Geophysical Research Abstracts
Vol. 17, EGU2015-11641, 2015
EGU General Assembly 2015

Regridding Scientific Mesh Data Using Arbitrary Cell Neighborhood Information

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A spacial case of the *regrid* operator uses information of neighboring cells of a cell of interest to perform interpolation on scientific meshes. Example use-cases are smoothing skewed data fields, computing value of the first derivative in oceanographic applications, etc. Using neighbors' information is proved to improve the accuracy of the computations for a cell of interest. The regrid works in two steps: mapping step which assigns to each cell of a mesh a set of its neighboring cells and interpolation step which estimates the data on each cell by combining the data from its neighbors.

The common method to specify a cell neighborhood is the *stencil* string which is originally defined only for structured meshes, e.g., five-point stencil. The stencil was later generalized to express neighborhood on unstructured meshes. A stencil w.r.t. an unstructured mesh consists of a sequence of digits representing the dimensions of neighboring cells of a cell. For instance, the stencil 010 w.r.t. a mesh means any calculation for a vertex needs to have access to all the adjacent vertices (i.e., vertices sharing an edge with the vertex of interest).

The stencil uses hard coded dimensions and thus contains no topological abstraction. Moreover, it is not obvious whether the result is the union of elements visited in each intermediate layer (*hull*) or the elements only in the last layer (*halo*). In addition, it is not possible to filter intermediate cells using predicates. Finally, existing mesh libraries (e.g., GrAL and *GridFields*) which accommodate the stencil concept do not provide a generic implementation, i.e., a specific Python or C++ APIs needs to be implemented for each stencil.

We propose a neighborhood expression which uses the topological relationships (i.e., boundary, co-boundary, and adjacencies) to express arbitrary cell neighborhood. The expression contains any number of the topological relationships w.r.t. to a mesh and a cell as initial context of the neighborhood search. Moreover, each function can have zero or more predicates which will be used to filter its output. To implement the expression, we designed a general mesh data model which allows traversing mesh topology using the relationships, i.e., the model explicitly stores incidence and adjacency relationships for each cell. The model is based on the property graph data model of graph databases, i.e., the graph nodes contain data fields and geometries and the links show the relationships. We implement a regrid operator which uses the proposed neighborhood expression to interpolate data. The operator is declarative meaning that the user does not need to write API for each particular expression. We evaluate the regrid on a real oceanographic dataset using four queries smoothing queries and compare the performance with GrAL implementations written in C++.