CYBERCITY: CONCEPTION, TECHNICAL SUPPORTS AND TYPICAL APPLICATIONS

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ABSTRACT  In this paper, the concepts about the CyberCity and the corresponding technique supports and typical applications are introduced. As the pilot projects, the applications of CCGIS software in CyberShenzhen and CyberShanghai are also presented. At last, some of key technologies such as the reconstruction of three dimensional city model, vast amount of data integration and its real time application of 3D animation are discussed.

1  CyberSpace

CyberSpace first appeared in the science fiction, "Neuromancer" by W. Gibson (1984), this term was applied for describing the desperate vision of the near future, urban decay, and neural implants. Recently, it is perceived as a word referring to an entirely new universe and the space virtually existing within the worldwide computer Internet.

Because CyberSpace is a new word up to now, there is not a definite conception about it yet. But we can understand it as follows: CyberSpace is a virtual space whose data information is stored in the computer Internet. Creating any virtual space depends on the electronical data in the Internet. Though it is less than a couple of decades since CyberSpace was brought forward, it had grown at such a remarkable speed that it had expanded to the widest computer net in the world — Internet. Now its increment still maintains at the double rate each year, and it is expected that the CyberSpace will bring a new paradigm of network society for the next century.

CyberSpace has special spatial characteristics. The physical distance is not valid in this space, so we must use a new approach to describe the distance. There are three methods. One is valid distance that is a functional distance, as the distance are described by time or cost. The second is a psychological distance. Namely, it is a subjective measurement that people apperceive distance as they are away from the object. The third is a holistic distance where each chain has its unit. On the other hand, most CyberSpace do not take account of the gravity. In fact, the bearing, magnitude or time consequence of the gravity can be defined at random and easily modified, however, the unit length and direction of the 3D vector change with the different positions in CyberSpace. In this sense, the scale or shape of a single building and street are not restricted by the spatial condition. The only factor maintaining the spatial shape is topology replacing the origin gravity, system time, color set and spatial dimension setup with the own psychological scale. We not only create a space with our taste but also enjoy this vision and video space with other users.
all over the world.

Obviously, CyberSpace is not our living space. It is a large space filled with all kinds of electronical information data. It is a new computer space. Users can access and modify this space; walk through freely; design the society with own taste; create the ideal living condition in dream; if you only have a computer with the local service you do realize the dream of travelling the world at home. You can meet, converse and exchange idea with the other who is not in the same district, country without restriction of condition and time. The CyberSpace provides the vision and video information. Though the CyberSpace can not give out the final answer about the living condition, it provides us more chances to explore and communicate.

2 CyberCity

Unlike the real city, CyberCity is a virtual city consisting of various electronical data stored in the computer or in the Internet. The information of 3D model, photorealistic-texture and topology about earth surface and objects is uploaded to the network through the local servers so that the long-distance users can access to this data and simply click the scene to query for more information. The CyberCity includes, besides the 3D modal, other information such as financial information, telecommunication information, tour information, some common commodity information and so on, which with users forms an available space. We can define the CyberCity as follows: the CyberCity is a virtual 3D city, which links the 3D GIS (Geographical Information System) with other city information and stores in computers. He or she can access, query modify and maintain those information and design his (her) own visionary city. With the aid of Virtual Reality Modeling Language (VRML) and other software the 3D modal can be uploaded to the Internet. All users accessing the Web can create their own space. Even for any non-specialist, it is easy and convenient to maintain and to update the scene. On the other hand, the different cities can be integrated together through IP address.

The CyberCities in the Internet can be approximately divided into three stages. The first supply information in the form of text. The information about cities is a Hypertext Markup Language (HTML) page or a site in the computer network. Because it is difficult to catch the city trace and its linked construct and this city can not be displayed as a concrete city. This city is more like a catalogue than a city. The second stage is 2D site presenting the 2D maps or the landscapes of the cities. A majority of the sites use the whole maps of the cities as the homepages and as long as users click the maps they will enter into the corresponding place and enjoy the cities’ scene. Even though those CyberCities present better dimensional order of the cities with the help of the maps and the landscapes the obvious image and transfers speed are at a discount. Furthermore, with the images and details increasing it is uneasy to find those images. The users, whether they like the designed cities or not, must accept them as this city is static. The third is a 3D space and that will be focused in this article. In the 3D real world’s view, it makes a perspective scene more easily than in the 2D view. As usual, we may use the graphical languages such as VRML, OPENGL to describe the various 3D scene. The 3D real world means to simulate the real world, reduces the processing images, and presents animate city space.

The history of 3D city model can be traced back to early 1980s, when Skidmore Owens and Merrill (SOM) were consulting firms. SOM’s Chicago wire frame at that time initiated much of early work in this area. This private firm made use of the virtualization to impress clients and won more projects. Another typical example is that the highly detailed geometric model of Melbourne was used in conjunction with virtual design studio teaching with the University of Melbourne. This model was constructed by using the architecture drawing and field estimate. The CASA research group of the Bath University used the surveying information to create even more detailed Bath City model, England in 1990. The City of Toronto’s Urban Design Department had used the assembly of a CAD model of extensive area of the city for decision-making for more than a decade. Now more and more research
departments are working on this area. With the development of World Wide Web technology, virtualization technology, spatial information system technology and so on, the 3D CyberCity will develop increasingly.

3 Key technologies for CyberCity construction

The realization of the CyberCity depends on the Internet technology to some degree, and it needs much more technologies, like the information technology. The key technologies, when we create the CyberCities, mostly include Infobahn and computer Internet, Remote Sensing, Geographic Information System (GIS), database management, virtualization and so on.

3.1 Infobahn and Internet

The Internet originated from the ARPA network which was used in the military in US, 1969. In the early time, the network had not been applied widely. It was not expanded actually until the academic Intranets dispersed all over the world were linked with the ARPA network one by one. Thereby, it has developed to nowaday Internet. The actual development of the Internet owned to the network commerce and supplying the World Wide Web (WWW) service in 1990. The Internet has a dramatic breakthrough since then and has been growing at rapid rate forward.

The expanding speed of the World Wide Web is more rapid than that of other technology. The data investigated in January, 1997 revealed that there were more than 16 000 000 hosts and more than 80 000 000 HTML pages, moreover, the homepages are increasingly uploaded at a double rate. At the same time, another data revealed that the services in the Web had been increasingly growing from 130 in 1993 to 660 000 in 1997, and it was up to a striking number 3 500 000 by the end of 1998.

The invention and popularization of the Web make each user linking up with it can access various data. The World Wide Web is a system for distributing all world information and users can use it to scan and search this world digital information in the Internet. The public can access to the CyberCity and 3D scene and make full use of this information through the Web. If 3D scene and 3D virtual city are available in the Web it is more convenient, flexible and vivid to acquire and query all kinds of information from the WWW. Users can "walk through" the streets of various cities, visit the virtual hotels before he (she) arrives at the city, thereby he can choose the hotel to stay, plan to travel on the mountain by bike, and design his garden himself with the help of the virtual city existing in the Internet.

The information about the cities must be uploaded to the WWW through the local service in order that the long-distance users can address this information and this information must run in the Infobahn in order that the users can acquire the real-time data. Under the drive of the fulminic increment of the data flow in the Internet the network has tried the telecom by the speed of 15G per second and the Internet with the speed of $10^{13}$ byte per second is being researched. The Internet of second generation has been experimentally run among the research institutions and the universities in the US.

Even so, if the mass image, texture, geometry and attribute data of the CyberCity run in the Internet, the problems, such as data compression, data transfer and data decompression will have to be resolved.

3.2 Remote sensing technology

The building is the most important part in the CyberCity, so the 3D reconstruction of the buildings is an important task in a CyberCity project. Aerial images have been and continue to be the predominant data source for building reconstruction, especially the digital photogrammetry supplies the most economical shortcut for acquiring the 3D city data. The aerial photogrammetry offers the following predominant data source for building reconstruction, especially the digital photogrammetry supplies the most economical shortcut for acquiring the 3D city data. The aerial photogrammetry offers the following predominant data source in the 3D city model: the 3D reconstruction model of buildings, the digital elevation model (DEM) and the digital ortho-images. Colour and multispectral aerial images can be used to distinguish between the vegetation and the man-made objects in the city.

Using the laser scanner to measure the surface geometry directly is an optimization when acquiring
the high precision DEM, especially in dense urban district, and some laser scanner can be used to measure the surface reflectance, thus it provides registered range and intensity data for facilitating object extraction. Accurate extraction of features suffers from the limited lateral resolution of the laser scanners, which is usually in the order of one measurement per square meter. However, the laser scanner mounted on the helicopter has higher resolution in the order of five or more measurements per square meter and it has been applied to extract the features of buildings. The structure of 3D roofs (usually that is the construction of the buildings) can be reconstructed automatically or semi-automatically by using the aerial images and the laser scanners. The laser scanner is also an effective tool for obtaining facades of the buildings.

In order to provide more detailed facade information of the building the terrain surveying can be used to obtain the facade data as well. However, the photogrammetry (specially the digital camera) with the control points of the geodetic measurement is more valid. The software of the close-range photogrammetry are more and more perfect and with it the photorealistic textured 3D model can be acquired. The 3S integration system based vehicles can also be used for this task.

3.3 GIS technology

3D GIS data is basic spatial information of the CyberCity. GIS provides not only a 2D map but also the information of a 3D city model, and provides management, storage and maintenance functions for a large city database.

When a 2D GIS is converted to a perfect 3D GIS, the management of the city data becomes a fashionable theme. In the CyberCity, the data of 3D buildings' reconstruction and displaying, the data of description of the surface and the data of texture parameters are included in the database. However, a perfect 3D database should include geometry information, photorealistic texture information and other additional information. Therefore, the data volume is up to hundreds of Giga bytes. For example, a CyberCity model of Shenzhen would reach at least 100 Giga bytes.

We must design an effective structure of the spatial data to manage such a large database and the frame of the data structure must meet users' requirements. The traditional 2D GIS has exploited the relational database management systems (RDBMS). To most of GIS tasks such as maintenance, update, spatial analysis and fast data renew, the system is good enough, but the modern city database have to deal with more requirements and maintenance more complex data. Obviously the old database management technique has to be replaced by a new one. The object-oriented database management system (OODBMS) or at least the object relational database management system (ORDBMS) are replacing the old one. In order to visualize the 3D GIS data, Kofler designed and implemented a data structure in 1998. His idea is integrating the R-tree concept with the level of detail (LOD) and exploiting the OODBMS to manage data. The hierarchical and object-oriented 3D database model can fast access the spatial data, provide multi-users access, input or output in the important presenting forms, support the traditional query especially to GIS and CAD, and so on. In order to run at high speed, it is important to reduce the number of data transformed from the database to the virtual program. Hence, the database should have capability of intellective presentation. It must extract the objects within the current view (in pyramid or cube) but the non-standard query language can not be used in this database. So we have to develop another new algorithm to support fast "perspective query". The hierarchical boundary frame, the R-tree structures and analogous techniques should be used to support fast indexing and searching. In a CyberCity, there are a lot of textures, so the database is required for intellective texture processing. As usual, the texture is stored in the form of multi-resolution bitmap (bitmap pyramid). The texture must be compressed (maybe in the JPEG format) in order to reduce the number of the storage and to speed up the progress. This technique can present the outline of the images before the data converted. Therefore, it is important to firstly extract the nearest objects to the viewpoint or to firstly extract the big objects in the low level of detail. Especially in the low speed network, this is
more important.

3.4 Virtual reality technique

The virtualization is one basic technique when people interact with computers and it supplies windows and tools when users design their living space. Only after the visualization technique came into being could users change the origin sets to realize their dreams.

The virtual reality technique was firstly applied in military field and in aerial field. Only after it became a commerce, it would be applied in wider fields: amusement, architecture design, urban designing and planning, art, medicine and so on. The growth of virtual reality can compare with that of the Internet.

Van Driel had been aware that the technique of virtual reality is changing the method used when we recognize the objects. It is estimated that 50% of the brain nerve is relative with vision, even the third dimension can stimulate more nerve cells, namely more nerve cells are involved during processing, for example, a notional terrain model is formed in brain before being analyzed in the 2D contour map. Furthermore, there are more complex terrains. Thus even to a very wise brain, it is difficult to comprehend the 2D map. However, with the development of virtual reality, the 3D model simulates the real space, so the observers can more rapidly recognize and understand the change in elevation.

The virtual reality technique has wider and wider applications: the evaluation of vision effect of the buildings, urban designing and planning, the change of climate, the environment, the transmission of electric wave and so on. The virtual reality and 3D mock are important methods for CyberCity presentation. With the help of visualization, the CyberSpace replaces the traditional abstract 2D map and the descriptive documentation used to explain, analyze and discuss the planning idea and the development of city. While the CyberCity displays some vivid pictures to users, the designers display the designed definite photorealistic texture to the people so they can view the designed city. The photorealistic texture 3D city model conveniences the public to understand the city because they can recognize the special element and adjust their sight according to spatial position and scale. Unless the people have rich experience of reading design, it is difficult for non-specialists to understand the traditional product and GIS and easy to diffuse. The virtualization overcomes this disadvantage. It displays a vivid 3D city model and overcomes the difference of culture between the specialist and the clients. They are personally on the scene when observing the nature, enjoying the scene and knowing the entities.

4 Applications of the CyberCity

One of the important application areas of the CyberCity is in the urban designing and planning. The 3D city model has become a main tool in urban designing and planning based on various spatial information in city management. There are two main relations between a CyberCity and urban designing and planning. One is using the Web to present the city planning. If people can access Internet they can provide some information and they will be encouraged to take part in the city planning. In fact, many governments and authorities have distributed the design information and the correlative standard in Internet. The city designers can make use of the CyberCity to design the city according to their own visual habit. The 3D city allows users to freely fly through. The virtual reality would make the urban designing and planning more flexible because designers can regulate the 3D model in the different design stages. We can conveniently analyze all kinds of the spatial information in a CyberCity: the population density and distribution of a city within short time, greenery and its relation to buildings and ecological significance, air pollution, public space and open spaces among buildings, and so on. In the second place, the CyberCity is a new city space. The CyberCity is composed of electrical data stored and managed in Internet. The descriptive information of the terrain and the topology information can be uploaded to Internet. Unlike the reality city which can not remain the information before it is changed, the data in CyberCity will be stored for ever unless they are deleted, and can be maintained and updated easily. Thereby, the designers can
compare the city models in different stages.

The CyberCity provides various information for users. The tourists can access their own interesting scene. Once they click the place on homepage they will enter into the corresponding scene and know the the city, tour route, traffic information, hotels and so on. The more detailed CyberCity allows to visit the rooms in hotels. In a word, users are personally on the scene in the CyberCity.

Figs. 1 ~ 4 display an example of the CyberCity (The 2D site provides some pictures in the different levels of detail).

![Fig. 1 A CyberCity homepage in the WWW](image)

![Fig. 2 Click the BD and RD to enter the business district shown in Fig. 3 and the residential district shown in Fig. 4](image)

![Fig. 3 The business district in CyberSpace, click the name and enter it](image)

![Fig. 4 The residential district in CyberSpace, click the name and enter it](image)

The 3D city model was first applied for designing and planning in a telephone company. Now it is expanded to other fields such as the study on military, the study on microclimate, the study on air pollution, the study on position in wireless company, the study on transmission of wireless signal, the analysis of noise transmission and the ecological study. The CyberCity are also linked to the estate information in Shenzhen, China.

5 CCGIS software and its applications

CCGIS is a new subsequent product of GeoStar which keeps an independent copyright and is a basic geographic information system software. It was developed and designed specially to create the CyberCity. The main characteristic of the software is exploiting the 3D coding data, GIS data, CAD data and the like extracted by the basic digital photogrammetric workstation (DPW), such as JX-4A, to reconstruct automatically the 3D city model, to integrate the three types of databases (DEM + DOM + DLG), to possess the function of real-time ramble seamlessly, to contain and to expand the spatial multimedia function of the traditional GIS such as query, presentation, analysis and decision. Fig. 5 shows the data flow of a CyberCity, Figs. 6 ~ 7 show some local views of the CyberShanghai and CyberShenzhen.

In order to describe the detailed geometry of a building we must sample some points and create dozens or hundreds of basic surfaces. Those data, especially in the roofs, are usually extracted from the aerial photogrammetry or remote sensing. There are mass images in order to present the ma-
terial or texture feature of each surface. Using a special algorithm the most data of the texture are extracted from images especially from the ground photogrammetry or simulated automatically. Obviously, this increases the data greatly. There is a standard pilot district in Shenzhen. There are 187 buildings with different size and shape and they contain more than 5000 surfaces. The digital photogrammetry workstation, such as JX-4A, can be used to extract the geometric coding data with 1 m resolution (the feature such as balcony can be presented out), which costs a person a half day. (To meet the requirement of buildings' 3D reconstruction and according to the feature of DPW, we designed specially a proper systematic coding rule, i.e., dividing various complex buildings into four classes such as plain roof, peculiar roof, building in building and sphere, then which can ensure efficiency during extracting data and integrity and veracity during creating). The 3D geometric model can be created automatically within a few seconds on the basis of measured data. The vivid city model can be acquired by using the actually photorealistic texture images of building profiles.

![Diagram](image)

Fig. 5 The data flow chart of CCGIS

Especially, CCGIS can use different data sources and creating-model strategy to reconstruct the 3D building model in order to meet the requirements of different levels of detail (LOD). For example, the DEM is used to reconstruct the animate earth's surface, the overlapped orthoimages are used to create the virtual landscape. We directly use the 3D coding data extracted by the digital photogrammetric workstation, such as JX-4A, to reconstruct the complex and significative buildings automatically and their surface texture features are obtained in the images taken actually by the digital camera. While the general buildings can be reconstructed according to the traditional vector database such as DLG in GIS with the corresponding height attribute and their surface texture are created directly with the simple data in texture and material database. The 3D creating and editing tool of CCGIS accomplish not only the automatical 3D reconstruction of buildings as described above but also the editing work such as changing the geometric shape, linking various attribute and texture, adding or deleting various entities (points, lines, surfaces, bodies) and so on. The system has special advantage for processing automatically the complex roofs (such as concaves, spheres) of buildings by the TIN method. In order to acquire more real virtual scene, some simplified methods are exploited for arranging the entities (trees, road signs, billboards, etc.) that offer many advantages such as the simple data structure, easy manipulation, fast processing, and good graphical visual effects, which provide a good idea to simulate realistically other scene. Fig. 7 shows the virtual campus after planting trees.

Creating a realistic building model is only one of the important steps in creating a CyberCity. We should do a lot to organize and manage more effectively such complex and great amount of data and to develop various useful applications. The CCGIS has explored and put forward the solution scheme
for spatial index, selecting and clipping the data in perspective space, dynamic loading, multithread technique and real-time application, and have also realized the fast browsing and the multimedia query of 3D electronical maps (see Fig. 6).

Fig. 6 The pilot district of CyberShanghai and its application

Fig. 7 The virtual campus after planting some trees

References
1 Shiode N. An Outlook for Urban Planning in CyberSpace: toward the Construction of CyberCities with the Application of Unique Characteristics of CyberSpace. http://www.caca.ucl.ac.uk/planning/articles/urban.htm
2 Chesher C. Colonizing Virtual Reality: Construction of the Discourse of Virtual Reality, 1984 ~ 1992. http://english-server.hss.cmu.edu/cultronix/chester
3 Kofler M, Rehatschek H, Gruber M. Institute for Computer Graphics. Graz Technical University Austria. http://www.hyperwave.de
4 Wolf M. Photogrammetric Data Capture and Calculation for 3D City Model. The 47th Photogrammetric Week, Stuttgart, 1999
5 Danahy J. Visualization Data Needs in Urban Environmental Planning and Design. The 47th Photogrammetric Week, Stuttgart, 1999
6 Graz G M. Managing Large 3D Urban Databases. The 47th Photogrammetric Week, Stuttgart, 1999
7 Brenner C. Interactive Modelling Tools for 3D Building Reconstruction. The 47th Photogrammetric Week, Stuttgart, 1999
8 LI D R, Guan Z Q. Integrated Approach and Realization of Spatial Data. Wuhan: Press of Wuhan Technical University of Surveying and Mapping, 2000 (in Chinese)
9 LI Z L, Zhu Q. Digital Elevation Model. Wuhan: Press of Wuhan Technical University of Surveying and Mapping, 2000 (in Chinese)