# MANAGEMENT AND VISUALIZATION OF HUGE RANGE IMAGES AND DIGITAL IMAGES

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**ABSTRACT:**

Generally speaking, a large number of range images data will be generated in the process of collecting 3D structure information of huge building based on the 3D LIDAR scanning technology. For instance, more than 500 range images data are collected in the project of digital survey in Taihedian. Every range image data is at least in 60MB. In the end, the whole size of range images data adding other palace are always more than several hundred GB. At the same time, for the modelling and computer simulation with range images data, accurate digital images data of huge building should be collected, too. Only in Taihedian, about 2000 pieces of photo are made, the size of every piece is about 8MB. It is obvious that it's not feasible to manage so huge data in OS'file management system. How to organize and manage range images data and digital images data will be a very important task in using LIDAR technology.FILE structure and Standard Template Library technology are used in reading huge range images file, which is in order to parse known format rapidly and efficiently. After rearranging the parsed data, the rearranged blocks in Bytes are put into BLOB field in Oracle databases. A new algorithm for interactive rendering of huge range images data based on view-dependent level-of-detail（LOD）and clipping windows-dependent exchange between main memory and Oracle database techniques is presented. In the process of reading huge range images file，range images data are partitioned into small blocks with the different size according to angle information and its MBB. Meantime, 3D R-tree spatial index is created by means of MBB in main memory. In the interactive rendering, range images data outside the clipping windows are not rendered. That is, several small blocks that their MBBs intersect the clipping windows by searching in 3D R-tree spatial index should be shown on the screen. The distance scan of center point of screen to centre point of MBB controls the resolution distribution of points on the screen, so that the small blocks are able to be searched and display fast. For the storage of digital images, generally, the whole file is considered as a block or BLOB to store in Oracle directly based on I/O data streaming transmission. At one time，some indispensable information should be analyzed into attribute field to store in Oracle with the block. At last, a table, which comprises range images and digital images table pointer field、corresponding points coordinate field、spatial attitude parameter field, will be created for uniform management in range images data and digital images data.The experiment system is developed in VC 6.0 program language and OpenGL 3D graphic library. The range images and digital images data sampled from several great halls of Forbidden City are used in experiment. These data are stored in Oracle databases with Oracle Objects for OLE (OO4O). Experimental results show that our approach can not only design to allow easy access to range images and digital images data stored in Oracle databases, but also realize real-time rendering for huge datasets. Those are the grounds for the modelling and computer simulation with range images and digital images data.

## 1.INTRODUCTION

3D laser scanning technology, also known as the "real replication technology," is a high-tech which began to appear on the mid-1990s, it is another breakthrough in mapping technology after the GPS. Because of its rapid, real-time, non-contact, initiative, digital, automated, high-density, high-precision performance and interface features, it also overcome the traditional measurement of certain technical limitations, its application may set off another revolution in measurement technology.

Beijing University of Civil Engineering and Architecture began to introduce a variety of different measurement of ground-3D laser scanners from 2004. In the ancient architecture protection, cultural heritage protection, an quality evaluation of the important building construction, building deformation monitoring and so on, there are not only gratifying results in these aspects, but also a lot of problems. For instance, in a digital measurement of ancient architecture project in Forbidden City we need to create three-dimensional simulation model, using short-range and medium-range ground laser radar and high-precision digital camera to scan ancient architecture in order to get the range image data and the color digital image data. Because of its large volume, such as in a digital measurement of Taihedian, there are more than 500 point sets in the scanning process, each data volume of point sets is at least 200 MB, the general scan data into text format PTX reached more than 500 M, together with other parts of range image data, the total volume often is as high as several hundred GB. Meanwhile, in order to carry out true three-dimensional modelling and simulation, it also needs to collect high-precision color digital image data, only in Taihedian it is the acquisition of about 2,000 digital images, each one is an average of 8 MB.

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As the total volume of two kinds of data is very large, obviously, it is not a good idea to use the file system to manage these data. How to use object-relational DBMS for large-scale range image data and digital image data for effective organization and management, and then achieve efficient distribution and real-time browse, for the next post-processing raw data to provide effective protection, a ground laser radar technology will be of vital significance in the application of the subject.

## 2. RELATED WORK

### 2.1 3D Spatial Grid and Maximum Bounding Box

In two-dimensional GIS, the smallest bounding rectangle (MBR) is usually used to manage the space geometric objects, and a two-dimensional R-tree index is created to select space geometric objects. Therefore, in order to facilitate the organization and management of raw data in the database, three-dimensional spatial grid is used to manage the range image. 3D space grid is composed of the object's Minimum Bounding Box (MBB). The eight vertexes of MBB is the grid vertex, and a MBB is a grid unit. MBB only include the three-dimensional coordinates of the bottom left corner and the upper-right corner,

The coordinate is expressed in double-precision real number (as shown in Figure 1), each MBB is parallel to coordinate axis.

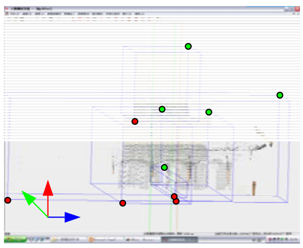

Figure 1：3D spatial grid

### 2.2 Range Image and Point Cloud

Depth Image, also known as range image, has links and differences with point cloud. Depth image after coordinate transformation can be calculated into point cloud data. If there are rules and the necessary information point cloud data can also be regarded as depth image data by anti-calculation (as shown in Figure 2 and the conversion formula). Point cloud is in the reference frame of Cartesian coordinate system, and range image is in the reference frame of Polar coordinate system and the spatial point is as a reference. In this paper, the range image is usually in the centre spot and the scanner's focal point is its reference. There is another major difference between range image and point cloud: point cloud is generally scattered and disorderly collection of three-dimensional coordinates, and range image is orderly 2.5 dimensional data collection. Its data organization is based on the combination way of matrix array. The horizontal angle and vertical angle between points is a fixed values, so the amount of range image data will be much smaller, which means that the actual storage object are the distance value r, initial angle and step angle.

$$\begin{cases} \alpha = \arctg(y/x) \\ \theta = \arctg(x/(z*\cos\alpha)) \\ r = z/\cos\theta \end{cases} \qquad \begin{cases} z = r*\cos\theta \\ x = r*\sin\theta*\cos\alpha \\ y = r*\sin\theta*\sin\alpha \end{cases}$$

where $\alpha$, $\theta$, $r$ = coordinates in Polar coordinate system of range image
x, y, z = object coordinates in spatial Cartesian coordinate system

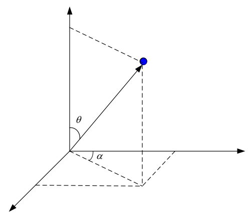

Figure 2：Conversion between range image data and point cloud data

### 2.3 Oriented-Object Database Storage

Oracle database take the advantages of stable performance, scalability, high availability, data security. Oracle database is very suitable to store range images, point clouds and digital images. Oracle database after version 8 offer huge storage capacity for data, that is, the introduction of the LOB (large objects) data types, including BLOB, NCLOB, CLOB, BFILE four types. Compared with the previous version, the size of its storage and storage efficiency has improved a lot. BLOB is object of binary sequence, the size of the type of field can reach more than 4 GB and it can store as objects of different sizes, and dynamically adjust storage space; Oracle database also provides a BLOB data compression optimization and other storage options to further enhance the performance data management system.

There are three methods for database management of document data: First, the file is still stored in a storage medium, only the file path links are retained in the database. Another data management method is: the whole file which becomes the binary data stream stored in BLOB field directly. The third method is that, in the object-oriented thinking, the heading part and actual data part of the file were stored in a database by category attributes. The file format should be known in advance.

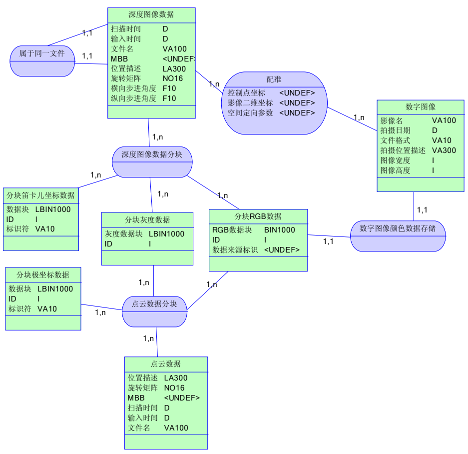

Figure 3：The design of database concept model



（MaxX,MaxY,MaxZ）

## 3. INITIAL DATA STORAGE AND MANAGEMENT

### 3.1 Database Concept Model

For this paper, the study objects are large-scale digital image and the depth image, the data object of database storage are also the depth images and digital images.

After analysis of the characteristics of the object storage and mutual links, the database entity-relationship (E-R) concept model is created(as shown in Figure 3):

### 3.2 Range Images and Point Clouds Storage and organization

According to PTX file's the structure and its large amount of data and the characteristics of Visual C + + software to read and write file provided by the very rich operational means, such as: 1. FILE * fp, fstearm ... (C / C + +); 2. CFile , CStdioFile ... (MFC); 3. CreateFile, ReadFile ... (API) etc. The memory mapping technology to read and write the text of the document provides a good support. Table 1 show a comparison among the read speed with three methods proposed above. Test environment is the same with Table 3.

| PTX file size （M） | 0.034 | 2.82 | 109.346 | 448.714 |
|---|---|---|---|---|
| Number of effect points /blocks | 206/1 | 43804/1 | 1710426/8 | 8347442/26 |
| FILE *fp+STL （ms） | 11 | 1340 | 55634 | 260851 |
| CFile+CArchive+STL（ms） | 26 | 1405 | 58830 | 260967 |
| Memory mapping file（ms） | 21 | 74757 | / | / |

Table 1: three ways to read documents rate comparison PTX

To sum up, for the actual data verification, reading and writing PTX using C / C + + or MFC-per-read its way more effective, the experimental system PTX document read data flow chart in Figure 2-8. Write data with similar operations.

### 3.3 Digital Images Storage and Organization

In order to retrieval and display the digital image data quickly, Creating the index of digital image data and reducing the amount of data should be two good idea. General establishment of huge image database is based on the content retrieval of the image data, and the purpose in this paper, is based on data management. The main selection way of digital image data are through images attributes and user interaction selection. The main image attributes include the file name, shooting or storage time, ID number, image format, location description. A selection way example of file name is made in this experiment.

In the process of digital image data retrieval, database records set is gradually filtered through overall index map of the path and MBR attribute of pixel coordinates of user box. In data entry the option of establishing rectangular index, unit net index,and two-dimensional R-tree space index will improve digital the retrieval efficiency.

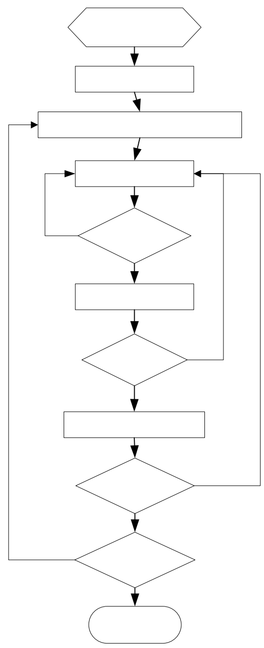

Figure 4: Data flow chart of reading PTX file

### 3.4 Unified Management

After read and conversion between range image and point cloud data and splitting are over, the data package of range image or point cloud should be stored into Oracle database. At the same time the MBB information and translation and rotation matrix of range image and other necessary information should be also stored into the database. One translation and rotation matrix information get directly from the document in the PTX file header. Each sub-block of range image and the MBB division of block is determined by the initial three-dimensional coordinates of the whole points, that is, the minimum and maximum X, Y, Z value of the MBB is minimum and maximum x, y, z value of coordinates of point sets. The overall MBB information and translation rotation matrix and other information is properties of range image directly; MBB information of the sub-block is stored into the attributes field of each sub-block range image.

All the grey and RGB color data were stored to sub-block's grey and RGB color information field in the table, including RGB color information storage table can be used not only with RGB value of the depth of color image data, Can also be used to store digital images of color data, particularly in the processing stage after the registration operation, when implemented, meet the conditions for registration should be stored in the pixel RGB color information in the table. In other words, the depth of the RGB color image data and digital image data in the color of the level of registration uniform.

The RGB colour information table can be not only used to store the color information of range image with RGB values, but also used to store color data of digital images. Especially after the processing of registration, the pixels which can meet the conditions for registration should be stored into the color information tables. In other words, the RGB colour information in range images and digital images are uniformed together.

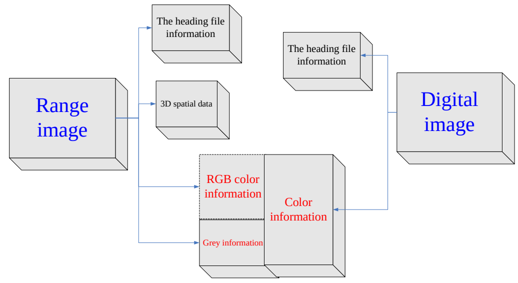


Figure 5: Range image and digital image unified management

## 4. INITIAL DATA VISULIZATION

### 4.1 Range Images Splitting and Reorganization

The splitting and reorganization of range image data is based on the horizontal step scanning angle of three-dimensional laser scanner, according to the level angle between the points of the range image data and the centre scan site. Scanner scans a fixed threshold of an angle, such as 60 degrees, the point within the scope of the threshold will be marked off and formed a block, and meanwhile calculate their MBB in local coordinate. At last, according to the MBB a 3D R-tree index will be created. A range image data segmentation result is shown in Figure 6.

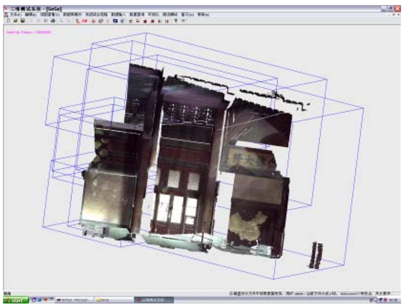

Figure 6: Range image data splitting and its MBB display (the inner of cining gong)

### 4.2 3D Spatial Index Construction

At present, the development of R tree from 2D to 3D space is a trend, and many three-dimensional GIS application systems and spatial databases all have R-tree applications.

The operation of creation and insert on 3-D R-tree, including three-dimensional R-tree node splitting algorithm, the specific method described as follows: In accordance with the conditions splitting each a piece of range image data, the new R-tree is inserted into a minimum bounding box data ,from the root node, inspects all existing minimum bounding box data of R-tree , in accordance with the "minimum coverage volume " optimization principles to find an index of: (1) surrounding the new incremental target data, the existent index of the smallest increment of the " volume " of the minimum bounding box.

(2) If the increment is the same, getting the index that is the existent smallest minimum bounding box data of “volume ". Then recursively search the selected index of the corresponding sub-tree in accordance with the optimization principle of the "minimum coverage volume", until the leaf nodes.

If the leaf node is not "full", directly insert the index information of the new incremental objectives into the leaf node, and then turn upward and adjust the existent minimum bounding box data of the index that is corresponding with the father node, until the root; If leaves node has "full", inserting the new incremental minimum bounding box will lead to leaf node overflow, so ,we need to split the leaf nodes (that is adding a leaf node), and add an index on the father node. If the father node overflows, there will be another splitting operation on it. In other words, the operation of overflow and splitting on nodes may progressively spread. Insert pseudo-code algorithm described as follows:

```
Algorithm R_Insert(N,P)
/*insert the root node N of R-tree into the MBB data P*/
Begin
  If N,LEVEL==0 Then //N is a leaf node
Begin
    Insert P into N;
    If N overfill Then Split N
   End
  Else //N is an intermediate node
  Begin
    R_Insert(N.CPi,W);
    Adjust N.MBBi to enclose all boxs in its child node;
End;
End.
```

In this paper, the R-tree in the path choice only adopt the expansion method of minimum coverage volume, and in the routing choice algorithm import the expansion method of minimum overlap, which is also a good choice (Li Jun, 2002), that is, choosing the child nodes who includes a cube and its MBB expanded has the smallest overlap with other child nodes’ MBB. But only using the method of minimum overlap will damage the overall performance of the index approach, and the calculation of the minimum overlap is high complexity. Therefore, in order to improve the speed of building and enquiries, it will be a more reasonable proposal to choose the path of several mixed-use methods in the different application.

### 4.3 Main-Memory Index Structures

To record the relationship among the separate data and Oracle database or data stored in external memory, we need to establish a three-dimensional R-tree to query the main-memory index structure, the structure of the core code is as follows:

```
typedef  struct  _PointCloudsIndex
    {
        int  m_ID;
        int  LOD_Range;
        CString  m_SpltFilePath;
        MBB    m_MBB;
        vector  <Point3DGrayRGB>  m_SamplePoint;
    } PointCloudsIndex;
```

The main-memory index structure include unified coding ID attribute of splitting data, LOD-level information, binary file path and file name in the disk, MBB information of a block and initial sampling data buffer pointer. ID attribute and LOD-level information are used to query the needful sub-block from the Oracle database, and the file names of the binary file stored in the disk are used to query the needful sub-block from the disk file.

Browsing the range image or point cloud in the current scene here, in the frustum there may be multiple sub-block data, and some of the details of the corresponding block are also not likely in the current main-memory. So a distributed algorithm to release some of the main-memory space should be designed, and at the same time the needful block will be transferred from external-memory into main-memory, and then specified details data are accessed and the work of data show and browse are completed. When the capacity of the requiring sub-block data is beyond threshold in the main-memory, there is a need for treatment. In order to ensure real-time display here, the memory data structure that support data distributed strategy for judging which one should be deleted and which one should be re-transferred, should be defined.

## 5. EXPERIMENTAL RESULTS

### 5.1 Experimental Environment

Experimental environment and tools in the paper are list in table 2:

| software | version | number |
|---|---|---|
| Configuration environment | Microsoft Windows XP Profesional Service Pack 2，Intel(R) Xeon(TM) CPU 3.00GHZ,2.00GB main-memory | 3 |
| database | Oracle 10g、PL/SQLlanguage、Oracle Objects for OLE (OO4O)development kit | 1 server，2 clients |
| Database model design tools | PowerDesigner 11，Rational Rose2003 | 1 |
| graphics library | OpenGL graphics library | |
| Software development environment | Microsoft Visual C++ 6.0 | 1 |

Table 2: Prototype system configuration Table

In this paper, a Personal Computer with Microsoft Windows XP Professional Service Pack 2, Intel (R) Xeon (TM) CPU 3.00GHZ, 2.00GB of memory is used and Oracle10 as a database platform, the database system design tools Power Designer is used for design of object model and database tables, PL / SQL language is selected to build the database and management, the system is based on Oracle Objects for OLE (OO4O) and OpenGL visual programming technology, uses Microsoft Visual C + + to develop a rapid browse and retrieval functions for the visual management system.

### 5.2 Database Management Function

This system provides functions such as reading and writing huge depth images, point cloud, digital image data , depth image models generating, stocking and the depth image and digital image management and retrieval operations etc, some specific functions are as shown in Figure 7 and Figure 8:

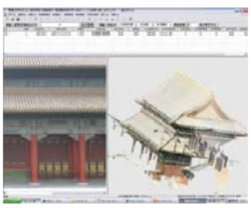

Figure 7：Range image query interface

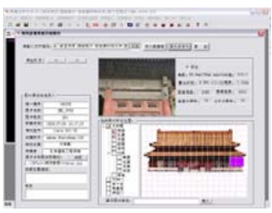

Figure 8：Model of digital image storage and retrieve

### 5.3 Distribution Efficiency

Volume of data (M) refers to the PTX file size; effective points number means sum of points in the PTX document with the non-"0 0 0 0.5" value; The separate sub-block number refers to the number of points (points that are valid or not) - Essentially by a horizontal partial angle of depth images, which is also the number of sub-block MBB; For the needs to test data, two-LOD levels are suggested for distinction, level 2 have larger storage points and richer details than level 1; The sub-block number of enquiries refers to the number of Cone and MBB intersection in user retrieval; The former column for the expression of time shows the time data read to screen, the back column revealed time that enquiries for all the sub-block data corresponding to the MBB to computer screen.

We can draw the following conclusions from Table 3:

(1)From line 1,2,3,4, we can see that the same data at the same level of LOD show,query time of sub-block data show a general direct proportion relation to the number of sub-blocks.

(2)From the line 5,6,7,14,15, we can see that enquiries for the same number of sub-block data, although disk storage mode is an indication that the coarse LOD1-level data, database storage model in the level LOD2 spends less time than disk storage mode, such as enquiries for 38 blocks we get the time comparation: 97525 ms: 76921 ms.

(3) from the line1,2,3,4,10,11,12,13,we can see that for the same data, weather in the disk storage mode or in the database mode, enquiries all sub-block data amount of time spent significant growth as the number of model increase, the growth of test data shows an order of magnitude, such as 22078 ms to 248469 ms, 24391 ms to 221328 ms.

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| number | Storage style | size（M） | Valid point number | Sub-block number | LOD lever | Queried sub-block number | time（ms） | |
|---|---|---|---|---|---|---|---|---|
| 1 | database | 198．457 | 5230149 | 20/500000 | 1 | 20 | 177828 | 22078 |
| 2 | database | 198．457 | 5230149 | 20/500000 | 1 | 5 | 177828 | 105 |
| 3 | database | 198．457 | 5230149 | 117/50000 | 2 | 117 | 228000 | 248469 |
| 4 | database | 198．457 | 5230149 | 117/50000 | 2 | 29 | 228000 | 67516 |
| 5 | database | 574．286 | 12036008 | 38/500000 | 2 | 5 | 457402 | 10102 |
| 6 | database | 574．286 | 12036008 | 38/500000 | 2 | 16 | 457402 | 32376 |
| 7 | database | 574．286 | 12036008 | 38/500000 | 2 | 38 | 457402 | 76921 |
| 8 | database | 574．286 | 12036008 | 17/5000000 | 1 | 4 | 427017 | 083 |
| 9 | database | 574．286 | 12036008 | 17/5000000 | 1 | 17 | 427017 | 27965 |
| 10 | disk | 198．457 | 5230149 | 20/500000 | 2 | 20 | 143235 | 24891 |
| 11 | disk | 198．457 | 5230149 | 20/500000 | 2 | 3 | 143235 | 593 |
| 12 | disk | 198．457 | 5230149 | 117/50000 | 1 | 17 | 138062 | 38797 |
| 13 | disk | 198．457 | 5230149 | 117/50000 | 1 | 96 | 138062 | 221328 |
| 14 | disk | 574．286 | 12036008 | 38/500000 | 1 | 7 | 359672 | 17028 |
| 15 | disk | 574．286 | 12036008 | 38/500000 | 1 | 38 | 359672 | 97515 |
| 16 | disk | 574．286 | 12036008 | 17/5000000 | 2 | 4 | 379953 | 17266 |
| 17 | disk | 574．286 | 12036008 | 17/5000000 | 2 | 7 | 371875 | 18609 |

Table 3：Disk storage and database query efficiency