REGULAR HEXAHEDRON TESSELLATION ALGORITHM FOR 3D COMPLEX ENTITY MODELS WITH INSIDE CAVITIES

GUO Jiateng[1], WU Lixin[1, 2], MA Hongbin[1], YANG Yizhou[1]

1 Institute for Geo-informatics & Digital Mine Research, Northeastern University, Shenyang, China
2 Academy of Disaster Reduction and Emergency Management, Beijing Normal University, Beijing, China

1. ABSTRACT

The 3D entity model with a data structure of regular hexahedron, which is usually called as 3D regular block entity model, is now widely used in many domains such as resources estimation (RE) and finite element analysis (FEA). In these domains, each regular hexahedron element of a 3D entity should be respectively evaluated with spatial related properties. However, 3D entity models are usually constructed based on finite and sparse geometrical elements such as feature points and contour line strings. These models are finally represented with connected triangles as their surface but nothing in their hollow interior part. We need a method to tessellate these models to blocks and fill the hollow interior with them. This paper mainly introduces an effective tessellation algorithm for converting 3D entity models which are represented as closed wire frames (collections of surface triangles) to 3D regular block models which are represented as collections of regular hexahedrons. With this algorithm, both simple 3D entity model with single outside boundary and complex 3D entity model with inside cavities can be tessellated to collections of regular hexahedrons which are constrained to the inside and outside boundaries.

There are usually three main steps to tessellate the 3D wire frame model to collections of regular hexahedrons. Firstly, we should compute out the axis-oriented minimum box (AOMB) of the model in preparation. We can determine the minimum space extent which we need to tessellate by the left-bottom-front point and the right-top-back point of the AOMB. Secondly, we need to fill the AOMB with regular hexahedrons which have three grid sizes on each coordinate axis. Thirdly, we need to judge whether the center point of each regular hexahedron is inside the 3D entity model. The ordinary method for this judgment is called as ray method. In this method, the intersection times between a ray which emit from the center point and model are computed and the parity of the times is used to make the determination, but this method doesn't always work because of the complexity of intersection situations. So we proposed a new algorithm named as ternary-axes-scan (TAS) method. In this method, three series of detecting needles array along the three coordinate axes (x-axis, y-axis and z-axis) are put on and cross through the 3D wire frame model; three series of intersection point-pair array, which record the

minimum and maximum x value, y value and z value between each judging needle and the model, are computed out. The point-in-or-out determination turns into judging whether the x value, y value and z value are in the coordinate scope of three point-pair along three axes at the same time. This method performed well in tessellation efficiency.

For complex 3D entity models with several inside cavities, the contents of intersection point-pair between detecting needles and the model need to be expanded. Not only the minimum and maximum x value, y value and z value should be record, but also the intersection point-pair between detecting needles and the inside cavities should be record. Several coordinate segments of each detecting needle indicate the center point's position, which can be outside the model, inside the cavities and inside the model.

In order to promote the tessellation accuracy, sub-grid-size is adopted in this method. The grid-size is re-divided into sub-size on three coordinate axes, each center point of the sub-grid is judged whether in the model to compute the volume factor for each main grid. An accurate regular hexahedron tessellation can be realized by this method.

We have made a sample application in resources estimation domain. A gold ore-body wire frame model is tessellated into regular hexahedrons. The inverse distance weighting (IDW) interpolation method is used to evaluate each regular hexahedron with gold grade. The 3D block model of this gold ore-body is visualized with Au-grade distribution information.

Keywords: regular hexahedron, tessellation, cavity, block model, resources estimation, finite element analysis, GIS

2. ILLUSTRATIONS AND GRAPHS

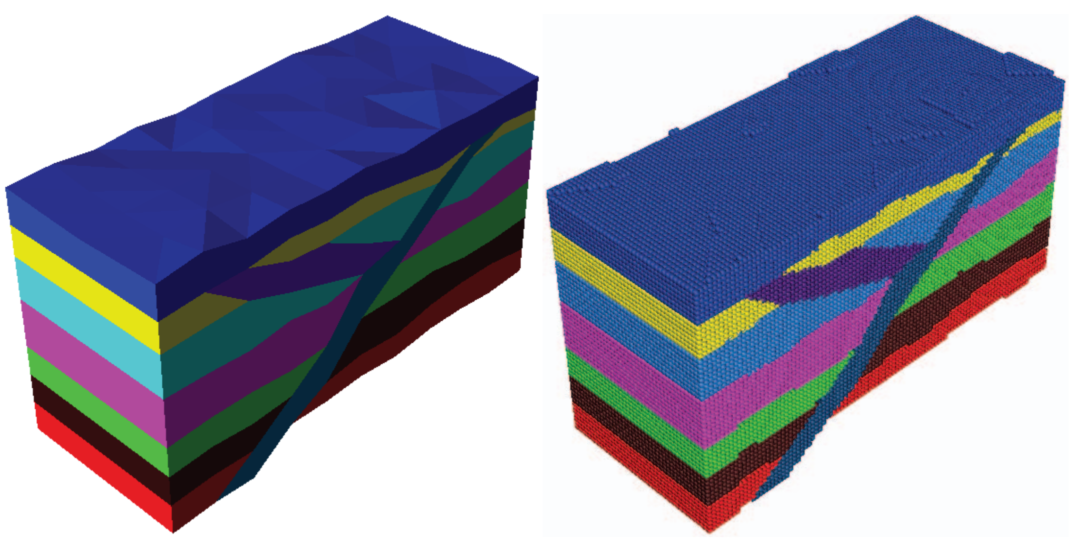

Fig.1 geo-entities represented as wire frame model and regular hexahedron model

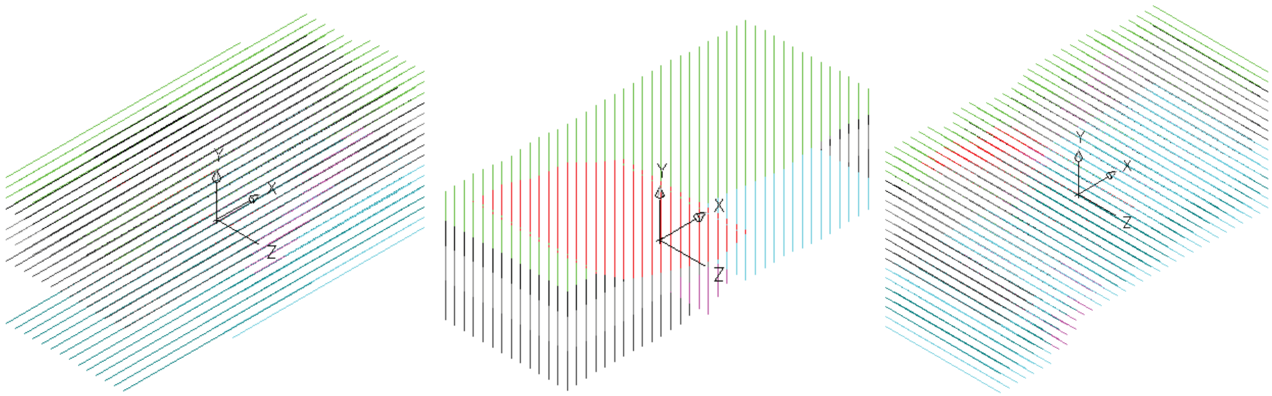

Fig.2 detecting needles array along x-axis, y-axis and z-axis

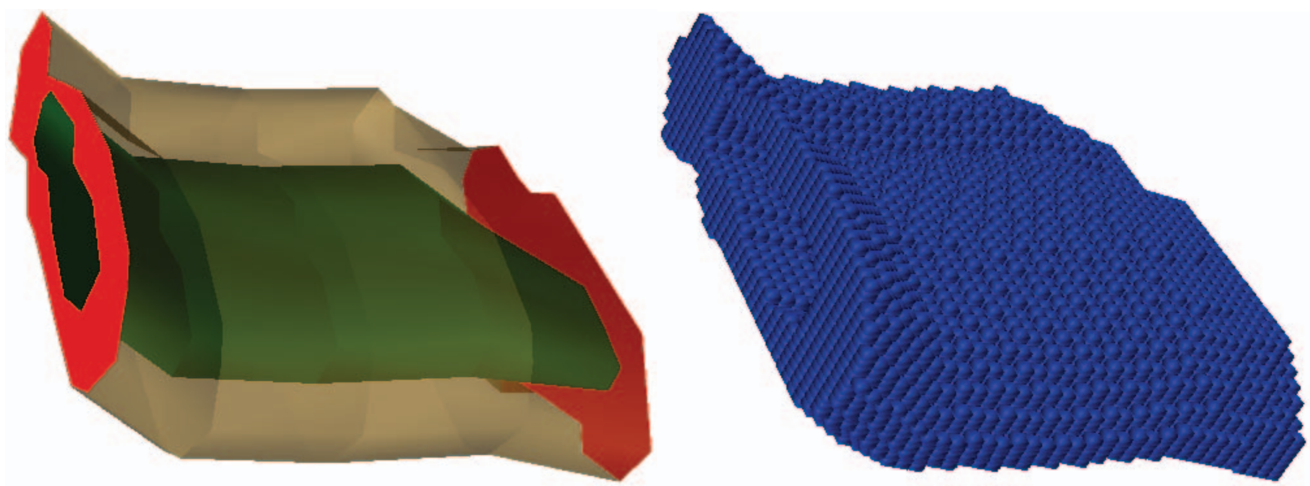

Fig.3 3D geo-entity with inside cavity

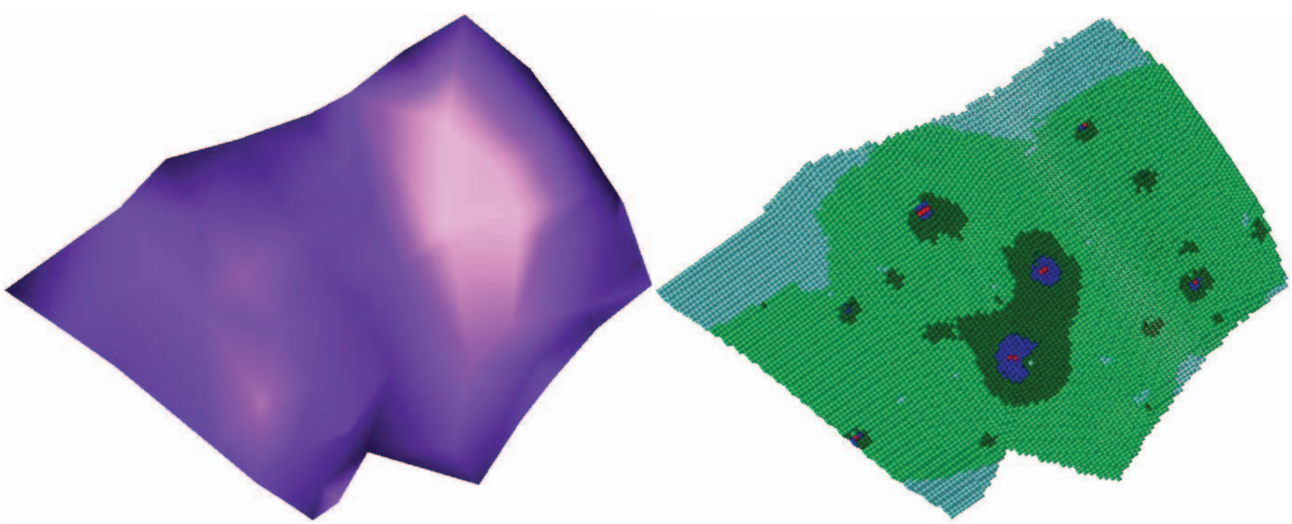

Fig.4 gold ore-body with Au-grade inverse distance weighting interpolation

3. REFERENCES

[1] Yaohong D. Jiang, "Block model conversion using binary space partitioning trees," *Computers & Geoscience*, Elsevier, vol. 22, pp. 409-417, 1995.

[2] Amanatides and Woo, J. Amanatides and A. Woo, "A fast voxel traversal algorithm for ray tracing," *Proc. Eurographics '87 (1987)*, pp. 3–10, 1987.

[3] B. Arnaldi, T. Pril, and K. Bouatouch, "A new space subdivision method for ray tracing CSG modeled scenes," *Visual Computer*, vol. 3, pp. 98–108, 1987.

[4] Jiange Tao, "3D GIS Integrated Model simulation algorithm Based on Block Model," *2008 IEEE Pacific-Asia Workshop on Computational Intelligence and Industrial Application*, Elsevier, pp. 315-319, 2008.

[5] Ding S, Mannan MA and Poo AN, "Oriented bounding box and octree based global interference detection in 5-axis machining of free-from surfaces," *Computer-Aide Design*, vol. 36, pp. 81-94, 2004.

[6] Liu Ch Y, "The Construction Method of Geometric Objects in 3D Terrain," *Computer Applications*, vol. 21, pp. 29-30, May, 2001.

[7] Norbert Pfeifer, "A subdivision algorithm for smooth 3D terrain models," *ISPRS Journal of Photogrammetry & Remote Sensing*, vol. 59, pp.115– 127, 2005.

[8] T.J. Tautges, T. Blacker, and S.A. Mitchell, "The wisker weaving algorithm: a connectivity-based method for constructing all-hexahedral finite element meshes," *International Journal for Numerical Methods in Engineering*, vol. 39, pp. 3327 – 3349, 1996.

[9] K.C. Chan, I. Gargantini, and T.R. Walsh, "Double connectivity filling for 3D modeling,", *Tech. Rep., Univ. Western Ontario, London, Ontario*, pp. 46, 1986.

[10] M. Tamminen, O. Karonen, and M. Mntyl, "Ray-casting and block model conversion using a spatial index," *Computer Aided Design*, vol. 16 no. 4, pp. 203–208, 1984.