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GIS – based Pre – processing tools for TOUGH2

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ABSTRACT

As well know, TOUGH2 [1] is a flexible and robust numerical simulator used all over the world mainly in the field of high enthalpy geothermal reservoirs studies. It is designed to work with non isothermal flows of multicomponent, multiphase fluids in one, two and three-dimensional porous and fractured media.

GRASS [2] is a Free & Open Source Geographical Information System, currently used in academic and commercial area around the world, as well as by many governmental agencies and environmental consulting companies.

An irregular grid with several blocks could enhance simulation prediction accuracy, but represents a limiting factor during the History Matching process and the sensitivity analysis because of the larger amount of data to be managed.

Thanks to the creation of advanced scripts in GRASS GIS environment, it's possible to generate irregular grids (according to the geometrical rules required by Integrated Finite Difference Method), and to populate automatically the numerical model with proper parameters previously determined, through the generation of an attribute table. This is then exported to be processed by AMESH [3] (a Free & Open Source Code distributed by Lawrence Berkeley National Laboratory, that has been properly adapted for our purposes) in order to create the mesh input file for TOUGH2. In particular we are referring to the TOUGH2 embedded in the iTOUGH2 code [4]. Finally, by means of a specifically developed software, the simulation's output file is reconnected to the numerical model, and the results can be queried through GRASS GIS.

We are successfully applying these tools to the full field simulation of an Italian high enthalpy geothermal reservoirs, with a substantial reduction of pre-processing times.

Further developments will include raster cross – sections, map algebra and voxel models to reduce population errors.

Preliminary tests are encouraging, showing that the new GIS approach effectively improve the creation, population and management of complex numerical models in terms of time and error reduction.

INTRODUCTION

The Integral Finite Difference Method (IFDM) used by TOUGH2 requires that the segment connecting two contiguous nodes to be perpendicular to the interface between the nodes themselves. This condition is generally satisfied by regular 2D polygons and by Voronoi Regions / Thiessen Poligons. A smart discretization of a spatial domain usually requires higher resolution only in some areas of interest, and this means that we need to refine the grid locally.

With regular grids the refinement involves also areas outside the interesting one, generating redundant useless blocks that have the only effect of both increasing computational time and calculation errors.

Irregular grids overcome this problem, generating IFDM compliant grids with smaller blocks inside refinement areas and greater ones outside, better fitting model complexity.

Generation and management of such grids are not so easy, and this is why only few research groups all over the world use them, thanks to home – made tools.

GIS software, combining geographical representation and database management systems, is the ideal tool to win the limits of such complex discretization work.

The use of a set of four dedicated GRASS-scripts with graphical user interface and AMESH is all the user needs to generate the geometrical input file for TOUGH2 in about one hour of work (almost independently of the grids dimension).

GIS – BASED PRE – PROCESSING

All pre – processing activities are executed through GRASS GIS, under Linux operating system. This let the user easily control and visualize all the available information (e.g. geographic domains, geological maps, etc) and choose the useful ones.

Once selected the information required, it's necessary to create a "refinement map", that is a vector map specifying domain's boundary and refinement areas. This operation has been automated in a bash script called "v.refine".

The second step is the most important one, and concerns the creation of the 3D grid vector map and its associated attribute table containing geometrical and structural information of the numerical model. The user has to select the areal constraints for the blocks generated inside and outside the refinement areas, the vertical bounds of the 3D domain and the layer's number for vertical discretization. The sequence of commands required to reach the goal (more than 40) are automatically performed by another bash script, called "v.t2irr".

Once created the default numerical model, the user can update the information stored in the attribute table through SQL queries with the GRASS command "v.db.update".

Finally, thanks to a third bash script called "g.amesh" that both manage the specific input and run the dedicated AMESH program, the user obtains the geometrical input file for TOUGH2.

A fourth and last script, called "v.t2out", thanks to a dedicated software, let the user catch simulation results from the output file, and creates an attribute table for each data set printed at every time step, all linked to the 3D grid vector map. In this way, the user is able to query all the available data for each grid node.

SOFTWARE ARCHITECTURE

The official release of GRASS GIS 6.4.0 svn has been enriched with "v.trimesh" [5], a GRASS module which embeds "Triangle" [6] to generate a Delaunay triangles grid with smaller entities in selected refinement areas.

Several dedicated software (mainly coded in C++) developed by the research team and AMESH have been installed to be run in background through GRASS scripts.

CONCLUSIONS

Pre – processing for TOUGH2 input file has been improved, thanks to GRASS GIS, in particular:

- The analysis and the correct use of all the data available for the creation and population of the numerical model is substantially simplified;
- the generation and management of 3D numerical models with irregular grid are easier and faster;
- the total time necessary to manage the large amount of data has been significantly reduced (from days to hours).

Thanks to these tools, our work for the full field geothermal reservoir simulation has been greatly optimized. They could be applied also within other TOUGH2 application fields (e.g.CO2 storage, nuclear waste disposal, environmental assessment and remediation) .

AKNOWLEDGEMENTS

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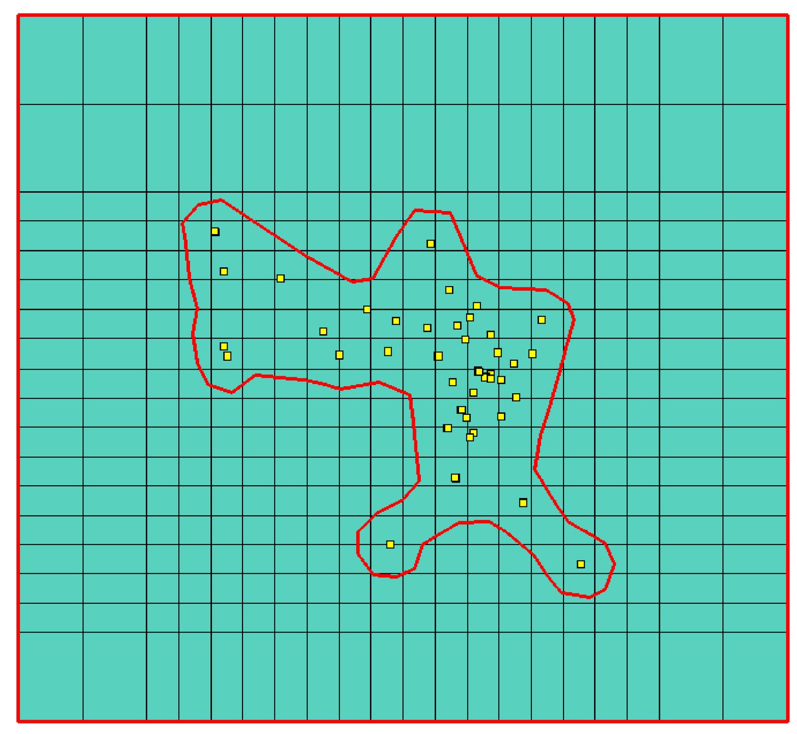
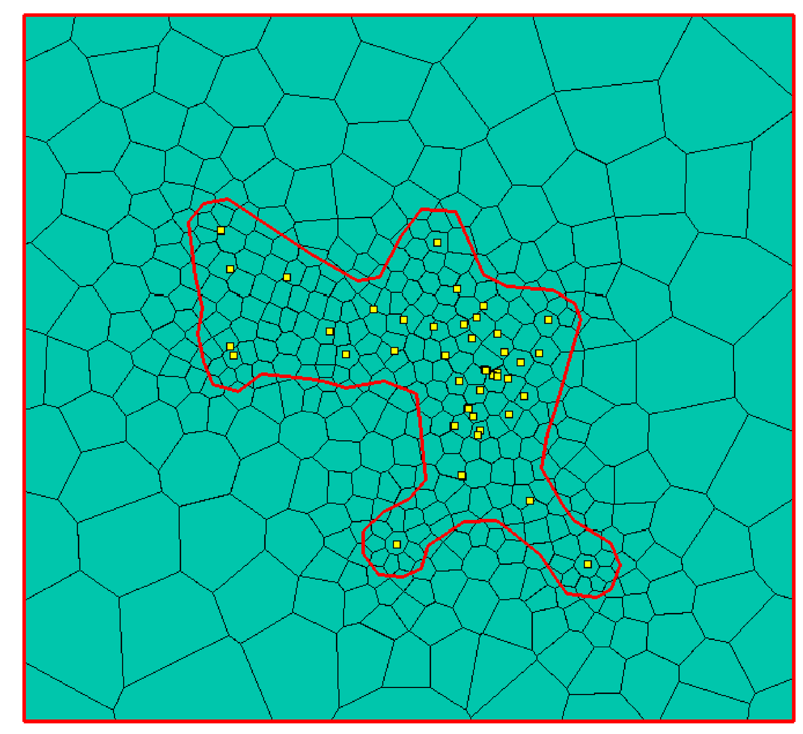
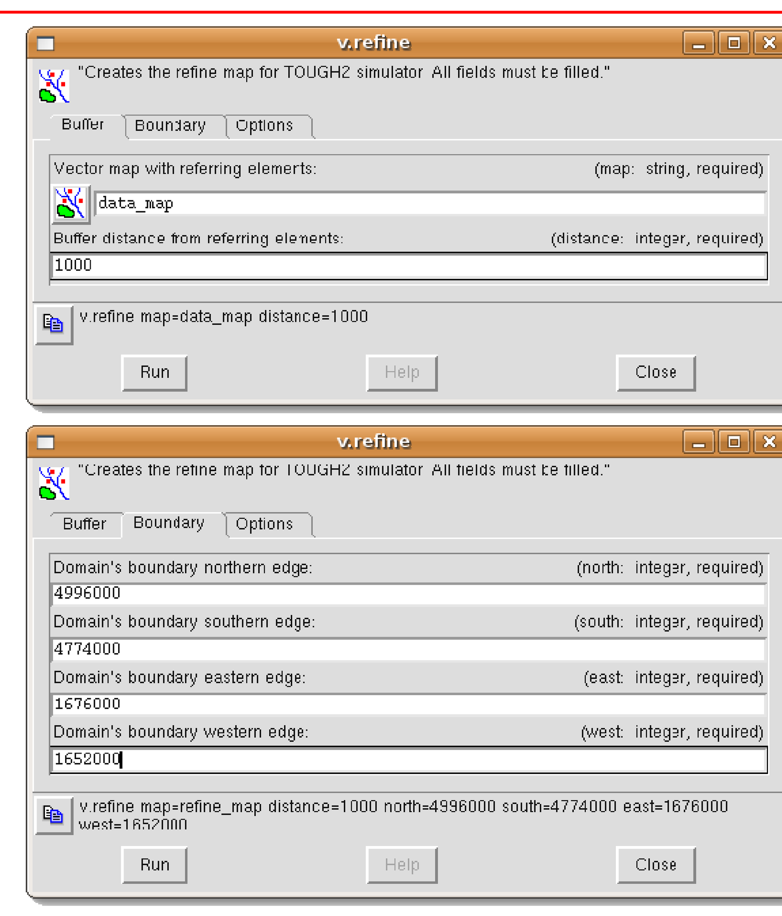
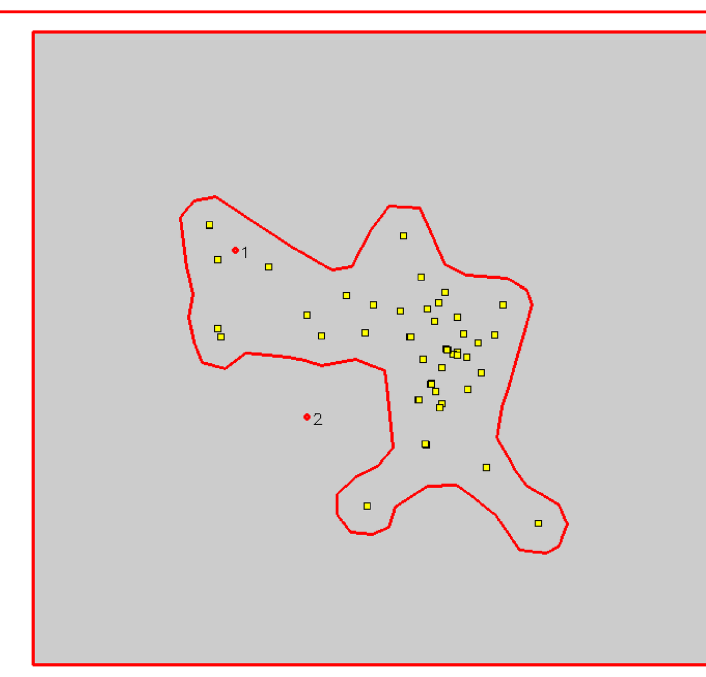


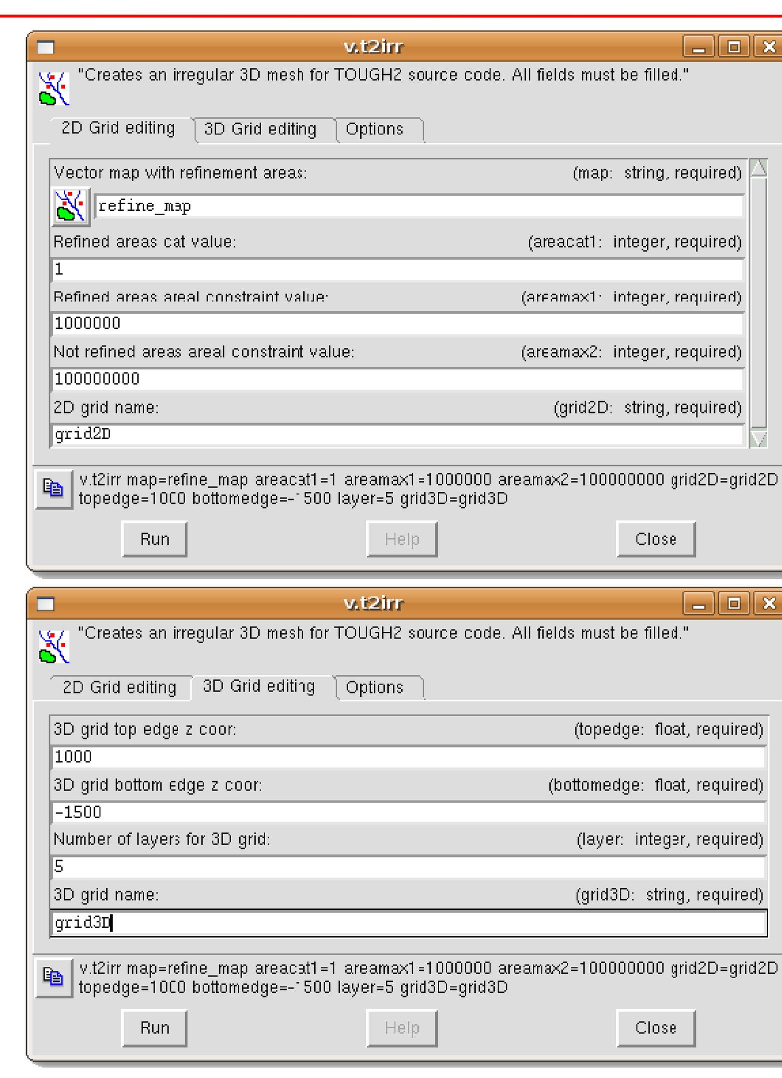


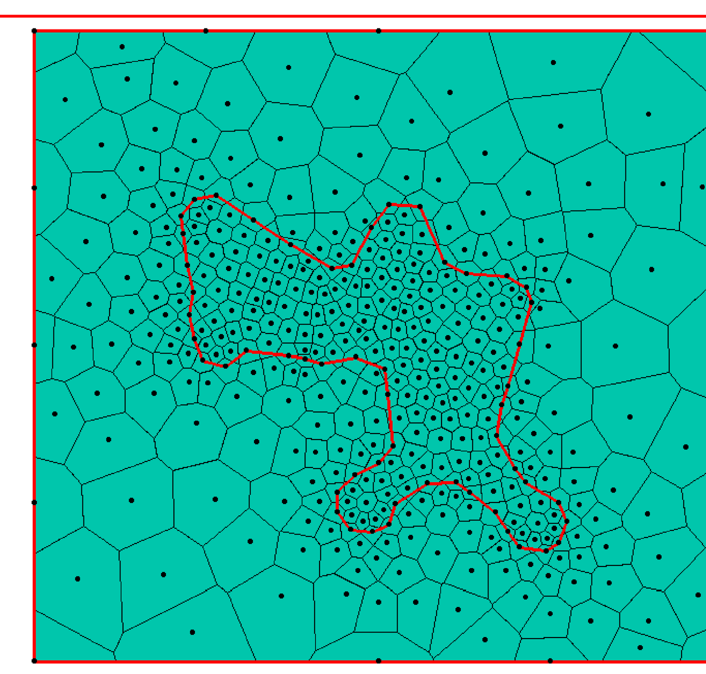
Comparison between regular and irregular 2D grid. The first one presents several unuseful small blocks outside refinement area (red line). Yellow boxes represent referring data for refinement.

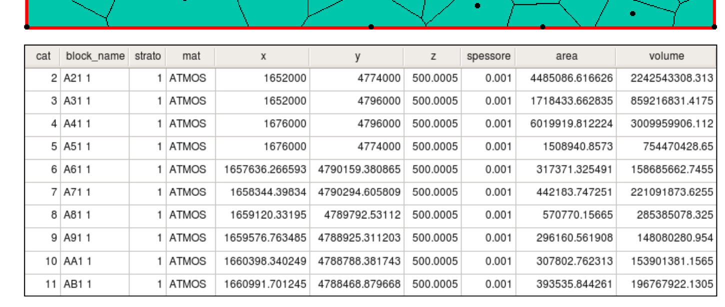




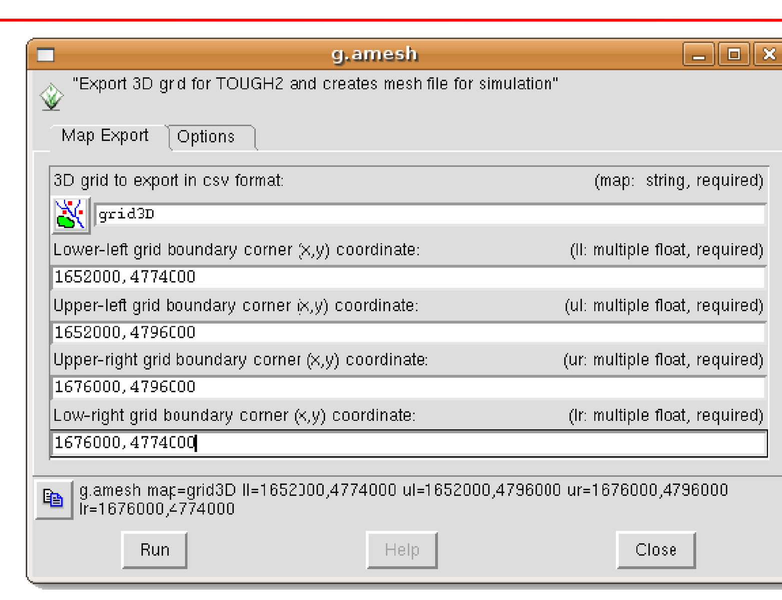
Screenshots from "v.refine" GUI and refinement map obtained (after a sharpening operation with GRASS vector digitizer). An accurate sharpening is fundamental to create a good refined grid.

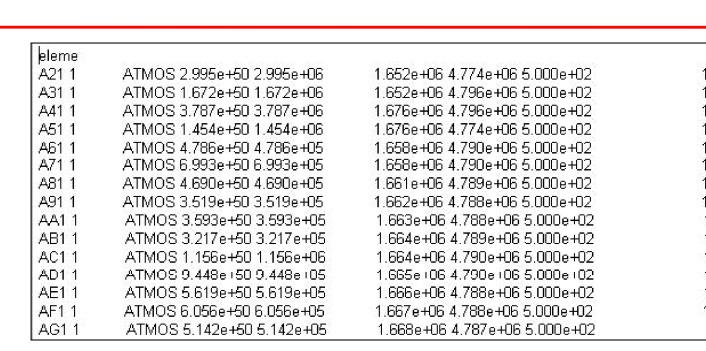






screenshots from "v.t2irr" GUI, 2D irregular grid obtained and related nodes (black dots), attribute table linked to 3D numerical model.





Screenshot from "g.amesh GUI and mesh file obtained from g.amesh. This file report material, volume, area, (x,y,z) coordinates for each grid's node, contiguous blocks node distance from common interface and interfaces area request by TOUGH2 input format.

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