Can Grid and TIN coexist?

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Abstract

The regular square grid (Grid) and the Constrained Delaunay Triangulated Irregular Network (TIN) are two main data structures of the Digital Elevation Model (DEM). To take advantage of both merits of the Grid and TIN, we proposed a new method to construct the Grid-TIN based DEM based on previous studies on the Grid-TIN hybrid mesh. Our Grid-TIN hybrid mesh can be constructed through embedding the local TINs into a global grid seamlessly. Our case study shows that this method can be used to construct the Grid-TIN based DEM successfully by use of local high precise spatial data and global coarse grid-based DEM. Both the local refined terrains and global coarse terrains are depicted well by the Grid-TIN based DEM. Although the Grid has raster data structure and the TINs belongs to vector data structure, our study shows that the Grid and TIN can indeed coexist well. Moreover, our study also indicates that the Grid-TIN based DEM can be indirectly visualized to some extent using existing commercial GIS software.

1. Introduction

The regular square grid (Grid) and the Constrained Delaunay Triangulated Irregular Network (TIN) are two kinds of main data structures of the Digital Elevation Model (DEM). The Grid-based model is the mainstream of DEM because of its simple data structure and high processing efficiency. However, it is relatively difficult for the Grid-based model to represent some important terrain characteristics (e.g. peaks, caves, and abrupt cliffs etc.) because of its unified spatial resolution. The only effective way of retaining these critical terrain characteristics as possible is to decrease the cell size of the Grid, which will greatly increase the amount of data and its data redundancy simultaneously. On the other hand, compared with the Grid-based model, the TIN-based model has better ability to retain these terrain characteristics. However, the TIN-based model also has relatively complex data structures and low processing efficiency. The real-world terrains are always relative complex and composed of different types of terrains, such as simple plains, the Loess Plateau with complex gully and abrupt cliffs, and so on. Therefore, as pointed out byYang et al. (2005), it is more reasonable to represent a terrain by applying the Grid-based model for flat areas and applying the TIN-based model for rough areas and man-made objects simultaneously. He also stated that such an integrated model can potentially be much more promising in principle, compared with a single type of model (either TIN-based or Grid-based model), for the terrain representation.

Since Ebner (1984)proposed the Grid-TIN hybrid mesh for high fidelity representing complex terrains, research has been focusing on developing methods for constructing multi-resolution models in areas such as 3D data compression, visualization of terrain (Ebner et al. 1988; Ackermann 1992; Amor et al. 2004; Kraus and Otepka 2005; Yang et al. 2005; Bóo et al. 2006; Amor and Bóo 2007; Zhao and Tang 2007; Zhao et al. 2011), simplification of models and progressive transmission. These studies pay more attention to the rendering speed, data volume, the continuity of land surface, and visual effects of landform. Moreover, several attempts have also been made to try to establish a new DEM with Grid-TIN hybrid mesh (Dieter and Dieter 1995; Ackermann and Kraus 2004; Wang and Tang 2009; Zhao et al. 2013; Zhou and Chen 2011; Chen and Zhou 2013). Though the optimization of Grid-TIN hybrid mesh, Grid-TIN based terrain analysis methods and visual methods have been taken into account to some extent in these studies, there are many theoretical and technical problems to be resolved. For example, how to embed the local refined TIN into global coarse Grid seamlessly, how to visualize the Grid-TIN based DEM, and so on. With the quick development of the technology of three-dimensional (3D) data acquire, such as high resolution Remote Sensing (RS), Light Detection and Ranging (LiDAR), and modern measurement techniques, it becomes easier and easier to obtains high precise 3D spatial data. The Grid-TIN based DEM maybe becomes more and more popular in the future. Therefore, we proposed a new method to embed the local refined TIN into global Grid seamlessly and our case study shows that the method can be used to construct Grid-TIN hybrid mesh DEM successfully.

2. Methodology

The technique flow of constructing the Grid-TIN based DEM is shown in figure 1. According to the characteristics of data structure of hybrid mesh, the Grid-TIN based DEM is particularly fit for representing complex terrains with global simple landforms (represented by Grid) and local refined landforms (depicted by TIN). Therefore, in order to construct the Grid-TIN based DEM, we must prepare the following spatial data, (a) global grid-based DEM in whole study area (global Grid), (b) one or more local TIN or some feature points and lines that can be used to build local TIN in one or more specific principal study area (refined area). The relationship among the Subgrid, SubTIN and refined area in a Grid-TIN based DEM is shown in figure 2. A Grid-TIN based DEM can be built by use of the above data and technique flow.

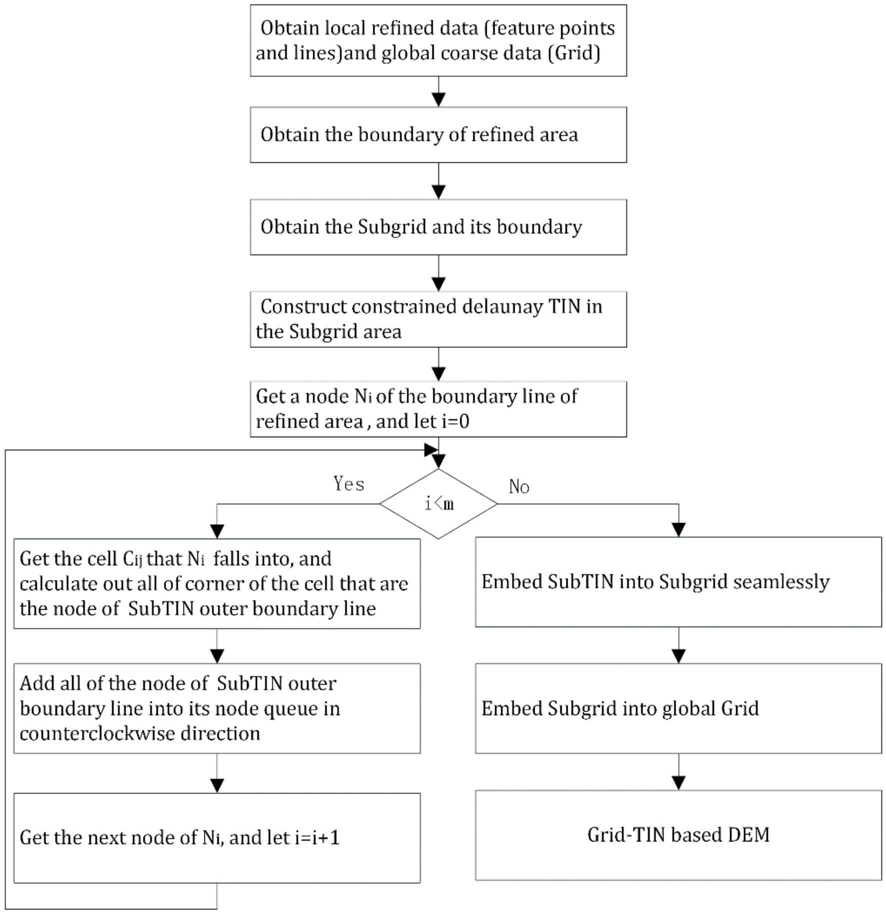


Figure 1. The technique flow of constructing a Grid-TIN DEM.

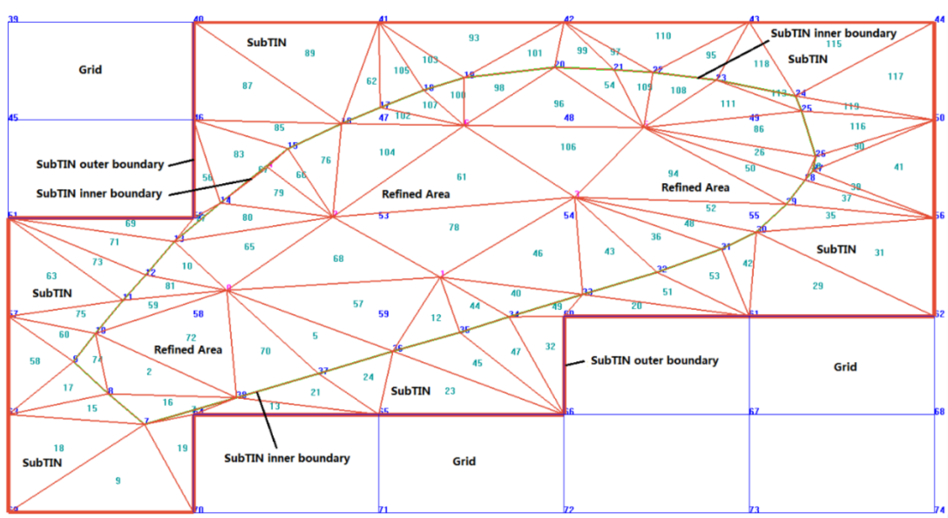


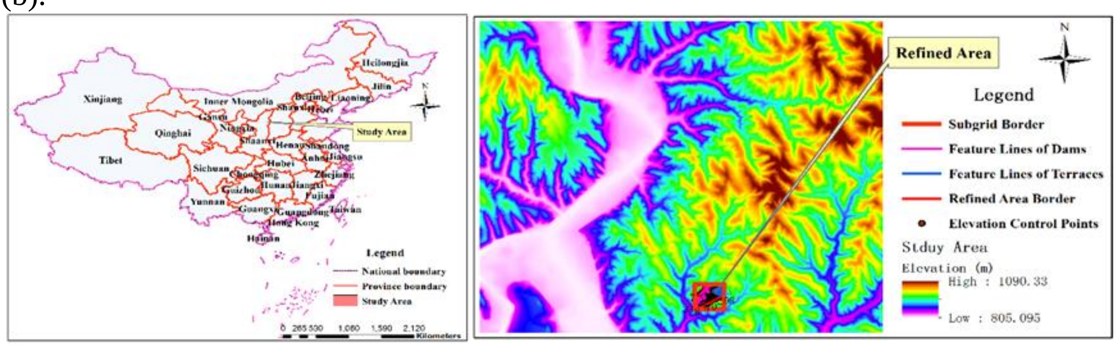
Figure 2. The relationship among the Subgrid, SubTIN and Refined Area in a Grid-TIN DEM.

3. Case Study

The technique flow of constructing the Grid-TIN based DEM is shown in figure 1. According to the characteristics of data structure of hybrid mesh, the Grid-TIN based DEM is particularly fit for representing complex terrains with global simple landforms (represented by Grid) and local refined landforms (depicted by TIN). Therefore, in order to construct the Grid-TIN based DEM, we must prepare the following spatial data, (a) global grid-based DEM in whole study area (global Grid), (b) one or more local TIN or some feature points and lines that can be used to build local TIN in one or more specific principal study area (refined area). The relationship among the Subgrid, SubTIN and refined area in a Grid-TIN based DEM is shown in figure 2. A Grid-TIN based DEM can be built by use of the above data and technique flow.

3.1 Study Area

In order to test the effectiveness of our method, a typical study area is chosen according to the requirement of constructing the Grid-TIN based DEM. The study area (see Fig. 3(a)) is located in the Loess Plateau of northeast Shaanxi province, China. The whole study area (global Grid) is located in the scope of a complete 1:10 000 DEM (cell size is 5 m) map sheet range. A local complex terrain with terraces and check dams is selected as our refined area. The spatial location of refined area and study area is shown in figure 3(b).

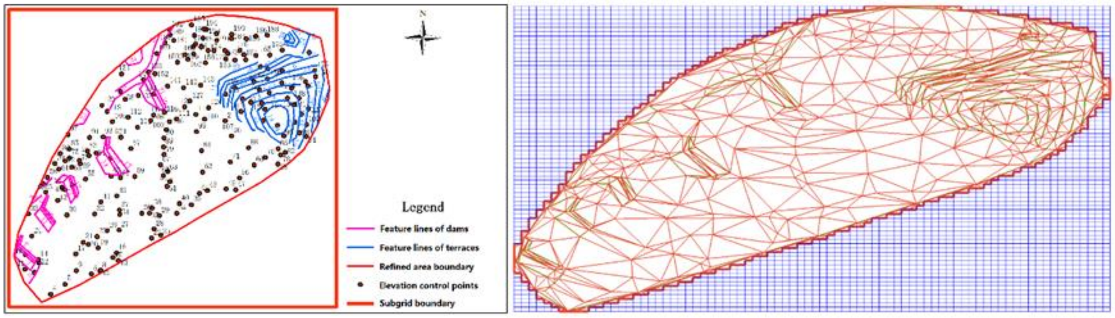


(a) (b)

Figure 3. Study area (a) located in Shaanxi Province; (b) consists of refined and coarse areas.

3.2 Results and discussion

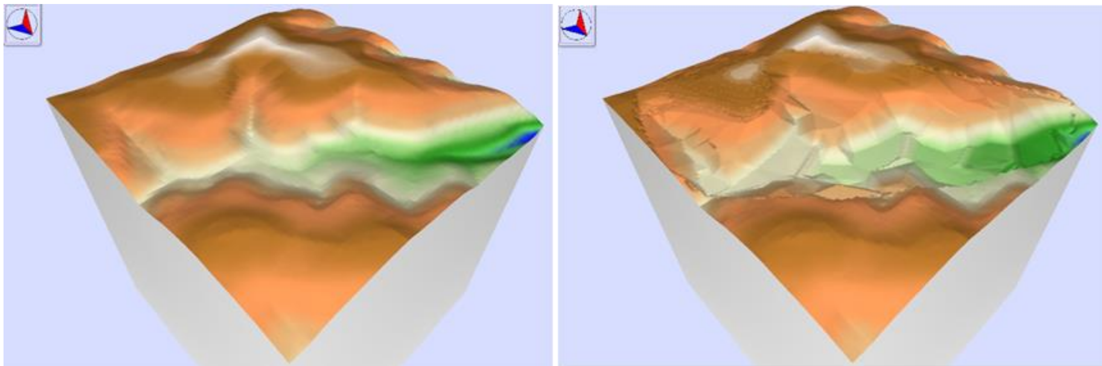
All of the feature points and lines (see Fig. 4(a)) in the refined area are acquired from 1:1000 topographic map. The feature points are all elevation control points. The feature lines are composed of edge lines of terraces and check dams. All of the feature lines are treated to meet the need of constructing local TIN (e.g., all of nodes of every feature lines must be assigned an elevation, etc.). The Subgrid boundary is the minimum rectangle of the polygon of refined area boundary. Therefore, the Subgrid is created from the global Grid by use of its boundary lines. All of the elevation control points, feature lines of terraces and check dams in the refined area, and grid points of the Subgrid are used to construct a TIN covering the Subgrid. Therefore, a hybrid mesh covering the Subgrid can be constructed according to the technique flow shown in figure 1. The results of hybrid mesh is shown in figure 4(b). As shown in figure 4(a), the hybrid mesh is composed of three parts, the refined area (i.e. the TIN within the refined area), the partial Subgrid on the outside of the refined area (the grids delineated by the blue lines), and the SubTIN (the TIN between the zigzag bold red line and the reddish yellow boundary line of the refined area). Moreover, all of the feature lines of terraces and check dams are taken into account and used to construct TIN as constrained lines condition. All of the results mentioned above are calculated out by use of our own developed programs except that some data are acquired and processed by use of ArcGIS software.



(a) (b)

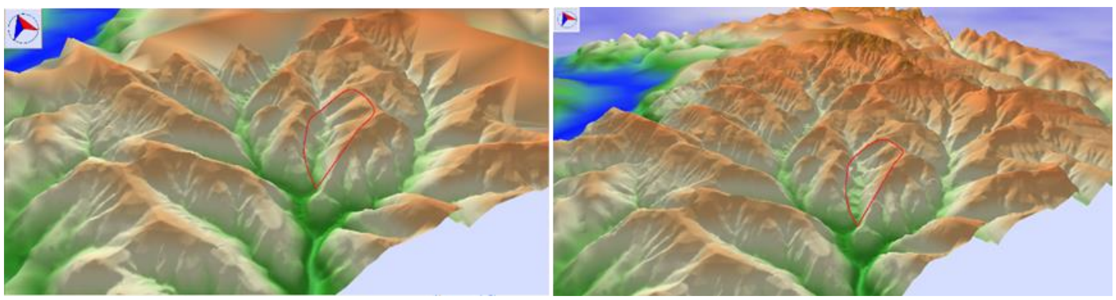
Figure 4. Distribution of (a) the feature points and lines; and (b) the hybrid mesh of the Grid-TIN DEM.

In order to evaluate the effectiveness of the Grid-TIN based DEM, the terrains within the Subgrid are visualized by use of MapGIS software. Because that there is no any existing commercial GIS software can be directly used to visualize the Grid-TIN based DEM, we have to convert the Grid-TIN hybrid mesh and original 1:10 000 DEM (cell size is 5 m) into Grid-based DEM (cell size is 1 m) through our developed program by use of bilinear interpolation method. The visualization of the original 1:10 000 DEM and the Grid-TIN based DEM are shown in figure 5. From figure 5(b), we can clearly see the terraces on the slope at the top-left corner and five check dams in the valley. The Subgrid with Grid-TIN hybrid mesh is also embedded into the global Grid by use of the method mentioned above. The visualization of original 1:10 000 DEM and the Grid-TIN based DEM in whole study area are shown in figure 6. As shown in figure 6, the five check dams can also be clearly seen while it is relatively difficult to clearly see the terraces. The only drawback is that there exist steep slopes along the refined area boundary. It is obviously that these steep slopes are created for the reason of the difference of elevation accuracy between the refined area and its outside. How to solve this problem needs further study in the future. The above results show that it is feasible to visualize the Grid-TIN based DEM through the way mentioned above, and the good visual effect of complex terrains in the refined area also demonstrates that our the Grid-TIN based DEM can be successfully used to represent such complex terrains very well.



(a) (b)

Figure 5. Visualization of (a) the 1:10,000 DEM; and (b) the Grid-TIN DEM in the scope of Subgrid.



(a) (b)

Figure 6. Visualization of (a) the 1:10,000 DEM; and (b) the Grid-TIN DEM in entire study area.

4. Conclusions

We proposed a new method to construct the Grid-TIN based DEM successfully based on previous studies on the Grid-TIN hybrid mesh. The Grid-TIN hybrid mesh can be constructed through embedding the local TINs into a global grid seamlessly. Our case study shows that this method can be used to construct the Grid-TIN based DEM successfully by use of local high precise spatial data and global coarse grid-based DEM. In other words, although the Grid has raster data structure and the TIN actually belongs to vector data structure, our study shows that the Grid and TIN can indeed coexist well. Moreover, our study also indicates that the Grid-TIN based DEM can indirectly implement its visualization to some extent by use of existing commercial GIS software. However, How to implement its visualization directly needs further study in the future.

5. Acknowledgements

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