Using game engine for 3D terrain visualisation of GIS data: A review

Ruzinoor Che Mat¹, Abdul Rashid Mohammed Shariff², Abdul Nasir Zulkifli¹, Mohd Shafry Mohd Rahim³ and Mohd Hafiz Mahayudin¹

¹School of Multimedia Technology and Communication, Universiti Utara Malaysia, 06010 UUM Sintok, Kedah
²Geospatial Information Science Research Centre (GIS RC), Universiti Putra Malaysia, 43400 Serdang, Selangor
³Faculty of Computing, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor

E-mail: ruzinoor@gmail.com

Abstract. This paper reviews on the 3D terrain visualisation of GIS data using game engines that are available in the market as well as open source. 3D terrain visualisation is a technique used to visualise terrain information from GIS data such as a digital elevation model (DEM), triangular irregular network (TIN) and contour. Much research has been conducted to transform the 2D view of map to 3D. There are several terrain visualisation softwares that are available for free, which include Cesium, Hftool and Landserf. This review paper will help interested users to better understand the current state of art in 3D terrain visualisation of GIS data using game engines.

1. Introduction
In recent years, a lot of research has been conducted with regard to 3D terrain construction. Most of the research has developed new applications for viewing and creating in 3D. Eventually this helps in promoting tourism and future planning for disaster and security [1]. It has been proven that the 3D terrain can be perceived a lot better compared to normal 2D map which requires certain level of comprehension in map reading. Currently, there are few categories of 3D terrain visualisation engines that are available on the internet using the game engine and open source. Each of these categories has advantages and disadvantages. Therefore, the aim of this paper is to provide a comprehensive review of 3D terrain visualisation of GIS data generated from the game engine. This paper begins with a brief history of game engine and continues with the detail of game engines such as Torque 3D, Unreal Development Kit (UDK), Unity3D and CryEngine. The second section covers the available 3D terrain visualisation software. The third section explains terrains visualisation using game engine and shows the terrain created using the game engine. The fourth section discusses on 3D terrain visualisation and 3D terrain visualisation using game engine and finally the fifth section concludes this paper.

¹ To whom any correspondence should be addressed.
2. Game engine

Game engine refers to a set of tools that help the developers to create games a lot faster and easier using commands that used to require a lot of coding through plug-in or asset provider of the game engine [2]. In the earlier days, game was limited to hardware capabilities. The earliest development of arcade games started in 1966 [2], and one of the most well known arcade game known as Pong was introduced [3]. This game utilised the advancement of technologies of arcade games which ported into the consoles. As the technologies grew, the game was then ported into the PC platform around 1990. During this time, the term “game engine” was introduced. Since then, many different types of game engine have been introduced including Torque 3D, UDK, Unity3D and CryEngine. Figure 1 shows the architecture of game engine that was introduced by Lewis and Jacobson [4].

2.1 The Torque Game Engine (TGE)

TGE is a game engine published by GarageGames [5]. Torque started around as a company by the name of Dynamix, then later after acquiring the tribes 2 source codes from Source, it have been changed to Torque 3D. The engine uses C++ as its main script which allows the user to have a better editing of the engines. Torque 3D supports PhysX, modern shader features, and advanced deferred lighting mode. TGE runs on most windows platforms, Mac and Linux. TGE also provides documentation for the users in creating and designing their own games. The database of this game engine supports MySQL and uses Torque script.

Shiratuddin and Thabet [6] discussed details on how TGE could be utilised to develop Design Review System from manual to 3D complete visualisation system. Besides that they also utilized this engine for application such as a Southern Miss’s Innovation and Commercialization Park [7]. Figure 2 shows the architecture of Torque 3D game engine as explained by Nilson and Söderberg [8].

2.2 Unreal Development Kit (UDK)

UDK was released by Epic Games Inc. and it is a free version of Unreal Engine 3 [9]. It has been used by professional studios and indie developers to create well known games such as Gears of Wars, X-men Origins and many others. UDK provides the developer with same functionality as paid version. UDK allows for visual scripting using Unreal kismet and its main script is called UnrealScript. Navarro et al. [10] explained that UDK has a lot of functionalities including skeleton animations. It uses NVidia’s PhysX and UDK behaviour editor. Shiratuddin and Thabet [11] explained the architecture of UDK in their research on “Virtual Office Walk-through Using a 3D Game Engine” as shown in figure 3.
2.3 Unity3D

Unity3D is a game engine created by Unity Technologies [12]. It can be used to create online and offline games. Unity3D provides a wide range of assets that help developers to create games as well as documentations and tutorials. It utilises the concept of assets which work like a plug-in where the user can import or just copy the asset file into a specific folder. Unity3D uses JavaScript, C# and Boo as the main programming languages. The main advantage of Unity3D is that it can run on multi-platform OS including Windows, Mac, Linux and also mobile. It is capable of importing other 3D models in fbx, sbx and obj formats. Wang et. al. [13] presented the architecture of Unity3D as shown in figure 4.

Figure 2. Torque game engine architecture (Source: Nilson and Söderberg [8]).

Figure 3. The UDK game engine architecture (Source: Shiratuddin and Thabet [11]).
2.4 **CryEngine**

CryEngine is a game engine created by Crytek, a developer based in Germany [14]. CryEngine provides a much rich environment to create games in a sandbox using “WYSIWYG” method. There have been four releases for CryEngine and each release is an improvement to the others. CryEngine is free for non-commercial development which allows developers to have first hand on the game engine. CryEngine itself uses sandbox editor to add objects into the world terrains. Trenholme and Smith [15] explained the detail functionalities of the CryEngine. Meanwhile, Herrlich [16] explained the features of CryEngine. Figure 5.0 shows the sandbox editor view of CryEngine.

![Figure 5. The sandbox editor view of CryEngine (Source: Herrlich [16]).](image)

3. **3D terrain visualisation software**

In recent years, a lot of 3D terrain modelling software as well as terminologies have emerged. The terminologies which include digital elevation model (DEM), triangular irregular network (TIN) and digital terrain model (DTM) are normally used for terrain data type and they are frequently used in software that have the capability to read and display 3D terrains. Ruzinoor et al. [17] reviewed the
techniques and software for 3D terrain visualisation of GIS data and explored different types of techniques for visualising 3D terrain [18]. The VRML technology has been used by Ruzinnoor et al. [19] for visualising terrain online. Horne [20] the original author of 3DEM created the software for commercial market and after a few years of development, he halted the project but still share the full version of the software for public used. The software has the capability of importing and generating 3D terrain from DEM data. This software also provides a surface view of Mars terrains. Zuse Institut Berlin & Lenné3D [21] created the BioSphere3D. This software has the capability to display the landscape of globe terrain by using data such as DEM, satellite and aerial images, 3D models (Collada), 3D plant models (Lenné3D Flora3D) and shapefiles. Cesium is a 3D terrain visualiser that uses globe view concept which has the capability to zoom and explore the whole world terrain. It uses WebGL libraries to load the shapefiles in producing the terrain. It is based on entire cloud and fully dependent on scripting [22].

Besides that, Earth3D was developed by Dominique Andre Gunia [23] using Java and C++ as its core programming codes. The data for this software is generated from NASA, USGS, CIA and the city of Osnabrück. GenesisIV is a landscape software created by Geomantics [24]. The advantages of this software is the capability in generating the photorealistic terrains. G3DGMV (3D Graphical Map Viewer) was developed by Yost [25] for terrain visualisation which uses DEM and DLG as its main data source. It also provides the functions for saving as image and creating guide based on user preferences. Hftool was introduced by Stock [26] which is a Unix based terrain viewer and the output from this software can be converted into different types of file formats. Integrated data viewer (IDV) was created by Unidata [27] and is based on java programming. The software is able to create an animation of satellite images, viewing a grid view of terrain plot and also displaying a data based on globe.

LandSerf a terrain visualisation software was created by Jo Wood [28] and it is also a Java based terrain visualisation. It can handle multiple files of GIS format and also provides high interactivity visualisation. This software also able to import and export raster format and able to integrate with Garmin GPS receiver. Guth [29] has introduced MicroDEM which is a portable terrain viewer where it can view DEM data and also able to merge the data. Virtual Globe was created by Sintef, a research organization in Scandinavia that cover a lot of research area until it was taken over by Norkart for further development. This software uses globe as its main view and data such as SRTM, GLOBE and GTOPO30 to display terrain model. This software was also developed using Java [30]. OpenEV was originaly developed by Atlantis Scientific Inc. [31], which is currently known as Vexcel. As of 2006, it was acquired by Microsoft and has ceased involvement in the project. OpenEV is a terrain viewer that uses OpenGL for rendering and it supports various types of raster and vector formats to create elevation.

4. 3D terrain visualisation software using game engine

As game engine development progresses, several new add-ons have been included such as terrain editor. Most game engines have their own terrain editor which helps in creating realistic terrains. In Unity3D, the developer is able to design a realistic terrain using terrain editor which can be viewed using the first person view. The terrain editor in Visual 3D allows the user to import DEM data to generate the terrain [32]. Torque game engine also provides the terrain editor as explained by Yang et. al. [33] on how the terrain can be created using TGE. Figure 6.0 shows an example of terrain generated using TGE. Besides that, UDK also provides a terrain editor that supports DEM data that can be manipulated using Unreal engine [34]. The DEM of TGE allows GIS data to be loaded but the data must be in a compatible format in order to generate the terrain. While Unity3D also has the capability to load GIS data and generating the terrain from the data and uses script to control the data to be more interactive. CryEngine requires a bit of works to get the GIS data into the game engine. Figure 6-9 show the images of terrain generated from different types of game engines which include Torque, UDK, Unity3D and CryEngine.
**Figure 6.** Images of terrain created by Torque engine. (Source: Yang et. al. [33]).

**Figure 7.** Image of terrain created by the UDK game engine. (Source: Epic Games Inc. [9]).
5. Discussion

Terrain visualisation software was first introduced in the early 1990’s whereby during this time the computing capability of the hardware was still limited. Table 1 shows a list of terrain visualisation software where most of them use C++ and Java as their core programming tools. Most of these software (Biosphere3D, GenesisIV, IDV, Landserf, MicroDEM, Norkart Virtual Globe and OpenEV) has their own graphical user interface (GUI) tools. Besides that, G3GDMV and Hftool use other tools such as GTK, GNOME and SGI with improved GUIs. All of these software was developed to load data locally. Some of the software does not read the data, but uses OpenGL technology for their rendering. Figure 10 shows the evolution of terrain visualisation software from 1995 till now.
Table 1. Terrain visualisation software.

| Terrain software          | Year | Language used                      |
|---------------------------|------|-----------------------------------|
| IDV                       | 1997 | JAVA                              |
| Htool                     | 1998 | Linux/SGI                         |
| G3GDMV                    | 1999 | GTK/ Gnome/Linux                   |
| Norkart Virtual Globe     | 2001 | JAVA                              |
| OpenEV                    | 2001 | OpenGL, C ,GTK                     |
| Landserf                  | 2004 | JAVA                              |
| GenesisIV                 | 2005 | C++                               |
| MicroDEM                  | 2007 | C++                               |
| 3DEM                      | 2009 | SGI/Microsoft OpenGL libraries    |
| Biosphere3D               | 2007 | C++, OpenGL 2.0                    |
| Cesium                    | 2012 | JavaScript/WebGL                   |

Based on the game engines that have been discussed in this paper, most of them have built-in terrain editor. It is easier for the user to generate the terrain without intensive coding, although using GIS data in game engine would require a few works on coding itself and some of the game engines provide plug-in which can be used by the user to create the terrain. An article by Green [34] looked at how DEM can be used inside UDK to view its data, Unity3D also allows GIS data to be viewed in specific format. The script written by Jeff Craighead allows Unity3D to be used with GIS data [12]. TGE also allows loading of GIS data but it requires the data to be loaded into a compatible format. Cryengine also requires a bit of works to get the GIS data into the game engine. This shows that most of the game engines have the capability in generating the terrain from GIS data. Table 2 compares the different types of game engines. It shows that most of the game engines were developed a few years ago and until now they can still be used for developing new applications.
Table 2. Comparison on different types of game engine.

| Game Engine | Year created | Level Editor | GIS support | Source code and SDK | Documentation |
|-------------|--------------|--------------|-------------|---------------------|---------------|
| Torque 3D   | 2001 Originate from Tribes 2 game | World Editor, Terrain Editor, Shape Editor, Forest Editor, Decal Editor, Mesh Road Editor | Custom imports | https://github.com/GarageGames/Torque3D | Available at http://docs.garagegames.com/tg/e/official/ |
| CryEngine   | 2004 | Sandbox, Terrain editor, Sound Editor | Custom imports | Available as a package | Available at http://freesdk.crydev.net/dashboard.action |
| Unity 3D    | 2005 | Game object, Effect, Physics, Terrain | Custom imports | SDK available for free as Unity3D source codes is available for purchase | Available at http://wiki.unity3d.com/index.php/Main_Page |
| Unreal Development Kit | 2009 originate from Unreal 3 game engine | Geometry Mode, Terrain Mode, Mesh Paint Mode, Static Mesh Mode, Landscape Mode, Foliage Mode | Custom imports | http://wiki.beyondunreal.com/UnrealScript_source_code | Available at http://www.unrealengine.com/en/udk/documentation/ |

6. Conclusion
As the technologies march forward into the future, several new technologies and new software to visualise terrain emerge and that include game engines. These software allows editing and creating of 3D terrains which can be a reliable source of reference to all. Game engines provide different approaches to the GIS data. Game engines also provide vast potential for customization in making GIS data useful in various applications such as tourism, future disaster planning, security and many others. With the help of game engines, GIS data can be viewed from different types of perspectives and angles.

7. References
[1] Wyld DC. 2010 The virtual tourist: using the virtual world to promote the real one Advances in Competitiveness Research. 18.
[2] Wikipedia. Game Engine. 2014 [cited 2014 12 January]; Available from: http://en.wikipedia.org/wiki/Game_engine.
[3] Wikipedia. Arcade. 2014 [cited 2014 12 January]; Available from: http://en.wikipedia.org/wiki/Arcade_game.
[4] Lewis M, Jacobson J. 2002 Game engines in scientific research: Introduction. Communications of the ACM. 45(1):27-31.
[5] GarageGames.com. Torque game engine. 2014 [cited 2014 12 January]; Available from: http://www.garagegames.com/products/torque-3d/overview.
Shiratuddin MF, Thabet W. 2011 Using a 3D Game Engine to Develop a Virtual Design Review System. *Journal of Information Technology in Construction*. **16**:39-68.

Shiratuddin MF, Fletcher D. 2006 Development of Southern Miss’s Innovation and Commercialization Park Virtual Reality Environment. *Proc. 6th Int Conf on Construction Applications of Virtual Reality*; Orlando, Florida.

Nilson B, & Söderberg, M. 2007 Game Engine Architecture.

Epic Games Inc. Unreal Development Kit. 2014 [cited 2014 10, January]; Available from: http://www.unrealengine.com/udk/downloads/.

Navarro A, Pradilla JV, Rios O. 2012 Open Source 3D Game Engines for Serious Games Modeling. *Modeling and Simulation in Engineering*.

Shiratuddin MF, Thabet W. 2002 Virtual office walkthrough using a 3D Game Engine. *International Journal of Design Computing*. **4**.

Unity3D. 2014 [cited 2014 12 January]; Available from: http://unity3d.com/.

Wang S, Mao Z, Zeng C, Gong H, Li S, Chen B. 2010 A new method of virtual reality based on Unity 3D. *Proc. 18th International Conference Geoinformatics 2010* Beijing University, Beijing, China: IEEE.

CryTEK. 2014 [cited 2014 12 January]; Available from: http://www.crytek.com/cryengine/cryengine3/.

Trenholme D, Smith SP. 2009 Computer game engines for developing first-person virtual environments. *Virtual reality*. **12** (3):181-7.

Herrlich M, 2007 A Tool for Landscape Architecture Based on Computer Game Technology. *Proc. International Conference on Artificial Reality and Telexistence*; Esbjerg, Denmark: IEEE.

Ruzinoor CM, Shariff ARM, Pradhan B, Rodzi Ahmad M, Rahim MSM. 2012/06/01 A review on 3D terrain visualization of GIS data: techniques and software. *Geo-spatial Information Science*. **15**(2):105-15.

Ruzinoor CM, Shariff ARM, Mahmud AR, Pradhan B. 2012 *3D Terrain Visualisation for GIS: A Comparison of Different Techniques*. In: Buchroithner M, editor. True-3D in Cartography: Springer Berlin Heidelberg. p. 265-77.

Ruzinoor CM, Sharif ARM, Mahmud AR, Pradhan B. 2008 Online 3D Real Time Terrain Rendering Algorithm for GIS Data: A Conceptual Idea. *Proc. 3rd International Workshop on 3D Geoinformation 2008*; Seoul, South Korea

Horne R. 3DEM. 2014 [cited 2014 10 January]; Available from: http://freegeographytools.com/2009/3dem-website-is-gone-but-3dem-still-available-here.

Zuse Institute Berlin, lenne3D Gmbh. Biosphere3D: Real-time open source Landscape Visualization. 2007 [cited 2014 10 January]; Available from: http://www.biosphere3d.org/.

Analytical Graphics Inc. Cesium. 2014 [cited 2014 2 January]; Available from: http://cesiumjs.org/index.html.

Gunia DA. Earth 3D. 2014 [cited 2014 10 January]; Available from: http://www.earth3d.org/index.html.

Geomantics. Genesis IV. 2014 [cited 2014 10 January]; Available from: http://www.geomantics.com/genesis4.htm.

Yost N. Introduction to g3DGMV (3D Graphical Map Viewer). 2014 [cited 2014 10 January]; Available from: http://g3dgmv.sourceforge.net/index.html.

Stock MJ. Hftools. 1998 [updated 1998-09-24; cited 2014 15 January]; Available from: http://markjstock.org/pages/hftools.html.

Unidata. Integrated Data Viewer (IDV). 2014 [cited 2014 12 January]; Available from: http://www.unidata.ucar.edu/software/idv/.

Wood J. LandSerf. 2014 [cited 2014 20 January]; Available from: http://www.landserf.org/.

Guth PP. MicroDEM. 2014 [cited 2014 20 January]; Available from: http://www.usna.edu/Users/oceano/pguth/website/microdem/microdem.htm.
[30] Norkart Company. Norkart Virtual Globe. 2014 [cited 2014 20 January]; Available from: www.virtual-globe.info.

[31] OpenEV. OpenEV. 2014 [cited 2014 20 January]; Available from: http://openev.sourceforge.net/index.php?page=features.

[32] Realmware Corporation. Visual 3D. 2014 [cited 2014 10 January]; Available from: http://www.visual3d.net/game-engine/features.

[33] Yang T, C. WB, Lobb RJ. 2004. Game Engine Support for Terrain Rendering in Architectural Design [Doctoral dissertation]. Private Bag 92019, Auckland, New Zealand. University of Auckland

[34] Green D. Terrains from DEMs: Using Digital Elevation Models 2012 [cited 2014 4 January]; Available from: http://udn.epicgames.com/Three/TerrainsFromDEMs.html.

[35] Tracy D, Tracy S. 2011. CryEngine 3 Cookbook: Over 90 Recipes Written by Crytek Developers for Creating Third-generation Real-time Games: (Packt Publishing Ltd)

Acknowledgments
The authors would like to express their sincere appreciation to Ministry of Education, Malaysia for funding this project under the Prototype Research Grant Scheme (PRGS). Without their support and helps, this project project could not be success.