



GRASS GIS Vector State of the Art – Gearing towards GRASS GIS 7

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Abstract

The upcoming GRASS GIS 7 release improves not only raster processing and general design but the vector processing in the first place. GRASS GIS, as a topological GIS, recognizes that the topology plays the key role in the vector processing and analysis.

Topology ensures that adjacent geographic components in a single vector map are related. In contrast to non-topological GIS, a border common to two areas exists only once and is shared between the two areas. Topological representation of vector data helps to produce and maintain vector maps with clean geometry as well as enables the user to perform certain analyses that can not be conducted with non-topological or spaghetti data. Non-topological vector data are automatically converted to a topological representation upon import. Further more, various cleaning tools exist to remove non-trivial topological errors.

In the upcoming GRASS GIS 7 release the vector library was particularly improved to make it faster and more efficient with an improved internal vector file format. This new topological format reduces memory and disk space requirements, leading to a generally faster processing. Opening an existing vector requires less memory providing additionally support for large files. The new spatial index performs queries faster (compared to GRASS GIS 6 more than 10 times for large vectors). As a new option the user can select a file-based version of the spatial index for large vector data. All topological cleaning tools have been optimized with regard to processing speed, robustness, and system requirements.

The vector engine comes with a new prototype for direct read/write support of OGR Simple Features API. Additionally vector data can be directly exchanged with topological PostGIS 2 databases. This enables GRASS to read and write topological primitives beside native file-based format also to the topological PostGIS 2 databases. Considering the wide spread usage of Esri Shapefile, a non-topological format for vector data exchange, it is particularly advantageous that GRASS GIS 7 offers advanced cleaning tools.

For power users and programmers, the new Python interface allows to directly access functions provided by the underlying C libraries; this combines the ease of writing Python scripts with the power of optimized C functionality in the library backend.

Topology support

The GRASS GIS native vector format stores objects in a topology format. The OGC Simple Features can be imported into and exported from the GRASS GIS format through topological vector conversion. For attribute management several database management system (DBMS) with SQL queries are supported including SQLite (default DB backend), DBF, PostgreSQL, MySQL, ODBC.

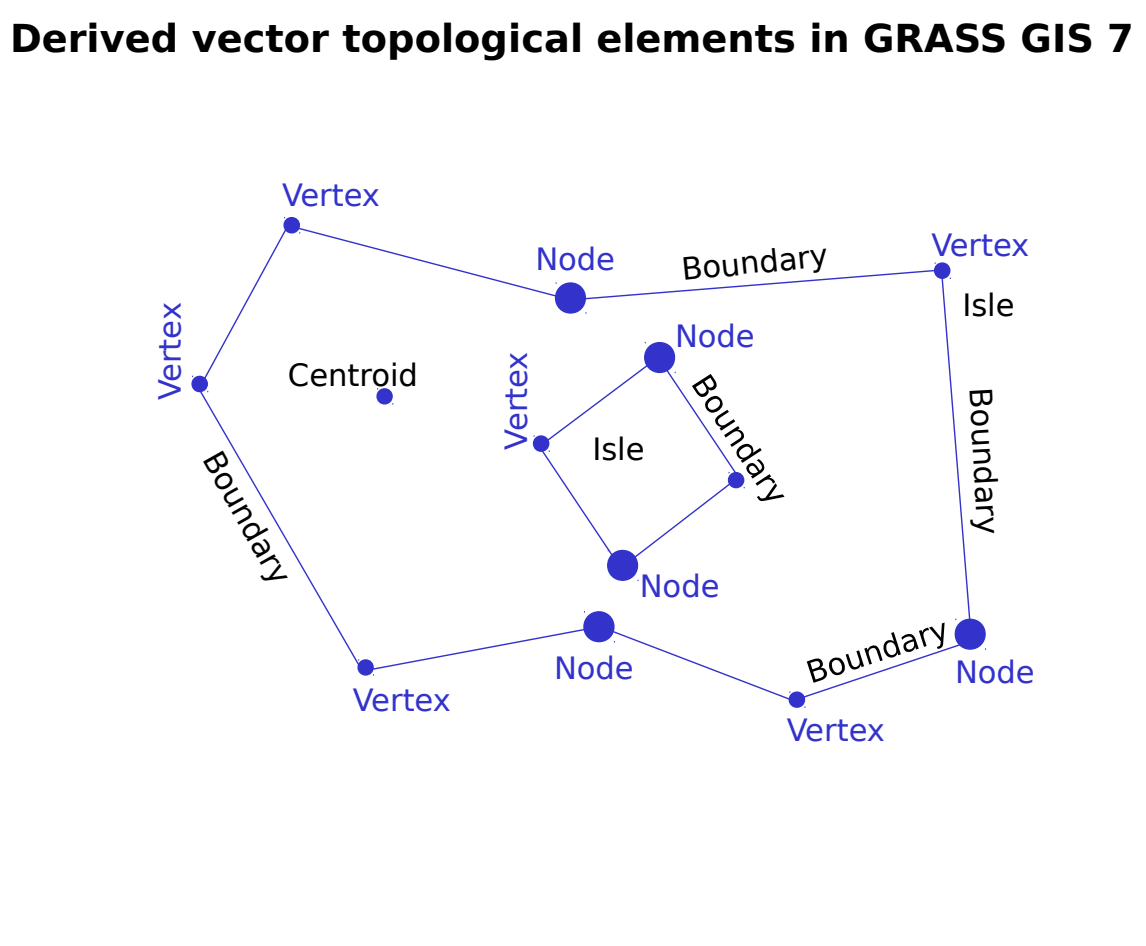
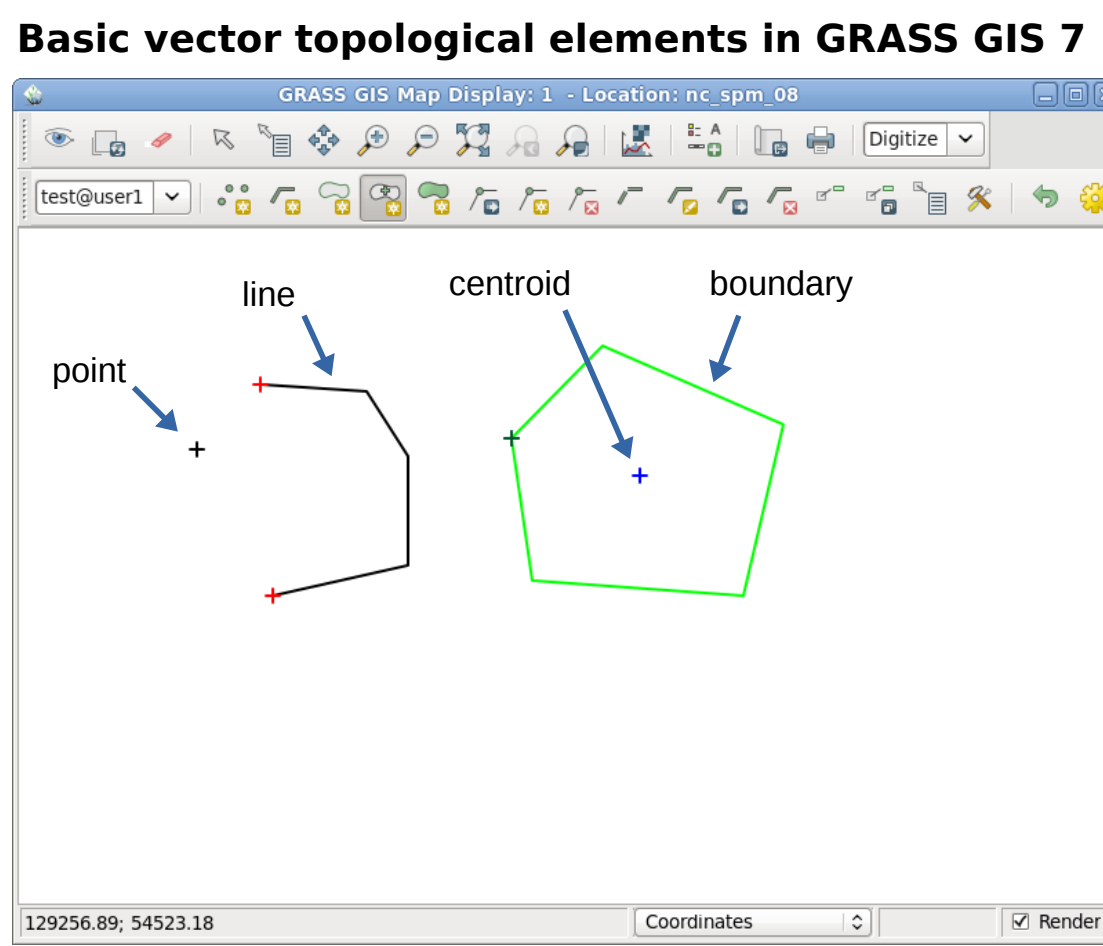


Figure 1a: Basic and derived topological elements in GRASS GIS 7

The following **basic topological elements** can be edited directly: point, centroid, line, and boundary. A GRASS vector map can contain a combination of several different types of the elements. From these basic geometry types the following **derived topological elements** can be generated: area (closed ring of boundaries + centroid), isle (closed ring of boundaries, no centroid), and node (at both ends of lines/boundaries). Isles and Nodes are not visible to the user. Furthermore face, kernel (3D centroid) and volume (3D area) as defined in the format.

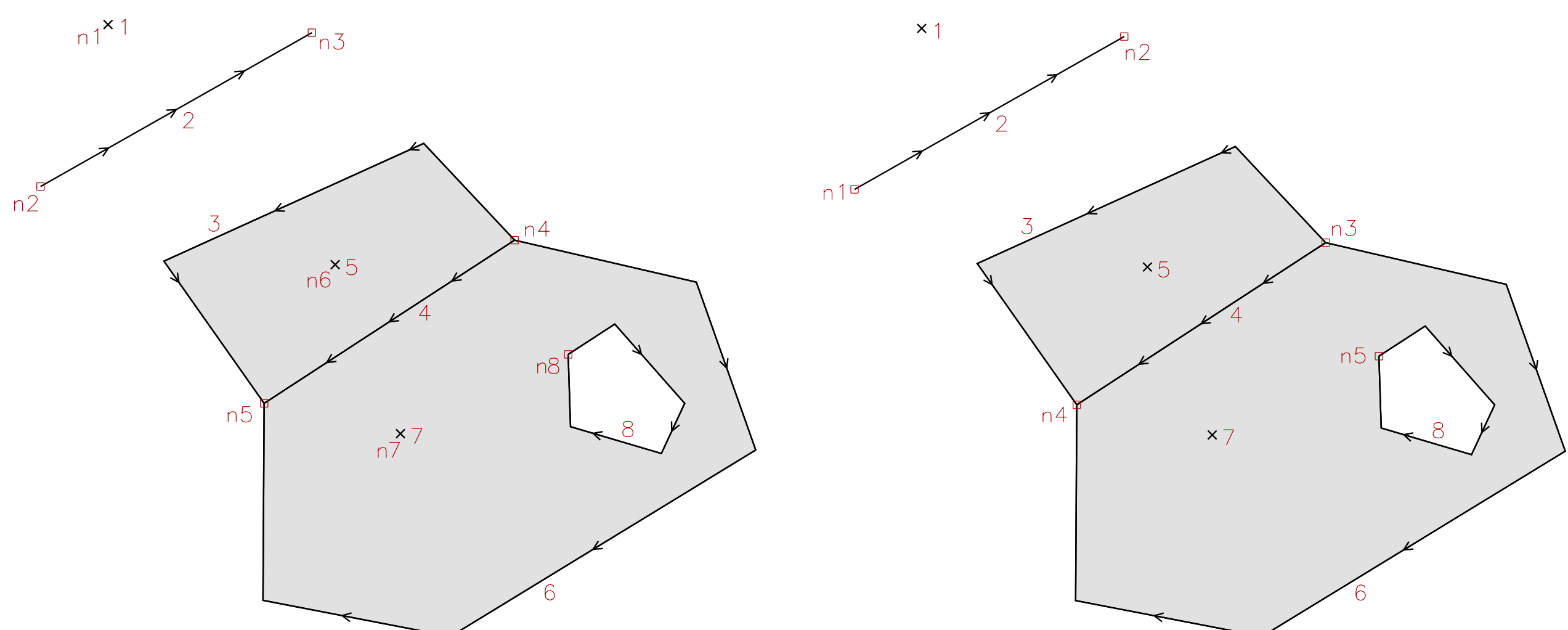


Figure 1b: Topology changes from version 6 to 7 after (points and centroids are represented by the nodes) [Landa 2013]

Data Sources

GRASS GIS 7 supports various data sources in read and write access. Beside native file-based raster and vector format GRASS allows to specify external data sources through GDAL/OGR library. GRASS GIS 7 also natively supports PostGIS database including its topological extension.

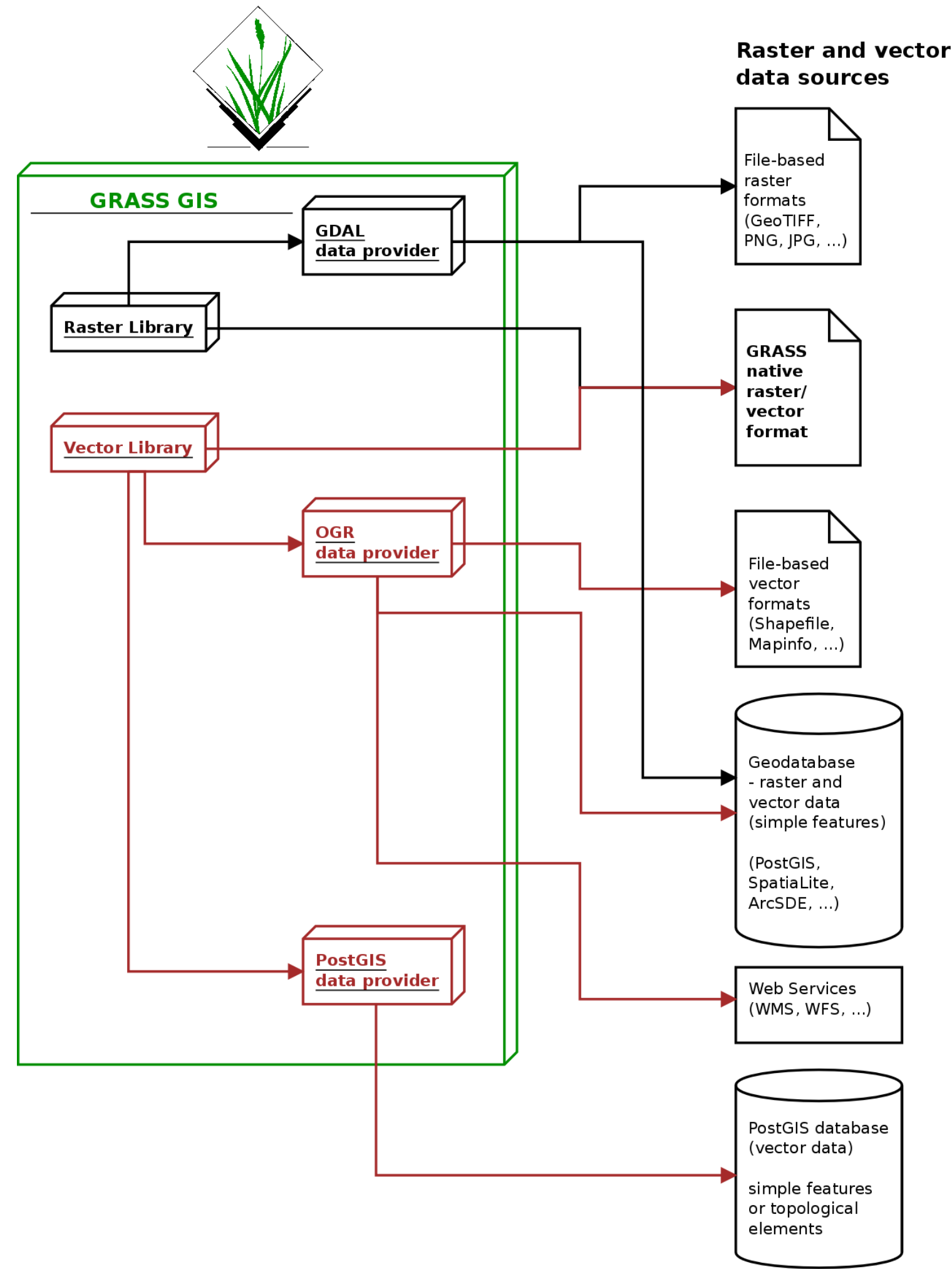


Figure 2: Supported data sources

PyGRASS: fast Python API

PyGRASS [Zambelli 2013] is an object-oriented Python API which allows efficient manipulation with GRASS rasters and vectors. It is easy-to-use but its performance is comparable to C code since it calls GRASS C API behind the scenes.

```
# create a point
>>> point = Point()
>>> point.x = 150.65
>>> point.y = 368.50
>>> point
>>> Point(150.650000, 368.500000)
# distance to another point
>>> point.distance(Point(160.2, 372.6))
10.39290623454286
# conversion to Well-known text (WKT)
>>> point.get_wkt()
'POINT(150.650000 368.500000)'
# bounding box of a line
>>> line = Line([(5, 12), (6, 13), (4, 19)])
>>> line.bbox()
Bbox(19.0, 12.0, 6.0, 4.0)
```

Other Improvements & Additions

- **v.distance**: Calculates distances from points, lines, or areas to points, lines, or areas.
- **v.overlay**: The processing speed has been substantially improved.
- **v.net.***: All vector network analysis tools provide now fine control over node costs.
- **v.voronoi**: New option to create Voronoi diagrams for areas.
- **v.rectify**: Vector data can now be georeferenced using various methods for 2D and 3D coordinate transformation.

GRASS GIS-PostGIS data provider: PostGIS 2 support

The native GRASS-PostGIS data provider allows the GRASS vector library to read and write PostGIS data directly without any external geospatial library. Beside simple features the provider also allows to work with topological elements through PostGIS Topology extension.

The support of PostGIS 2 Topology in GRASS GIS 7 is as follows:

- Points are stored as isolated nodes (*containing face* is null),
- Centroids are stored as isolated nodes (*containing face* is not null),
- Lines are stored as edges (*left face* and *right face* is 0),
- Boundaries are stored as edges,
- Areas are stored as faces (with id > 0),
- Isles are stored as faces (with id <= 0) (including universal face defined by PostGIS Topology).

Additional topological data related to nodes, lines, areas, and isles are stored in separated tables (see figure below).

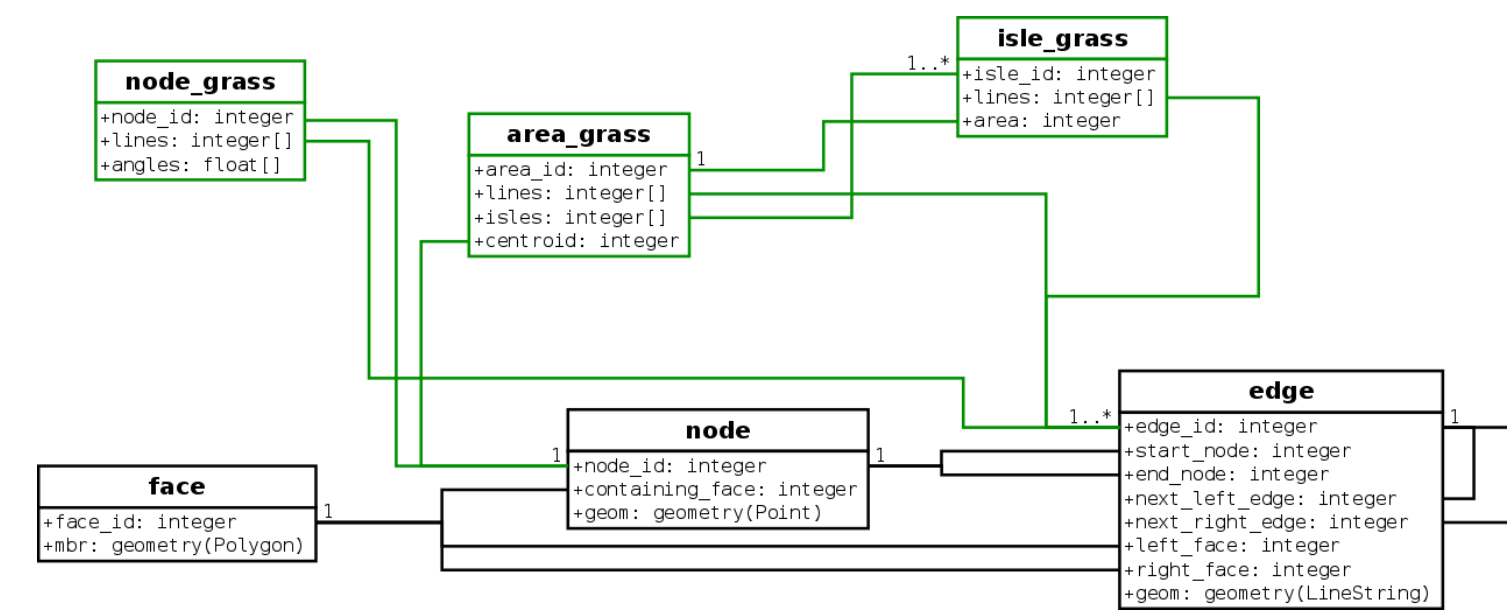


Figure 3: Extended PostGIS Topology structure

Dedicated modules

- **v.out.postgis**: Exports a vector map layer to PostGIS feature table.
- **v.external**: Creates a new pseudo-vector map as a link to a PostGIS feature table.
- **v.external.out**: Defines vector output format.

Lidar

The Lidar library (www.liblas.org) used by GRASS GIS permits the import of LAS Lidar data. The imported data can be in raster (**r.in.lidar** using statistics of choice) or in vector format (**v.in.lidar**).

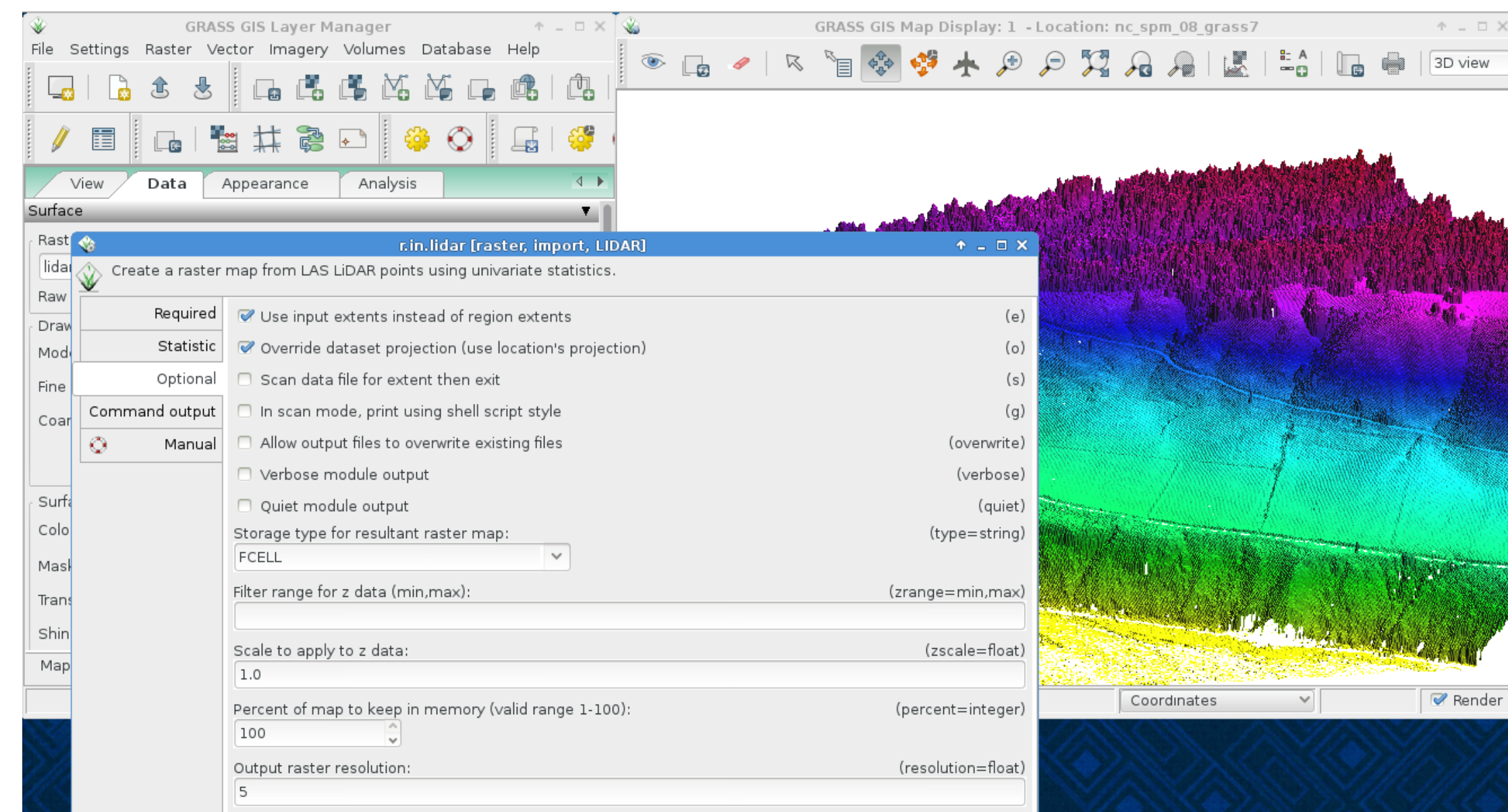


Figure 4: Example for LAS support in GRASS GIS 7: rapid LAS data assessment through binning

On-farm water storage study with lidar data in NSW (Australia) developed a full remote sensing monitoring methodology of water availability with lidar-based bathymetric survey and multi-source remote sensing survey [Chemin 2011].

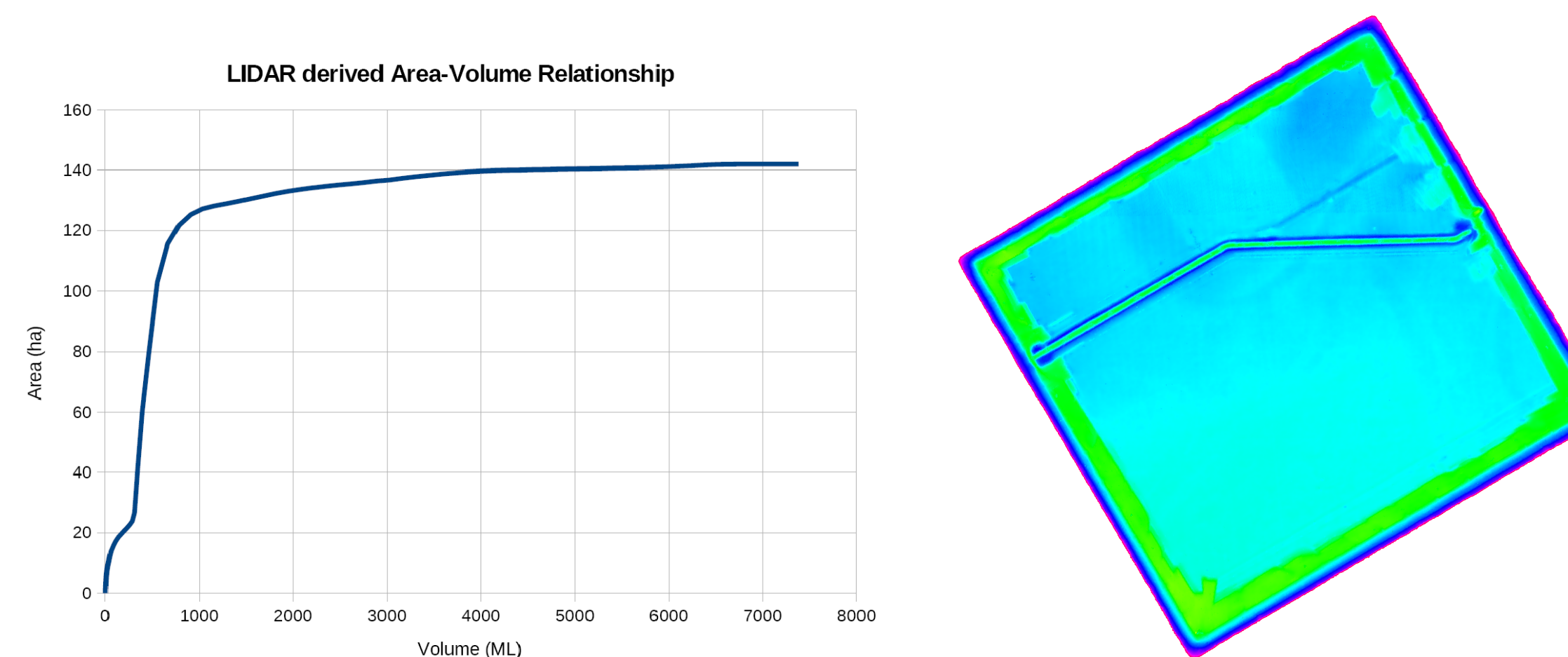


Figure 5: On-Farm-Water-Storage Lidar survey and Depth-Volume-Area surveying [Chemin 2011]

3D

GRASS 7 has 3D topological capabilities, as described in Figure 5a. An application to buildings is found in Figure 5b.

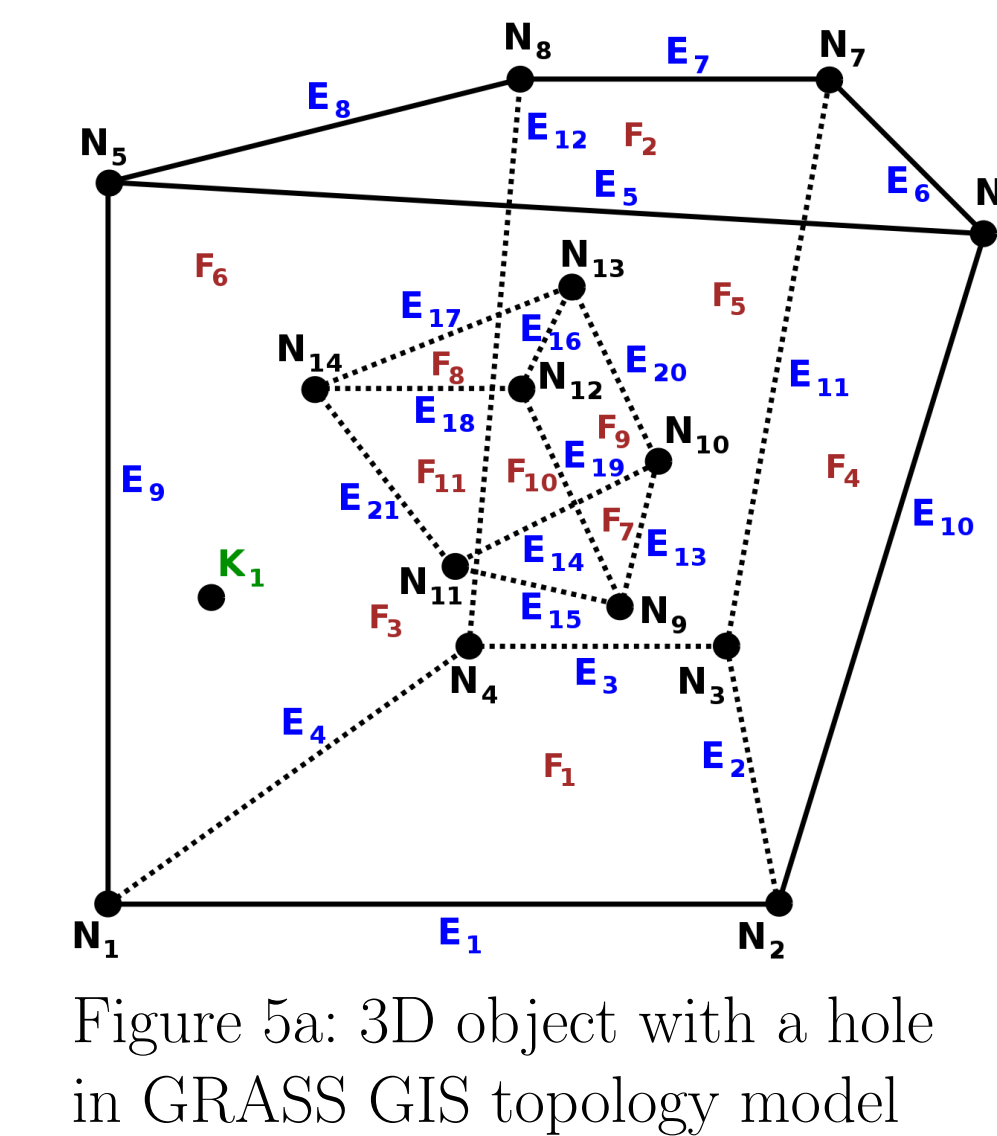


Figure 5a: 3D object with a hole in GRASS GIS topology model

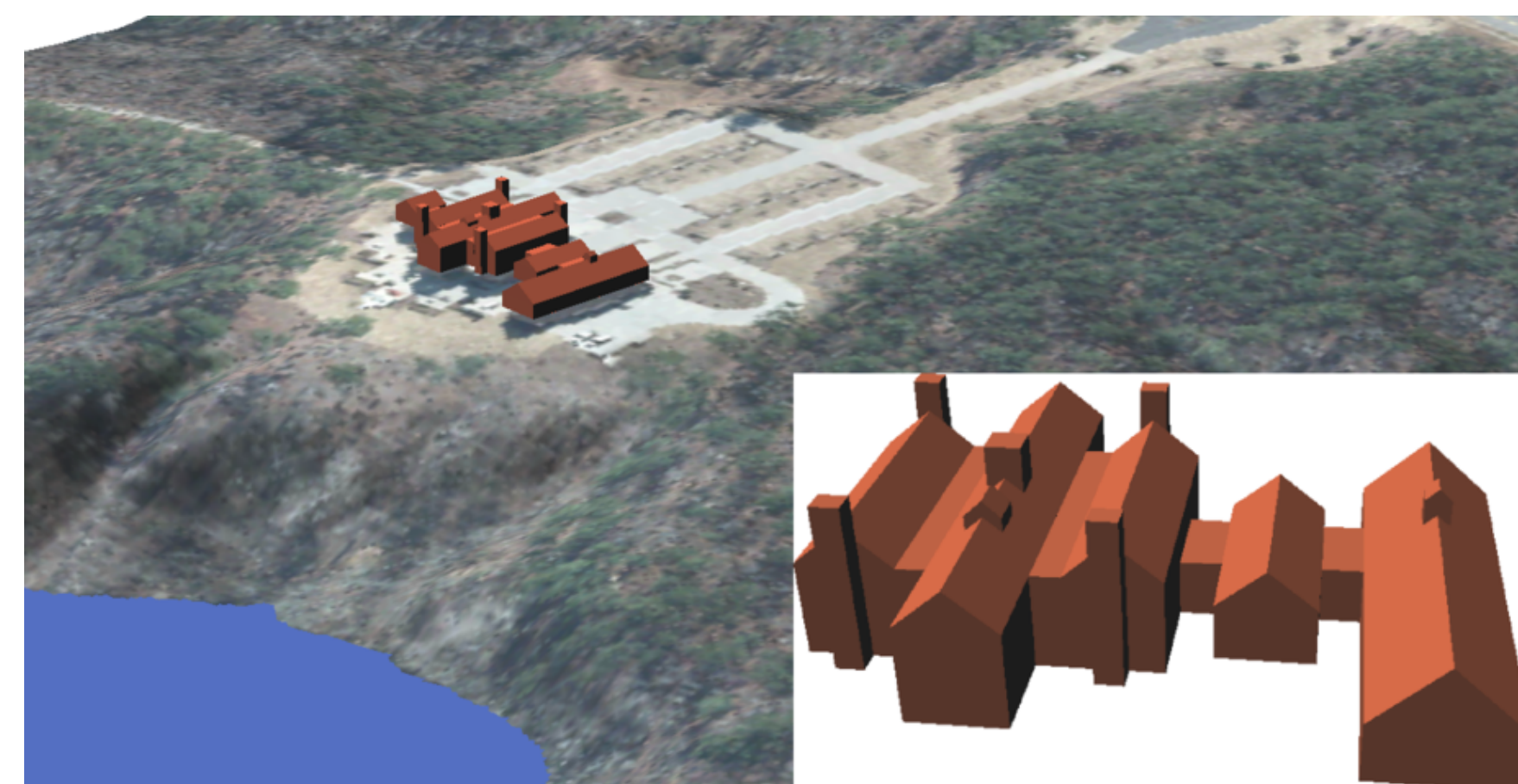
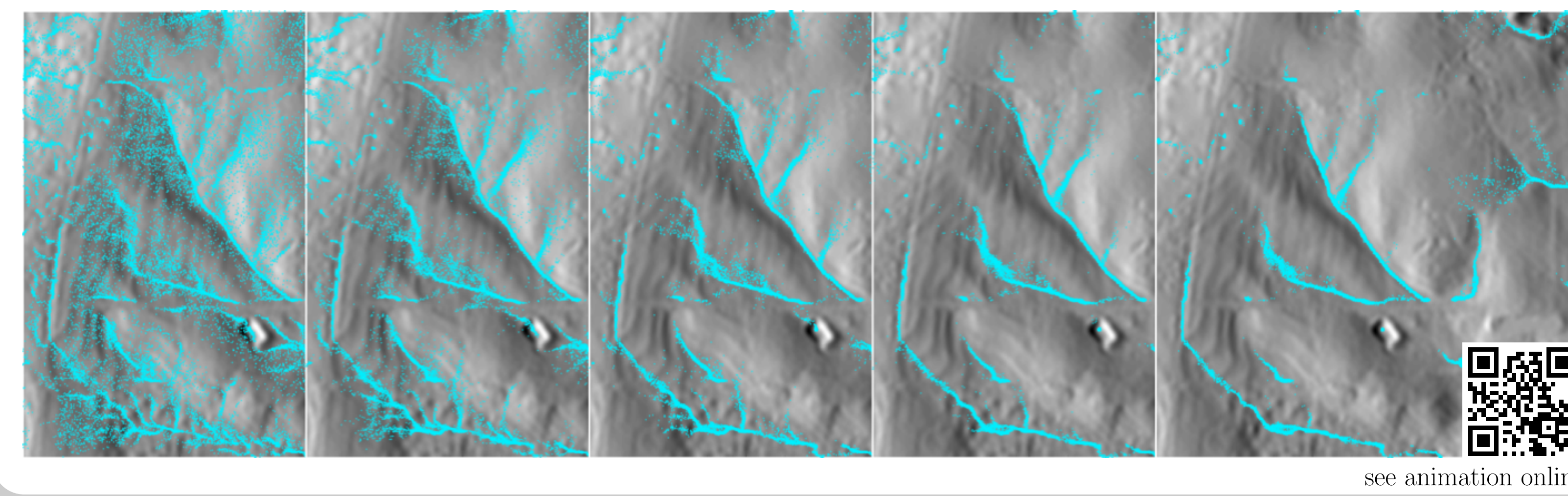


Figure 5b: 3D model of Chancellor's House (NC State University) visualized in GRASS GIS

TGRASS: temporal framework

TGRASS [Gebbert 2014] provides support for large spatio-temporal data handling and analysis, and is fully integrated into GRASS GIS 7. It introduces the concept of space-time dataset as a series of vector, raster, or 3D raster data with temporal metadata. In the simple example below, we computed a series of vector data representing particles in a water flow simulation, created a space-time dataset and registered the vectors to this dataset based on time stamps assigned during the vector creation. The result can be then quickly visualized using GRASS GIS Animation Tool.

```
r.sim.water -t elevation=elev lid792 1m dx=dx dy=dy depth=depth outwalk=walker outiter=1
t.create output=particles type=stvds temporaltype=relative semantictype=mean title="Particles" desc="Particles"
t.register input=particles maps='g.mlist --q type=vect pattern=walker* separator=' type=vect
g.gui.animation stvds=particles
```



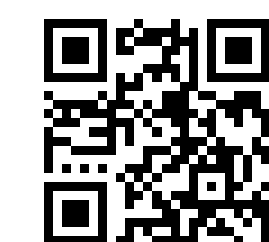
see animation online

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