A GRASS GIS based Spatio-Temporal Algebra for Raster-, 3D Raster- and Vector Time Series Data

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Enhancing the well known and widely used map algebra proposed by Dr. Charles Dana Tomlin [1] with the time dimension is an ongoing research topic. The efficient processing of large time series of raster, 3D raster and vector datasets, e. g. raster datasets for temperature or precipitations on continental scale, requires a sophisticated spatio-temporal algebra that is capable of handling datasets with different temporal granularities and spatio-temporal extents.

With the temporal enabled GRASS GIS [2] and the GRASS GIS Temporal Framework new spatio-temporal data types are available in GRASS GIS 7, called space time datasets. These space time datasets represent time series of raster, 3D raster and vector map layers. Furthermore the temporal framework provides a wide range of functionalities to support the implementation of a temporal algebra.

While spatial capabilities of GRASS GIS are used to perform the spatial processing of the time stamped map layers that are registered in a space time dataset, the temporal processing is provided by the GRASS GIS temporal framework that supports time intervals and time instances. Mixing time instance and time intervals as well as gaps, overlapping or inclusion of intervals and instances is possible. Hence this framework allows an arbitrary layout of the time dimension.

We implemented two ways to process space time datasets with arbitrary temporal layout, the temporal topology and the granularity based spatio-temporal algebra. The algebra provides the functionality to define complex spatio-temporal topological operators that process time and space in a single expression.

The algebra includes methods to select map layers from space time datasets based on their temporal relations, to temporally shift time stamped map layers, to create temporal buffer and to snap time instances of time stamped map layers to create a valid temporal topology. In addition spatio-temporal operations can be evaluated within conditional statements. These operations can be assigned to space time datasets or to the results of operations between space time datasets.
The temporal vector algebra adds spatial overlay and buffer operations that can be performed on temporal related vector map layers that are registered in space time vector datasets. Whereas the temporal raster and 3D raster algebra uses a subset of the arithmetic operators and spatial functions from the raster algebra in GRASS GIS. It provides in addition spatio-temporal neighborhood operators and spatio-temporal functions. All operations between multiple space time datasets can be combined in nested expressions and are preprocessed by meta data topology analysis before the relevant expressions are computed with parallel processing.

[1] Tomlin, C. Dana., 1990. Geographic Information Systems and Cartographic Modeling. Englewood Cliffs, NJ: Prentice-Hall.

[2] Gebbert, S., Pebesma, E., 2014. A temporal GIS for field based environmental modeling. Environ. Model. Softw. 53, 1-12.