Resampling structured grids into regular ones

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Abstract

Structured grids and some of their applications in natural sciences are discussed. The problem of their visualization and quantitative evaluation is considered and possible ways for its solution sketched. Resampling a structured grid onto a regular one is one of the possible solutions offering the additional benefit of opening up more possibilities for qualification and quantification, too. Some methods for achieving this goal are presented, their advantages and disadvantages compared, and preliminary results from the application of our own method shown.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Graphics data structures and data types

1. Introduction

In natural sciences like geological or material sciences, measurement data are often acquired on topologically regular but geometrically irregular sampling grids. Topologically regular data is data that can be accessed in rectangular fashion using an *i*-*j*-*k* index. Such grids are commonly referred to as structured grids[1]. Subsequent FEM-calculations run on such grids provide their results naturally also on these (or related) structured grids. But it is often desired to obtain results on regular sampling grids - for purposes like visualization or quantification. The question is how to achieve this. Basically, it is an interpolation problem for a specific kind of data–structured one. Scattered data interpolation methods would work, but since they don't take into consideration the topological regularity of the structured sampling grid, they can't be expected to deliver optimal results. Brute-force methods, like finding for each of the resampling points the enclosing cell of the structured grid, and interpolating a new value from the cell vertices would also work but only very slowly and inefficiently which is infeasible in a production environment. We encountered this problem in connection with earth measurement data pertaining to a specific mining area in Ostrava, CR, and collected on a structured grid over decades (Fig. 1).

It has been used in numerous simulations ever since for calculating and predicting the stress situation in the area. This was done on another structured grid suitable for doing the FEM-calculations (Fig. 2).

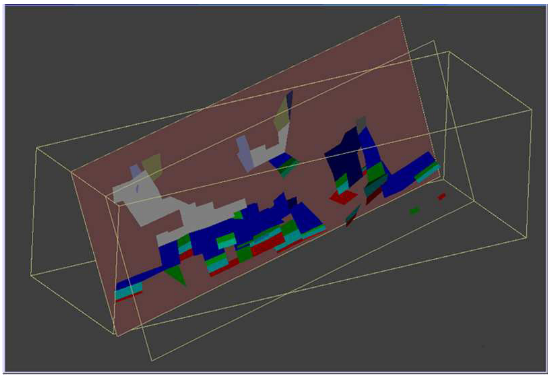

Figure 1: *A mining area with a structured grid used for collecting measurement data.*

Subsequently, the simulation results were visualized and used for judging the present and future stress situation in the area. Unfortunately, only two-dimensional cut-plane images were possible with the calculated structured grids carrying the simulation results (Fig. 3).

Our task was initially to propose and develop an efficient structured grid visualization method. After studying

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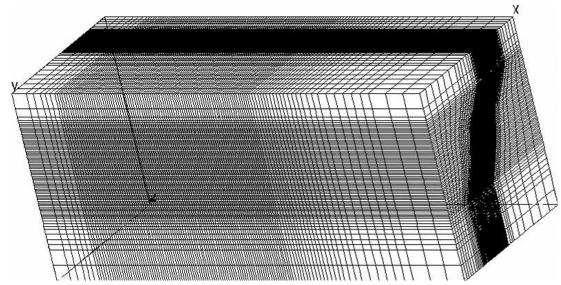

Figure 2: *A structured grid over the mining area used for FEM-calculations.*

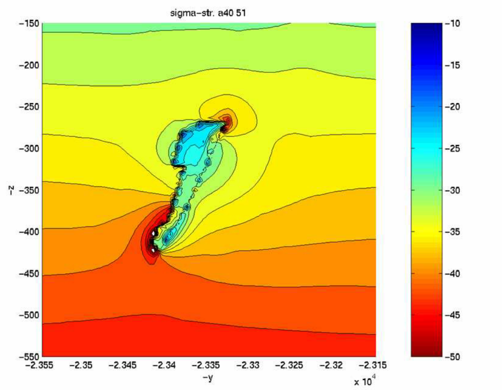

Figure 3: *A cut-plane through the results of an FEM-simulation stress situation.*

the problem and considering the previous work in the field, we reached the conclusion that visualization is only part of the task, and actually more is needed—vis. precise measurements and quantitative statements. For achieving the goal, we decided the best way to go is through resampling the whole structured dataset and generating a regular volume/grid. This would allow the use of legacy volume visualization methods–which abound in soft- and hardware[2] meanwhile, and also enable the use of quantification techniques on the resampled data, like calculating volumes, areas and lengths.

2. Previous Work

Having clarified the goal, we set about studying the field of resampling various sample grids and learning about specific techniques for regularizing structured grids. Astonishingly enough, a thorough research of the literature didn't turn up any specific reference for resampling structured data grids. There are some papers dealing with isosurfacing of such grids[3, 4], or visualizing them[5, 6], or resampling[1, 7] resp. visualizing[2, 8, 9, 10] *unstructured* grids but not a single one deals with the problem at hand!

However, isosurfacing or DVR visualization is often not enough or not even applicable—e.g. when there are no implicit surfaces in the data set at hand, or when more then just visualizing the data is required, e.g. quantitative measurements.

3. Method and Implementation

Having realized that, we decided to develop our own method from scratch.

For realizing our goal, we chose to implement Gaussian splatting in a first step. It consists of the following approach: each sample of the structured grid is injected and spread (splat) over a spherical neighborhood in a new regular, cartesian grid. While doing so for every sample of the structured grid, the newly calculated distribution values are accumulated in the initially empty voxels in the new grid/volume. The radius of the splats is controlled through an input parameter and depends ideally on the average inter-sample distance of the original structured grid. The sample values in the splats fall off towards the periphery of the sphere according to a 3D Gaussian distribution, i.e. Gaussian splatting.

The method was implemented in the framework of our volume processing and visualization package `VORTEX`[11] using our `f3d`-file format and library for storing and manipulating volumetric data sets[12] which was specifically extended to deal with structured grids. It was then tested on simulated and real structured grids.

The next steps would be to compare this first results with such from a typical scattered data interpolation method, e.g. Shepard interpolation, or nearest-neighbor interpolation, and also with results achieved through a generalized scan-conversion method, which still has to be developed and implemented. This is left for the future now.

4. Results

We implemented Gaussian splatting in the framework of our `VORTEX` package[11, 13] and tested it on simulated structured grids we calculated from the MRI dataset of the brain which has been in the public domain for test purposes for quite a while now and also on the earth measurement and simulation data we introduced in the beginning.

Figure 4 shows an original slice of the MRI dataset.

Figure 5 shows the corresponding slice of an artificial structured data set derived from the first one by severely undersampling it as clearly seen.

The result of applying Gaussian splatting on this resampled structured grid is seen in Figure 6 and, in our opinion, clearly shows the potential of the method.

The method was then applied to the structured grid data

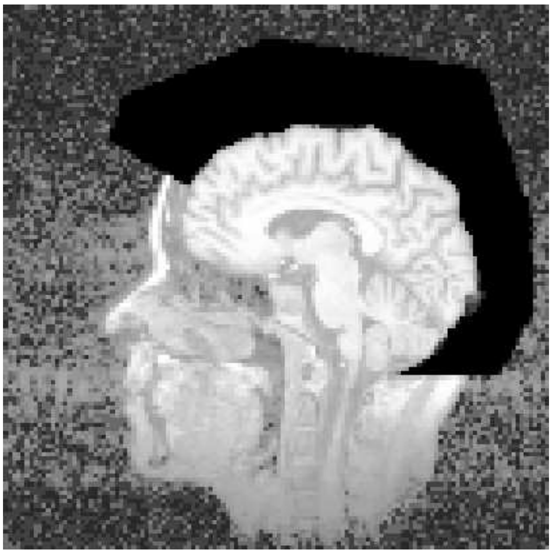

Figure 4: *An original slice from an MRI dataset.*

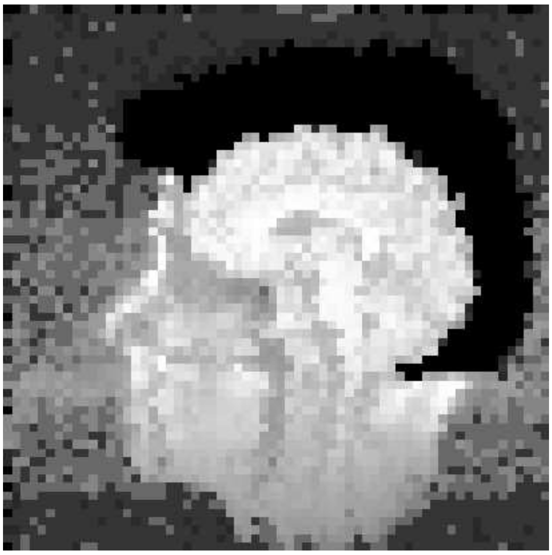

Figure 5: *The corresponding slice of an artificial structured grid.*

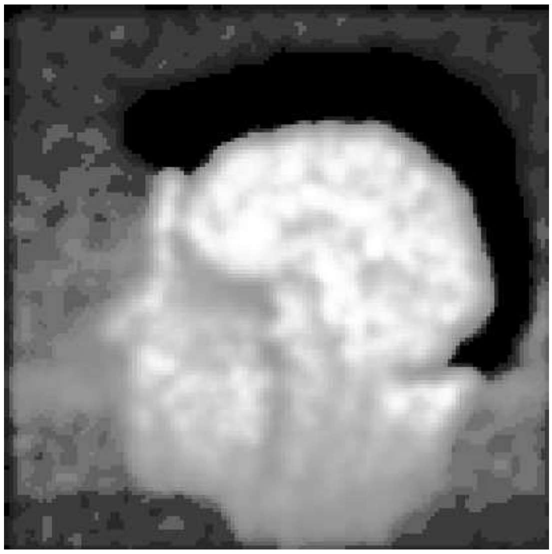

Figure 6: *The resulting slice after Gaussian splatting.*

Figure 7: *A volume-rendered visualization of the resampled grid.*

from Fig. 1. The results of resampling the earth measurement data from this mining area comprise now a regular volumetric dataset. It was then visualized applying direct volume rendering as implemented in our VORTEX. One image from the resulting animation sequence is shown in Fig. 7.

Many more visualization possibilities are now open with the resampled regular volumetric dataset as well as evaluation ones.

5. Conclusions

Resampling structured grids is a necessary operation and a still not completely solved but interesting problem. Providing effective and efficient algorithms for performing the resampling operation would open up the whole meanwhile vast field of volume visualization means and methods. This seems the better way to go instead of developing specific structured grid visualization algorithms. The more so, considering the fact that visualizing the structured grid is often only part of the task—the other part consisting usually of answering quantification queries like calculating volumes, areas and lengths in the resulting grid of simulation results which is also much easier done on regular grids. We showed in our preliminary study that Gaussian splatting is a promising and worthwhile way to go. The next steps would be to implement other resampling methods, e.g. scattered data interpolation, or scan conversion, and see how they compare in terms of efficiency and results' quality with Gaussian splatting.

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References

1. Steven J. Owen. A survey of unstructured mesh generation technology. In *7th International Meshing Roundtable*, pages 239–267, 1998. 1, 2

2. R. Yagel, D. M. Reed, A. Law, P. Shih, and N. Shareef. Hardware assisted volume rendering of unstructured grids by incremental slicing. In *Proceedings 1996 Symposium on Volume Visualization*, pages 55–62, 1996. 2

3. Yarden Livnat, Han-Wei Shen, and Christopher R. Johnson. A near optimal isosurface extraction algorithm using the span space. *IEEE Transactions on Visualization and Computer Graphics*, 2(1):73–84, 1996. 2

4. Han-Wei Shen, Charles D. Hansen, Yarden Livnat, and Christopher R. Johnson. Isosurfacing in span space with utmost efficiency (ISSUE). In Roni Yagel and Gregory M. Nielson, editors, *IEEE Visualization '96*, pages 287–294, 1996. 2

5. H. Lu and R. Hammersley. Adaptive visualization for interactive geometric modeling in geoscience. In *The 8th International Conference in Central Europe on Computer Graphics, Visualization and Interactive Digital Media 2000*, 2000. 2

6. Chandrajit L. Bajaj, Valerio Pascucci, and Daniel Schikore. Fast isocontouring for improved interactivity. In *VVS*, pages 39–43, 1996. 2

7. Randolph E. Bank and Jinchao Xu. An algorithm for coarsening unstructured meshes. *Numerische Mathematik*, 73(1):1–36, 1996. 2

8. Eric C. LaMar, Bernd Hamann, and Kenneth I. Joy. Multiresolution techniques for interactive texture-based volume visualization. In David Ebert, Markus Gross, and Bernd Hamann, editors, *IEEE Visualization '99*, pages 355–362, San Francisco, 1999. 2

9. Prashant Chopra and Joerg Meyer. Incremental slicing revisited: Accelerated volume rendering of unstructured meshes. In *2nd IASTED International Conference Visualization, Imaging and Image Processing (VIIP 2002)*, Benalmadena, Malaga, Spain, September 9-12, 2002. 2

10. R. FARIAS, J. MITCHELL, and C. SILVA. Zsweep: An efficient and exact projection algorithm for unstructured volume rendering. In *Volume Visualization Symposium*, pages 91–99. ACM Press, October, 2000. 2

11. Leonid I. Dimitrov. Object-oriented design and implementation of VORTEX: a C++-class library with Tcl-interface for volume visualization. In Emanuel Wenger and Leonid I. Dimitrov, editors, *Proceedings of the 6th Intl. Workshop on Digital Image Processing and Computer Graphics (DIP-97), Applications in Humanities and Natural Sciences*, volume Proc. SPIE 3346, pages 155–166, Vienna, Austria, 1998. SPIE—The International Society for Optical Engineering. 2

12. Miloš Šrámek and Leonid I. Dimitrov. `f3d` — a file format and tools for storage and manipulation of volumetric data sets. In *1st International Symposium on 3D Data Processing, Visualization and Transmission*, pages 368–371, Padova, Italy, June 19–21, 2002. 2

13. Igor Hollander, Leonid I. Dimitrov, Miloš Šrámek, D. I. Hobday, and N. A. Thacker. Visualization of Talairach co-registered fMRI findings using the VORTEX rendering package. In H. U. Lemke, M. W. Vannier, K. Inamura, A. G. Farman, and K. Doi, editors, *Computer Assisted Radiology and Surgery*, Proceedings of the 14th International Congress and Exhibition, San Francisco, 28 June - 1 July 2000, page 1020, Amsterdam, 2000. Elsevier Science Ltd. 2