UPDATING AND REFINEMENT OF NATIONAL 1:500000 DEM

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ABSTRACT

TIN based interpolation is one of the most popular and efficient methods for generating DEM since it makes it is possible to convey more comprehensive information including height, geomorphic feature, and hydrologic feature and so on during the process of interpolation. However, some defaults exist in this method, especially in flat area. It may reduce the precision of DEM and make DEM products cannot meet the requirements of practical applications. In this paper, a new method is presented for updating the DEM based on the updated 1:50,000 DLG database. The automatic extraction algorithm of geomorphic features is introduced. The practical work flow is designed and a software system is developed. The method has been applied to the update of the national 1:50,000 DEM database.

INTRODUCTION

1:50,000 Digital elevation model (DEM) is the digital model representation of a terrain's surface. DEM consists of the elevation matrix of some ground point sampled at regular intervals, storing the elevations of ground points and the morphological characteristics of the undulation of earth's surface; it is widely applied in many aspects of national economic construction and social development, such as land-use planning, environmental management and protection, disaster prevention and relief, and national defense construction.

The methods for the generation of DEM include mathematical interpolation of the contour lines, digital photogrammetry, and LiDAR. In the contour-line-based mathematical interpolation method, DEM is generated using mathematical interpolation algorithm based on the information of the contour lines, elevation points, and water system, as well as various terrain features.

Mathematical interpolation algorithms are typically divided into the vector-based interpolation algorithms and raster-based interpolation algorithm. In vector-based interpolation algorithm, the interpolation of triangulated irregular network (TIN) is more common, because it can make full use of many information sources, such as elevations, topographical features, and hydrological information, by employing some mathematical interpolation methods, such as linear interpolation, polynomial surface interpolation, or directly adjacent interpolation. Furthermore, the results of interpolation have less redundancy, but higher terrain fitting accuracy than the other two methods.

Nevertheless, the TIN-based interpolation method cannot adapt to some flat or sharp undulating regions, and the results of interpolation depend on the richness of the topographical features. Thus, these deficiencies exist in the 2001 version of the 1:50,000 DEM database.

With the completion of the national 1:50,000 database update, more accurate and real-time topographic data will be obtained, and this will make it is possible to update the 1:50,000 DEM dataset better and faster. For these reasons, we discussed the aspects of the update of digital elevation model based on the updated version of 1:50,000 topographic data, presented a novel and automatic algorithm for the extraction of topographical features and the raster-based DEM interpolation, and developed a practical software system for a quick update and refinement of 1:50,000 DEM.

TECHNICAL ROUTES

The overall technical routes for the update and refinement of 1:50000 DEM is shown as follows. First, the reasonable update areas are found out by analyzing the changes of geomorphic features; second, the topographic features, including the contour lines, elevation points and water system, are picked out from the updated version of the 1:50000 topographic database; third, an updated version of the DEM data is generated by employing one of appropriate mathematical interpolation methods, according to the designed grid size.

For the refinement of DEM Interpolation, a fully automated software system with a novel and effective algorithm for the collection of a terrain feature points is developed.

For the generation of the high-precision and realistic DEM data, a mathematical interpolation algorithm that adapts to various topographic types is developed. In most areas, linear interpolation can be used on triangulated irregular network to build the regular-grid DEM data; however, regular raster interpolation should be directly used to build the regular-grid DEM data in some special areas, such as plains and coastal areas.

The process of the update of 1:50,000 DEM is shown in Fig. 1.

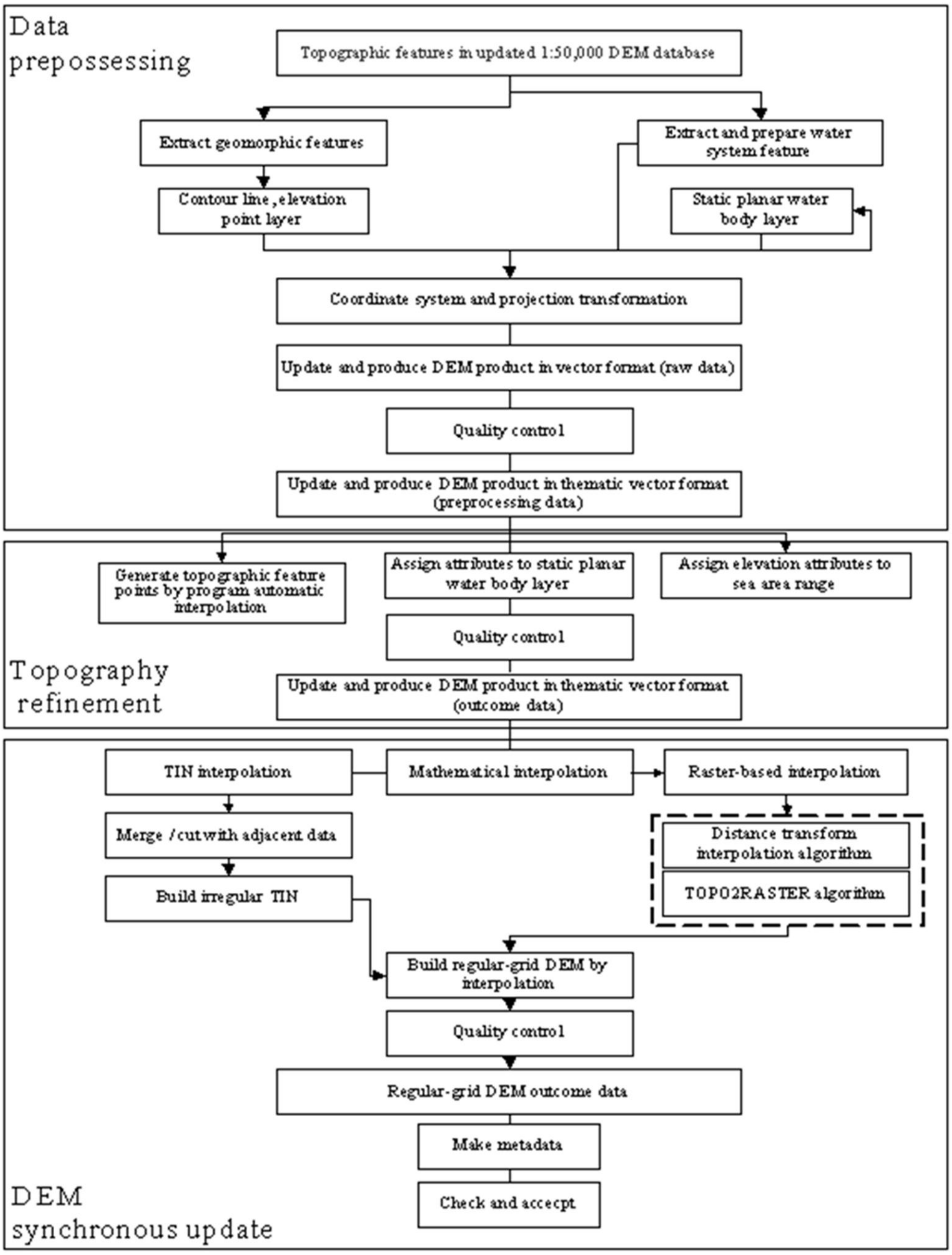

Fig. 1 The work flow of DEM production

KEY TECHNOLOGIE

Change Detection of Geomorphic Features

Compared to the changes of ground features, the overall changes of geomorphic features are small, and the changes are often some small topographic changes of local areas. The types, variance, and distribution area of geomorphic changes can be approximately determined from geomorphic change detection. Furthermore, the update and refinement of 1:50,000 DEM can be achieved by designing more adaptive technical routes and interpolation algorithms if the targeted regions with higher priorities of update and refinement can be identified out.

The contour lines and elevation points in the current updated version of the 1:50,000 topographic database are interpolated and compared with these of the earlier versions of 1:50,000 DEM data interpolation. Using the interpolated result, a mathematical statistical model is then built to define the topographic change rate that reflects the degree of landscape changes.

The rate of geomorphic change is the ratio of the area of the regions on the map, where elevation changes are more than a certain threshold, to the total area of the map.

The work flow of change detection of geomorphic features in 1:50,000 DEM is shown in Fig.2.

On the basis of a detailed statistical analysis of the maps, we found that the rate of geomorphic change of 21% maps is more than 5% when the change threshold is set as 1 meter.

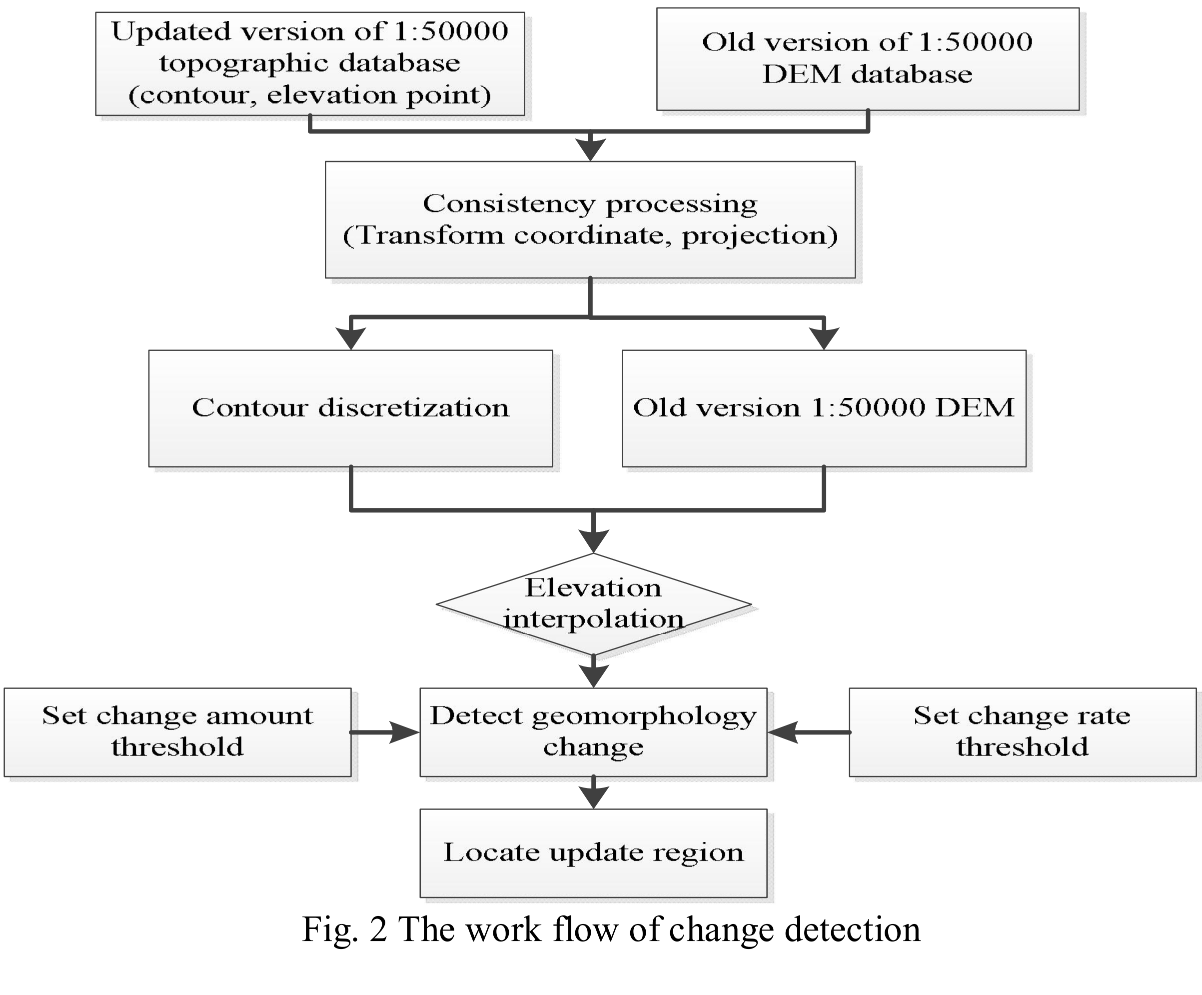

Fig. 2 The work flow of change detection

Automatic Extraction of Topographic Features

In the process of the interpolation of DEM data based on contour lines, topographical features, such as the ridge lines, valley lines, and terrain transform lines with elevation information, are one of the most important interpolated data sources.

Rational use of various types of terrain features can greatly improve the final terrain simulation of the DEM data, but can also optimize the relative height accuracy of the DEM data.

During the production of the older version of DEM data, some the topographical features have been collected by automatic extraction or manual interaction. However, the spatial distribution and geometric features of these topographical features are not reasonable enough, the elevations of these topographical features are not consecutive enough, and there is lots of redundant elevation information among these topographical features.

There are many methods for the extraction of terrain feature information, such as the contour skeleton extraction methods based on the degree of the contour curvature, Delaunay triangulation network and Voronoi diagram; the extraction methods of combining raster and vector; and the flat triangular elimination method. On the basis of a comprehensive comparison and analysis of these algorithms, a topographical features extraction algorithm based on iterative triangulation optimization is proposed, as shown in Fig. 3.

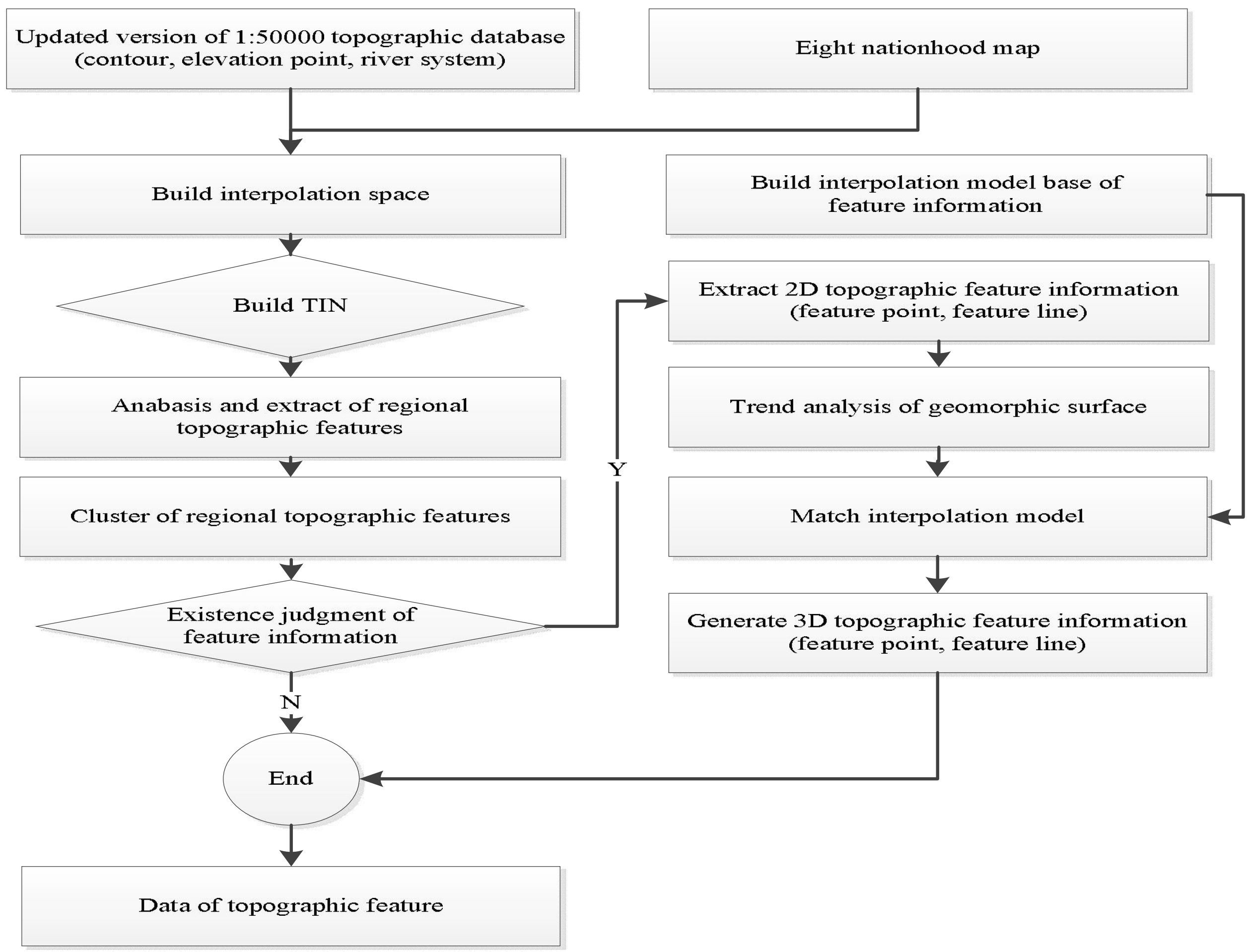

Fig. 3 The technological flow of feature point interpolation

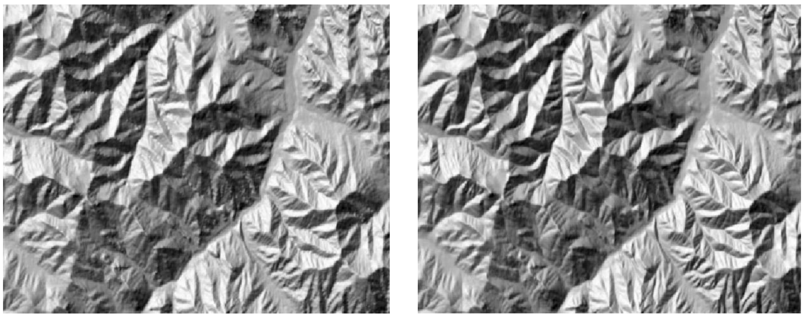

Fig.4 Comparison of the old version of DEM and the current version of DEM

Raster-based DEM Interpolation Algorithm

According to the problem that TIN interpolation algorithm is unable to express the real terrain of flat or sharp undulating regions, a DEM grid interpolation algorithm that can direct interpolate to generate DEM data is designed.

Raster-based Distance Transform Interpolation Algorithm

This algorithm works as follows. First, the elevation information, such as contour lines and elevation points, is rasterized. Second, the contour lines with the mean elevation of two adjacent contour lines is inserted between the two adjacent contour lines by employing the cartographic algebra middle distance transform algorithm and considering weight coefficients of these elevation points. Third, the second step is repeated to complete the interpolation until every grid cell on the map sheet is filled with the elevation information. The interpolated map sheet is the final DEM we expected. The work flow of raster-based distance transform interpolation algorithm is shown in Fig. 5.

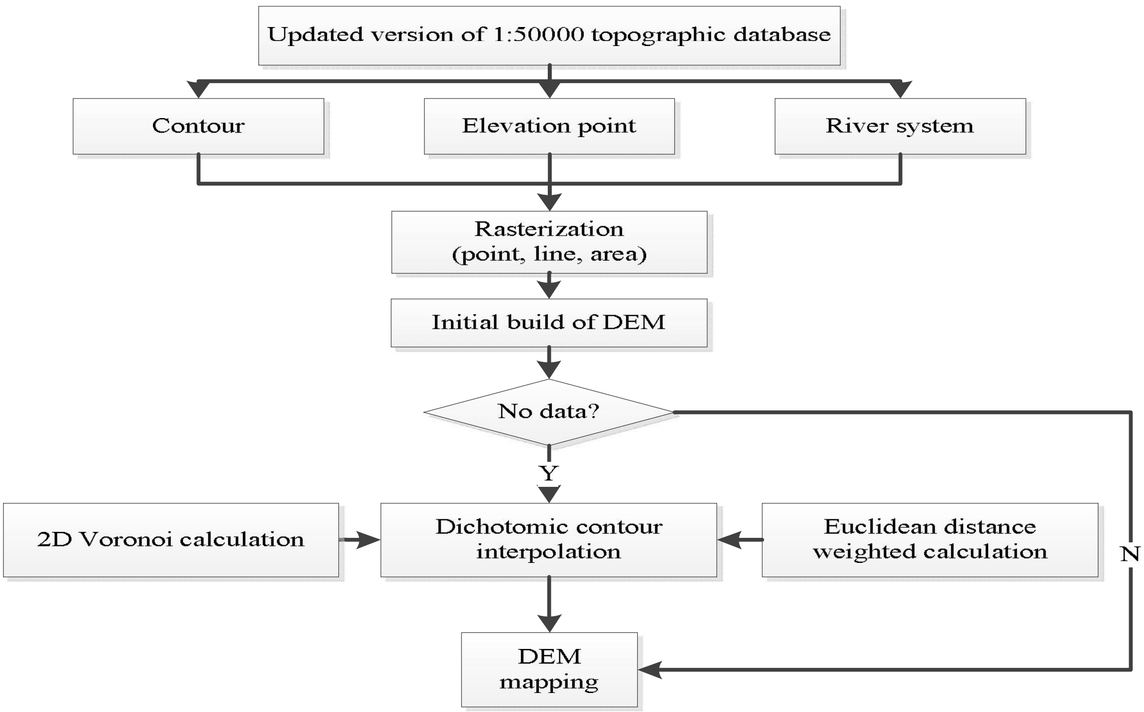

Fig. 5 The work flow of raster-based distance transform interpolation algorithm

Raster-based Topographical Features Interpolation Algorithm

This algorithm considers not only direct elevation information, such as contours, elevation points, but also hydrological information, such as the distribution of lakes and the trend of rivers, for the analysis and prediction of the elevation to be used for raster-based interpolation. The detailed steps are shown as follows. First, the original elevation information, such as contour lines and elevation points, is rasterized. Second, the trends of rivers are determined according to the trend and distribution of rivers, before the estimated elevations of points sampled along the rivers are calculated by considering the relationship between the trends of rivers and its surrounding contour lines. These estimated elevation information is rasterized and filled into the original grid. Third, Thin-plate spline operator is iteratively used to refill the new grid until the whole raster map is covered with the elevation information. Finally, the elevations of lakes are calculated by considering the surrounding elevation information of the lakes, and are reassigned to get the final raster map sheet.

After the application of the proposed raster-based DEM interpolation algorithm, the deficiencies of the traditional TIN interpolation algorithms are avoided, and the overall DEM quality of flat or sharp undulating regions are also improved. Figures 6 and 7 show the comparisons of the three interpolation methods mentioned above.

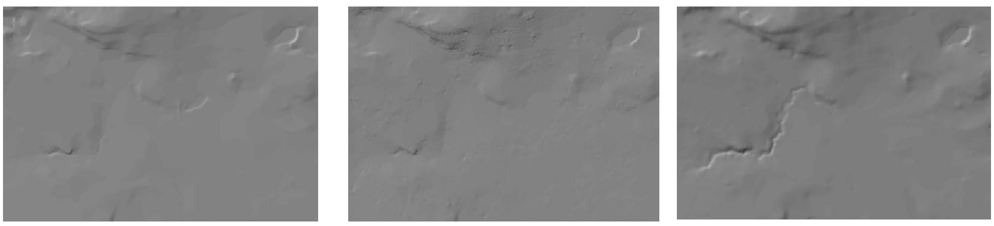

Fig. 6 Comparisons of three interpolation methods
(the DEMs, in sequences, is generated by the TIN interpolation method, the distance transform Interpolation method, and the topographical features interpolation method)

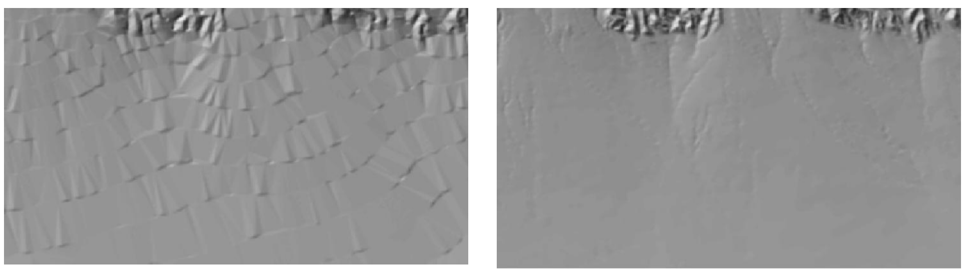

Fig. 7 Comparisons between the older version of DEM (generated by the TIN interpolation method) and that of the current version (generated by the raster-based topographical features interpolation method)

DEVELOPMENT OF THE SOFTWARE

Given that the update and refinement of nearly twenty thousand of the 1:50,000 DEM, including data production and project acceptance, must be completed within only a few months, we established a principle of "centralized storage, distributed production, unified management of tasks", and developed a fully automatic 1:50000 DEM updating software system, which allows a high degree of integration across the customization of production programs, data preprocessing, automatic extraction of topographical features, DEM interpolation, quality inspection, metadata entry, batch processing and other functions. The design of the software system is shown in Fig. 8.

The system consists of three modules, including the management module, the DEM production module, and the data access module. The management module is designated to manage the whole DEM production, including the dispensation of production tasks, and the linkage display of production progresses; the DEM production module is designated to control each sub-process of DEM production; and the data access module is designated for data compression, data sources download, outcome data upload and backup and other functions.

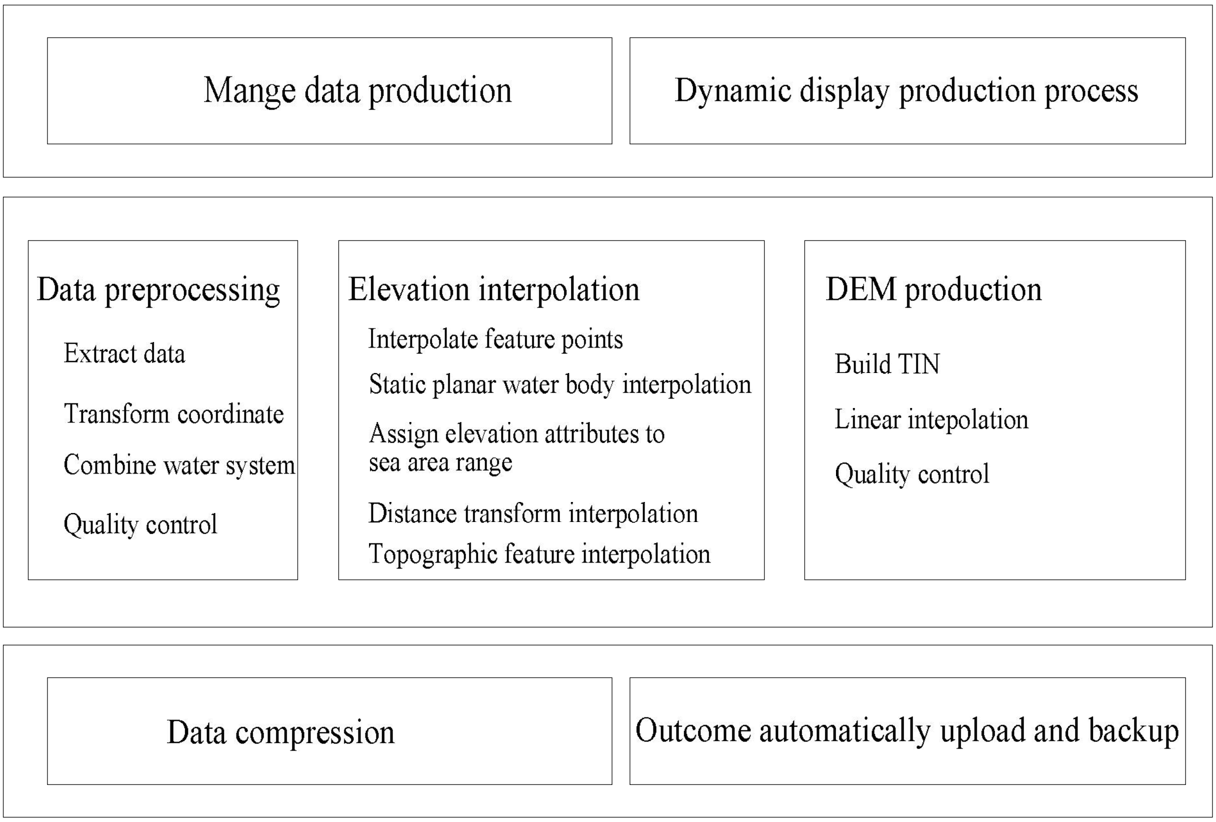

Fig. 8 The design of the software system for the update and refinement of the national 1:50,000 DEM

CONCLUSION

According to the national urgent need of updating 1:50,000 database, a technical route for updating 1:50000 DEM based on an updated version of the 1:50000 topographic data is proposed; moreover, many algorithms are proposed, such as the algorithm for the extraction of topographic features based on iteratively optimized triangulation networks, the raster-based distance transform interpolation algorithm, and the raster-based topographical features interpolation algorithm; finally, a practical software system is developed for the national quick update and refinement of the 1:50,000 digital elevation model.

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