WebVRGIS: A P2P Network Engine for VR Data and GIS Analysis

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Abstract. A Peer-to-peer(P2P) network engine for geographic VR data and GIS analysis on 3D Globe is proposed, which synthesizes several latest information technologies including web virtual reality(VR), 3D geographical information system(GIS), 3D visualization and P2P network. The engine is used to organize and present massive spatial data such as remote sensing data, meanwhile to share and online publish by P2P based on hash. The P2P network makes a mapping of the users in real geographic space and the user avatar in the virtual scene, as well as the nodes in the virtual network. It also supports the integrated VRGIS functions including 3D spatial analysis functions, 3D visualization for spatial process and serves as a web engine for 3D globe and digital city.

Keywords: P2P network, WebVR, VRGIS, Big data, 3D Globe.

1 Introduction

With the development of VR (Virtual Reality) technology and widely applications in various areas, the requirements to VR are also increasing rapidly. Users do not only need to obtain the landscape geospatial data dynamically but also need to perform some analyses, calculations, managements and transfers based on data. Virtual Reality Geographical Information System (VRGIS), a combination of geographic information system and virtual reality technology [8] has become a hot topic. With the popularity of network, the VRGIS platform based on the network environment also becomes a trend. The application of VRML, X3D and other online VR technologies have achieved networking of VR systems, because of the mass data, the network bandwidth constraints of transmission, a large number of request and multi-user collaboration controls, the online virtual reality technology still face numerous challenges. To improve the accuracy of modeling, the city planning has an increasingly high demand for the realistic display of VR system, however this will inevitably lead to the growth of the volume of data transmission. Virtual scene from a single building to the city scale is also resulting in the increased amount of data. The increasing number of user increase the server load and in more severe cases the server has to deny the services. These challenges and problems directly lead the on-line VR

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technology failure to provide high-quality service to public base on the current network frame. Currently, few companies are investing mass of money to set up a large amount of data server nodes in order to break through the bottleneck of the network transmission speed. Therefore it is necessary to seek new, more efficient and more economical mechanism to create a WebVRGIS system on Internet. Using advanced computer technology to construct digital city has attracted the attentions from many walks of life. By integrating the friendly interactive interface of Virtual Reality System and spatial analysis specialty of Geographical Information System, WebVRGIS is preferred in practical applications, especially by the geography and urban planning. Urban simulation is becoming widely noticed nowadays, and some simulation systems have been developed in this area;e.g., ArcView3D Analyst, Imagine Virtual GIS, GeoMedia, etc. The above mature platforms are limited to a single computer running, while the publish methods based on network environment are proposed. WebVRGIS engine supports steadily real time navigation in virtual scenes which are constructed with massive, multi-dimensional data from various sources. VR and GIS modules are integrated seamlessly. All kinds of requirements for large-scale landscape simulation and a data management can be satisfied. 3D urban landscape database with various data sources can be produced to implement spatial analysis and 3D visualization and published in the Internet environment.

2 Background

In the early 1990s, Koller and others had an integration research about VR and GIS, and put forward the concept of VRGIS [9]. VRGIS is based on VR technology as a front-end interaction with users and supports GIS spatial data storage, processing, query and analysis functions of the system from bottom. With the development of VR technology and computer hardware technology, massive data management and 3D visualization technologies have been greatly improved. In VR field, massive data management and accelerated rendering technology include the following areas of study such as architecture design based on out-of-core, accelerate the 3D rendering, network optimization. However, most of current commercial platforms lack a timely application of these research results, which makes the combination of VR and GIS not in place and reduces the speed of city digitization. WebVRGIS integrates various up-to-date VR technologies, which can solve the problems in 3D visualization of massive data, P2P based massive 3D data share, realize the seamless integration of VR and GIS and provide a strong support for the city digitization. The stand-alone environment VRGIS [7] was developed. Based on VRGIS platform, WebVRGIS updates the overall framework as well as part sorts of key technologies, in which can support data publish on the network, and to support the mass data transmission and large numbers of users online simultaneously based on P2P technology.

3 Engine Overview

WebVRGIS engine designation uses object-oriented project database, whose data storage and management are based on object-oriented nodes, which is divided as core, middle and extended level. The core level is responsible for the organization and management of data and P2P virtual network management and also integrating rendering engine. The middle level supports the interface by encapsulating the core level and exporting the accessing interface for the extended level. The extended level implements extended function to fulfill the demand on application layer. With design patterns such as factory, visitor and singleton, the engine has good flexibility and extensibility.

4 Key Technology

Both VR and GIS systems need massive data, which can be provided from various sources. In the engine, DEM and DOM are used to construct the virtual terrain, and a 3DS MAX plug-in is developed to implement the combination of WebVRGIS and 3DS MAX. Because the virtual city needs massive data and computes too much, WebVRGIS engine introduces several optimization and acceleration technologies. Build up a P2P virtual network for multi-users and accelerate the 3D data transmission speed. VR and GIS modules are integrated seamlessly in the engine.

4.1 Support of Massive Geospatial Data

Virtual city simulation encounters the problem about massive data, which means that the data is dozens of GB or even more, and too large to load in the memory at one time. The WebVRGIS engine is designed to support massive data. Data transfer methods used in WebVRGIS engine make the ability of present large-scale scenes perform well online.

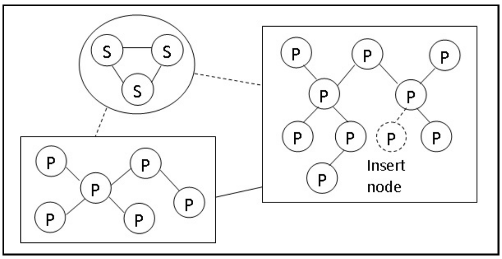

Fig. 1. Network Topology Structure of WebVRGIS

P2P Based VR and GIS Data Sharing. WebVRGIS exploits hybrid P2P structure. Cavagna et al has proposed a P2P model based on theory of space division of Voronoi diagram [5], to the transfer of cites 3D (three-dimensional) scene for online games, it supports streaming 3D scene index structure PBTree [11] for the 2.5D data compression out of the 3D model. Varvello et al combined the KAD network model with the mathematical model of the virtual environment [13], and tested in Second life as a framework [12]. Hu et al. have developed a set of P2P model Flod [14] based on the Voronoi diagram theory of the space partition. The model has solved the problem of user neighbors distributed storage by dynamic classification method. However, the global scope of the real geo-spatial environment is relatively stationary; there is no need of dynamic division. WebVRGIS exploit hash value to index VR and GIS data. In order to avoid the information silos, there are one and/or more servers to keep the hash value of all the users logged, the level of health, distances list, etc. Each client will connect with the server at first, request information of users which have higher health level in the list. After receiving the user list, the client disconnects with the server, the list received is integrated with the existing list to form a new one, and then it tries to update and make connections with other clients. Hash value is utilized as index of data block and user nodes, the XOR algorithm is used to calculate the logical distance. Obtained logical distance determines the distance between the nodes in the network and the user avatar in the 3D scene. Further more, the relative position can be obtained. This approach makes a mapping of the user in real geographical space and the user avatar in the virtual scene, as well as the nodes in the virtual network. Figure 1 is the virtual P2P network topology structure in WebVRGIS. WebVRGIS has following major components:

SERVER. The server is not necessary, but a sufficient condition for each node to be linked in the virtual network. Server uses I/O completion port ($IOCP$), which provide an efficient threading model for processing multiple asynchronous I/O requests on a multiprocessor system. After the server is initialized, the system created several threads, each thread do the I/O operation with Internet through IOCP. The server is not only used to preserve the user list, but also can be used as the Internet server providing the transit services for the whole P2P network, and make the connection request penetrate the firewalls and NAT smoothly, and improved the rate of nodes connection.

P2P Virtual Network. The client is adopted the P2P scheduling algorithm which is belong to the Kademlia algorithm [10]. Figure 2 is the P2P Engine hierarchy of P2P virtual network.

General P2P Service Layer. Kademlia regards each client as a node in P2P virtual network. That store and query the object information use $(key, value)$ methods. The key is a $128-bit$ identifier. When it is used in node identifier, $value$ is calculation by IP address and port. When used for data identifier, $value$ is the content of the data block. The result of two hash value XOR operation is the logical distance. Each $(key, value)$ stored in the node which has the shortest logic distance from the value. The routing table is constructed by the table called $K-B$ (K bucket). For each $i(0 \leq i \leq 128)$, each node

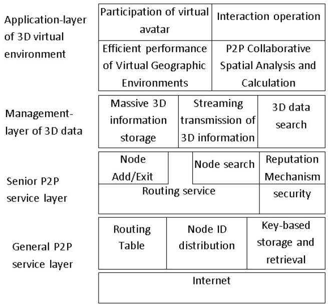

Fig. 2. P2P Engine hierarchy

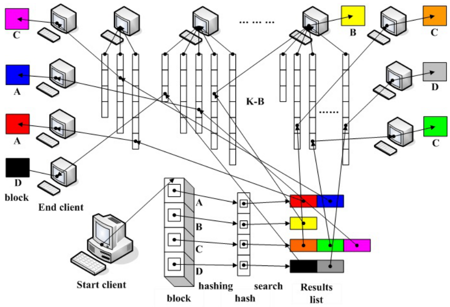

Fig. 3. File Block Search Process

have kept some node information that in the range of $m(2i < m < 2i+1)$,the table structure of which is the same as that of server-side. Each $K - B$ has the data item that has the same ID prefix no more than k. The location of the $K - B$ is arranged according to the time order. In each node, using binary tree structure organizes the $K - B$ and neighboring node hash, and storing them in the leaf nodes. As shown in Figure 3.

Senior P2P Service Layer. The responsibilities of this layer is to monitor the nodes adding and withdraw behavior in real-time, and the node searching traverse in the data structure. The data changing and traverse of the data structure based on Hash value are referenced since Kademlia. During the node query process, the configuration will be automatic transmitted, the node sends and receives the massage meanwhile update their routing table. Because each query gets information from the $K-B$ that closer to the target node, this mechanism ensures the effect that every recursive operation can reduce at least $1bit$, as well as half of the distance. Because of using the index mode divide the interval, for a network containing N nodes, at most inquiry $logN$ step, the target node can be accurately located.

Management-Layer of Remote Sensing Data. The data searching process which is the most important function of P2P is realized in this layer. Node makes the published file information store in certain position of Kademlia, If each message has a $128 - bit$ ID, information will be stored in the corresponding nodes. Each piece of information contains three parameters: $< File\ Hash\ Value,\ Publisher\ IP\ Address,\ Publisher\ Port >$ at least. The publisher will store the information in the node whose ID equals file hash value. For any node, it stored the information of the publishers who publish the same file. The object in large-scale scene is stored as a number of model files according to different LOD level. Model file contains the hash values of textures, not only the file names. After downloading and parsing the model file, a texture hash list will be got, and then searching the hash list in the virtual network. While finding the file list, dividing this file as blocks and then searching the hash value of every block, the result is stored in the transmission list.

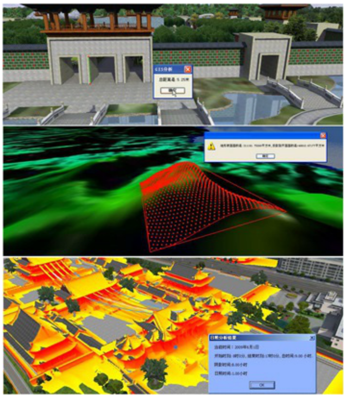

Fig. 4. VR-GIS function on web

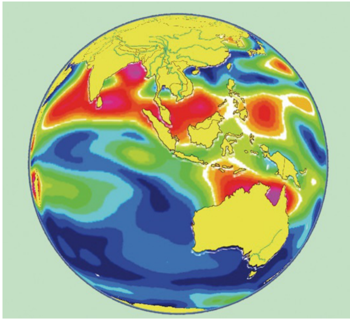

Fig. 5. The Sea Surface Temperature in WebVR-GIS

4.2 Seamless Integration of VR and GIS

Data sharing and function unification are the main goals of the integration of VR and GIS. By abstracting VR data and GIS data uniformly and inheriting their traits, the engine provides uniform external access interface and makes nodes have their own render and access mode, so that unification and sharing of VR and GIS data are achieved. As to the function unification, 3DGIS analysis functions are developed based on the uniform geospatial data. Combining the data's 3D traits, GIS analysis algorithm is applied in the 3D virtual scene, includes: measurement of the point, lines, faces and volumes, flooding analysis, muter-invisibility analysis, contour analysis, shadow analysis, path analysis, etc. The top one in Figure 4 shows the result of measure an arch door distance. The others in Figure 4 show 3D area measuring and sunshine analysis.

4.3 Multi-dimensional Data Support

The geometry data model is designed complied with the simple feature rules of $OGCOpenGIS$. Map establish optional indexing mechanism either $R-tree$ or $quad-tree$. Each geometry regarding a data record is stored into the feature dataset with unique index. It is released for com, as a server-side real-time vector data rendering engine, meanwhile provide web service interface for the browser-side. The engine supports almost every format of vector and raster data by integrating the FDO [1] of OSGEO and GDAL/OGR [2]. The fused data can be published on the surface of 3D digital earth divided following the digital earth data blocking mechanism. We use WebVRGIS to do verification. The Figure 5 shows the outcome of the fusion of spatial patterns of identified principal precipitation modes with the global land vector data [6].

Fig. 6. 2008 Qingdao Olympic Sailing

Fig. 7. Shenzhen Coastal

5 Implementation and Application

The oriented city region simulation WebVRGIS engine is developed based on OpenGL and C++, which integrates VR and GIS seamlessly and supports massive data. It was released in the forms: application and Com components. Based on WebVRGIS engine, we have developed some applications. We have tested the engine on a PC with a i3 M330 2.13GHz CPU, 8 GB, and an GeForce GT 330M GPU (1GB) by using data of Shenzhen city which about 8G including 62sq.km. DEM, DOM and model files exported from 3DS Max. The experiment can run 24fps averagely. Figure 6 and Figure 7 proves the applications, and the virtual scene of 2008 Olympic regatta in Qingdao rendered in WebVRGIS is shown in Figure 6, and the virtual Shenzhen seashore is shown in Figure 7.

6 Conclusion and Perspectives

WebVRGIS engine is developed, in which the integration of VR and GIS is researched. In the engine, massive data shared by the two systems (VR&GIS) is supported by the P2P virtual network. It can meet the requirements for virtual city construction, GIS analysis. GIS data has several characteristics, ie. large scale, diverse predictable and real-time, which falls in the range of definition of Big Data defined by Intel Fellow Faye Briggs [4]. In 2008, Nature published a special issue concerned with the subject of Big Data [3], which makes people focus on the use of existed massive data (ie. analysis, visualization). The future work will focus on the augmented reality extended application of WebVRGIS engine and more intelligent process with considerable urban image search algorithm. At the same time, we have plans to play full potential of P2P, combined with the advantage of the cloud computing, provide the cooperating VR/AR roaming function and GIS analysis for multi-users.

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References

1. Feature data object (fdo), http://fdo.osgeo.org/
2. Geospatial data abstraction library, http://www.remotesensing.org/gdal/
3. Big data specials. Nature, 455(7209) (September 2008)
4. Briggs, F.: Large data - great opportunities. Presented at IDF 2012, Beijing (2012)
5. Cavagna, R., et al.: P2p network for very large virtual environment. In: Proc. ACM Symp. V. R. Soft. and Tech. (2006)
6. Chen, G.: A novel scheme for identifying principal modes in geophysical variability with application to global precipitation. J. Geophys. Res. 111, 11103 (2006)
7. Chen, G.: etc. An integrated vrgis navigation platform for city region simulation. Comput. Animat. Virtual Worlds 21(5), 499–507 (2010)
8. Huang, B., Jiang, B., Li, H.: An integration of gis, virtual reality and the internet for visualization, analysis and exploration of spatial data (2001)
9. Koller, D., et al.: Virtual gis: A real-time 3d geographic information system. In: Proc. 6th Conf. on Vis. (1995)
10. Maymounkov, P., Mazières, E.: Kademlia: A peer-to-peer information system based on the xor metric. In: 1st Int. Workshop on Peer-to-Peer Sys. (2002)
11. Royan, J., Bouville, C., Gioia, P.: Pbtree: A new progressive and hierarchical representation for network-based navigation in densely built urban environments. Annales Des Telecommunications 60(11-12), 1394–1421 (2005)
12. Varvello, M., Diot, C., et al.: P2p second life: experimental validation using kad. In: Infocom, Rio De Janeiro (2009)
13. Varvello, M., et al.: A networked virtual environment over kad. In: Proceedings of the 2007 ACM CoNEXT Conference (2007)
14. Yun Hu, S., et al.: Flod: A framework for peer-to-peer 3d streaming. In: Proc. 27th Conf. Computer Communication, INFOCOM 2008 (2008)