ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 154 (2016) 138 – 145
Procedia Engineering
www.elsevier.com/locate/procedia

12th International Conference on Hydroinformatics, HIC 2016

A Study on the Construction of the Unity 3D Engine Based on the WebGIS System for the Hydrological and Water Hazard Information Display

Su-Myung Gang[a], Hyeoung-Wook Choi[b], Do-Ryeong Kim[b], Yun-Jae Choung[b]*

[a]*U&GIT Co., Ltd., 419, Hwarangro, Dong-Gu, Dae-Gu, Korea, 41164, Republic Of Korea*
[b]*GEOC&I Co., Ltd., 436, Hwarangro, Dong-Gu, Dae-Gu, Korea, 41165, Republic Of Korea*

Abstract

As natural disasters are occurring more and more frequently, the need for a system that monitors the precipitation and hydrological information in real time and that predicts the potential occurrence of water hazard is growing. As disasters represent the natural phenomena occurring in a country's territory, they are closely linked with spatial data. In the case of the geographic information system (GIS), which utilizes an increasing amount of spatial data, the 3D WebGIS utilizing high-precision DEM and aviation images is fast becoming the norm thanks to the advancement in the related hardware and software, thereby enabling the users to perform multi-faceted and multi-dimensional analysis of diverse pieces of information fused with spatial data. The establishment of a hardware system with high specifications, however, is indispensable in terms of the operating environment because the 3D GIS is usually built upon a vast amount of collected data. To address such shortcoming, a toolkit was developed in this study using Unity 3D, which is frequently being used in mobile games and is capable of representing geographic data without any limitation. In addition, a system capable of mashing up water hazard data based on a given environment, and of providing services on the Web, was completed. As such, it has become feasible to fuse diverse hydrologic resource data based on 3D GIS information, thereby enabling real-time observation and disaster prediction.

Peer-review under responsibility of the organizing committee of HIC 2016

Keywords: 3D WebGIS; hydrological information; water hazard information; Unity 3D; water resource management;

* Corresponding author. Tel.: +82-53-857-7312; fax: +82-53-857-7313.
E-mail address: chyj@geocni.com

Peer-review under responsibility of the organizing committee of HIC 2016
doi:10.1016/j.proeng.2016.07.431

1. Introduction

1.1. Background

A brief look at the trend of the geographic information system (GIS) construction will show that there has been advancement in the hardware technology as well as in the spatial data acquisition technology, thereby enabling the industry to experiment with increasing incidences of 3D system construction by liberating them from the confinement of the conventional 2D system[2, 4]. The remarkable advancement in the hardware and software technology for the past couple of decades has exerted a substantial influence on the 3D graphic technology, whose palpable impact is again rippling through the related industries, including the game, film, and virtual reality (VR) industries, as well as through the aforementioned GIS sector[7]. The number of studies on the 3D GIS that was implemented in the context of the national R&D efforts has increased while diverse 3D GISs for both commercial and emergency purposes are being constructed to provide services to the general public. A brief look at vWorld [9], an open platform for GIS built by the Ministry of Land, Infrastructure, and Transport, will show that the portal provides 3D modeling of interior design templates as well as the detailed specifications of the buildings that have been built in the country. In addition, the portal provides 3D interior spatial information almost identical to that of the real world by performing accurate texture mapping of each building[1-8].

The advantage of such 3D GIS is that it allows researchers to perform spatial analysis with a degree of accuracy that is unattainable with the conventional 2D-based system. In particular, the disaster prevention and meteorological sector is benefitting the most from the 3D GIS advancement. The effectiveness of the diverse meteorological data culled from all over the national territory is maximized when they are analyzed with the 3D system, as they represent the real world. For disaster forecasting, the legacy data accumulated over the past decades would be most useful for making an accurate prediction when they are fused with the observation data of the real world, which again is driving an explosion of studies on the fusion of 3D analysis and spatial data. There are a number of available 3D GIS construction methods depending on the unique characteristic of the developer as well as on the function that one intends to offer, which will be realized by integrating high-resolution spatial data, massive meteorological observation data, and disaster data. In general, one may choose from the commercial 3D GIS engines used to construct the GIS system; an open source, which guarantees a high degree of freedom and good accessibility for the developers; or an engine developed for 3D games. The drawbacks of the open source and the commercial GIS are that they cannot meet an adequate level of development difficulty as well as desirable acquisition cost and posterior maintenance levels [2,4]. In this study, therefore, these researchers aimed to build an integrated system capable of analyzing meteorological data by employing the 3D game engine that is increasingly being adopted by game developers as well as by the engineering and other sectors, and of responding to disasters.

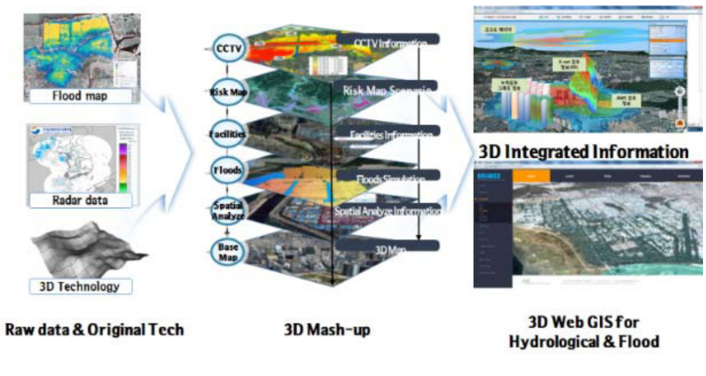


Figure 1. A 3D WebGIS for providing hydrological and water hazard information.

1.2. Preceding Studies and Research Trend

Many advanced countries are striving to minimize their damages from climatic changes by performing real-time meteorological observations with more precise and smaller precipitation radars installed in the urban regions that have been ravaged by abrupt climatic changes such as localized torrential rains or typhoons. In general, it is necessary to determine the spatial distribution of the precipitation to be able to predict the migration path or precipitation amount of each precipitation cluster in the outbreak of a typhoon or convection-type localized torrential rains[8]. Given that meteorologists are still relying on 2D spatial analysis when utilizing the data projected intuitively from high-resolution weather maps, the progress of the related study is still slow compared to the development speed of the underlying technology. Lately, however, studies have been increasingly concentrating on building a system capable of analyzing radar data from multi-faceted angles by aligning the observation data on a 3D topographical map[1, 3]. The importance of meteorological observation has come to grow since only recently not only because it provides simple weather forecasts but also because it helps people prepare for floods and typhoons, which are growing in size and intensity. With regard to the fusion of disaster and GIS information, it is essential to perform integrated data management as well as data fusion and simulation by leapfrogging from the simple alignment of meteorological observation data with 3D topography [2, 4-7].

The number of cases where VR (virtual reality) and AR (augmented reality) are being actively utilized to maximize the effectiveness of the simulation has been growing of late [5]. In fact, 3D simulations are currently being applied to diverse areas to analyze the actual cognitive mechanism of humans[1-8].

2. Research Methodology

2.1. Scope and Contents

As mentioned earlier, the current studies on the GIS system tend to focus on building observable meteorological data or disaster simulations for the purpose of disaster control on a 3D space with a near-perfect verisimilitude to the real world to be able to analyze them from multiple angles. Such system enables a prompt response to unusual situations depending on the weather condition, provided that such data are fused with the building information and attributes of the key facilities built across the territory. It is also hoped that the capability to simulate a near-real situation in the event of a disaster would help minimize the affected area, and when fused with the database on emergency shelters, would also minimize the human casualties. This study focused mainly on two areas: (1) the 3D game engine was used in constructing a 3D topographical map by converting the diverse file extensions specific to geographic data to a grid, thereby enabling the mash-up of the spatial data obtained from the territory on the 3D topographical map; and (2) large raw files may be processed for the mash-up to enable fast graphic processing of the data. After the completion of the 3D topographical map, the radar data acquired from the precipitation radar shall be visualized based on the 3D topographical data. An expression mechanism that would ensure the efficient observation of the 3D radar data shall be constructed to enable layer-by-layer analysis. In addition, a simulation mechanism shall be constructed by visualizing the grid-type flood data on the 3D space. As such, the precipitation and flood data shall be expressed simultaneously in the real world[1, 2, 4].

2.2. Construction of 3D Topographical Data Based on DEM and Aviation Images

As the existing commercial 3D GIS engines were not used in this study, the DEM and SHP file extensions in the geographic data were converted to ASC or TXT files so that the 3D engine would be able to recognize them. Figure 2 is a flowchart showing the process of expressing geographic data on the 3D engine, with Global Mapper used as a conversion tool. The original database in the main system shall be preserved while the converted data are being constructed[1, 2, 4].

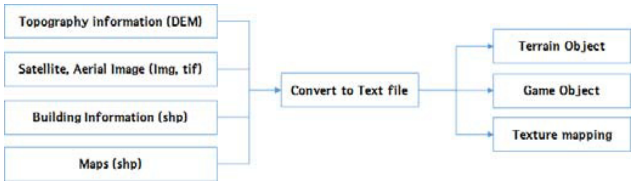


Figure 2. Schematic diagram showing the expression of spatial data on the 3D engine.

In addition, the aviation images that can be mapped with the texture on the corresponding spatial area, as shown in Figure 3(a), shall be divided appropriately so that they can be expressed with low- to high-resolution images depending on their respective levels in LOD[1, 2, 4].

Figure 3. Division of images for the mapping of aviation images on the 3D topographical map.

The information on the artificial objects built on the topography can be made into shp files. Shp files contain attribute information linked with polygons representing each building, and such information is again linked with dbf. As mentioned earlier, however, shp files cannot be applied to the 3D engine in their original data format. The buildings represented by polygons are given coordinates for each of their corners, and their respective elevations from the surface level can be extracted from the topographical map and expressed on the 3D map when the elevation data can be extracted from dbf. The data extracted as such can be expressed as buildings after being fused with the topography on the 3D space. The need for the 3D data on the key buildings in the event of a disaster is justified by the fact that such data can be used as the underlying data required toperform detailed analyses of the amount and status of the damage inflicted on a building if the affected building is one of the major buildings. The building's shp files are read as txt files before they are structured in terms of their arrangement and before they are matched with the number of attribute files with a dbf extension to form the database. As such, the no. 1 building among the shp files shall be matched with the no. 1 attribute among the dbf files before they are expressed. The most important aspect in the construction of such buildings is that the building shape is not formed as rectangular or square-shaped. This is because the spatial data were constructed as vector data and the 3D game engine is capable of recognizing only Raster files. The possible resolution of the aforementioned issue associated with polygonal buildings can be found in the example of a building with a pentagonal shape. Figure 4 shows a pentagon indexed clockwise with the numbers 0 to 4 along its five angles. If the indexing of the bottom of the pentagon was completed, it shall be copied and pasted to form the top before being indexed with numbers[1, 2, 4].

Figure 4. Example of the top and bottom of a pentagonal building.

The unique characteristics associated with mesh generation have to be understood to be able to form the sides as the mesh is formed based on triangles. For this reason, the rectangles that would make up the sides shall be composed of two triangles. In short, they should be bundled together as in [1, 6, 5] and [1, 5, 0] to realize a mesh covering an area represented by [0-1-5-6]. As such, the sides of the building can be formed as shown in Figure 5[2, 4].

6 5 1 0	7 6 2 1	8 7 3 2	9 8 4 3	5 9 0 4

Figure 5. Scheme for forming the sides of a pentagonal building.

The buildings superimposed as such on the 3D space shall be constructed on the topographical map according to their coordinates[2].

2.3. Expression of Meteorological and Flood Data Fused with 3D Spatial Data

Among the many methods used to express radar data, the 2D visual data that are fused with spatial data and applied with the legend table are the most frequently used. A large dataset covering the comprehensive range of space and time could be expressed most effectively on the national unit, but it would make detailed analysis at smaller regional units impossible. For this study, therefore, the radar data were constructed in such a way that they could be expressed on a 3D topographical plain and analyzed from multiple angles. In addition, the radar data were divided according to the levels specified in the legend for their analysis, thereby allowing researchers to come up with a new paradigm in the analysis of radar data[1, 2, 4].

In this study, the precipitation history data in the Seoul and Gyeonggi areas provided by KICT were used. The analysis of the collected precipitation data showed that the resolution was 100 m across the entire area of the grid (808*808; effective area: 800*800), with the analyzed precipitation history data expressed with text values. To visualize the aforementioned precipitation data by fusing them with the topographical data, grid-type text data shall be composed in 2D arrangement in the 3D engine module before they are converted to pseudo color legends corresponding to numerical values. Figure 6(a) shows the radar data aligned with the spatial location[1, 2, 4].

(a) Alignment of radar data (b) Flood data of protected lowland

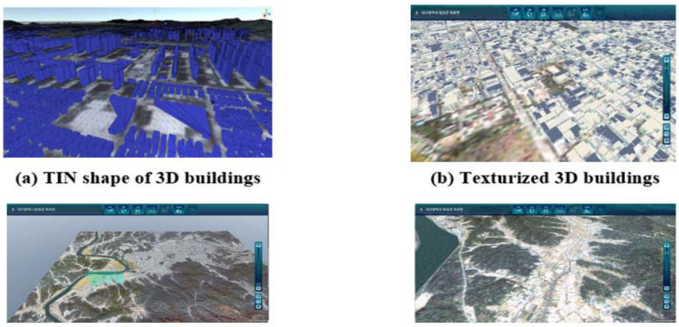
Figure 6. 2D hydrologic and flood data fused with spatial data.

The radar data can be fused with the coordinates of the topography, which were constructed based on the spatial data via the coordinates corresponding to the corners of the arrangement before they can be mashed up. Further, a separate layer shall be applied to numerical values that were divided along different segments in the range according their pseudo colors, thereby making it convenient to set the elevation value differently for each layer[1, 2, 4].

In addition, a flood simulation capable of performing integrated disaster information management based on the topographical or building information can be realized. As such, it would be able to more effectively fuse with the onsite situations that are being generated simultaneously, while the CCTV information in the concerned area shall be fused with the facility manager status information, thereby enabling the simultaneous prediction of and reaction to a given situation. The flood data should also be constructed with txt files so that the information outputted from the module capable of displaying the floods can be uploaded to the engine. As such, the radar data can be fused with the onsite situations that are being generated simultaneously based on the geographic information, and when the data on the CCTV and the facility managers in a given area are fused together, it becomes possible to make predictions and to react in the concerned area at the same time. The flood data should also be constructed with txt files so that the information outputted from the module capable of expressing the floods could be uploaded to the engine. Figure 6(b) shows a grid-type flood information interlaced with spatial data. In the simulation program that predicts real floods, the flood information is being extracted by the hour or by the day, thereby enabling the integrated disaster response system to build multiple scenarios in advance and to build a dataset on the flood situation by considering the flood streams, levels, and continuation. As mentioned earlier, the underlying data applicable to the 3D engine that was used in this study are the grid-type text data on which flood simulation can be realized[1, 2, 4].

3. Results and Analysis

In this study, a 3D GIS was constructed by employing methods that satisfy the cost and degree of freedom requirements in the development, the two most critical factors in the system, by forgoing the conventional commercial GIS engine. The satisfaction of the degree of freedom requirement in development is essential because an additional module can be developed whenever necessary to mash up diverse datasets originating from varying sources. With the existing commercial GIS engine, the development of an additional module is either impossible depending on the policy of the software vendor or may require additional costs. GIS construction as realized in accordance with the method proposed in this study, however, will enable the performance of analysis from multiple angles by fusing diverse source data via the construction of a GIS utilizing the commercial game engine proposed by this study. Figure 7 shows the 3D topographical plain and buildings that were constructed based on spatial data[2].

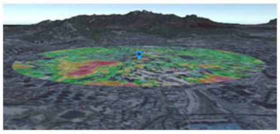


(a) TIN shape of 3D buildings (b) Texturized 3D buildings

(c) Expression at Level 1 in LOD (d) Expression at Level 20 in LOD

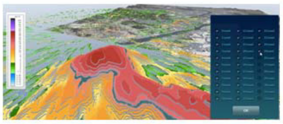
Figure 7. Construction of a GIS using the 3D engine

The aspect of driving speed can be sufficiently considered by using the LOD method provided by the 3D engine. In addition, it provides the clue required for the prompt pinpointing of the key buildings and facilities that will be directly affected in the event of a disaster by expressing 3D buildings in the flood simulation. It also allows researchers to analyze precipitation data by considering the elevation value in the topographical plain. The precipitation and flood data represent the real data culled across the territory. Figure 8 shows the precipitation and flood information fused with the 3D topographic plain that was constructed earlier. It is possible to identify the fusion information, including those on the building attributes.



(a) Radar data expressed on a 3D topographical plain

(b) Flood data expressed on a 3D topographical plain



(c) Stratified expression of radar data

(d) Expression of the attributes of various buildings

Figure 8. Expression of various information on a 3D topographical plain.

Table 1. Specifications of the system development hardware and software.

Criteria	Contents
OS	Windows 7 Professional sp1
Processer	Intel(R) Core(TM) i5-4570 CPU @3.20GHz
RAM	8.00GB
Graphic card	NVIDIA GeForce GT 630
DBMS	Oracle
Authoring tool	Unity 5.0.1f
	Microsoft Visual Studio 2013

In the case of the integrated system designed to provide all the data expressed in Figure 7 and 8, it was developed in accordance with the specifications shown in Table 1 and was constructed on the Web after it was built as a 3D viewer, which is supported by the developed engine. The values that were measured for the system operation are shown in Table 2.

Table 2. . Measured values of the system operation speeds.

Criteria	Speed(s)
Loading speed	8.21
Average data loading speed	5.24
Average 3D building display speed	9.21
Average Google Map API speed	1.23

When constructing a GIS system equipped with the large database required for disaster control or meteorological management, it is indispensible to consider the management of information integration as well as the user convenience. As the expectations for a highly efficient system are going up ever higher along with the rising performance of the hardware and software, it is necessary to construct a system capable of demonstrating a more powerful performance in terms of speed. The numerical data shown in Table 2 indicate that the operation will be challenging on a low-spec graphic card from the perspective of the users. The system will be considered an expert system running only on high-spec computers. In the case of the system that was developed in this study, it was developed as an expert system for professionals who are qualified to handle precipitation and disaster data. In view of the ever-advancing information technology, however, it would be inevitable to consider a low-spec system for general users someday in the future should the uses of the system be expanded in the coming years.

As the 3D GIS was developed based on the 3D game engine that guarantees the development of additional modules, it is hoped that the system could be improved by overcoming its various issues by coming up with diverse parallel processing schemes in terms of the speed acceleration within the system. In addition, thanks to the potential of uninterrupted additional development, a more accurate and detailed meteorological observation would be feasible by tapping on the information supplied by weather satellites covering larger areas. Furthermore, it is possible to construct an integrated system that oversees both the weather and disasters at the same time by extracting real-time disaster scenarios anticipated from meteorological observations.

As the system currently being used by public officials and many government agencies has limitations not only in terms of the expertise in the respective professional areas but also in terms of the hardware operation, those functions are not integrated into a one-stop concept. Therefore, should an effective platform capable of consolidating both meteorological observation and disaster control be organically provided, the efficiency of the work process would be improved, thereby enabling prompt decision making in the event of an exceptional situation, such as a disaster.

Acknowledgement

This research was supported by a grant(13SCIPA01) from Smart Civil Infrastructure Research Program funded by Ministry of Land, Infrastructure and Transport(MOLIT) of Korea government and Korea Agency for Infrastructure Technology Advancement(KAIA).

References

[1] Choi HW, Kang SM, Kim KJ, Kim DY and Choung YJ, *Development of the Visualization Prototype of Radar Rainfall Data Using the Unity 3D Engine*, Journal of the Korean Association of Geographic Information Studies, 2015;18(4):131-144

[2] Gang SM, Kim DR, Choung YJ, Park JS, Kim JM and Jo MH, *A Plan for a Prompt Disaster Response System Using a 3D Disaster Management System Based on High-Capacity Geographi and Disaster Information*, Journal of the Korean Association of Geographic Information Studies, 2016;19(1):180-196

[3] Jang BJ, Lee KH, Lee DR and Lim SH, *High-Precision and 3D GIS Matching and Projection Based User-Friendly Radar Display Technique*, J. Korea Water Resource. Assoc., 2014;47(12):1145-1154

[4] Kim DR, Gang SM, Ryu DH, Park JS and Jo MH, *A Plan to Provide Effective Risk Map Information by Linking a 3D Disaster Information Display System with an On-site Assistance Application*, Journal of the Korean Association of Geographic Information Studies, 2016;19(1):141-153

[5] Kim HK, Kim JH, Kang YA, Shin SC, Kim IK and Han SH, *Collaborative Visualization of Warfare Simulation using a Commercial Game Engine, Journal of The Korea Society for Simulation*, 2013;22(4):57-66

[6] Lee HJ, Kim SY, and You JH, *Development Environment for Open-pit Mine Monitoring System using Geospatial Open Platform and Open Source Software*, Journal of the Korean Society for Geospatial Information System, 2014;22(4):165-173

[7] Lee SY, Kim TG, Lee GM and Seo G, *Development of Multi-platform 3D Interactive Rural Landscape Simulator with Low-cost Web GIS and Game Engine*, Journal of the Korean Society of Rural Planning, 2013;19(4):177-189

[8] Park JH, Kang BS, Lee GS and Lee ER, *Flood runoff analysis using radar rainfall and Vflo Model for Namgang dam watershed*, Journal of Korean Association of Geographic Information Studies, 2007;10(3):13-21

[9] vWorld, http://map.vworld.kr/map/maps.do (acessed Feb., 22, 2016)