GRASS GIS loves lidar
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available at
wenzeslaus.github.io/grass-lidar-talks
all in one
- hydrology modeling, image segmentation, point clustering, ...
- from small laptops to supercomputers
- Raspberry Pi, Windows, Mac, GNU/Linux, GNU/Hurd, FreeBSD, IBM AIX
- learn now, use forever
- over 30 years of development and interface refinement
- probably used more than you think
- similarly to C/C++ is often not mentioned but is somewhere in there

latest release 7.0.4
Sunday, May 1, 2016
Welcome to GRASS GIS 7.1.svn (r68305M)
GRASS GIS homepage: http://grass.osgeo.org
This version running through: Bash Shell (/bin/bash)
Help is available with the command: g.manual -i
See the licence terms with: g.version -c
Start the GUI with: g.gui wxpython
When ready to quit enter: exit

To run a command as administrator (user "root"), use "sudo <command>". See "man sudo_root" for details.

GRASS 7.1.svn (nantahala):~/dev/grass/gcc_trunk > g.region vector=points
GRASS 7.1.svn (nantahala):~/dev/grass/gcc_trunk > g.region res=5
GRASS 7.1.svn (nantahala):~/dev/grass/gcc_trunk > r.in.lidar input=/gisdata/lidar/points.las output=mean
```python
#!/usr/bin/env python

import os
import grass.script as gscript

def main():
    region = gscript.region()

    vectors = []
    for lidar_file in os.listdir('.
        if lidar_file.endswith('*.las'):
            bbox = gscript.read_command('r.in.lidar', input=lidar_file,
                output='foo', flags='g').strip()
            bbox = gscript.parse_key_val(bbox, wsep=' ', val_type=float)
            if (bbox['n'] < region['s'] or bbox['s'] > region['n'])
                or bbox['e'] < region['w'] or bbox['w'] > region['e']:
                gscript.info('Skipping file %s % lidar_file')
                continue
            name = 'tile' + lidar_file.rsplit('.', 1)[0]
            vectors.append(name)
            gscript.run_command('v.in.lidar', input=lidar_file, output=name,
                flags='r', class_filter=2)
            gscript.run_command('v.patch', input=vectors, output='merged_points',
                flags='b', overwrite=True)
            gscript.run_command('g.remove', type='vector', name=vectors, flags='f')

if __name__ == '__main__':
    main()
```
Python versus CLI

Documentation, Command Line (Shell, Bash, cmd.exe):

```
r.in.lidar input=points.las \ 
  output=elevation -e
```

Python:

```python
from grass.script import run_command
run_command('r.in.lidar',
    input="points.las",
    output="elevation",
    flags='e')
```
Module GUI

The image shows the GUI for the GRASS GIS module `r.in.lidar`, which creates a raster map from LAS LiDAR points using univariate statistics. The module settings include:

- **Name for output raster map**: `elevation`
- **Grid-decimated point cloud**: `points.las`
- **Optional**: `resolution=float`

The command line equivalent of the GUI settings is:

```
r.in.lidar -e input=points.las output=elevation
```
Points

- collected by lidar
- generated by Structure from Motion (SfM) from UAV imagery

Surface interpolated from points and visualized in GRASS GIS
Workflow overview

- Points
  - Decimation
  - Binning
  - Raster
    - Interpolation
      - Vector
        - Analysis
Surface interpolation

- **v.surf.idw**
  - Inverse Distance squared Weighting
- **v.surf.bspline**
  - Bicubic or bilinear Spline interpolation with Tykhonov regularization
- **v.surf.rst**
  - Regularized Spline with Tension
  - **v.surf.rst.mp** (experimental)
    - 2 millions of points in 11 minutes
Import and decimation

- \textit{v.in.lidar}
  - libLAS
  - LAS/LAZ to GRASS GIS native vector
  - data stored in GRASS GIS database
- decimation $\approx$ thinning $\approx$ sampling
  - count-based decimation (skips points)
  - grid-based experimental, others needed?
  - fast count-based as good as more advanced decimations
GRASS vector model and format

- topology and index
  - can be disabled (-b flag)
- attributes in a database
  - SQLite, PostgreSQL, . . .
  - can be disabled (-t flag)
- each feature can have any number of categories/classes
  - without attribute table
Linked external data

- *r.external*
  - raster data (GDAL)
  - *r.external.out* for newly created data

- *v.external*
  - vector data
    - GDAL/OGR
    - PostGIS including topology
  - *v.external.out* for newly created data
  - alternative: @OGR
    
    ```
    v.info map=.../directory@OGR
    layer=file
    ```

- missing: libLAS/PDAL backend
  - intermediate C API needed in PDAL or GRASS GIS
Current state of integration with PDAL

<table>
<thead>
<tr>
<th>PDAL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ Point Data Abstraction Library</td>
<td></td>
</tr>
<tr>
<td>▶ format conversions</td>
<td></td>
</tr>
<tr>
<td>▶ processing, filtering</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experimental integration</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ <code>v.in.pdal</code></td>
<td></td>
</tr>
<tr>
<td>▶ next: <code>r.in.pdal</code>, <code>r3.in.pdal</code></td>
<td></td>
</tr>
<tr>
<td>▶ runs PDAL filters during import</td>
<td></td>
</tr>
<tr>
<td>▶ filters are followed by GRASS processing</td>
<td></td>
</tr>
</tbody>
</table>
- \textit{r.in.lidar}
- Import and analysis
- Statistics of point counts, height and intensity
  - \( n, \min, \max, \sum \)
  - Mean, range, skewness, \ldots
Read multiple tiles as one

- `r.in.lidar`, option `file`
  - read multiple tiles as one
  - no merging

0.5 billion points in 90 files in minutes
Filtering points

- filter points by
  - range of Z
  - return
  - class
  - ...

- at the time of binning with
  *r.in.lidar*
  - minimal additional cost

zrange=180,250

zrange=180,250

175
160
162
257
235
Height above a surface

- `r.in.lidar`, option `base_raster`
- given surface + points cloud $\rightarrow$ height of features

- low additional memory requirements
Height above a surface

- different resolutions
  - 1m ground surface
  - 30m height above ground
- different statistics
- different combinations
  - surface can be e.g. top of the canopy
  - combine with zrange
  - combine with intensity
many algorithms are raster-based
  - a lot of data with continuous nature
  - natural spatial index

example:
1. count of ground points
2. count of non-ground points
3. used as image bands
4. segmentation using \textit{i.segment}
3D raster

- stacked 2D rasters
- challenging to visualize
- same principles as in 2D
  - e.g. 3D raster map algebra
3D raster

- stacked 2D rasters
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Binning points to 3D raster

- `r3.in.lidar`
- proportional count
  - count per 3D cell relative to the count per vertical column
- intensity can be used instead of count

- difference in vegetation structure
- vertical slice of 3D raster
- point count percentage
- dense
- sparse
Point heights reduced to surface

- `r3.in.lidar`, option `base_raster`
- height reduced by raster values
Trade-offs

Raster processing

- high memory (RAM) usage – fast
- low memory usage (high I/O) – slow

Vector processing

- slower than raster
  - e.g., interpolation much slowed than binning
- hard to make general statements

Visualization: range from binning on interpolated surface

Example: binning with base elevation subtraction: $\approx 1000$ files, $> 9$ billion points
$\approx 3$ hours, $\approx 10GB$ of memory (in-memory mode)
Ground detection

- `v.lidar.edgedetection`, `v.lidar.growing`, `v.lidar.correction` by Brovelli, Cannata, Antolin & Moreno

- `v.lidar.mcc` - multiscale curvature based classification algorithm by Blumentrath, according to Evans & Hudak

- PDAL filters.ground - now in `v.in.pdal`, progressive morphological filter by Zhang provided by PCL

Vaclav Petras (NC State University)
Sky-view factor

- $r.\text{skyview}$ (percentage of visible sky)

Comparison of shaded relief and sky-view factor
Local relief model (LRM)

- \textit{r.local.relief} (micro-topography, features other than trend)

30-60cm wide, 30cm deep, 60m long gully (resolution 30cm)
Landforms

- *r.geomorphon*
  - new landform classification approach
  - by Jasiewicz & Stepinski
libfreenect2 + PCL + GRASS GIS = \textit{r.in.kinect}

\textit{r.in.kinect}

- scans using Kinect
- OpenKinect libfreenect2
- Point Cloud Library (PCL)
- GRASS GIS libraries
  - C API
  - raster processing
  - regularized spline with tension interpolation

used in
Tangible Landscape
Summary

- rasterize early
- GRASS modules can work with large data
  - sometimes a special flag is needed
  - if not, report a bug
- 3D rasters, PDAL integration

Get GRASS GIS 7.1 development version at grass.osgeo.org/download

Slides and paper available at wenzeslaus.github.io/grass-lidar-talks

GRASS user mailing list
lists.osgeo.org/listinfo/grass-user
Acknowledgements

Software

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Datasets

Lidar and UAV Structure from Motion (SfM) data for GIS595/MEA792: UAV/lidar Data Analytics course
Nantahala NF, NC: Forest Leaf Structure, Terrain and Hydrophysiology. Obtained from OpenTopography.
http://dx.doi.org/10.5069/G9HT2M76
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Presentation software

Slides were created in \textsc{LaTeX} using the \textsc{beamer} class.