Online 3D terrain visualisation using Unity 3D game engine: A comparison of different contour intervals terrain data draped with UAV images

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Abstract. The main objective of this paper is to discuss on the effectiveness of visualising terrain draped with Unmanned Aerial Vehicle (UAV) images generated from different contour intervals using Unity 3D game engine in online environment. The study area that was tested in this project was oil palm plantation at Sintok, Kedah. The contour data used for this study are divided into three different intervals which are 1m, 3m and 5m. ArcGIS software were used to clip the contour data and also UAV images data to be similar size for the overlaying process. The Unity 3D game engine was used as the main platform for developing the system due to its capabilities which can be launch in different platform. The clipped contour data and UAV images data were process and exported into the web format using Unity 3D. Then process continue by publishing it into the web server for comparing the effectiveness of different 3D terrain data (contour data) draped with UAV images. The effectiveness is compared based on the data size, loading time (office and out-of-office hours), response time, visualisation quality, and frame per second (fps). The results were suggest which contour interval is better for developing an effective online 3D terrain visualisation draped with UAV images using Unity 3D game engine. It therefore benefits decision maker and planner related to this field decide on which contour is applicable for their task.

1. Introduction
In recent years, Geographical Information System (GIS) technology have advanced a great deal with the internet, this is due to terrain visualisation technology that uses the internet as the main platform for presentation such as Google earth, Marble and Bing Map3D has emerged rapidly thus increase the user expectation and demand for terrain visualisation [1]. These platforms are capable of producing a 3D visualisation of GIS data with more realism. Most of the terrain data is derived from the offline system before it being used inside online environments. This is due to that online system is very dependent on the offline system for visualising the terrain, for example if the terrain data and file size of 3D data too large, it will slow the loading and rendering time considerably.

This study aims to compare three different contour intervals (1m, 3m, 5m) terrain data that have been draped with UAV images, this study will utilize GIS data of palm oil plantation in Sintok, Kedah which consist of terrain data and UAV images. The study will utilize three different software’s, which are ArcGIS from ESRI (http://www.esri.com), Global Mapper [2] and Unity 3D. The objective of this paper is to compare the effectiveness of visualising online 3D terrain draped with UAV images for different contour intervals data based on the data size, loading time (office and out-of-office hours), response time, visualisation quality, and fps.
2. Related works
Terrain visualisation has advanced a lot in these recent years. Thus, there are a lot of different platforms that GIS data is applied. Ruzinoor et al. [3] have done a good review on 3D terrain visualisation of GIS data starting from the earlier stage of the technology emerged. They also produce many related work regarding this research by utilising Virtual Reality Markup Technology (VRML) as main platform by performing different kind of experiment for online 3D terrain visualisation such as using different contour interval data [1], different GIS software’s [4], different rendering technique [3, 5], different web servers [6], and different multi-sensor satellite images [7]. Besides that, Ruzinoor also study on how to utilized Unity 3D game engine in developing online 3D terrain visualisation for an oil palm plantation [8-10]. In another study by Shin et al. [11], Unity 3D game engine also used to visualize 3D terrain but their project focus more on sea navigation. In a study by Lv et al. [12], they visualize 3D multi-layer seabed terrain in Smartphone environment. Resch, Wohlfahrt, & Wosniok [13] studies the effectiveness of 3D seabed visualisation with time control in different platforms. Horowitz & Schultz [14] uses 3D printing technology to print digital terrain models of Mars surface. Wu, Deng, & Paul [15] studies on terrain visualisation using graphic card technology and openGL. Mazurek, Paces, & Filla [16] uses 3D visualisation technology with electronic flight instrument system to solve flight disorientation during flight for aircraft pilots. Finally, Zocco, Livatino, & De Paolis [17] studies on improving military operations by providing 3D visualisation of the area of military operations.

3. The implementation of online 3D terrain visualisation using Unity 3D game engine
Terrain visualisation is using the terrain data in a 3D view that would allow a much more detail view of the terrain surface and elevation. The process of analysis begins with contour data preparation, continue with UAV data preparation and finally Unity 3D implementation. The URL used to launch the applications is at "http://www.hafsaruz.net".

![Figure 1: The flow of contour data preparation.](image)

3.1 Contour data preparation
The contour data used for this study was gathered from palm oil plantation in Sintok, Kedah. The size of the study area was 2.08829 acre. The projection used was WGS 84 UTM Zone 47N. The contour data of the study area obtained from Digital Terrain Model (DTM) generated from UAV images that capture from the aerial imagery of the study area. As mentioned earlier, the contour data is divided into three different intervals which is 1m, 3m, and 5m. In order to generate different contour intervals
from DTM, the Global Mapper software [2] by Blue Marble Geographic was used. This three different
contour intervals contour data need to be clipped. These contour data are in vector format which
contain the height value of the terrain based on their intervals. The contours data, however, do not
used the same projections as the UAV images data and have to be changed into similar projections.
ArcGIS define projection tool being utilized to set this two types of data into similar projections. In
order to clip the contour data, the process begins by generating new SHP files which contain the size
of the clipped area needed. The size of the clipping area is set to 712331.186567 top, 665056.150775
left, 712241.534425 bottom and 665150.415246 right. After that, each of the contour intervals data
was clipped based on this clipped area. Figure 1 show the whole process of contour data preparation.
When the contour data being clipped, its need to be convert into Triangular Irregular Network (TIN)
format. After that, the data were converted into raster format. Finally, the data were converted into
float file (.FLT and .HDR) using the conversion tools that available in ArcGIS.

Figure 2 shows the three contour data with different interval of the same area when the clipping
process was done.

![Figure 2: Different contour interval data.](image)

3.2 UAV data preparation
The UAV images data of the study area are collected by flying over the area using UAV at 318.309m
altitude with Canon Powershot s100 (5.2 mm). These UAV images need to be clipped with the same
size of the contour data clipped earlier. Again, the ArcGIS software was used to clip this data. The
same size of the clipped area was used which is 712320.63 top, 664934.95 left, 712231.96 bottoms
and 665044.44 right. The process begins by opening the UAV images data. After that, open the
clipped area SHP files. Then the UAV images were clipped based on the clipped area selected. Figure
3 show the UAV images data after clipped. This file then need to be export as JPG image in order to
be used in Unity 3D game engine.

![Figure 3: The UAV images data after clipped.](image)
3.3 Unity 3D implementation
After finishing the contour data preparation and UAV images data preparation, the data is imported into Unity 3D. In Unity 3D, the terrain is generated based on terrain data that was clipped before. 3D object of the terrain is generated using unity 3D terrain engine and viewing functions is added such as zoom in and out. It is then published for web environments. The file is uploaded at web server with address link "http://www.hafsaruz.net". Figure 4 show the flow on how the terrain visualisation being published into web environment using Unity 3D game engine.

![Flow of publishing terrain visualisation](image)

**Figure 4:** The flow of publishing terrain visualisation for web environment.

4. Results and discussion
The result of this study was three Unity 3D web player format that was created from different contour interval data which are 5m, 3m, and 1m. The output was measured based on data size, loading time (office and out-of-office hours), response time, visualisation quality, and fps. The first output is from 5m interval. Figure 5 show the image of this output. The results of this image show "Acceptable" of visualisation quality where the area inside the circle can be seen clearly but difficult to identify the slopes. Overall the area of oil palm plantation can be viewed clearly.

![View of UAV images draped with 5m interval contour data](image)

**Figure 5:** The view of UAV images draped with 5m interval contour data.
The second result is from 3m interval output. Figure 6 show the image of this output. The results of this image show "Clear" of visualisation quality where the area inside the circle can be seen clearly but with slight slopes, overall, most of the area inside the oil palm plantation can be viewed clearly.

![Figure 6: The view of UAV images draped with 3m interval contour data.](image)

The final result is from 1m interval output. Figure 7 show the image of this output. The results of this image show "Very clear" of visualisation quality where the area inside the circle can be seen very clearly with a good view of slopes, overall, most of the area inside the oil palm plantation can be viewed clearly.

![Figure 7: The view of UAV images draped with 1m interval contour data.](image)
Table 1 shows the results produced from each contour intervals data. As mentioned earlier, there are five criteria to be measured which are data size, loading time (office and out-of-office hours), response time, visualisation quality, and fps. The results of data size for 1m data interval produce the bigger file size after published compared to 3m and 5m data interval. This is due to usually 1m data interval holds a lot of data compare to 3m and 5m data interval. The same size of UAV images was overlaid on each data interval. The visualisation qualities in these three outputs were already discussed earlier in this section.

**Table 1: Result of each contours data.**

| Criteria                  | Contour Intervals |
|---------------------------|-------------------|
|                           | 1m                | 3m                | 5m                |
| Data size                 | 1.401 kb          | 1.399 kb          | 1.399 kb          |
| Loading time (Office)     | Off 3.2 sec       | Out 2.0 sec       | Off 1.2 sec       |
| Loading time (Out)        | Out 2.0 sec       | Off 1.2 sec       | Out 1.3 sec       |
| Response time             | 139 ms            | 109 ms            | 110 ms            |
| Visualisation quality     | Very clear        | Clear             | Acceptable        |
| Frames per second (fps)   | 58.11 fps         | 57.54 fps         | 56.45 fps         |

The other criteria to be measured was fps value where Comodo Dragon browser performance tool is used for the purpose of this testing. Testing was done by recording the web page in five seconds for different contour interval to show the value of fps. For 5m data interval 56.45 fps value was recorded while for 3m data interval 57.54 fps value was recorded and 1m data interval recorded fps value of 58.11. After that, the test continue with measuring the response time for each contour intervals data using Yslow by Marcel Duran [18]. In order to view the response time value, YSlow plugin are installed inside Mozilla Firefox web browser. The results of the response time acquired are 139 ms for 1m, 109 ms for 3m, and 110 ms for 5m. The response time of each contour intervals are slightly different from each other. Finally, the loading time was measured using tools from App.telemery name “page speed monitor” by Fabasoft group [19]. The results that was recorded are from two-time frames that are during office hour and out-of-office hour. The time taken for office-hour was between 8 am to 5 pm while the out-off-office hour was after 5 pm. The results recorded for office hour are 3.2 sec for 1m, while for 3m and 5m each recorded an average of 1sec. While the results for out-of-office hour is 2 sec for 1m, 1.3 sec for 3m and 0.9 sec for 5m is slightly faster compare during office hour.

5. Conclusions

In conclusion, it can be concluded that in order to develop online 3D terrain visualisation overlaid with UAV images by different contour intervals terrain data using Unity 3D game engine, there is some consideration that has to be looked upon. One of it is the accuracy of the data used. By converting the terrain data in multiple formats of data which is raster to vector in ArcGIS, the terrain data has extra features when generating terrain in Unity 3D game engine. Thus, the result shows slightly different from the expectation on 1m, 3m, and 5m contour intervals. As for 1m contour interval, it shows that the result as expected where 1m contour interval generated bigger data size compared to 3m contour interval, however, the data size of 5m contour interval is slightly bigger than 3m contour interval. This
situation occurred, may be due to the extra features generated from the 5m contour interval. It can be concluded that the most appropriate and suitable data to be used for implementation of online 3D terrain visualisation draped with UAV images using Unity 3D game engine was 3m interval data. It giving promising results as same as 1m interval data which has less data size, less loading time and response time and less fps value compare to 1m interval data.

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