WebVR——Web Virtual Reality Engine Based on P2P network

Zhihan Lv
College of Information Science and Engineering, Ocean University of China, QingDao, China
CNRS UPR9080/ IBPC, 13 rue Pierre et Marie Curie, F-75005, Paris, France
Email: lvzhihan@gmail.com, lu@ibpc.fr

Tengfei Yin, Yong Han, Yong Chen, Ge Chen*
College of Information Science and Engineering, Ocean University of China, QingDao, China

Abstract: WebVR, a multi-user online virtual reality engine, is introduced. The main contributions are mapping the geographical space and virtual space to the P2P overlay network space, and dividing the three spaces by quad-tree method. The geocoding is identified with Hash value, which is used to index the user list, terrain data, and the model object data. Sharing of data through improved Kademlia network model is designed and implemented. In this model, XOR algorithm is used to calculate the distance of the virtual space. The model greatly improves the hit rate of 3D geographic data search under P2P overlay network. Some data preprocessing methods have been adopted to accelerate the data transfer. 3D Global data is used for testing the engine. The test result indicates that, without considering the client bandwidth limit, the more users, the faster loading.

Keyword: Virtual Reality; P2P; WebVR; Web3D; GIS; Geocoding; Kademlia

I. INTRODUCTION

Geographic Information Science is developed on the basis of Geography, Cartography, Surveying and Computer Science Disciplines, the software entity implied based on which is Geographic Information System (GIS). Virtual Reality (VR) technology is reflection of the real world to simulate and generate a three-dimensional virtual space with computer. The combination of Geographic Information System and Virtual Reality technology generates VRGIS, which not only possesses GIS function such as spatial data storage, process, query and analysis, but significant improves friendly interface and intuitive interaction combined with VR technology.

With the developing of Internet era this century, theories and practices combined with Web demonstrates its unprecedented vigor and vitality, and WebVR-GIS becomes the inevitable outcome of this trend, which implies VR-GIS on Internet, providing data sharing, collaborative roaming and GIS analysis function, while shows the whole "global virtual environment" in a scene. One case of WebVR-GIS extension to multi-user is Web Virtual Environment, where each user has a virtual role. Virtual scene inflects with real environment and efficient information sharing makes each virtual role interactive entertainment and work together free from limits of time and spatial. It is necessary that virtual districts turn to virtual cities and virtual earth in virtual environment for the rapid increase of users and people explore desire for new things. Virtual earth is the most macro-scale implement of virtual environment. People are inspired by its real reflection of real world, and eagerly waiting its characteristics such as massive user collaborative interaction, massive virtual environment data sharing, global real geographic location reflection, etc.

However, a series of new problems will arise while the level of virtual environment extends to earth. For example: (1) Global geographic location is complex, so the space partition methods of traditional GIS based on topological can't meet its demand; (2) Global virtual scene data is enormous, which can't be deposited from inside and external memory at one-time; (3) Global-scale nodes was enormous, frequent changes, unpredictable behavior, so the controllability faces tough challenges.

The normal solutions for the three problems above are as follows: Common methods known as latitude and longitude region division model, map projection division model and Voronoi diagram region division used in geographic information system are used to divide GIS region (geographic area dividing) efficiently. The problem that loading enormous global virtual scene data is attributed to "global spatial data partition model". Earth model division method in three-dimensional space include traditional "grid (cell) partition", "G2PS model", etc. The reasonable division and organization of earth model will reduce virtual scene data effectively. The third problem can be attributed as "distribute network model", which is much related with hardware. The better solution is server cluster[1] technology. For example, the terrain and image database of Google Earth containing 70T in 2007 is support with a huge "cloud storage" server cluster in Google Inc. "Second Life" use each computer to simulate 90 square meters of virtual scenes, which has 5000 servers running now in Linden Inc.

In practice, firstly, the effectiveness and feasibility of "geographic area division" and "global special partition model" is eagerly to be improved. Secondly, global net supporting similar "cloud computing storage" hardware requirements coupled with higher maintenance costs will discourage many institutions. At the same time, the existing distributed network algorithms are with virtual network (P2P) on the basis of DHT algorithm based, the user ID of which is mostly based on logic distance, rather

*Corresponding author, email: webvr@vip.qq.com

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than related to geographic location, and even network address such as IP. It can reduce index time for user based on logic distance, but bandwidth waste and traffic congestion while file transferring cross-regional and cross-country has become a problem that can't be ignored.

Taking all the above into consideration, we propose a new space division method to encoding map global geographic environment model based on Hash, which makes it apply to divide real world, virtual scene and network, and be the spatial division method of overlap world in network virtual environment. The method belongs to the reasonable combination of geographic information science, virtual reality and virtual network, with higher innovation and better scalability. The universal of the method will take "earth virtual environment" to everyone, providing global users a platform in which interacting with 3D avatar in virtual reality environment. All these will not only shorten distance between people, but also provide a better data share and cooperation means for science research work, while provide data base and theoretical basis for interaction between people and environment.

II. RESEARCH

Through the problems on the P2P network of virtual geographic environment, the following points are worthy of studying:

(1) A supporting mass, précising model of the real world environment, classification and indexing of space, mapping with the real location, enhancing fidelity, meet the deep planning needs on three-dimensional data. Cavagna R., C. Bouville, J. Royan developed a P2P model based on theory of space division of Voronoi diagram[2], for the transfer of cites` three-dimensional scene, and planed to use for online games in the future . However, its support of streaming three-dimensional scene index structure PBTree[3] for the 2.5-dimensional data, with a high degree of property from two-dimensional vector data compression out of the three-dimensional model of the true model does not support the fine. M. Varvello, C. Diot, and EW Biersack combined the KAD network model with the mathematical model of the virtual environment[4], and tested in Second life as a framework [5]. He still used the original data partitioning Second life and organization as the core model, without importing space division and the advanced theory of real-world mapping.

(2) It can improve stability and data retrieval efficiency by using distributed Hash structure, which is based on space partition to virtual index structure in peer networks. In distributed network, frequently joining in or quitting of nodes will cause a large number of networks Churn, which on the overall robustness of the distributed network architecture puts forward higher requirements. Hu SY, TH Huang, SC Chang, et al. have developed a set of P2P model Flod[6] based on the Voronoi diagram theory of the space partition. The model has solved the problem of user neighbors distributed storage. Dynamic classification method applies to rapidly changing data in 3D game scene. However, the P2P model based on the theory of division space is constantly in a dynamic, it will trigger the whole user list traversal each time the user moves, which costs a lot of computing performance. Under the conditions of the existing hardware, it can not be extended to the global field. The global scope of the real geo-spatial environment is relatively stationary; there is no need of dynamic division. Therefore, Approach with pre-partition manner can completely make the land division, without changing zoning process with the mobile node, greatly improving the system running in real-time. Using the distributed Hash structure, based on space partition to store, can realize retrieve distributed resources, achieve the load balancing requirements, and also improve the hit rate and data retrieval efficiency.

(3) Creating a set of the space partition model applied to the real world, the global virtual environment and the global network structure can organically couple geographic addresses, network addresses and user identity. In the regular research, geo-coding, spatial data partition model and the virtual peer networks are as an independent branch of study. Use the virtual network architecture on the virtual environment scene to share data, while associate the information of virtual geographical world and real users, can effectively solve the model for low precision, a large amount of data, multi-user interaction delay, waste of network bandwidth optimization and other issues.

III. SYSTEM OVERVIEW

A. Data flow

The design principle is trying to support more load quantity of online users, to reduce the data transmission quantity, to improve data compression ratio, and to increase the data download source. Different types of data are preprocessed, and the result is stored to data servers.

While the client is browsing scene, according to the neighborhood search strategy, it choose the source of data transfer, loading from server if the source can`t be find.

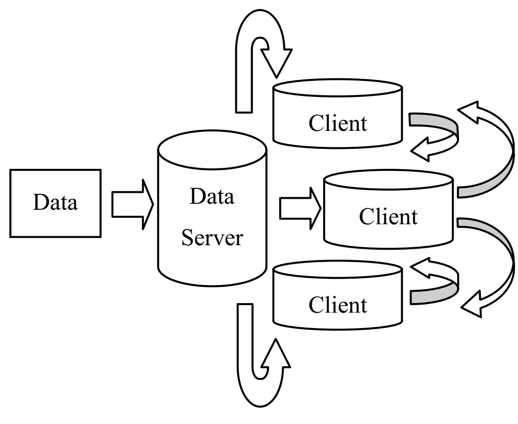

Figure 1 Data Flow

Ⅳ. THE KEY ISSUES

A. Graph-based scene topology

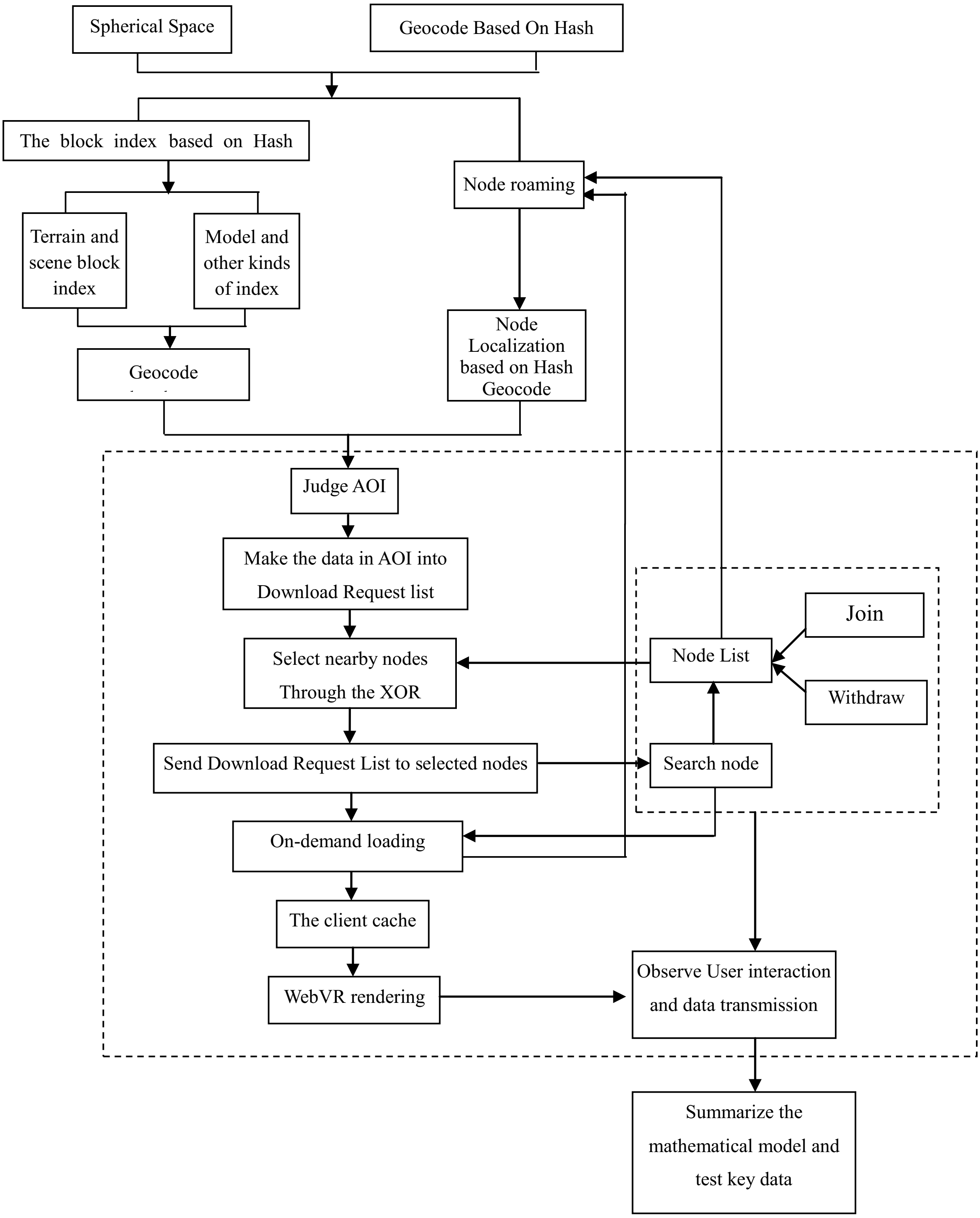

Figure 2 Engine Architecture

The scene graph is managed by hierarchical bounding box, using bounding sphere and bounding box to achieve the scene bounding volume hierarchy. The information is stored by a directed acyclic graph structure. A scene graph includes a root node, multi-level interior of the side nodes, and multiple terminal leaf nodes. The root and side nodes take charge of the construction of the level of the nodes, and the completion of certain functions; the leaf node is saved to one or more object information can be drawn. Each node maintains its own bounding volume, and so on, constitute a distinct level. This level bounding box diagram can speed up the correct information in the expression of the composition of the scene graph, and also expedite the reduction of scene objects, intersection tests, collision detection and a series of operations. This structure allows each node to have multiple parent nodes. When the same geometric object needs to be repeatedly referenced by more than one parent node pointing to the same child node, with each parent node pointing to a new child node of the tree than the total number of nodes, memorizing utilization and scene traversal steps reduced, rendering the final results remain unchanged.

B. Data file partition

The nodes in scene graph include terrain, objects and other types, based on different data types, different partition methods are adopted.

Quadtree-based multi-scale geographic data block

Geographic data includes terrain model using Tin Triangulation, the real image in the terrain covering the surface, and vector data. These geographic data are the surface data and little overlap in the vertical direction, so as to evenly split the region based on quadtree classification and index structure, each quadtree level represents a level of precision. An example of mature application is worldwind[7]. Quadtree construction processes the whole terrain as root, starting from the root node, checking whether the root partition to satisfy certain conditions. If it is not satisfied, not partition, it will be used as a leaf node preserved. Otherwise, recursively to the root node continuously divided into four equal sub-regional nodes, until it not split up any longer. The last step is drawing and rendering all the leaf nodes. The greater depth of division, the resolution will be higher. That is, each raising separate layer of depth, sampling density doubled. For the earth's surface, it is the need for separate ways after a projection from the plane to the latitude and longitude of the projection transformation.

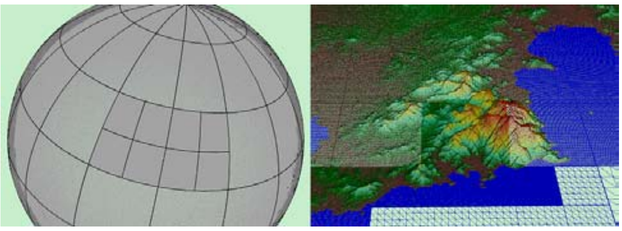

Figure 3 Quadtree block

Object node as unit data block

The scene contains a variety of objects nodes, including the following ones. (1) Construction information extruded from attributes information with a high degree of vector data; (2)3D model information import from 3DsMax; (3) geometry data. In the traversal of scene, each node of the outermost layer under the root is considered as a unit.

C. Multi-scale data preprocessing

The topographic data according to the different quadtree levels, divided the LOD data and stored it to external memory. For object nodes, each node object to the crude unit are generated from the refined precision of the data L1 4 to L4, in which L2 and L3 as L1 generated by collapse of law on the simplified model, L4 Impostor generated by image cache node. The texture object node based on cell aspect ratios of 2:1 generated three simplified texture memory to external memory, L2-L4 in four levels corresponding to the simplified model. The texture data is compressed as DTX3 by GPGPU in the way of calling the CUDA library. External memory models in different scales in turn are called as needed, more efficient than single MIPMAP file to be transferred.

D. Data request depends on culling result

For large-scale scenes, when a large number of models are read into memory, the computer system will inevitably result in a huge burden and could lead to insufficient memory. At this point, we need a dynamic scheduling mechanism. Time is unidirectional and cannot accurately predict the behavior of users in the future, and therefore the data loading to pre-deployment of space-related scheduling. Dynamic scheduling can produce the node when he was on the scene of some child nodes, while drawing long term without any participation. Child nodes can be automatically uninstalled, free memory space; On the contrary, he cannot load certain child nodes in memory, the dynamic scheduling of its control of the scene sub-tree.

E. Memory release in time

Using the time-related scheduling on the data withdraw after called. LOD node of a level of detail rendering scenes, if not involved in long-term, it will uninstall it, otherwise it is loaded. Design of smart pointers in the realization of the base class for all nodes, effectively prevent the memory leak caused by incomplete release.

F. P2P-based data sharing

Advanced Kademlia-based protocol scheduling discipline

Node ID and files are geo-coded with HASH for an index purpose.

1. Building geo-coding database

Multiple data formats are involved in this research, such as vector data, DEM data, image Data, and three-dimensional model mesh and texture data. It is necessary to build up an index for data after creating the earth three-dimensional model. First, vector data, DEM data and image Data are partitioned in a multi-scale way according to space information. Each level is labeled by a 16-bit binary HASH which called “prefix”. After eight-times partition, each type of data can be expressed as a 128-bit binary HASH, which is made up of eight prefixes in the order left to right, the most significant byte is the first-scale data (big-endian byte order). The 128-bit binary HASH will be used as its geo-coding, which also mapping the sign of different scales. Second, as for the three-dimensional model mesh and texture data. The first 7 partition are combined in the same way as vector data and DEM data. Accordingly, the result is a 112-bit binary HASH. Meanwhile, the three-dimensional model itself is also labeled by a 16-bit binary HASH, adding the preceding result then the three-dimensional model mesh and texture data are expressed as a 128-bit binary HASH as well. Similarly, its 128-bit binary HASH will be used as its geo-coding, which mapping the sign of different scales. Next, the geo-coding and corresponding mappings of various data formats are put into different fields of a database and established an index. In addition, filename of data are renamed to relevant geo-coding.

In a Kademlia network, node's ID is created randomly and data's ID is generated according to the contents of documents [8], therefore, there is time correlativity between data and their forms of expression. By contrast, the HASH ID of our study is calculated by using the space division method, which has space correlativity.

contained in the adjacent area are added into the user neighbor lists.

3. Joining and quitting network

Every time when the node logs on to the network, it is expected to finish three tasks. They are generating its ID, generating its neighbor lists, and downloading required item of data according to its new location.

When node quit the network, it is impossible for other nodes to receive this node's response. As a result, this node will be regarded as off-line. Thus, it is predicted that the stability of network won't be affected.

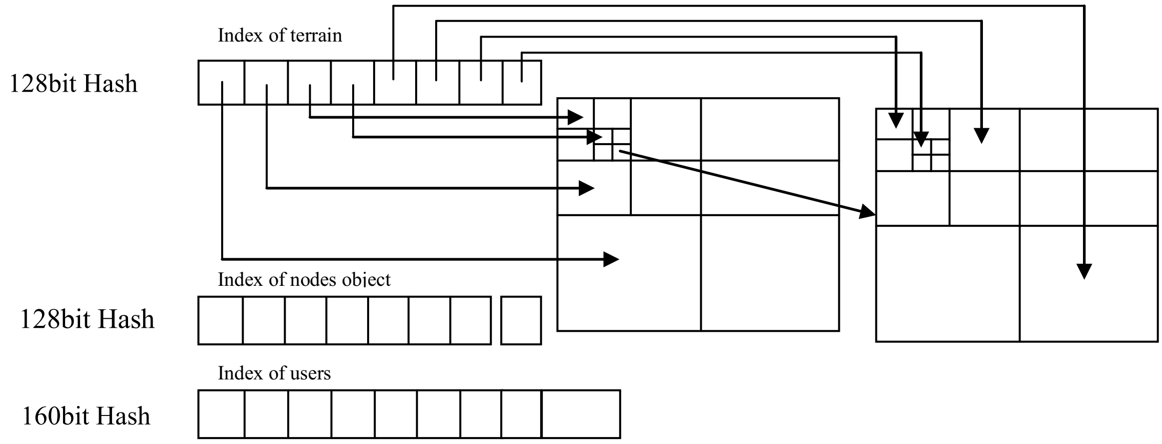

Figure 4 Index Structure

2 . Constructing Peer-to-Peer network based on geocoding

For each user, its final ID used for positioning is made up of two parts. The first part is the geo-coding that is the first eight geographical prefix, which is relevant to its current location; the second one is its 32-bit binary user ID.

On user neighbor lists, every node keeps a list of neighbor's information(IP address, UDP port, Node ID). Those lists are stored in a quadtree. The quadtree is divided into 7 layers and each layer is marked with a prefix. Every neighbor's 32-bit binary user ID is included in the leaf nodes.

Logical distance. Given two 160-bit identifiers, A and B, we define the distance between them as their bitwise exclusive or (XOR) interpreted as an integer, d (A, B) = $A \oplus B$. The distance is related to their geographical position, during to the fact that the generation of node's ID which depends on geographical division. Consequently, smaller distance means they are geographically closer.

User neighbor lists generating. The locale-sensitive area of nodes is a circle with radius-r. The adjacent area is formed by the intersection of this circle and the spatial-quadtree leaf nodes. If the adjacent area has no nodes at all, the radius-r would become bigger constantly until there is node being contained in. At the same time, all the nodes being

4. Nodes shifting

There are mainly four changes when a node is moving from one place to another. First, its ID will be regenerated quickly. Second, starting to search required data on the basis of the new position. Third, its neighbor lists will be regenerated as well. Fourth, the node has to inform its neighbors of leaving, send request to its new neighbors and ask for establishing friendship, which aiming to insert itself into other nodes' neighbor lists as necessary.

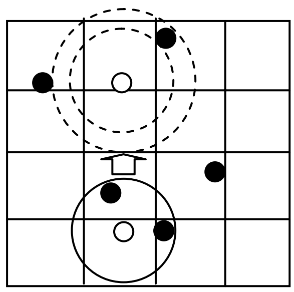

Figure 5 Node AOI change

5. Neighborhood Selection

Some software for file sharing, such as emule would be in operative condition except at zero searching hit rates. We need to guarantee the occurrence rate of the geographical neighbors, or we may lose them. We can reach the conclusion that the node searching way of DHT cannot be used in virtual environment.

After trigger event of neighborhood selection occurring, the peer send its information, I for short, to any neighbor in its neighbors list. I, will go through the following process when any peer which receives the information. P for short, calculating its geocode ID by the first 128 bit hashID of the sending peer, then judge whether the receiving peer owns the same geocode by XOR algorithm. If the answer is yes, it will send I to its neighbors list, then any neighbor receives I executes P, which is a recursive process. It occurs under the following conditions. If the hashID of peer receiving information is different, from me at the geocode bits between 64 and 128, then P stops. The condition of all the searching process stops, the distance between peers executing P and starting peer is beyond the value of (scene side/24). It is different from the method of limiting recursion frequency by depth in Kadmelia. In fact the whole process is distributed traversal.

6. Data Searching

When trigger event of data searching occurs, the peer will recalculate the logical distance between any peer in its neighbors list and itself. That is XOR value between its ID and other IDs. Then it sends data index value to the nearest n peers, after any peer online receives the information. It doesn't only execute local research, but also sends geo-code info to its peers list, and so on. According to the small world theory, we could get the data we need when the recursion frequency is 6. We make the recursion frequency is 8 by default, which is used by the radius of data searching. When we get the data, we add the peer with the data into our local neighbors list. Then they begin to execute multi-source transmition.

Server based on IOCP for large numbers of peers

Because users' list is stored among lots of clients, some clients may not add it into the network. One of the extreme situations is that, when a peer logins in, all of its users on the list are offline, so it can't take part in the network. We call this situation "Information isolated island". In order to prevent this situation, we designed the Server based on IOCP. It stores the recent login user info, including the user's name, IP address, and geocode info. After each user login in the network, it will send its info to server to store. Then it will totally break the link with server. After it login in the server, it will download the latest 20 users without any active user on its users' list, and add them into its neighbors list. The model of IOCP and multi-thread can be the best way to use resources, which supports lots of users.

Transmission Strategy

After data searching, we begin to transmit data according to resource list by searching.

1. Cache Mechanism

The process is manifested in two aspects. First, on the sending side, when file block is being sent, the mechanism will control the data bytes sent by a single running thread all the time, which is a limiting process. Second, on the receiving side, it will create a buffer with the same size with source file before file transmission. Transmission is pigeon-holing. When the software quits, it will remember every position of downloaded data in the file. When the software restarts, it will execute Resume from break point.

During the transmission process, model data is pressed by zip-standard while texture data is compressed by Jpeg2000-standard.

2. File Distribution

In order to improve the number of data resources, we don't only store the whole data in neighbor peers, but also peers nearby after file data is cut into blocks. On the data distribution side, cutting and calculating every file into a lot of blocks with the same size by hash algorithm, each block can generate unique ID by file geocode and block content. Distribute and store data resource by the principle of file HashID being closed to geocode on clients. The process is prepared for data searching. On the receiving side, searching process is based on parameter of file name. Ask some peers whose hashID is closed to the file name ID, if the answer is yes, then we can find some peers which owns the file, and ask for downloading.

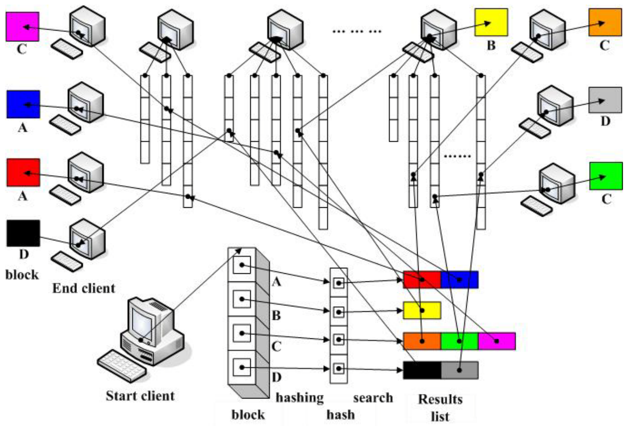

Figure 6 P2P file share structure

Network adaptability

Realize penetrating NAT by the way of holing, and penetrating firewall based on UPNP.

Ⅴ. IMPLEMENTATION AND TEST

A. Implementation

The component is encapsulated by Microsoft ATL library. Pack security certificate and the component into the style of CAB. Interact by the way of JavaScript calling components interfaces.

B. Test

We use 1 ° × 1 ° global elevation and image data provided by Noaa web site to do data partitioning and geocoding index generatation for free. Among them, Qingdao City's elevation and image data is high accuracy ASTER G-DEM data. Model data is part of building models of Qingdao. We use Sqlserver Database and do the geocoding of number and connectivity of parts of the database using C#. Rendering and the network part use C++. Some pages use script called component functions of JavaScript, and achieve interface effects based on exits library.

Table 1 Data preprocess time

Data type	Globe DEM	Globe DOM	Globe 9 level LOD	Qingdao DEM	Qingdao DOM	Qingdao 5 level LOD	Building Model 4 level LOD
size	911M	683M	990M	25M	479M	15M	5G
Time			87min			2min	900Min

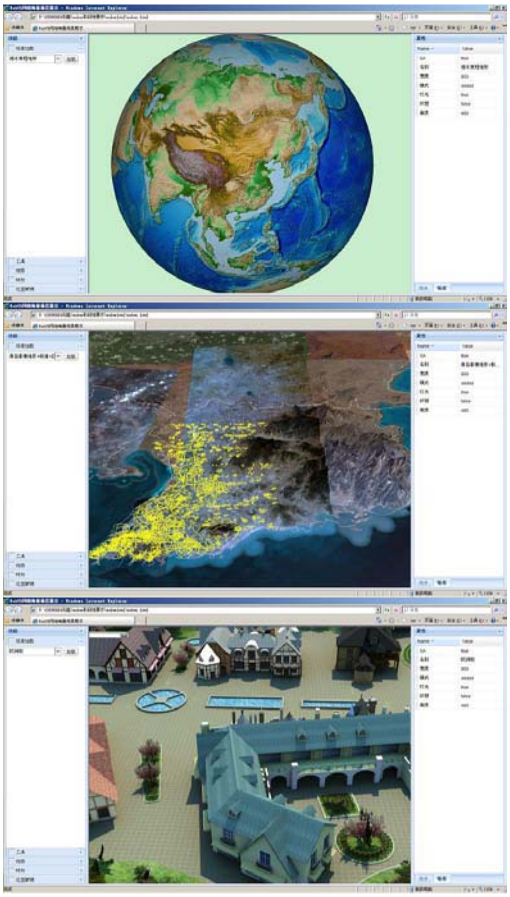

Figure 7 From Globe to City

Usually the rendering engine and networking engines are separately tested, such as people usually test the amount of data supported by rendering engine and its rendering efficiency, while testing network engine on the transmission efficiency. For P2P networks, Consistency, Persistency, Scalability and other properties are usually tested. Some researches on P2P networks of the virtual environment also test the changes in performance caused by AOI region changes.

Because WebVR engine has compact architecture and it is tightly integrated with rendering, Data Division, Dispatch and network part, we just test the overall performance.

The users number / User information server load

Test the server bandwidth changes in the second period when users were respectively (1, 5, 10, 50, 100, and 200). They login in the user information server at the same time. The figure shows that the server only provided the neighbor list download in the initial phase. Then it disconnected with the node, no longer has traffic.

The users number / Data server load

Test the data server bandwidth changes in 10 seconds when the number of users were respectively (1, 5, 10, 50, 100, 200), and they come into a new scene. The figure shows that when the node could not get the scene from other nodes, the data server provides data for download.

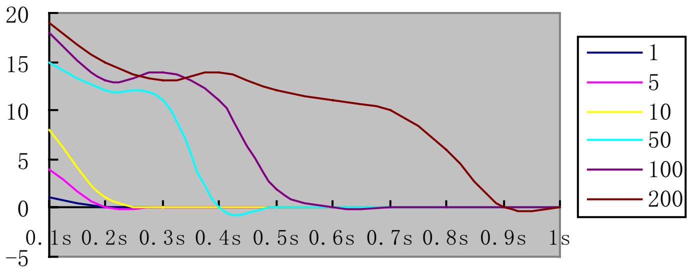

Figure 8 User information server load

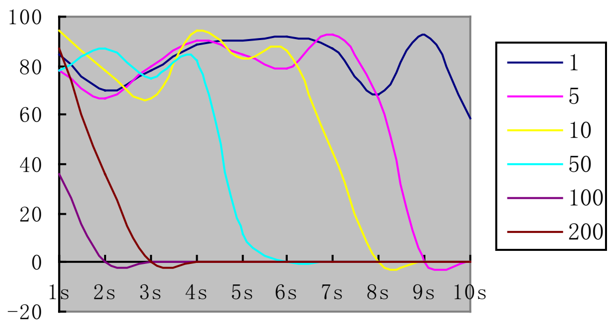

Figure 9 Data server load

The users number / Data loading speed

Test the loading times changes when users were respectively (1, 5, 10, 50, 100, 200), and a node comes into a new scene. It can be observed that with the increasing of the number of users, data loading speed increased.

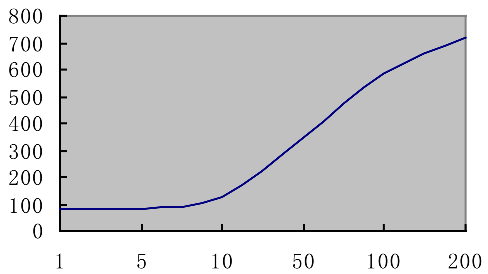

Figure 10 Data loading speed

Data size / Loading time and Data size / Rendering frame

Test the data load time and rendering frame rate changes of a node when data volume is respectively (50, 100, 200, 500, 1000, 5000) MB. When the amount of data increases by the various engine optimizations, it still maintains a smooth roaming rate.

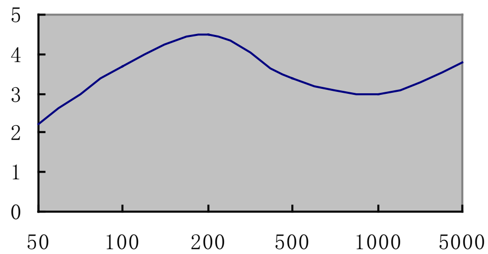

Figure 11 Loading time

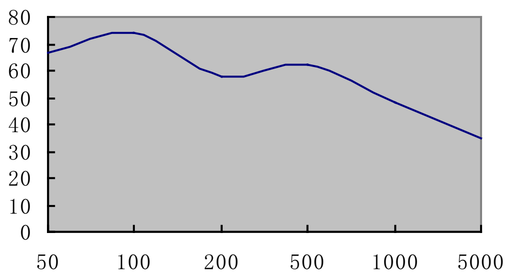

Figure 12 Rendering frame

VI. CONCLUTION

This paper introduced a multi-user online virtual reality engine. The main contributions are mapping the geographical space and virtual space to the P2P overlay network, and dividing the three spatial by business-oriented quad-tree method. The geographical code is identified with Hash value, which is used to index the user list, terrain data, and the model object data. Achieve sharing of data through improved Kadmelia model. In this model, XOR algorithm is used to calculate the distance of the virtual space.

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Zhihan Lv is a Ph. D candidate of Marine Information Technology laboratory, Ocean University of China, China. His research interests include virtual reality, 3D Visualization, computer network and software architecture.

He has been an intership at the Immersion technology Co., LTD for four years and at the Key Lab of Marine Resource and Environmental Geology, First Institute of Oceanography, SOA for four months. From 2010 Sep, he had been a visiting Ph.D student at French National Center for Scientific Research (CNRS) in France for one year, with the support of China Scholarship Council.

Tengfei Yin is a master student of Marine Information Technology laboratory, Ocean University of China, China. His research interests include Web based virtual reality and P2P network.
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Yong Han is a professor of virtual reality in the keylaboratory of Ocean Remote Sensing, Ministry of Education, Ocean University of China, China. His researchinterests include virtual reality, computer animation, and GIS.

Yong Chen is a lecturer in college of information science and engineering at Ocean University of China, China. His research interests include computer technique and computer graphics.
He has gone to New York University for his postdoctoral fellow at 2009.

Ge Chen is a professor of physical oceanography at Ocean University of China, China, the dean of the School of Information Science, Ocean University of China. His main research interests include marine remote sensing, virtual reality, and GIS, PhD supervisor.
He has been to IFREMER in France for his postdoctoral fellow for two years.
Prof. Chen is an International Member of New York Academy of Sciences, and an international member of AAAS. He have served as president of the international conference session six times.