3D virtual barrier lake platform building method of based on multi-source sensing data

Liming Sun*, Yingqi Wei, Jun Yan
China Institute of Water Resources and Hydropower Research, Beijing 100084, China

*Corresponding author: limingsun@iwhr.com

Abstract. The huge flood disaster caused by the barrier lake in a short time usually requires precise emergency decision-making, and the 3D virtual platform of the barrier lake is one of the most important informational support. Traditionally, there are few studies on the reconstruction technology of scale 3D dam lake model based on multi-source perception data. This paper summarizes the types of multi-source perception data used for 3D modeling of barrier lake, and proposes a method for designing and defining 3D data models of barrier lake, a large-scale and a fine local-scale 3D model reconstruction method are studied, building methods are summarized for the main steps of 3D dynamic event simulation, and finally this gives the software architecture design of the barrier lake 3D model platform, Baige barrier lake is taken as an example for practical development and verified the rationality of the method and Feasibility, the software platform provides an important basis for the rescue and disaster relief of the barrier lake in the future.

1. Introduction
China is the country with the widest distribution and the most types of barrier lake. In recent years, there have been many extraordinary floods in the main river caused by the bursting of barrier lake, causing huge losses of life and property. It is also one of the key research topics of the water conservancy industry [1-3]. The inducement of barrier lake is mainly the sudden events such as earthquakes, heavy rainfall, and volcanic eruptions located near the major rivers, which are caused by landslides, debris flows, volcanic eruptions, moraine deposits, and other materials that block the river horizontally. The barrier body will increase the water flow in the upper reaches of the barrier body to form a large submerged topography of the lake area. The upper reaches may form a submerged area of tens of kilometers. After the barrier lake breaks, the lake water will form an extraordinary flood, which will affect the lives of people in the lower reaches of the river. Property safety will cause great harm. Compared with conventional hydraulic structure damage accidents, it has the characteristics of greater harm, shorter time, and higher emergency rescue challenges. Therefore, information-based auxiliary methods are important for emergency rescue of barrier lake disasters. It plays an important role, especially in the typical barrier lakes such as Baige in Jinsha River, Medog in Tibet and Tangjiaashan [4] [5].

In the rescue and relief process, the multi-source information related to the barrier lake is an important basis for decision-making. In the short time of the disaster breaks, satellite remote sensing, UAV, LiDAR, InSAR, surveys, real-time reporting, internet data obtained by multiple data perception methods such as data and maps are fused and processed, and then a 3D model reconstruction method is
used to build a 3D model of the barrier lake related barrier body, barrier lake, submerged area, and downstream influence area for real-time visual management and spatial calculation analysis, which provides emergency rescue and disaster relief functions, such as flood risk map, barrier body calculation, barrier lake change process map, upstream inundation map, and rapid habitat information query, so the existing 3D barrier lake software platform is the most urgently needed functions in the rescue and relief. However, due to the sporadic nature of barrier lakes, the urgency of emergency rescue time, and the multi-scale issues involved in the 3D barrier lakes model, there are few researches in relevant directions, and relevant research is urgently needed. Building a spatial data software platform that could manage the multi-source perception. On this basis, building a 3D virtual environment software platform for the dynamic simulation, from the barrier lake to the barrier lake’s rescue and disaster relief, which can provide rapid informatization support for the rescue and disaster relief of barrier lakes in the future, and it solves the current difficulties in data fusion, different standards, and multi-scale model construction difficulties, and other issues.

Traditional barrier lake informatization software platform research is more of an informatization system for a single perception method, data and functional requirements. The future 3D information management system for barrier lakes first needs to consider the actual situation in remote areas of high mountains and valleys, especially the hardware and software infrastructure conditions requirement and the use of a variety of new sensor sensing methods in the current GIS and remote sensing fields [6, 7], which will be used to meet the needs of multi-sectoral data perceive, update, and the construction of multi-scale 3D Model rapidly. Based on the types of multi-source sensing information of the barrier lake, this paper will study the design method of the multi-scale 3D data model of the barrier lake, and then proposes the construction method of large-scale model, refined model and dynamic event simulation method, and finally proposes the overall architecture of 3D barrier lake software platform design, and Baige barrier lake as an example, to illustrate the feasibility of the method.

2. Multi-source perception spatial data of barrier lake

The multi-source perception spatial data of the barrier lake mainly refers to the data that can express the position of the object and the spatial data that can be used for three-dimensional spatial modeling and query.

2.1. Remote sensing geographic information data

The occurrence of barrier lakes is usually off the beaten track areas lacking monitoring. After the barrier lakes happened, the topography and images of the place where the barrier lake occurs, the water of the barrier lake, the upstream inundation area, and the downstream inundation area after the dam break can be quickly obtained to grasp the upstream and downstream topography and ground conditions of the barrier lake, and quickly output high-precision 3D topographic maps, thematic maps, contour maps, deformation maps, etc. This could provide basic geographic topography and image data for disaster relief decision-making and analysis [8].

The collected remote sensing data mainly refers to the method of using satellites, drones, etc., equipped with optical sensors or laser sensors to perform remote measurement to obtain the DEM and DOM. Remote sensing can be used to quickly and accurately obtain large-scale fine terrain and images data. Large-scale geographic information in the multi-source data of barrier lakes, InSAR landslide monitoring data and underwater terrain data, etc. [9]. Generally, the large-scale terrain of the upstream and downstream basins needs to be collected by optical satellites or fixed-wing large aircraft, and it takes a long time, while the local high-precision terrain and images use rotary-wing drones, 3D laser scanners, multi-beam sounders, and airborne LiDAR for rapid measurement, the data structure is mainly geographic raster image and point cloud data.

2.2. Hydrological and meteorological data

The hydrological data includes the rainfall data, flow capacity, water level and flow rate monitored by the hydrological station network before and after the occurrence of the barrier lake. This is the most
important dynamic data for the emergency rescue of the barrier lake and the downstream disaster risk assessment. The hydrological stations monitoring data of the river upstream and downstream is an important basis for flood warning and forecasting. Specific hydrometeorological data mainly include measurement data of hydrological stations, such as water level, flow rate, flow velocity, horizontal and vertical sections; meteorological data include rainfall and weather, etc.; time range includes time period before and after the occurrence of barrier lake and historical data; spatial location mainly includes hydrological stations and the barrier lake inbound, outbound and over-current locations.

2.3. Habitat information data
In view of the serious social hazards caused by the barrier lake accident and the social factors involved in the emergency treatment and post-disaster recovery and reconstruction, the habitat data should be fully considered in the assessment of the upstream geological disaster risk chain, and the specific impacts along the river the population and residents, transportation infrastructure, large-scale factories and mines, cultural relics and other elements circle of influence.

When a barrier lake accident occurs, the first concern is the impact on the downstream population and major facilities. Based on the results of the simulation analysis, corresponding and accurate personnel evacuation and loss assessments need to be carried out. Grasping the important engineering facilities downstream, population distribution, village location and river width is the mainly needs. These data include population distribution, transportation infrastructure, large-scale factories and mines, tributaries of rivers and water catchments, etc. [10].

2.4. Measurement data of barrier body
The barrier body information includes geometric parameters and measurement data related to the landslide body, as the position, volume, length, width, height, slope ratio, material and other basic parameters of the barrier body. The first time a landslide barrier lake occurs, and other remote sensing data are combined to reconstruct the 3D model, it could obtain the basic characteristics of the dam and perform a analysis and calculation quickly.

3. Multi-scale 3D data model design of barrier lake
In order to design a 3D software platform for barrier lake 3D scenes management through the multi-source data types, range scales and precisions. Firstly, it is necessary to study the integrated management method of spatial data and 3D models, design method of different models’ storage and construction, determine method of the multi-scale 3D barrier lake data model, the storage method of the existing basic scene model, so that it can realize rapid storage, query and update, and display of a large number of 3D models rapidly. Design a multi-scale 3D data model of the barrier lake, specifically including the following key parts:

3.1. Geometric data structure
In the 3D scene of the barrier lake, there are barrier body 3D models with refined and complex shapes, so the TIN (Triangulated Irregular Network) data structure is the most suitable, while the terrain model uses more quadrilaterals and triangles, and there is no need for other solid models, so quadrilaterals is not used. Therefore, the terrain model and the barrier body model are considered to be used in a unified manner, and the quadrilateral can be quickly converted into a triangle, so this is the definition of the geometric data structure model of the 3D platform of the barrier lake.

3.2. Model scale definition
According to the range and accuracy of the model, the expression model can be divided into scales to facilitate the adoption of different model construction methods and management methods. According to the specific conditions of the 3D scene of the barrier lake, the four definitions are as follows:
3.2.1. Large scale. It needs to consider the rapid construction and rendering of large scale model, and both scope and accuracy in the large scale model are the basis property, all terrain model in areas affected by barrier lakes is large scale, especially time-series change models,

3.2.2. Local area scale. It is necessary to focus on high precision expression in refined scene models in a local range, for local scale models, such as the area where the barrier lake is located and the barrier lake area.

3.2.3. Engineering scale. It includes refined models of barrier dam and landslide, which are used for analysis and calculation, excavation and height calculation of accumulations, etc., it needs to be obtained using fine ground measurement data and refined measurement methods.

3.2.4. Component scale. For specific landslide body cracks, building bridges and other parts that need to be used for accurate calculation and analysis, they are processed according to the component scale, it represents higher accuracy and location.

3.3. Scale conversion method
Large scale and local area scale models require conversion and fusion process. The seamless fusion model can be obtained by converting the local scale to the large scale. The scale conversion method of the TIN structure model usually is the adopts methods, such as insertion points and local reconstruction. The parameters of the conversion fusion need to be determined according to the accuracy.

3.4. Model object organization method
The 3D platform of the barrier lake needs to focus on the model objects: the 3D terrain model of the landslide body, the 3D model of the barrier body, the downstream terrain model, the multiple housing facility models, the bridge model, the dynamic model of the river and lake area, the filling and excavation part model, etc., and the data sources and construction methods of different models are usually different, and the number is huge. In the process of constructing 3D virtual environment, it is necessary to study a fast spatial object organization method to quickly index and query related models. This paper studies the 3D space octree method to manage the barrier lake scene model. According to the center position of the model and the boundary scope of the 3D AABB bounding box, it is then stored in the octree according to the definitive rules. The octree can be used to quickly query the corresponding features according to the location and model scope. For the storage of large area and large-scale topography in the downstream of barrier lakes in an octree [11], the terrain can usually be divided into several parts according to the quadtree model, see (2), for small scale model, then the whole model performs octree node calculation, as shown in Figure 1.

Fig 1. The octree diagrams.
3.5. Model LOD (level of detail)
Take the Baige barrier lake as an example. After the barrier lake accident occurs, the upstream inundation area reaches 60 kilometers and the downstream exceeds 700 kilometers. The model of the entire area usually uses raster data obtained by satellites and drones and DEM data using regular grids. The network model algorithm is constructed, and the quadtree model is used for fragmented storage. When constructing 3D visualization rendering, the LOD level is automatically calculated and cut by the distance between the viewpoint and the model, so as to ensure that the viewport is fixed during the browsing process. The model size is close to realize the fast browsing and loading process of the model.

4. Multi-scale 3D model construction
Based on the 3D data structure model designed in 2, and then according to different scale model construction methods, to build a complete 3D model of the affected area of the barrier lake.

4.1. Construction method of large-scale 3D model of barrier lake
It usually cannot be produced by manual modification and generation in the 3D model construction within a large area space, this method is inefficient and difficult to ensure the seamless connection of models. Moreover, the field measurement has poor timeliness for the rescue of barrier lakes, which cannot meet actual conditions need. With the rapid development of satellite remote sensing and UAV remote sensing technology in recent years, high-resolution optical remote sensing satellites, radar satellites, rotors and fixed-wing UAVs can be used to quickly obtain high-resolution time series spatial data. The satellite optical remote sensing method has reached an accuracy of more than 1 meter, and the UAV can even reach the centimeter-level accuracy. The data obtained is regular grid data, which is also convenient for rapid calculation and analysis. This is the most important for the rescue and relief of barrier lakes. Data perception means. Therefore, the construction of a large-scale model of the barrier lake includes classification methods such as large-area terrain models, underwater models, and inclined photography models collected by drones [12]:

4.1.1. UAV tilt photography model. It can be quickly obtained the data of the mountain and valley area according to the UAV optical lens to quickly obtain, using OpenDroneMap and other cloud-based computing methods [12], and it can be quickly obtained a 3D LOD model by using photos taken by drones for air three calculation and model construction.

4.1.2. Model construction based on satellite remote sensing images and DEM. If the impact area of the barrier lake involves large rivers, the impact range is often hundreds of kilometers or more. In the limited rescue time, the use of existing satellite remote sensing data is faster and more efficient than the drone method, and it can also be used. Obtaining historical terrain and image data is more conducive to emergency analysis and calculation. Using terrain and image raster data to achieve elevation and texture mapping can quickly build a large-scale 3D terrain model. The model usually uses raster pyramids or remote the tile call is used to construct the LOD model to realize fast rendering and browsing.

4.1.3. 3D model construction based on LiDAR. Compared with the insufficiency of the drone tilt photography model in the accuracy of elevation measurement, the 3D laser scanner has the characteristics of long measurement range and high stability, which is particularly suitable for scanning slopes or landslides, and quickly obtaining high-precision terrain data. For a larger scale, it is more convenient to use UAV LiDAR for modeling. The data format generated by LiDAR is a point cloud, and the modeling method can be directly converted into a high-precision DEM, and then a 3D model could be rebuilt.

4.2. Refinement of local scale 3D model reconstruction
Refined local models include dam body accumulation model, post-excavation model, dam body model, residual body model after dam break, etc. These models are usually used for calculation analysis and
situation simulation. These are usually high-precision models that need to be constructed using LiDAR point clouds, remotely sensed terrain data and specific parameters. There are two main types, one can be obtained directly from other data collection methods, and the other requires a combination of the two.

1. Using methods such as 3D lasers and drone low-altitude photography to obtain LOD-based high-precision models, the levels obtained are more and finer than large-scale 3D models.

2. Accurate curved surface model (TIN), and then use the relevant geometric parameters to simulate and calculate. Taking the construction of the 3D model of the dam as an example, first determine the basic geometric form of the dam, including the ratio of the upstream and downstream slopes, the elevation of the dam, and the drop. The basic parameters such as the center position are then simulated based on the surface shape of the dam, and then the refined DEM topographic surface is intersected and sealed to obtain a complete 3D dam model, which is used to calculate the square volume and Trial calculation of weir crest elevation, etc.

4.3. Time sequence dynamic event simulation
Dynamic events in a barrier lake events is such as the sliding process of landslides, the dynamic rise of the river, the dam break process, and the inundation of the upstream of the barrier lake. The simulation method is mainly to use the state of the 3D model corresponding to different times along the time Axis, using time changes to complete the playback of the 3D model state. Take the sliding process of a landslide as an example:

1. First, collect satellite imagery and terrain data in different time periods.
2. Build 3D LOD models separately.
3. Set the playback period according to the time change, and then perform partial switching of the 3D model.

5. Design of 3D modeling software for barrier lake

![Fig 2. 3D barrier lake platform software architecture diagram.](image)
The design of the 3D software platform of the barrier lake needs to follow the data compatibility, multi-source heterogeneous data could be flexibly accessed in real time, and the multi-source data perception, data storage, and 3D modeling of the barrier lake will be realized for the 3D visualization and application. The core support layer provides the definition and reconstruction method of the multi-scale 3D model of the barrier lake; the 3D display layer provides the core components of the 3D digital earth to ensure that large-scale models can be quickly rebuilt and browsed efficiently. The analysis layer realization includes the models that need dynamic modeling analysis and specialty calculation, and then all business functions are realized to meet the goals of rapid building and using during emergency rescue of barrier lakes. The specific software architecture design diagram is shown in Figure 2. Taking Baige barrier lake as an example, The 3D model management system of the barrier lake based on this architecture research and development realizes the construction and management of the 3D digital earth, the large scale topographic model of the affected area, the management of the drone tilt photography model, and the 3D barrier body, which provide a 3D platform foundation for subsequent barrier lake risk assessment, analysis and calculation, and emergency decision-making, such as model construction and 3D simulation of river evolution.
The 3D virtual simulation platform of Baige barrier lake uses the optical satellite remote sensing data in the air to provide the large-scale DEM (10m) and DOM (1m) constructed by the three-dimensional platform to build the large-scale three-dimensional model of the basin scale; use UAV LiDAR the 10cm point cloud data of the data constructs the 3D model of the dam body and the attachment of the landslide body. The surface texture adopts the 5cm DOM obtained by the quadrotor UAV. The software uses the octree hybrid method to achieve multi-scale and fine-scale 3D Model dynamic scheduling realizes efficient browsing and access, as shown in Figure 4. Based on this platform, the analysis and evaluation function based on the three-dimensional barrier lake platform is realized.

The 3D barrier lake model and the software platform building method for the emergency rescue and disaster relief needs of the barrier lake are studied through this article.

6. Summary
The 3D barrier lake model and the software platform building method for the emergency rescue and disaster relief needs of the barrier lake are studied through this article.

(1) The types and characteristics of multi-source spatial data of the barrier lake are summarized;

(2) The design method of multi-scale 3D data model of barrier lake is proposed, and it is applied to the building of large scale and fine scale 3D model of the barrier lake, and the time series dynamic event simulation is discussed;

(3) Finally, based on these theories, the key technologies for the architecture design and software implementation of the barrier lake 3D software platform are proposed, which provides a new design method and implementation technology for the research and development of the barrier lake 3D platform. Taking Baige lake as an example, it verifies the theories and methods in the article and provides a basic software platform for relational specialty analysis and calculation.

In addition, the specific experimental and application verification of the barrier lake 3D platform needs to be carried out in the actual rescue case, while the barrier lake occurrence is an accidental event, which can only be tested with the less existing measured data of barrier lake happened, this objectively puts forward higher requirements for the application and development of the 3D software platform of the barrier lake. In addition, you can try to study more methods of building of 3D model’s internal structure of the barrier dam, the underwater terrain and ground surface fusion method to build a more scientific and refined 3D virtual platform, it meets the 3D integration of surface, underwater, and ground Integrated modeling, which provides a more specialty 3D software platform support for the rescue decision of the barrier lake, this is the following future research direction.

Acknowledgments
This paper is supported by the National key research and development program (Grant No.2018YFC1508602) and the Joint Funds of the National Natural Science Foundation of China (Grant No. U19A2049)

References
[1] Li J, Cao Z, Cui Y, et al. Barrier lake formation due to landslide impacting a river: A numerical study using a double layer-averaged two-phase flow model[J]. Applied Mathematical Modelling. 2020, 80: 574-601.

[2] Xing W, Hu H, Zhang Y, et al. Magnetotactic bacteria diversity of and magnetism contribution to sediment in Wudalianchi volcanic barrier lakes, NE China[J]. Science of The Total Environment. 2020, 718: 137348.

[3] Chen C, Zhang L, Xiao T, et al. Barrier lake bursting and flood routing in the Yarlung Tsangpo Grand Canyon in October 2018[J]. Journal of Hydrology. 2020, 583: 124603.

[4] Li J, Cao Z, Cui Y, et al. Barrier lake formation due to landslide impacting a river: A numerical study using a double layer-averaged two-phase flow model[J]. Applied Mathematical Modelling. 2020, 80: 574-601.

[5] Xing W, Hu H, Zhang Y, et al. Magnetotactic bacteria diversity of and magnetism contribution
to sediment in Wudalianchi volcanic barrier lakes, NE China[J]. Science of The Total Environment. 2020, 718: 137348.

[6] Chen C, Zhang L, Xiao T, et al. Barrier lake bursting and flood routing in the Yarlung Tsangpo Grand Canyon in October 2018[J]. Journal of Hydrology. 2020, 583: 124603.

[7] Fichot C G, Matsumoto K, Holt B, et al. Assessing change in the overturning behavior of the Laurentian Great Lakes using remotely sensed lake surface water temperatures[J]. Remote Sensing of Environment. 2019, 235: 111427.

[8] Yuan L, Yu Z, Luo W, et al. A 3D GIS spatial data model based on conformal geometric algebra[J]. Science China Earth Sciences. 2011, 54(1): 101-112.

[9] Goodchild M F. Geomorphology Scale in GIS : An overview[J]. Geomorphology. 2011, 130(1-2): 5-9.

[10] Mattheus C R. GIS-based geomorphologic study of Presque Isle Peninsula, a compound lacustrine barrier-spit system along the south-central Lake Erie margin[J]. Journal of Great Lakes Research. 2016, 42(2): 336-347.

[11] Kim J E, Hong C H. A Proposal of Spatial Indexing Algorithm for Effective Visualization of GIS Based-BIM Data[J]. International Journal of Engineering and Technology. 2015, 7(6): 6-11.

[12] Berry P, Bonduá S, Bortolotti V, et al. A GIS-based open source pre-processor for georesources numerical modeling[J]. Environmental Modelling & Software. 2014, 62: 52-64.

[13] Yuan Y, Huang W, Wang X, et al. Automated accurate registration method between UAV image and Google satellite map[J]. Multimedia Tools and Applications. 2019.

[14] Zheng X, Wang F, Li Z. A multi-UAV cooperative route planning methodology for 3D fine-resolution building model reconstruction[J]. ISPRS Journal of Photogrammetry and Remote Sensing. 2018, 146: 483-494.

[15] Tang L, Ying S, Li L, et al. An application-driven LOD modeling paradigm for 3D building models[J]. ISPRS Journal of Photogrammetry and Remote Sensing. 2020, 161: 194-207.

[16] Liu H, Xie L, Shi L, et al. A method of automatic extraction of parameters of multi-LoD BIM models for typical components in wooden architectural-heritage structures[J]. Advanced Engineering Informatics. 2019, 42: 101002.

[17] Biljecki F, Ledoux H, Stoter J. An improved LOD specification for 3D building models[J]. Computers, Environment and Urban Systems. 2016, 59: 25-37