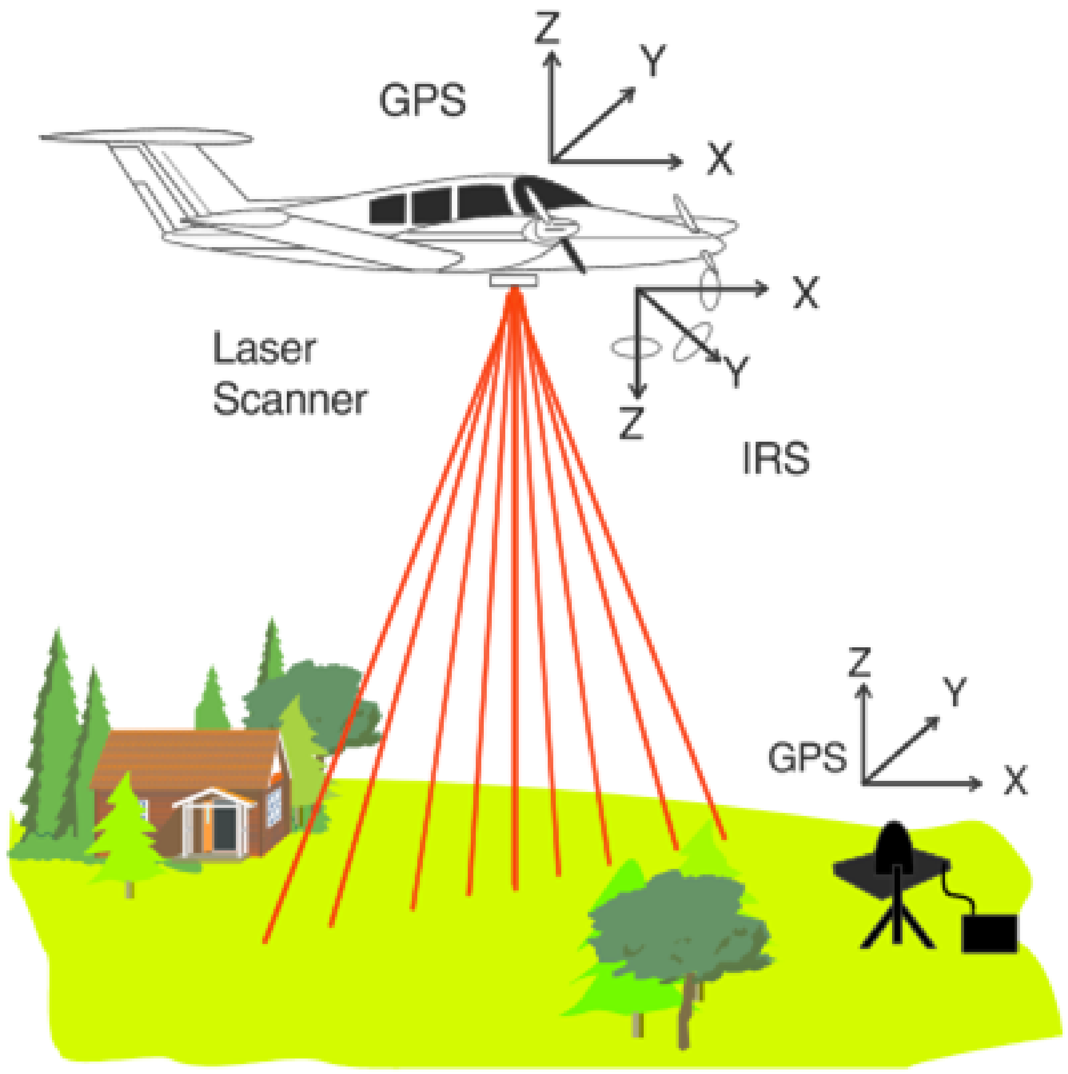
Time it takes for emitted pulse to reflect off object and return to scanner.

$$Distance = \frac{Speed\ of\ Light\ x\ Time\ of\ Flight}{2}$$



Light Detection And Ranging

- Distance is calculated by measuring the two-way travel time of a laser pulse.
- Need very accurate clocks

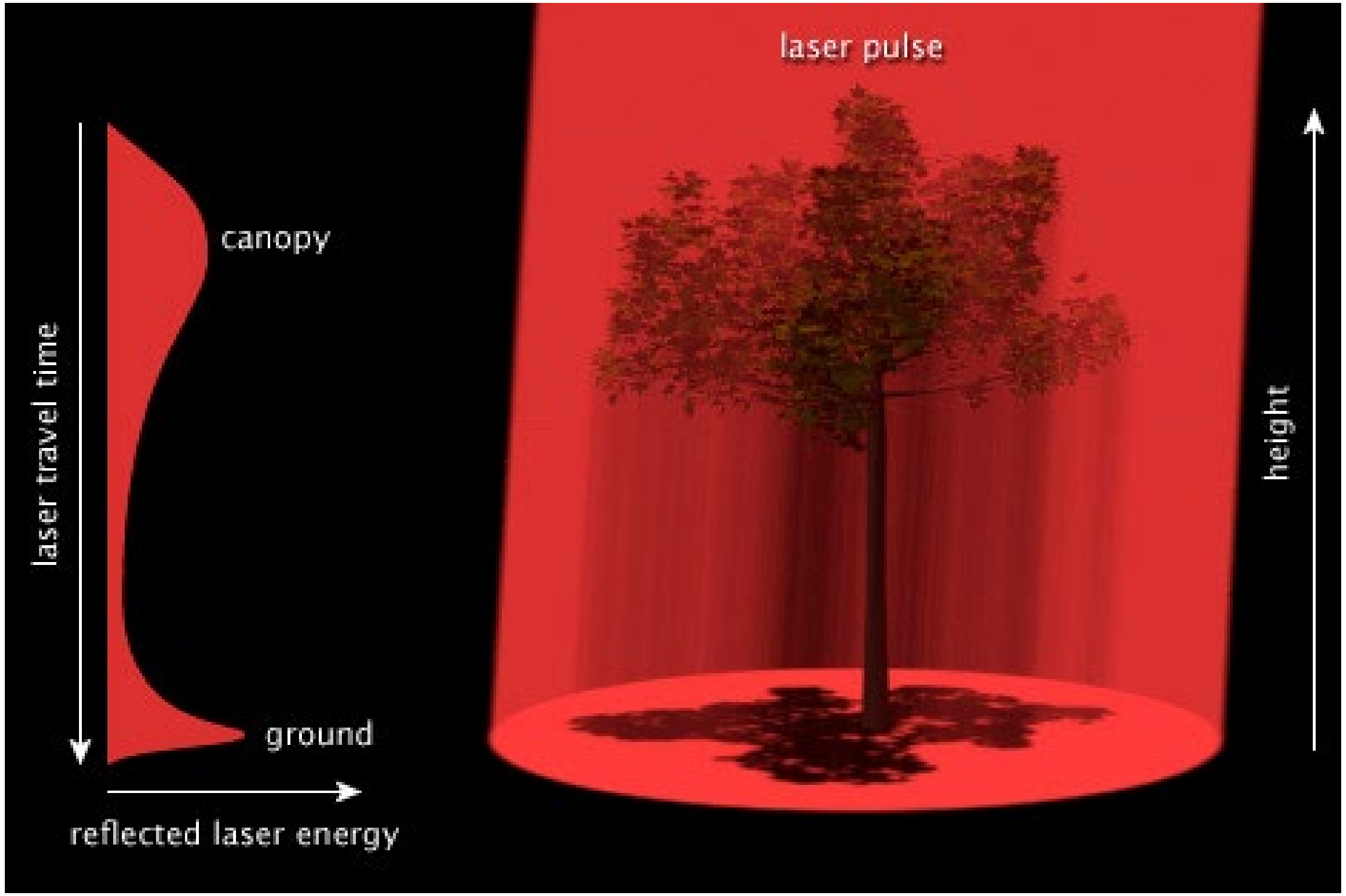


Three main components to provide a georeferenced elevation measurement:

- Laser & Sensor
- Inertial Measurement Unit (IMU)- precision navigation- measures acceleration and velocity
- GPS

Realistic Scenario:

- "flashlight" analogy with eye as sensor
- Laser is intense and coherent, but still diverges



Idealized Scenario:

- Nadir pulse
- Photons intersect Vegetation
- Photons return to detector

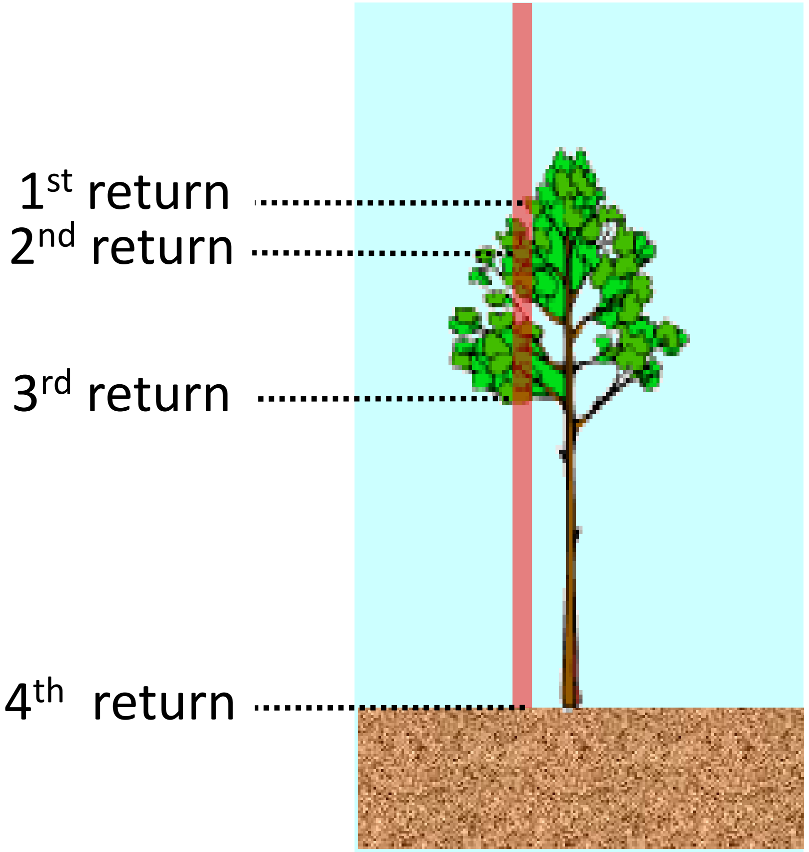


Image credit: Stoker/USGS

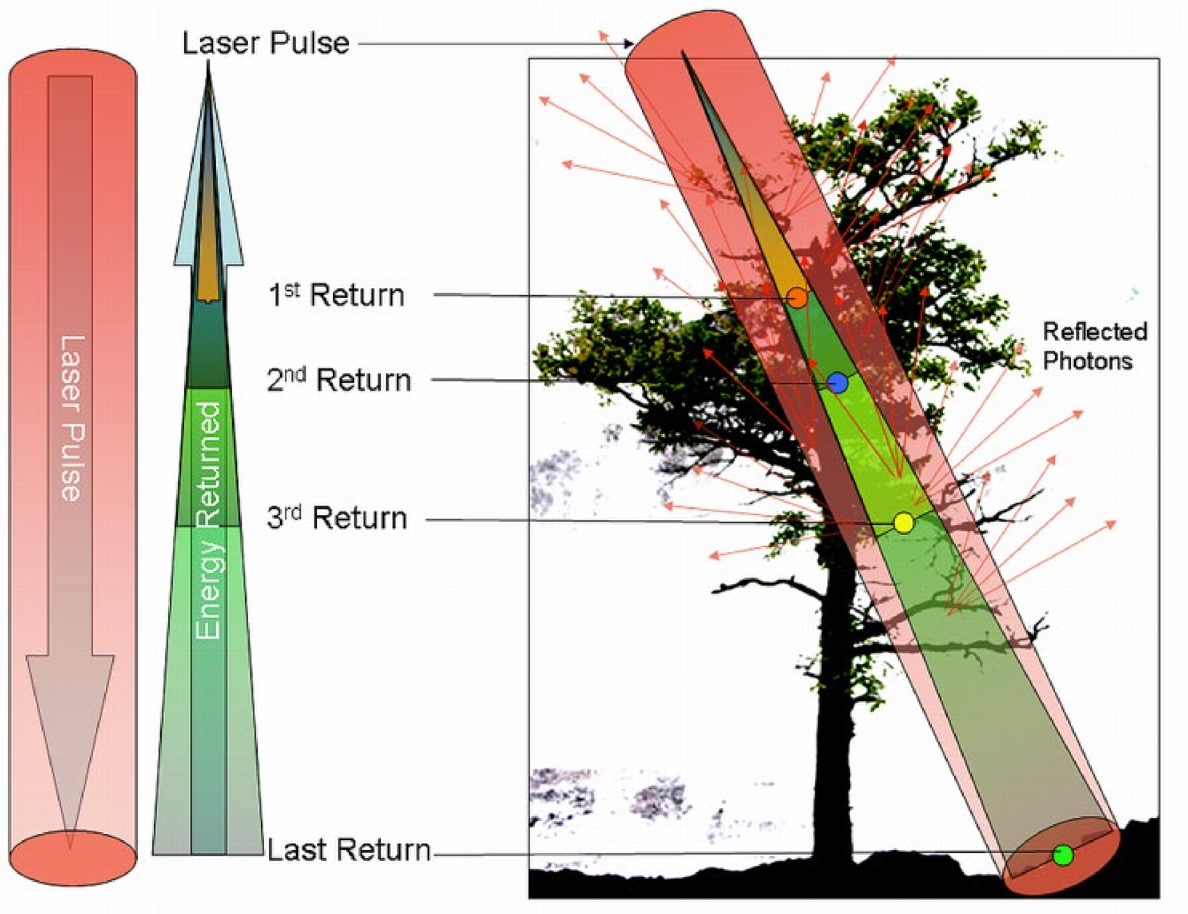


Image credit: Stoker/USGS

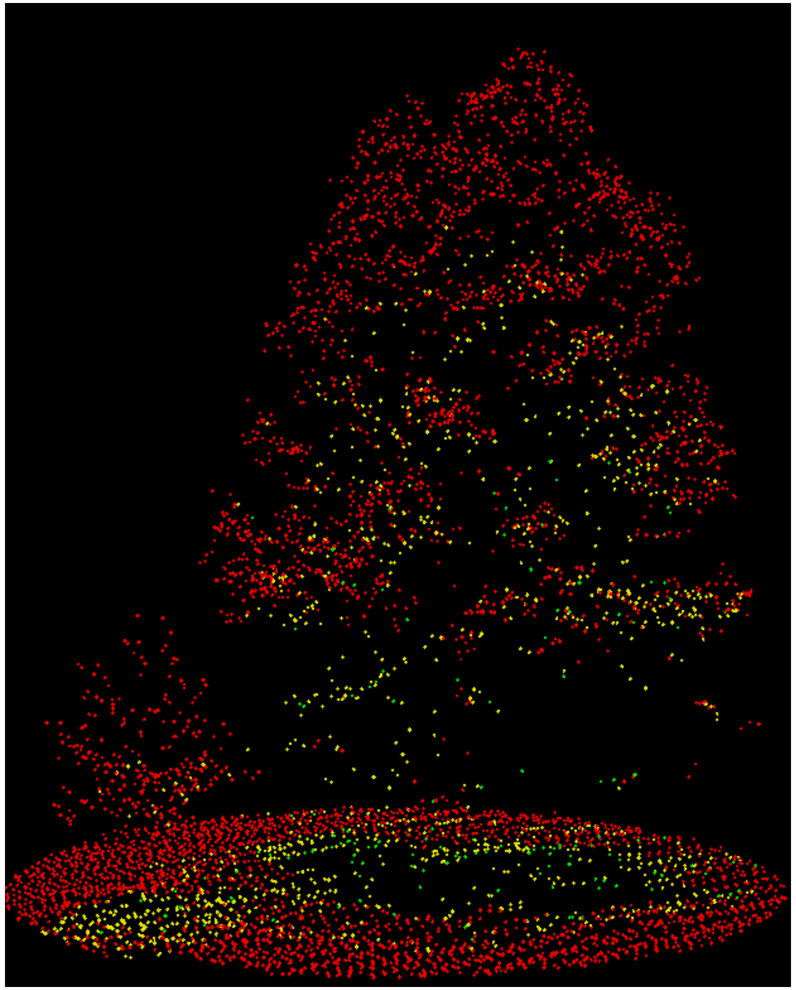
More Realistic Scenario:

- Off-Nadir pulse
- Pulse spreading and energy loss as beam travels to the ground
- Scattering of light – most photons are reflected or absorbed and don't make it back to the detector.
- Some photons intersect vegetation and/or ground
- Some photons will return to detector
- Issues with water with both nadir and off nadir angles. Some roughness will help.

Point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

Red = 1st return
Yellow = 2nd return
Green = 3rd return

Credit: Ian Madin, DOGAMI



OpenTopography

Rasters: Digital Elevation Models

- Digital representation of topography / terrain
  - "Raster" format – a grid of squares or "pixels"
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - Not True 3D - "2.5D"
  - Important metadata: Coordinate reference system, pixel size

- Grid resolution is defined by the size in the horizontal dimension of the pixel
  - 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	150	200	200	200	200	200	200	200	200	200	150	100	50	0
0	50	100	150	200	250	250	250	250	250	250	250	200	150	100	50	0
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
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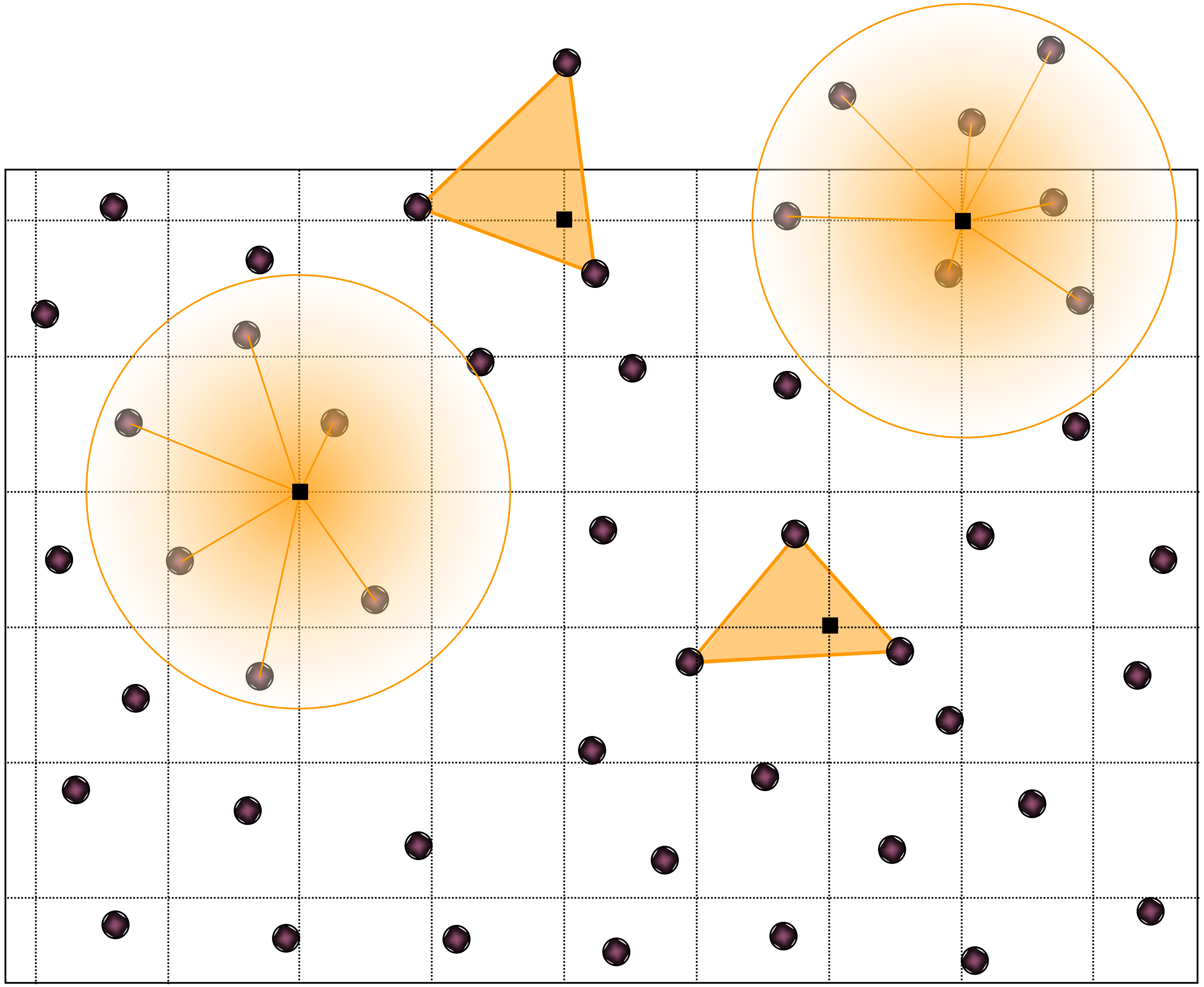
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html

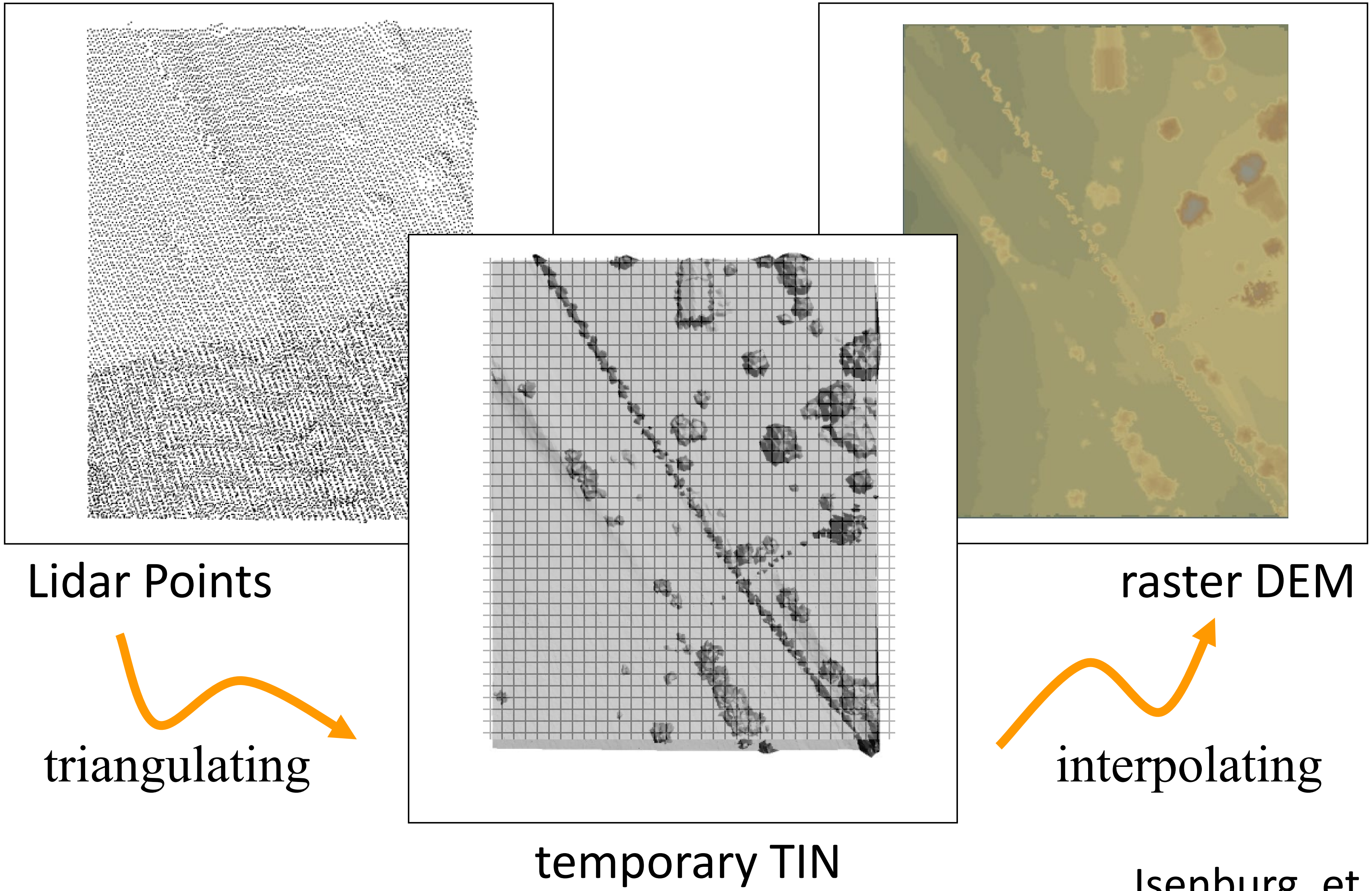
Rasters: Interpolation Methods

- Inverse Distance Weighting (IDW)
- Natural Neighbors
- Nearest Neighbor
- Kriging
- Splines
- TIN



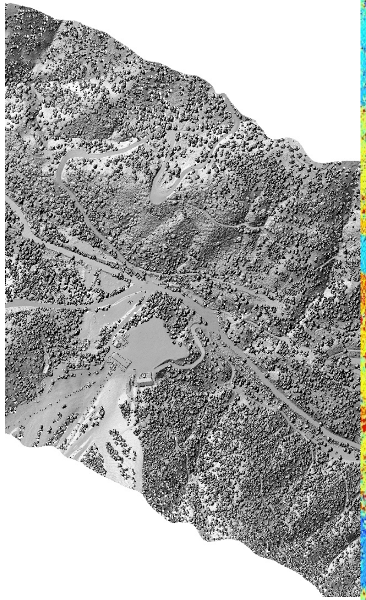
Isenburg, et al., 2006

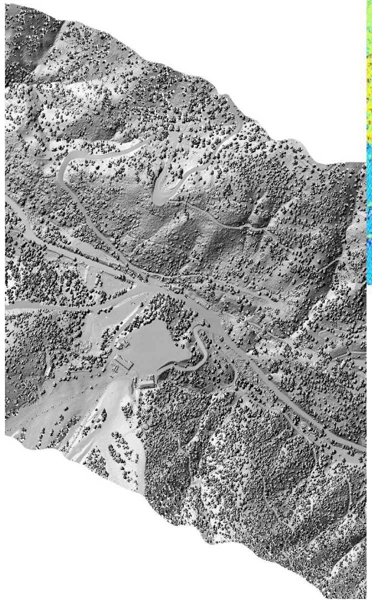
Rasters: Raw Lidar to Digital Elevation Models

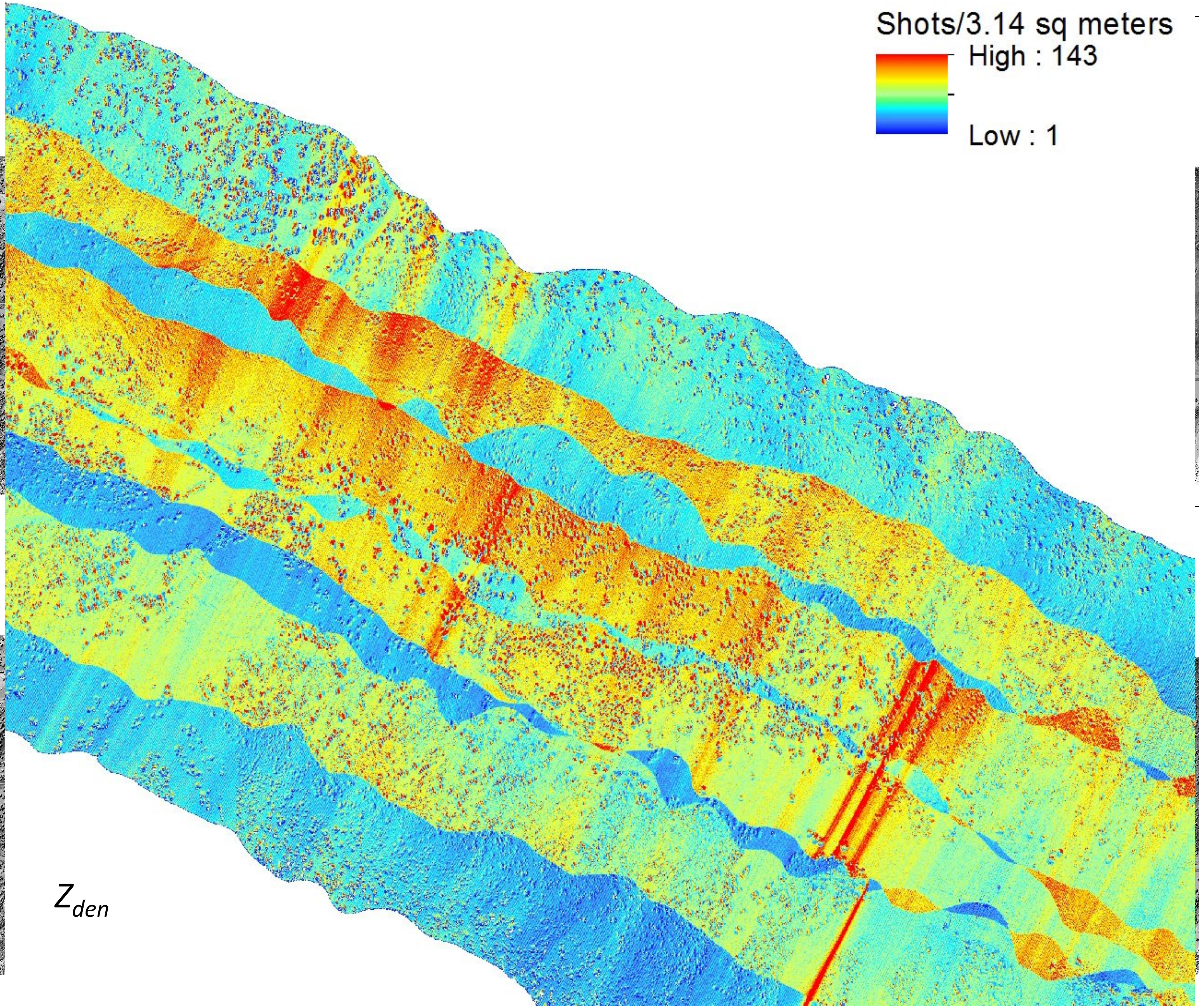


Isenburg, et al., 2006

Rasters: Gridding

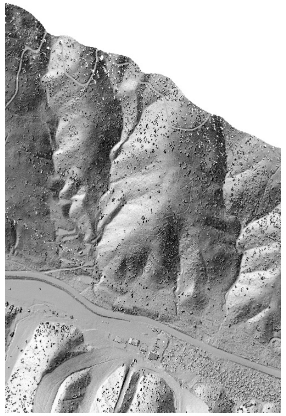




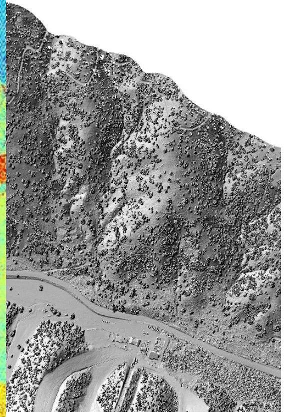


Z_{den}

Z_{min}



Z_{idw}



Rasters: Artefacts

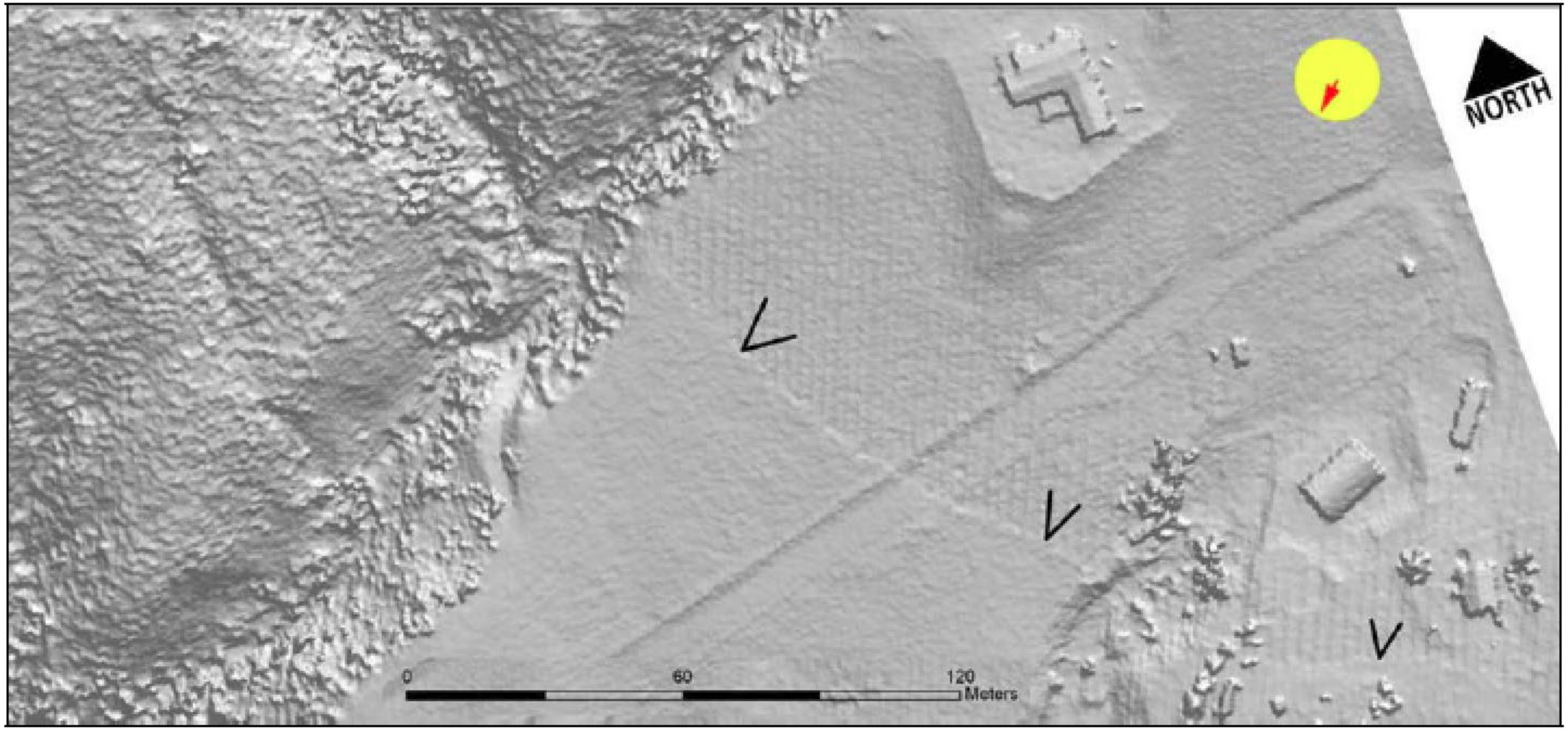
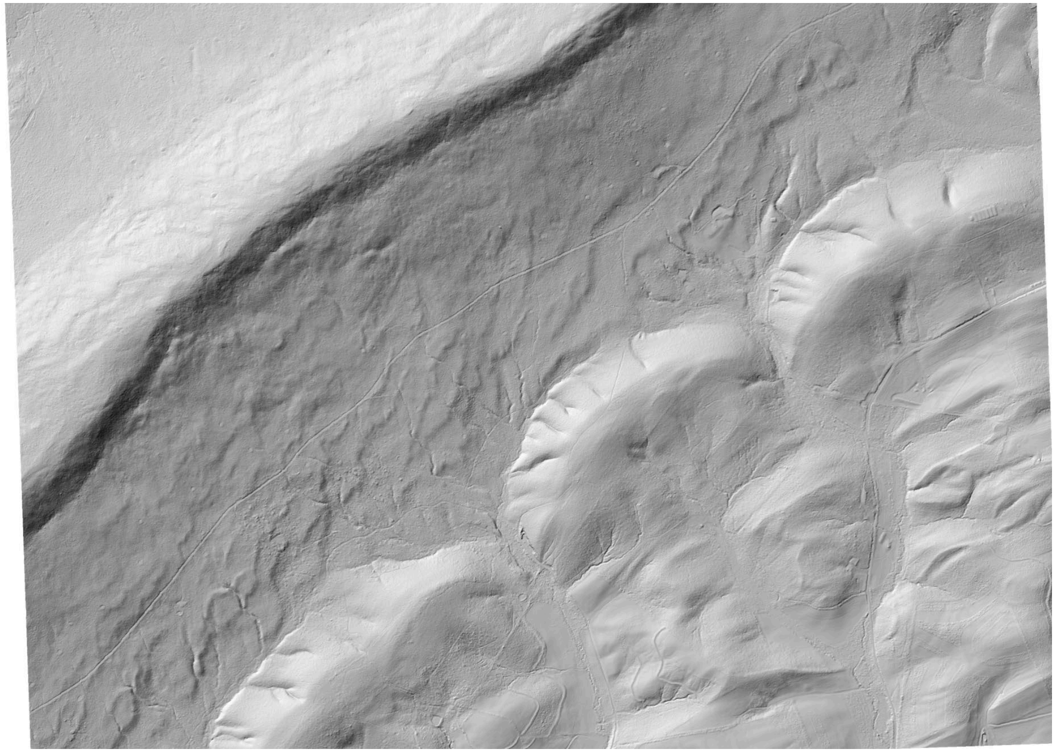


Figure 7a. LiDAR artifact (arrows) in the Yucaipa study area. The artifact appears as a linear highlight suggestive of an east-facing scarp. However, the evident “corduroy” texture on one side versus the other alerts one to the likelihood that this is an artifact. Indeed, it corresponds to the overlap margin between LiDAR swaths.

Treiman, Perez, & Bryant, 2010, USGS Award No. 08HQGR0096 Final Tech. Report

Susquehanna Critical Zone Observation, PA

Digital terrain model

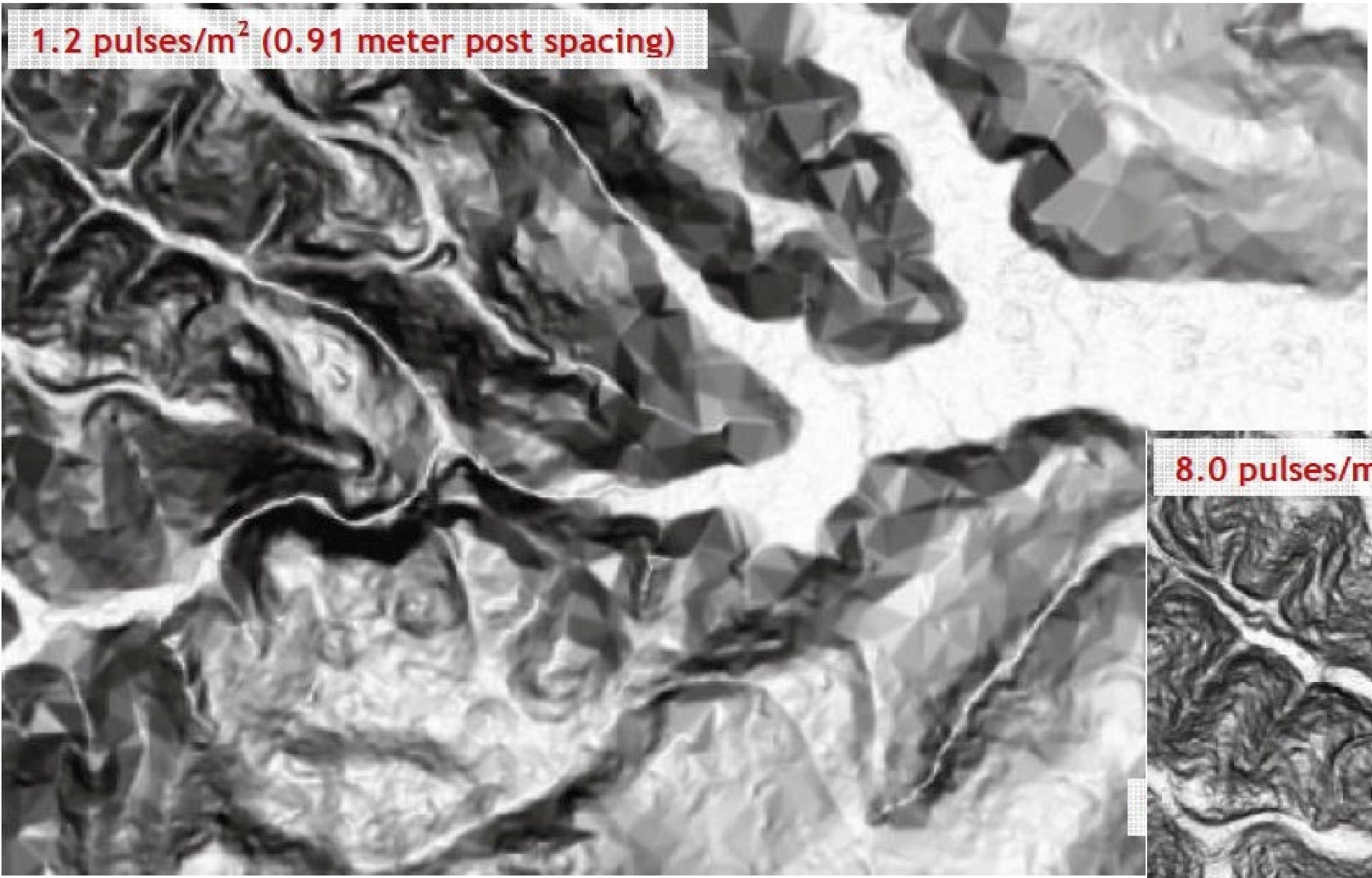


Bare earth: Remove vegetation and built structures
Process with ground points only

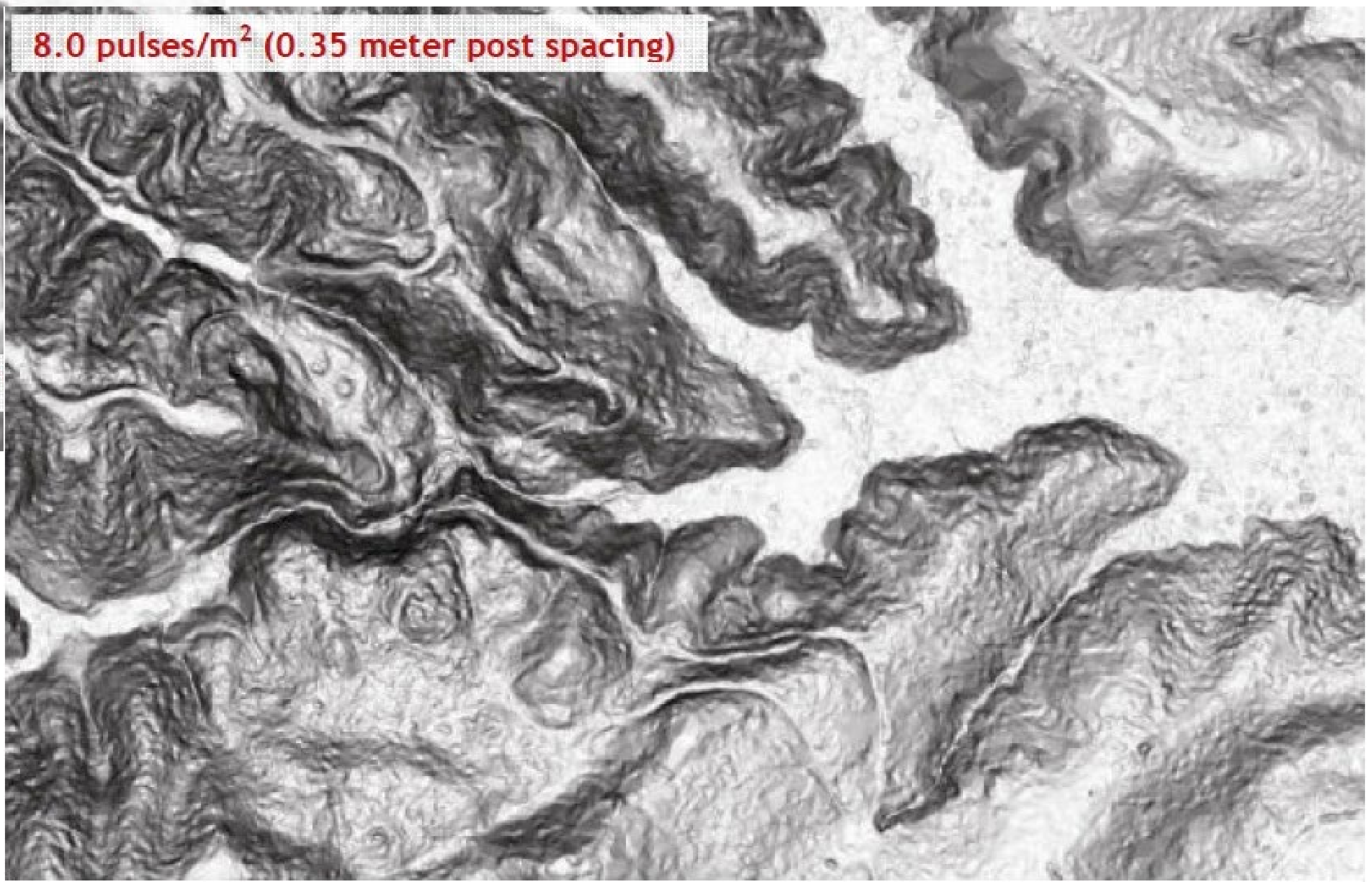
Digital surface model

Highest portion of the landscape- top of canopy & buildings
Process as max elevation (ideally) or all points

Intro to Lidar: Point Spacing/Density



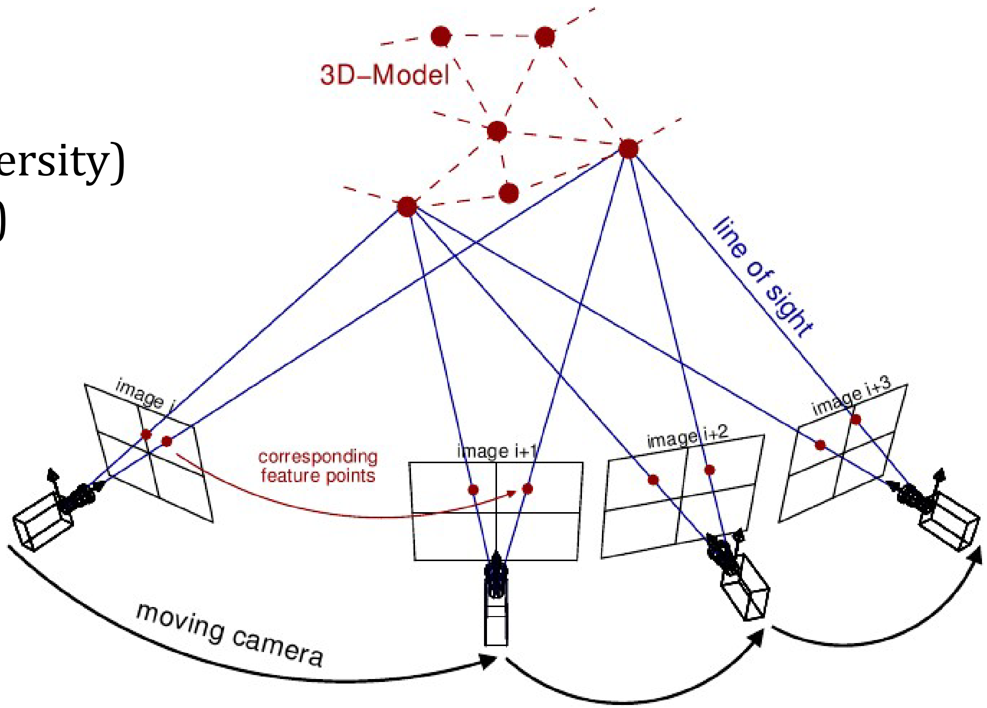
Lidar quality and resolution spacing has increased over time.

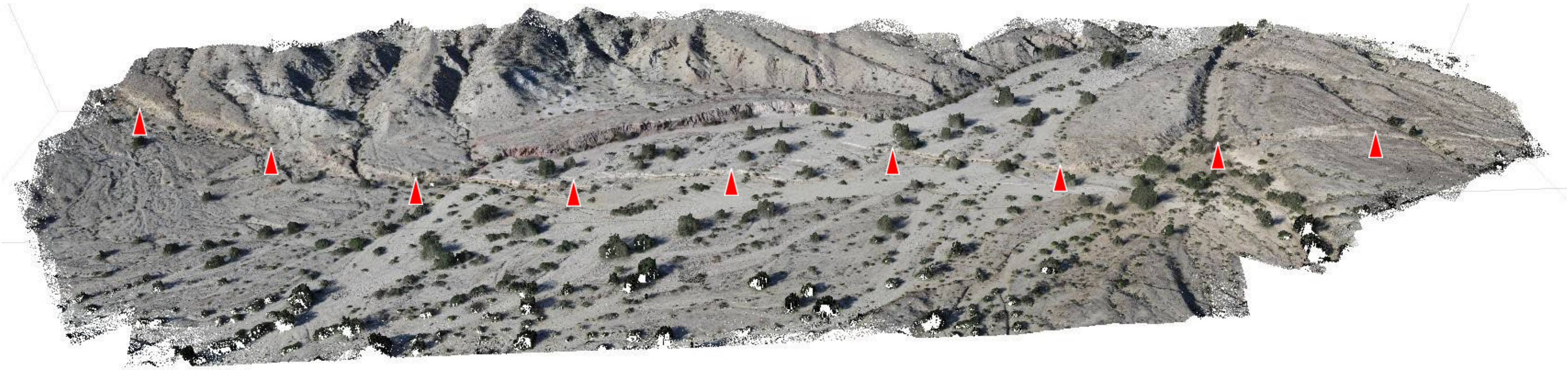


Minimum LiDAR Considerations in the Pacific Northwest
Watershed Sciences, Inc.
http://www.oregongeology.org/sub/projects/olc/minimum-lidar-data-density.pdf

Introduction to Structure-from-Motion

Edwin Nissen (Colorado School of Mines)
J Ramon Arrowsmith (Arizona State University)
Chris Crosby (UNAVCO/OpenTopography)





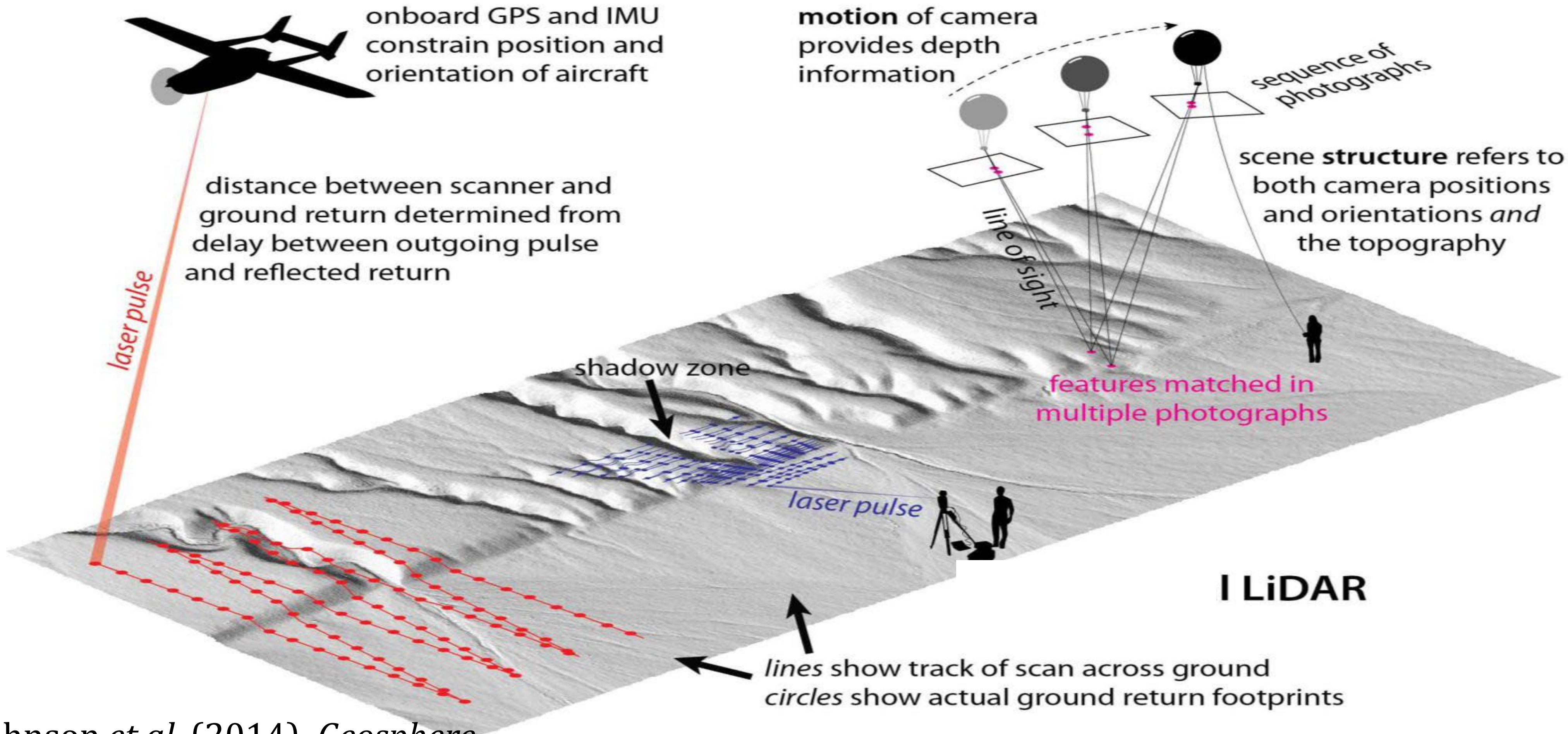
~500 points/m^2 coloured point cloud along a ~1 km section of the 2010 El Mayor-Cucapah earthquake rupture generated from ~500 photographs captured in 2 hours from a helium blimp

Lidar (ALS, TLS, MLS)

- Expensive laser equipment required
- Works in densely-vegetated landscapes
- Uses precise time-of-flight measurements but prone to artifacts from GPS and IMU

Structure-from-Motion

- Requires only a cheap camera
- Coloured points & orthophoto for texture mapping
- Back-solves for camera parameters; warping artifacts are a common problem but easily mitigated



Johnson *et al.* (2014), *Geosphere*

Where it all started…

The original idea

Proc. R. Soc. Lond. B. **203**, 405–426 (1979)
Printed in Great Britain

The interpretation of structure from motion

BY S. ULLMAN
Artificial Intelligence Laboratory, Massachusetts Institute of Technology,
545 *Technology Square* (*Room* 808), *Cambridge, Massachusetts* 02139 *U.S.A.*

(*Communicated by S. Brenner, F.R.S. – Received* 20 *April* 1978)

The interpretation of structure from motion is examined from a computional point of view. The question addressed is how the three dimensional structure and motion of objects can be inferred from the two dimensional transformations of their projected images when no three dimensional information is conveyed by the individual projections.

Where it all started…

The algorithm that powers SfM

Proc. of the International Conference on Computer Vision, Corfu (Sept. 1999)

Object Recognition from Local Scale-Invariant Features

David G. Lowe

Computer Science Department
University of British Columbia
Vancouver, B.C., V6T 1Z4, Canada
lowe@cs.ubc.ca

Abstract

An object recognition system has been developed that uses a new class of local image features. The features are invariant to image scaling, translation, and rotation, and partially invariant to illumination changes and affine or 3D projection.

Where it all started…

- The **Scale Invariant Feature Transform (SIFT)** (Lowe, 1999) allows corresponding features to be matched even with large variations in scale and viewpoint and under conditions of partial occlusion and changing illumination

Where it all started…

First use of the SIFT algorithm to generate large point clouds

Snavely *et al.* (2006). Photo Tourism: Exploring Photo Collections in 3D, *ACM Transactions on Graphics*

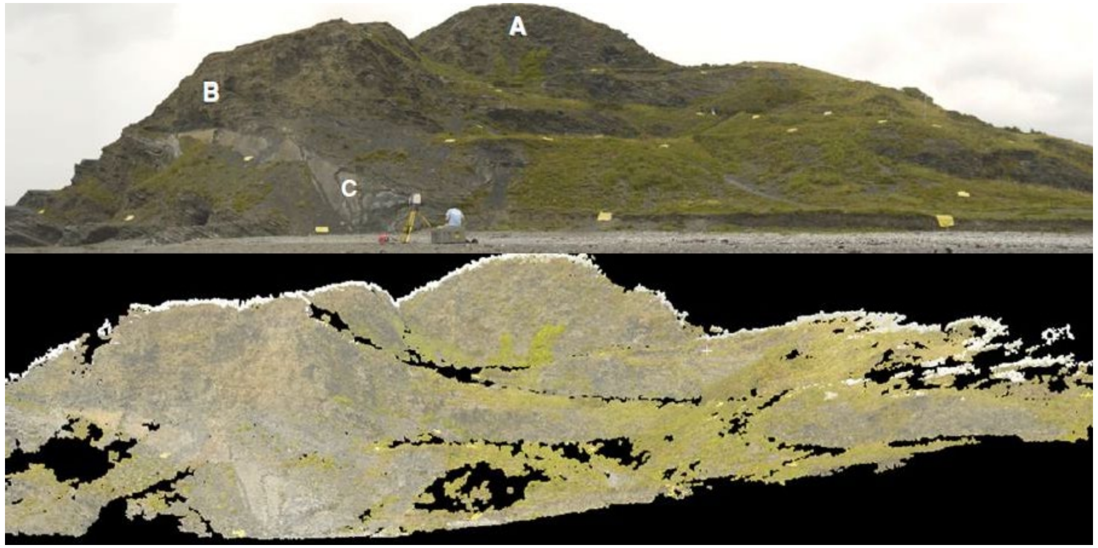
Snavely *et al.* (2007). Modeling the World from Internet Photo Collections, *International Journal of Computer Vision*

Using photographs from a **moving** camera (or cameras)…

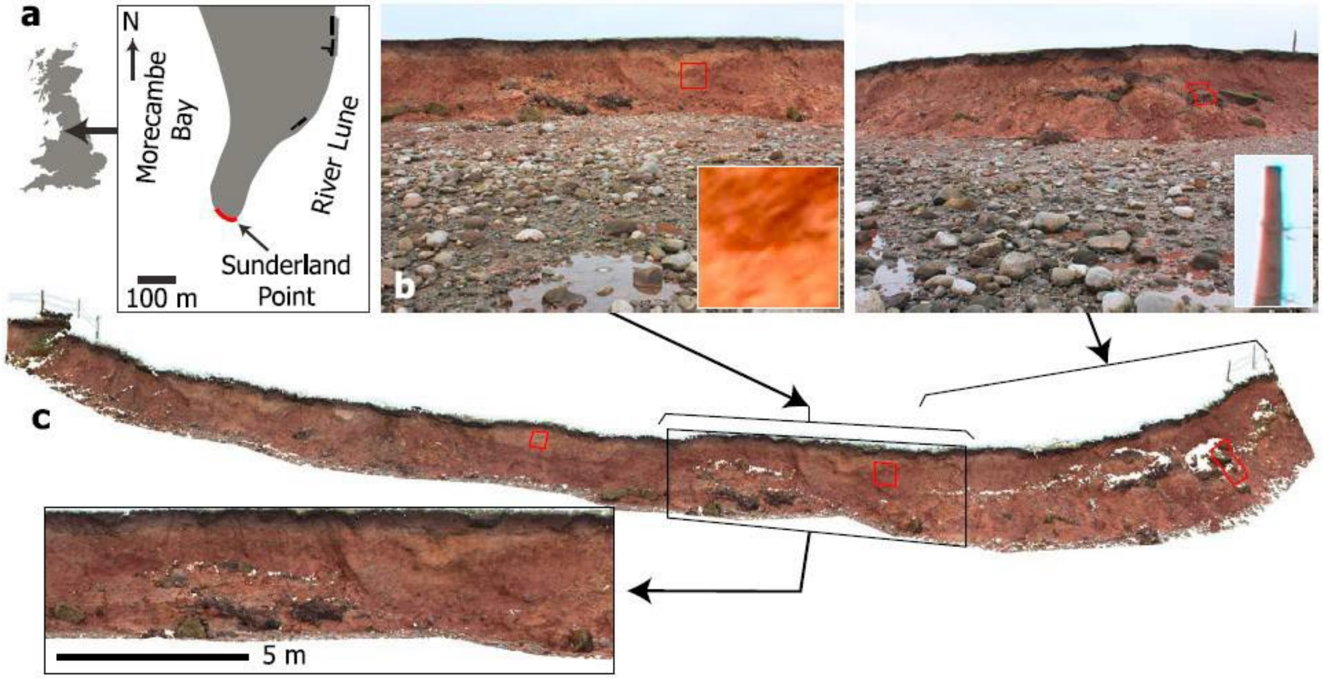
… reconstruct the scene **structure** (i.e. the geometry of the target *and* the positions, orientations & lens parameters of the cameras)

Where it all started…

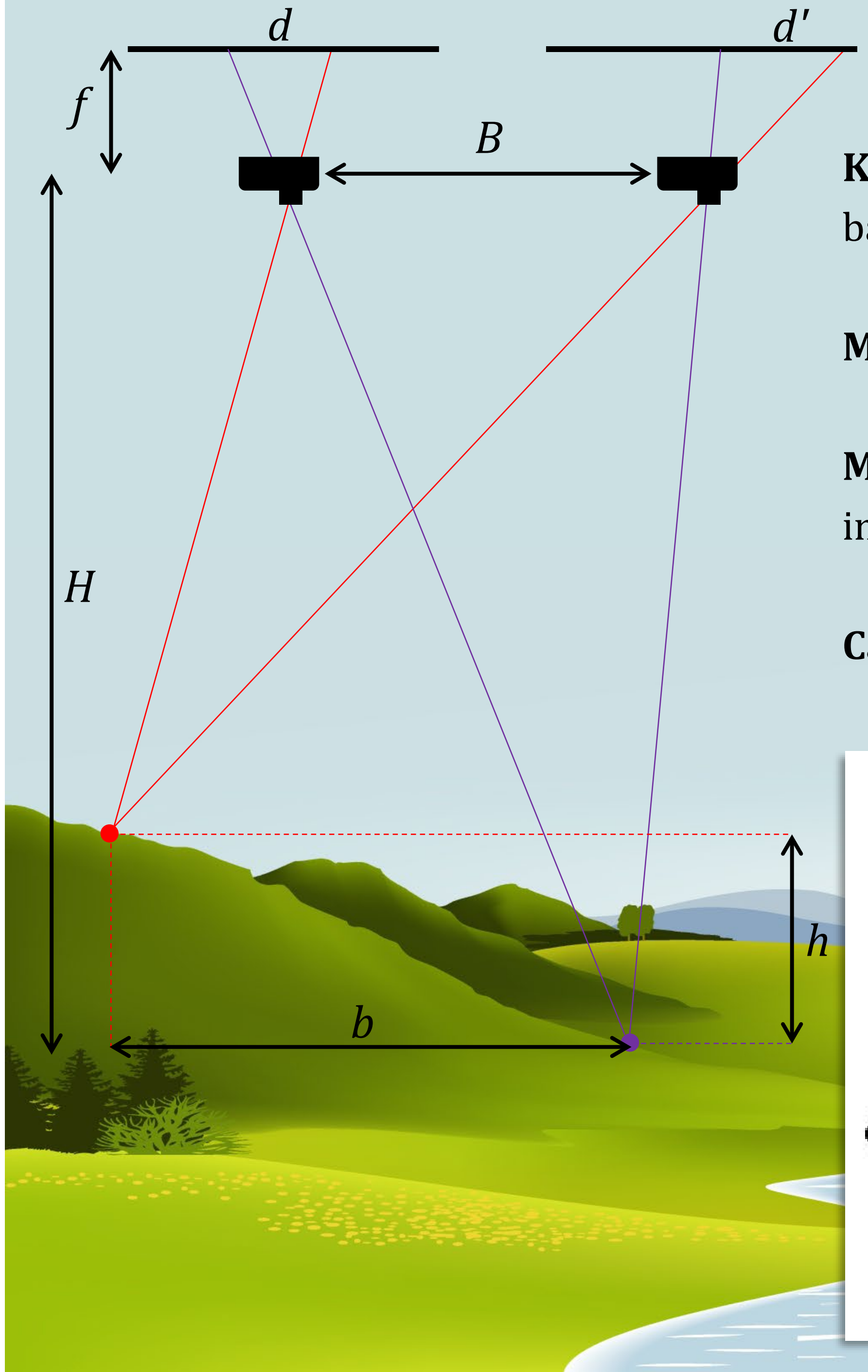
First geoscience applications



Left. Westoby *et al.* (2012). Structure-from-Motion photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*



Right. James & Robson (2012). Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application. *Journal of Geophysical Research*



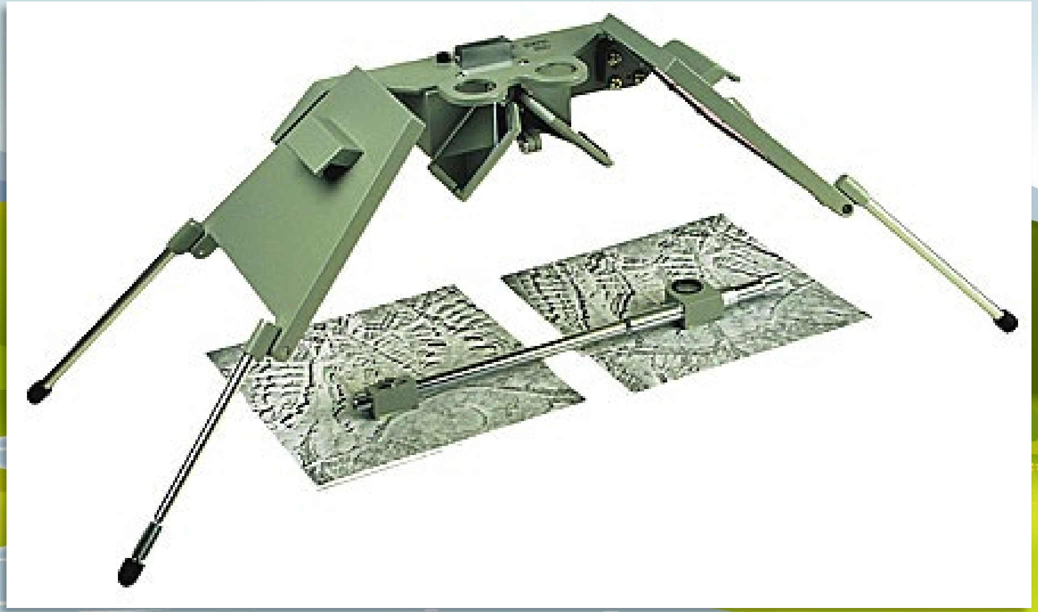
Traditional stereo-photogrammetry

Known camera height *H* and focal length *f*, and the baseline *B* between images

Match corresponding features

Measure distances between features on the camera image plane *d, d'*

Calculate relative positions of features *b, h*

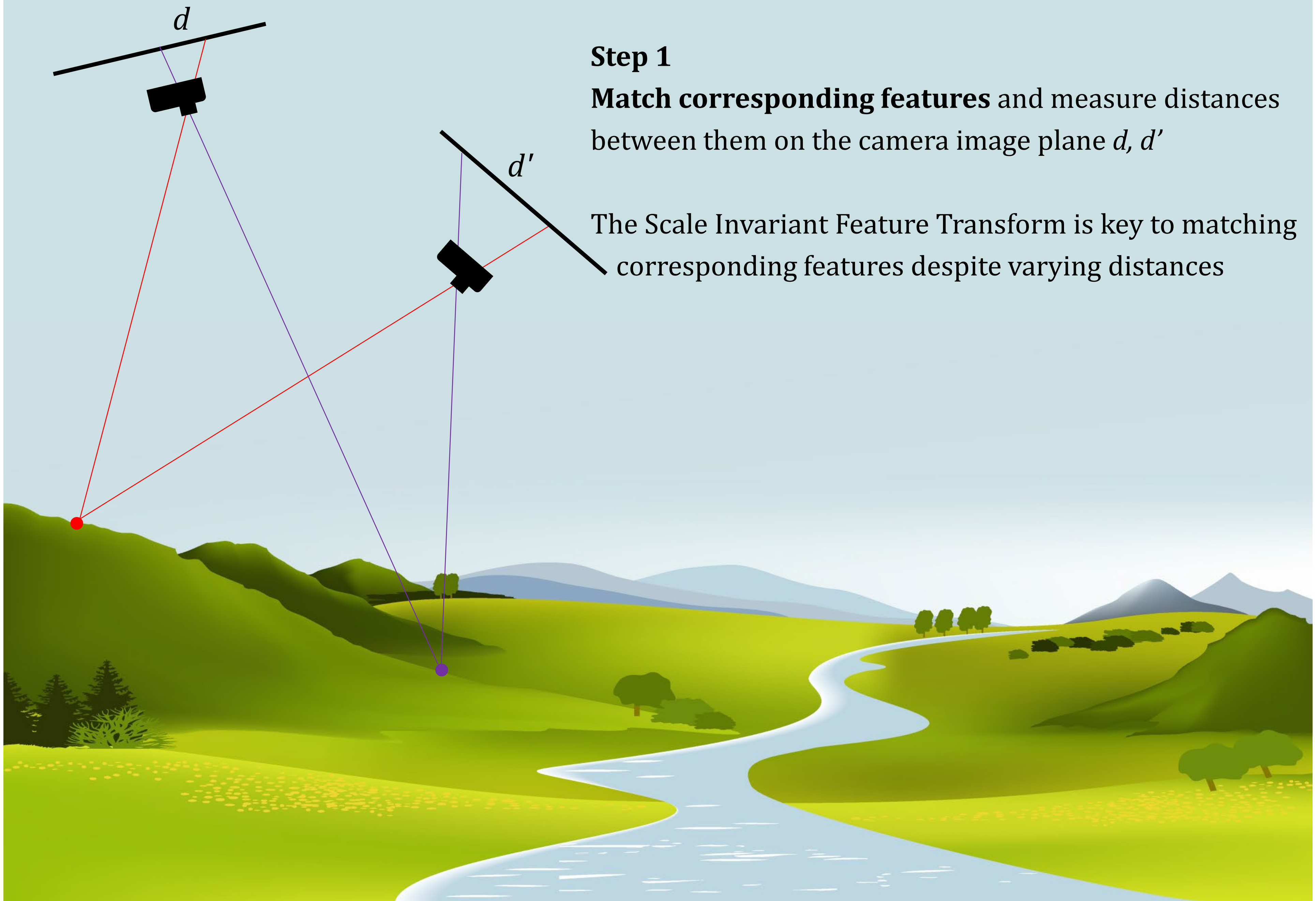


Structure-from-Motion

Step 1

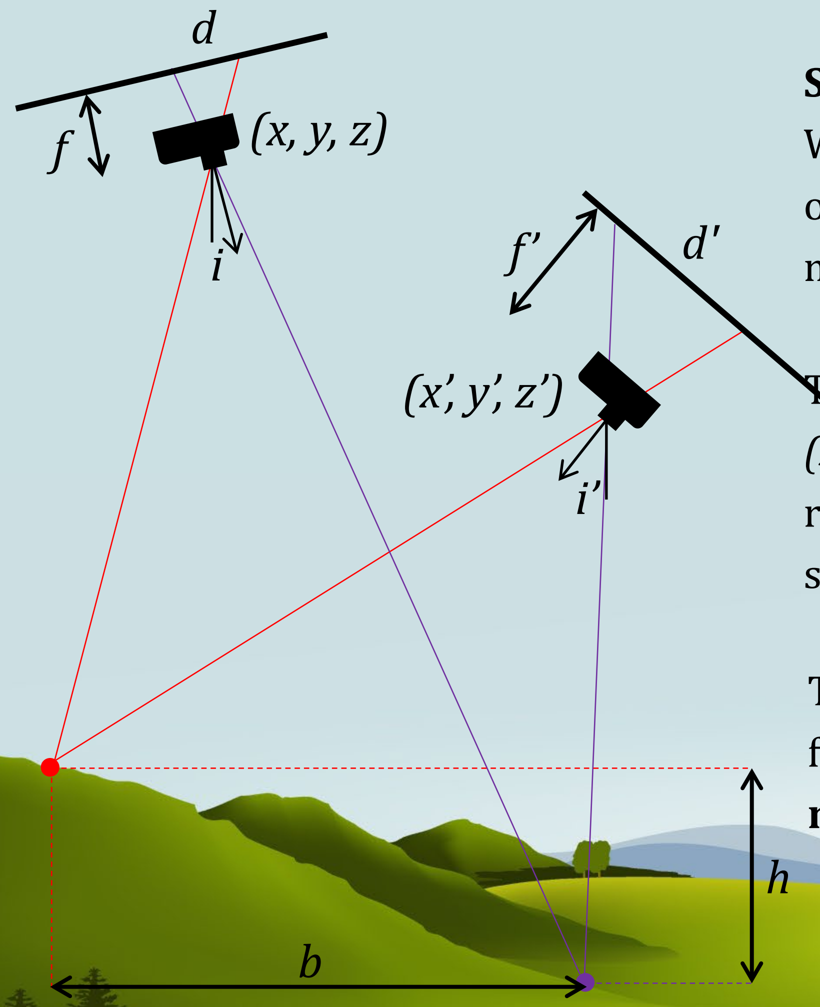
Match corresponding features and measure distances between them on the camera image plane *d, d'*

The Scale Invariant Feature Transform is key to matching corresponding features despite varying distances



• The **Scale Invariant Feature Transform (SIFT)** (Lowe, 1999) allows corresponding features to be matched even with large variations in scale and viewpoint and under conditions of partial occlusion and changing illumination

Structure-from-Motion



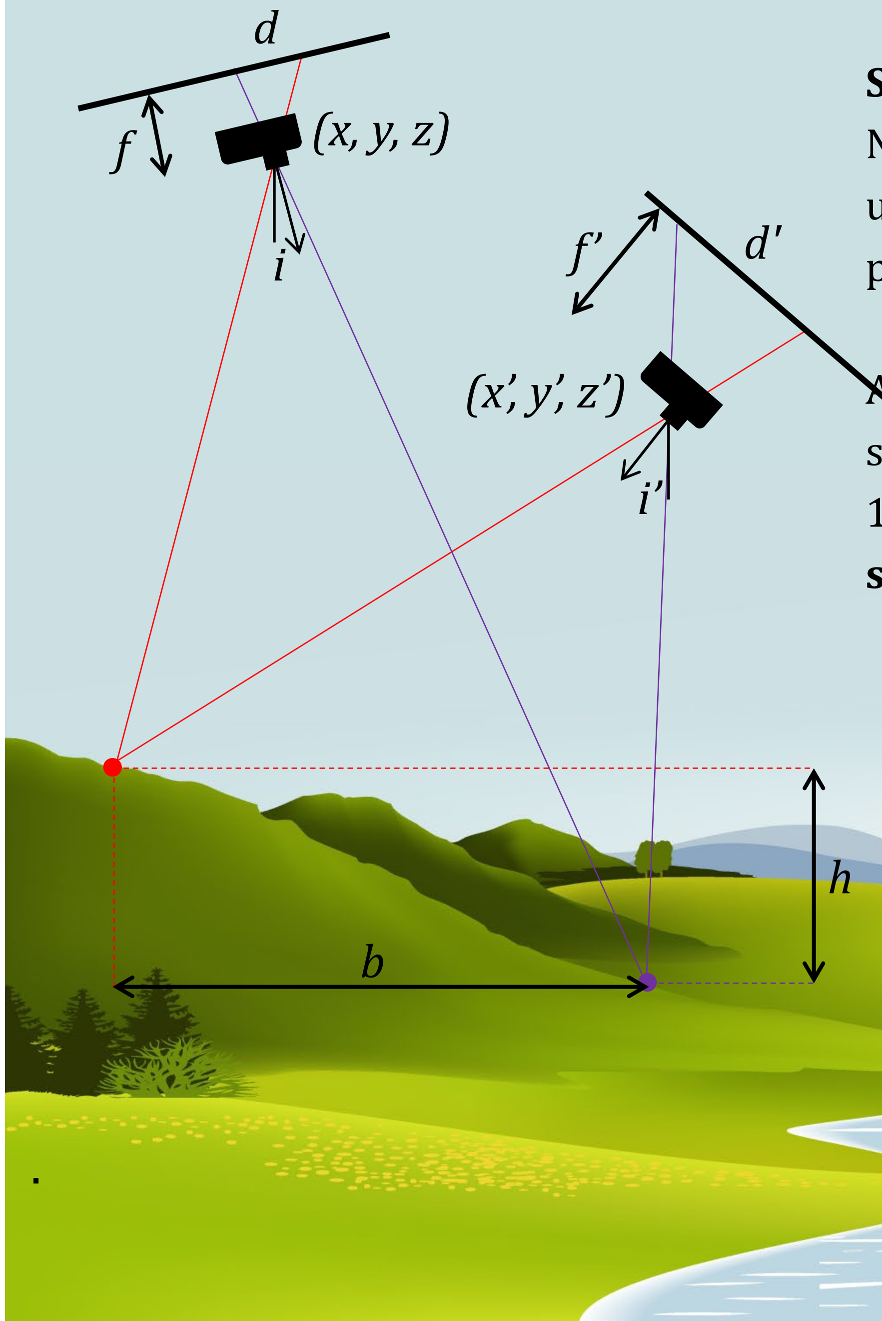
Step 2

When we have the matching locations of multiple points on two or more photos, there is usually just one mathematical solution for where the photos were taken.

Therefore, we can calculate individual camera positions *(x, y, z), (x’, y’, z’)*, orientations *i*, *i’*, focal lengths *f*, *f’*, and relative positions of corresponding features *b, h,* in a single step known as **“bundle adjustment”.**

This is where the term Structure from Motion comes from. Scene **structure** refers to all these parameters; **motion** refers to movement of the camera

Structure-from-Motion



Step 3

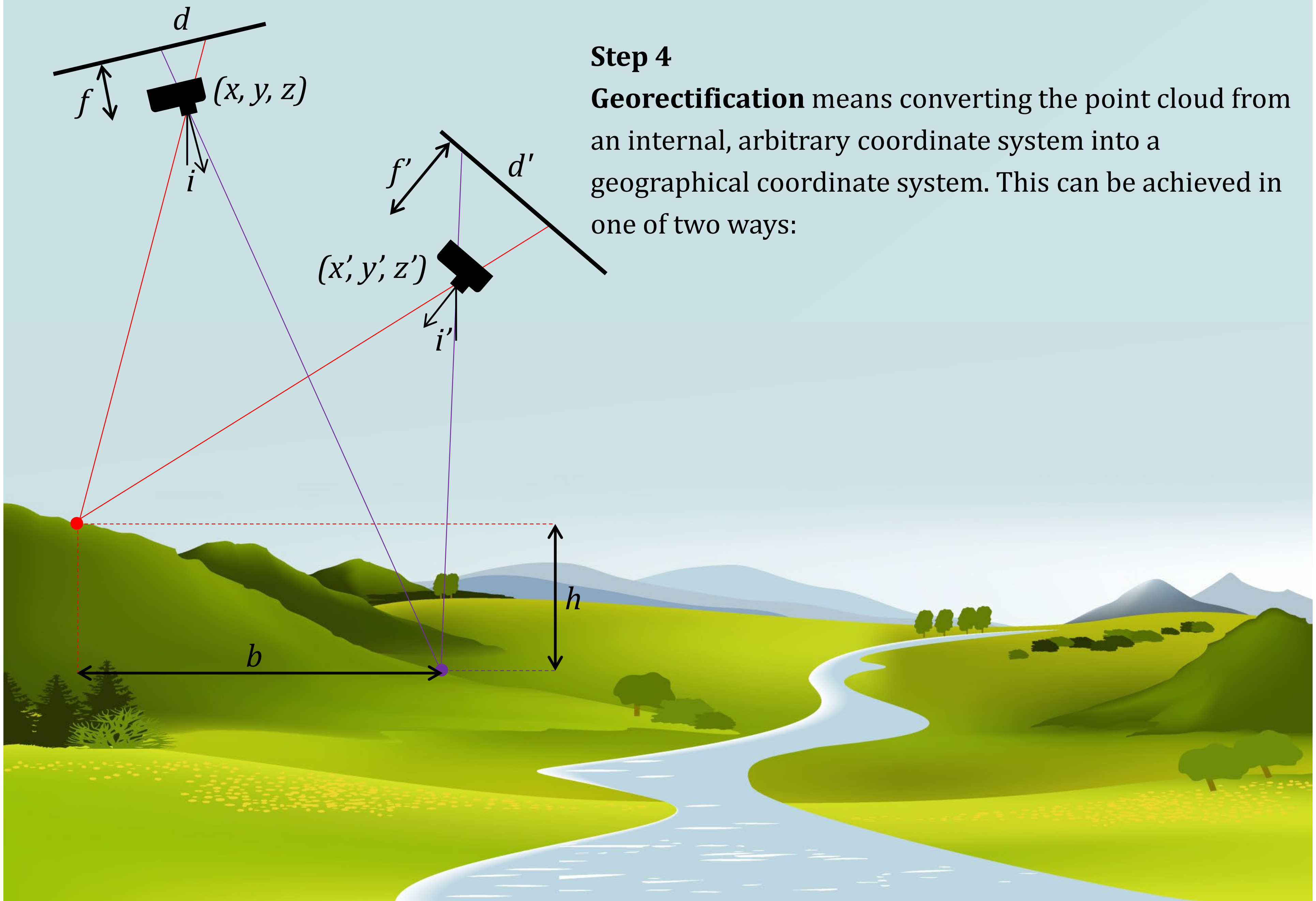
Next, a dense point cloud and 3D surface is determined using the known camera parameters and using the SfM points as “ground control”.

All pixels in all images are used so the dense model is similar in resolution to the raw photographs (typically 100s – 1000s point/m^2). This step is called “**multiview stereo matching” (MVS)**

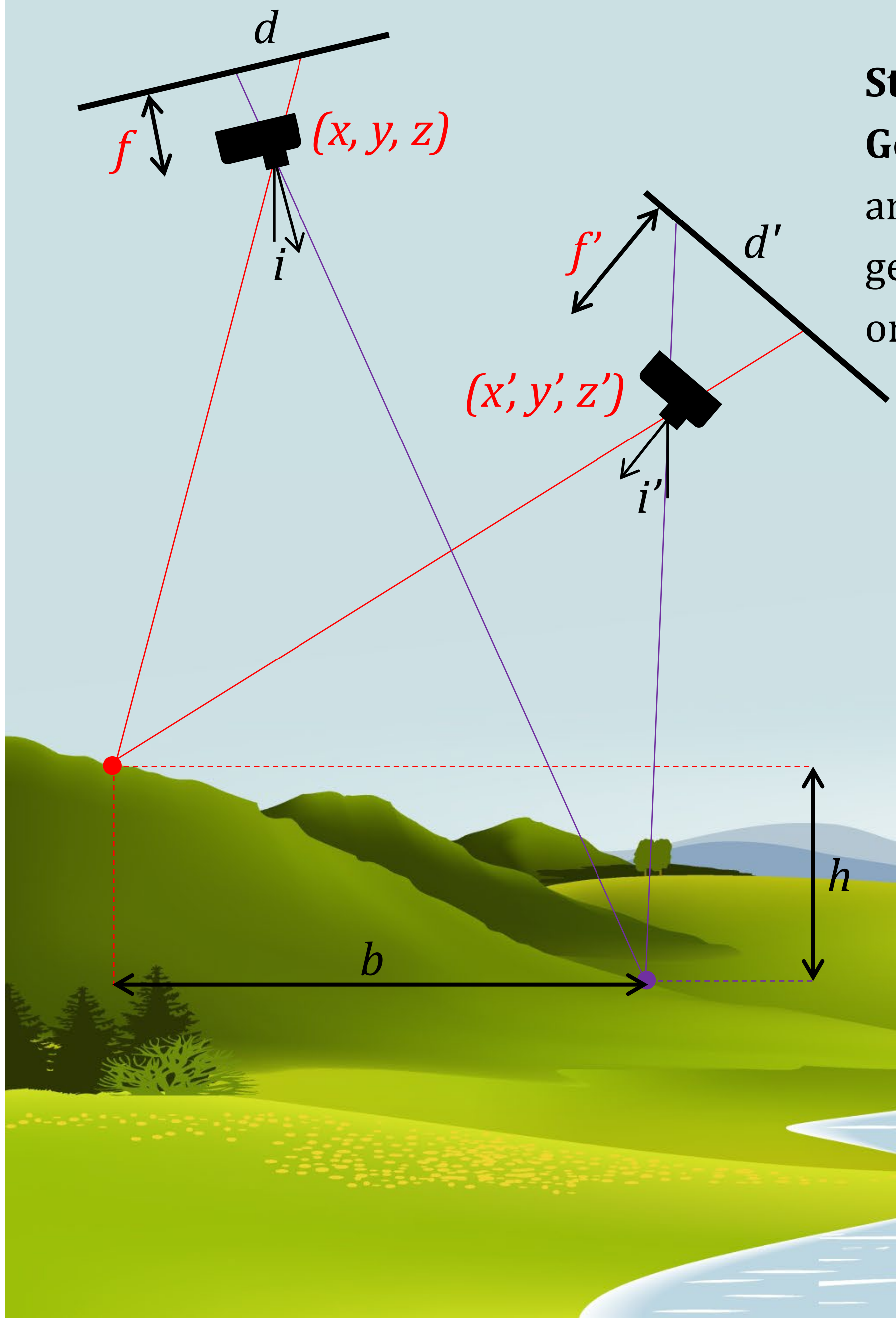
Structure-from-Motion

Step 4

Georectification means converting the point cloud from an internal, arbitrary coordinate system into a geographical coordinate system. This can be achieved in one of two ways:



Structure-from-Motion

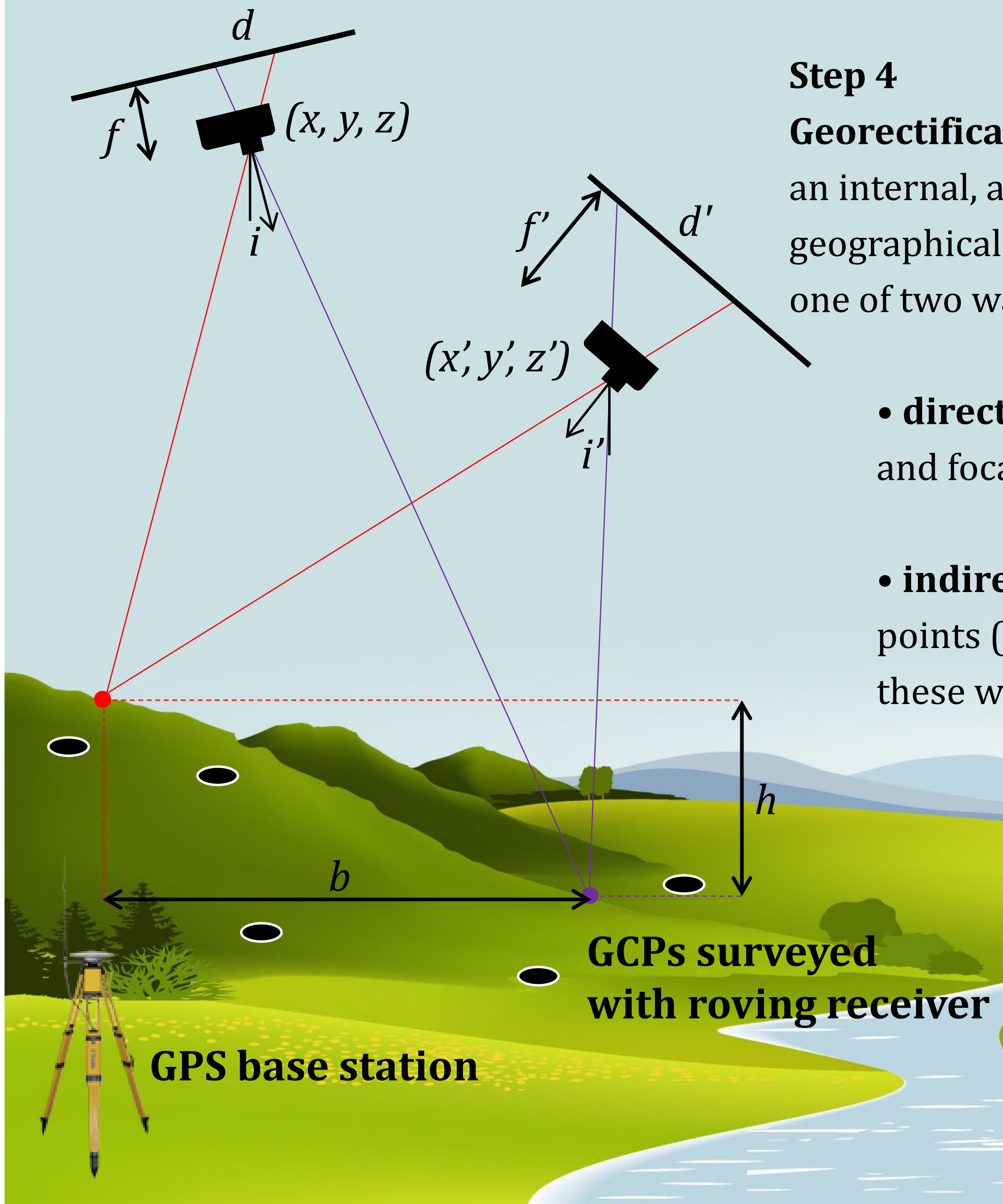


Step 4

Georectification means converting the point cloud from an internal, arbitrary coordinate system into a geographical coordinate system. This can be achieved in one of two ways:

- **directly,** with knowledge of the camera positions and focal lengths

Structure-from-Motion



Step 4

Georectification means converting the point cloud from an internal, arbitrary coordinate system into a geographical coordinate system. This can be achieved in one of two ways:

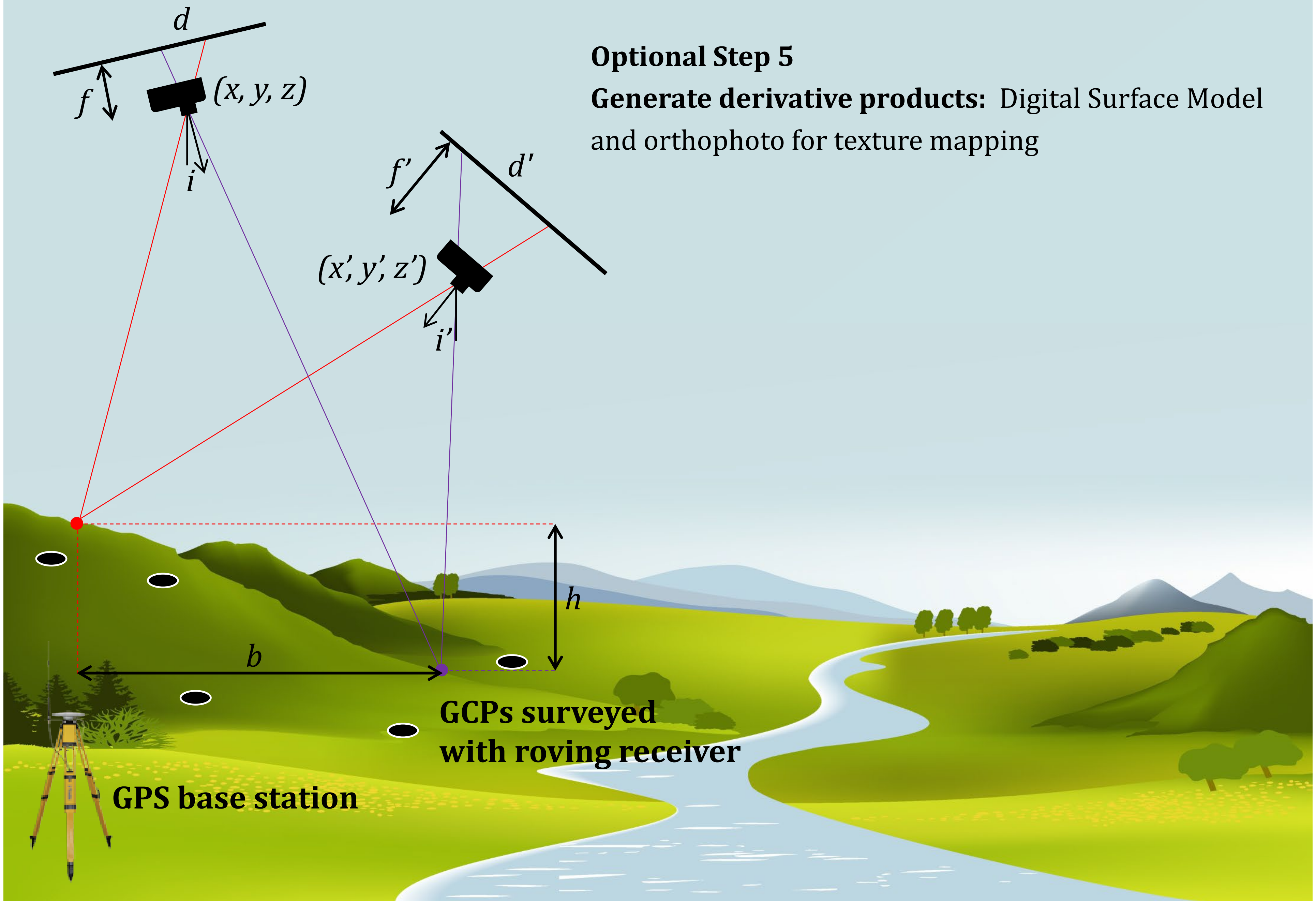
- **directly,** with knowledge of the camera positions and focal lengths

- **indirectly,** by incorporating a few ground control points (GCPs) with known coordinates. Typically these would be surveyed using differential GPS

Structure-from-Motion

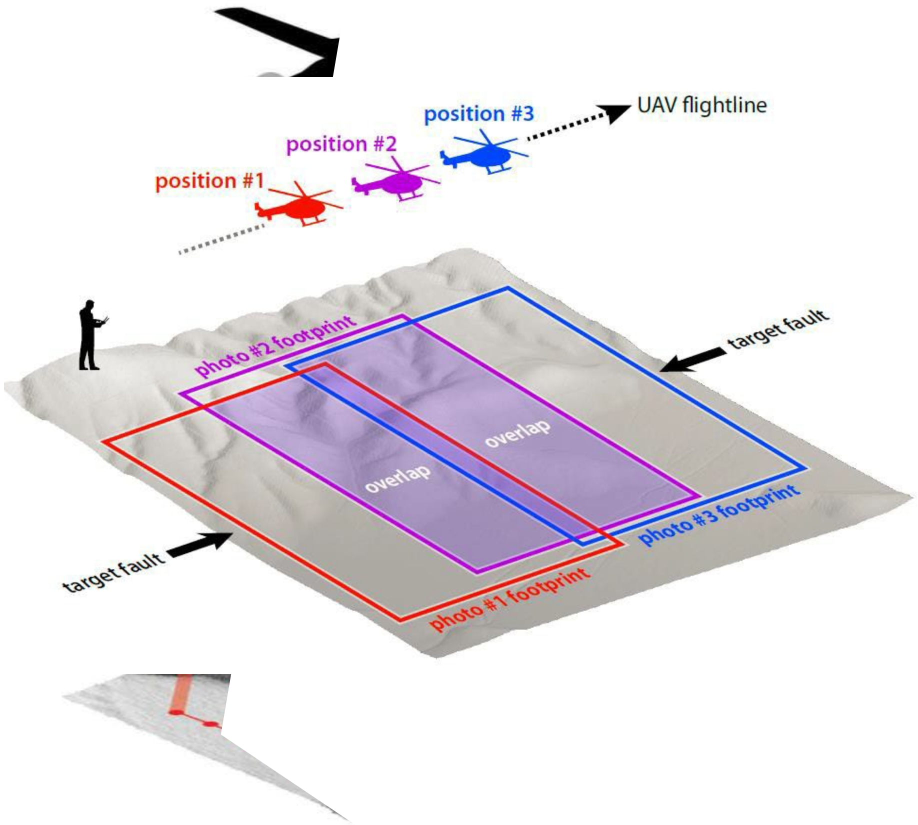
Optional Step 5

Generate derivative products: Digital Surface Model and orthophoto for texture mapping



Traditional stereo-photogrammetry

- Requires a stable platform such as a satellite or aeroplane at a fixed elevation
- Photographs collected at known positions with fixed orientations and incidence angles



Structure-from-Motion

- Photos from many angles and distances can be used, with no *a priori* knowledge of locations or pose
- Enables "unstructured" image acquisition from the ground, legacy air-photosets, or unmanned platforms