3-D GIS AND INTELLIGENT TRANSPORTATION SYSTEMS

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Abstract

Traditionally, road networks are viewed as 2 dimensional entities in GIS and have offered limited access to transportation engineers. Emerging digital elevation model (DEM)-based GIS layers can provide additional useful information such as road slope and visibility information using Viewshed functions of ArcGIS Desktop from ESRI. In addition, new kinds of route choice analysis can be conducted where drivers upstream on the road in higher elevation, looking down the road, can make different route choices which traditional 2-D models cannot capture. This paper tests the feasibility of using 3-D DEM layers in ArcGIS for intelligent transportation systems (ITS) and presents initial findings in using the 3-D layers with respect to road slopes, visibility and drivers' route choice. It is found that 3-D GIS analysis can enhance ITS related applications significantly.

Keywords: 3-D GIS, Intelligent Transportation Systems, Digital Elevation Model, Visibility, 3-D Building

1 INTRODUCTION

This paper reviews recent applications of 3-D GIS in the field of intelligent transportation systems (ITS). Emerging GPS devices for consumers in forms of GPS navigator and Smartphone provide convenient travel experiences to drivers. Those devices compute travel distance and travel times. More advanced ones incorporate real-time traffic conditions and points of interest in computing the optimal path. However, most maps used in these devices assume the road networks are two dimensional (2-D) entities. The 2-D approach misses out potential benefits that can be harvested by utilizing the 3-D nature of the road information. One of the pioneering works in three dimensional (3-D) navigation is SONY XYZ [1] product line sold in Japan. The product can reproduce 3-D images of buildings near roads that drivers can visually compare with the actual observation at major intersections of the city. This approach has evolved into applications offered in Street View of Google™ and iOS 6 map on iPhone 5. The visual confirmation method is user-friendly while it does not provide transportation engineers with quantitative information with which rigorous computation for certain ITS objectives can be carried out. If the third dimension (height) information can be accessed in GIS in a form of GIS layer, it is possible to carry out quantitative analysis for the ITS purposes.

2 RELATED WORKS

Schmitt and Jula [2] classifies and compares different branches of route guidance systems. The route guidance systems are classified into "Static vs. Dynamic", "Deterministic vs. Stochastic", "Reactive vs. Predictive" and "Centralized vs. Decentralized". 3-D GIS concepts in this paper can créate new categories such as “2-D vs. 3-D” or “Travel Time based vs. Visibility or Road slope based”. Scholossberg [3] presented a method of evaluating the walkability of routes based on GIS street data and Scholossberg et al. [4] developed a GIS based method of auditing the walkability on the roads by collecting data from handheld PDAs. Hagelin [5] analyzed the bike-on-bus (BOB) programs and recommends ways for transit agencies to overcome bike rack limitations, in the hope of integrating bicycles and transit. Bos and Vrugt [6] provided insights in implementing “Park and Bike” strategies. In order to successfully integrate the bike mode with other modes, an effective route guidance system for bikes that is sensitive to the unique features of the bike mode is required. Lafer [7] et al. developed a methodology for implementing a GIS-based disaster management system. It is expected that adding our 3-D GIS layers into their system will enhance the functionalities of the disaster management system. For example, if some of the roads in the network are flooded, a route guidance algorithm that computes the shortest non-flooded route can speed up the evacuation process. Byon et al. [8] suggest multi crieteria based route guidance methods that are based on 3-D GIS and this work is the main platform on which this conference paper is developed with more emphasis on specific GIS techniques and specific functions in ArcGIS from ESRI in mind for introducing and educating the readers in UAE.

3 DIGITAL ELEVATION MODEL

By utilizing a digital elevation model (DEM) layer in GIS software such as ArcGIS from ESRI, it is possible to treat the roads as three dimensional (3-D) objects. Figure 1 shows an example of DEM layer of Greater Toronto Area (GTA), Ontario Canada. The brighter areas represent higher grounds while the darkest areas represent the sea level.

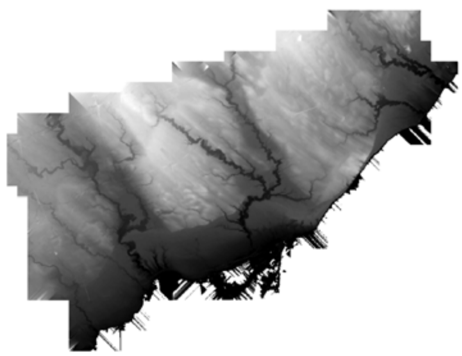

Figure 1. Canadian Digital Elevation Model (CDEM) of Toronto. [9]

Figure 2 shows the transformation of a 2-D road network into 3-D road layer in GIS using ArcGIS, ESRI. The DEM model shown in Figure 1 is fed in as a GIS layer in ArcInfo and geospatially corresponding road networks are elevated in 3-D according to the elevation information from the DEM layer.

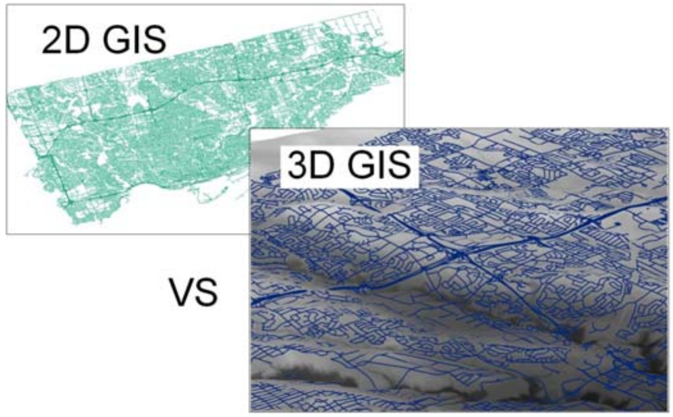

Figure 2. Comparison of 2-D and 3-D road maps in Toronto [8]

GIS can aid the driver in choosing a scenic route between a particular origin-destination pair. A scenic route is roughly defined as a route with visually pleasing sights. However, if hills or other man-made structures block their view, a route in the middle of scenic regions can be considered a non-scenic route. Therefore, GIS computes a visibility factor which is useful in determining scenic ratings of different routes. Visibility heavily depends on the height of the roads, which is information available via digital elevation models (DEM). With aids of 3-D tools in GIS, the DEM can be processed to produce valuable information on roads such as visibility and slopes.

4 3-D BUILDINGS

Visibility information assists the driver in finding the best scenic route or determining the sight distance of drivers for the road-safety-related analysis. In order to have accurate visibility information, one needs to know both the DEM and height information of man-made buildings. Then the layers of DEM and the building information sum up to provide effective elevation information for visibility. At the time of writing, the height information of the buildings is not available and only the DEM is available. However, in the future, as such data is collected; the visibility information will be more accurate. Google Earth^{TM} has already started including 3-D models of famous buildings around the world in their "3-D Buildings" layer with height information built into the models. Figure 3 shows 3-D building models of Tokyo, Japan.

Figure 3. 3-D building models in Google Earth^{TM} for Tokyo, Japan.

(Google Earth^{TM}, Accessed Septermber 2012)

5 ROAD SLOPE

The road slope information can provide bike riders and pedestrians with the least inclined path and be fed into pollution-generating models to estimate pollution levels on roads for transportation planning purposes. Elevation and slope information can be combined to determine the areas that are most susceptible to flooding and the submergence contours, which may be valuable information in cases of emergency evacuation. Figure 4 shows the road slope distribution of Toronto, Canada. Yellow lines indicate valleys. In other words, for bike riders, it is more difficult to cross the yellow lines due to steep paths even if the roads are physically connected.

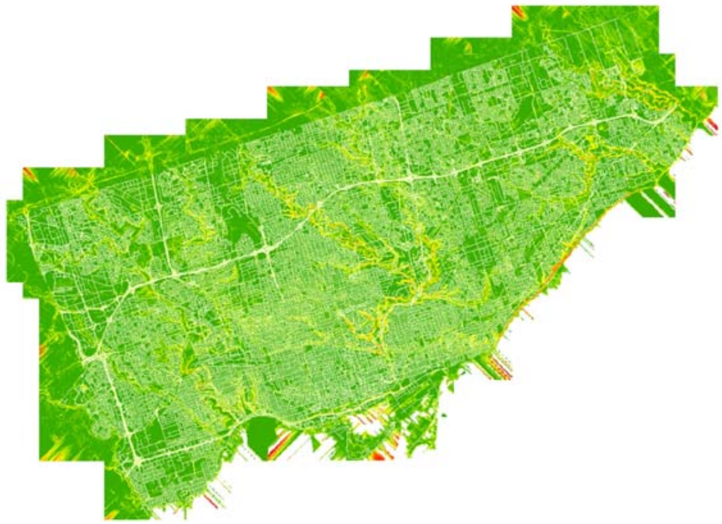

Figure 7. Slope variations across Toronto. [8]

6 VISIBILITY ANLYSIS

ArcObject Desktop has embedded advanced 3-D processing tool called "viewshed". It can compute visible areas from any arbitrary points on a map by observing views in 360 degrees around the given locations. Areas over the hills are not visible and if visible areas are aesthetic, drivers might prefer to travel the route with better scenic views. Arcs representing roads can be evaluated for scenic views and that can be used for computing the best scenic routes for drivers. Figure 4 describes the parameters used in the viewshed funtion in ArcGIS. Figure 5 shows visible areas from two different major highways in Toronto, Canada. Figure 6 illustrates the processing of intersecting the two layers namely "scenic value" layer and "visibility" layer.

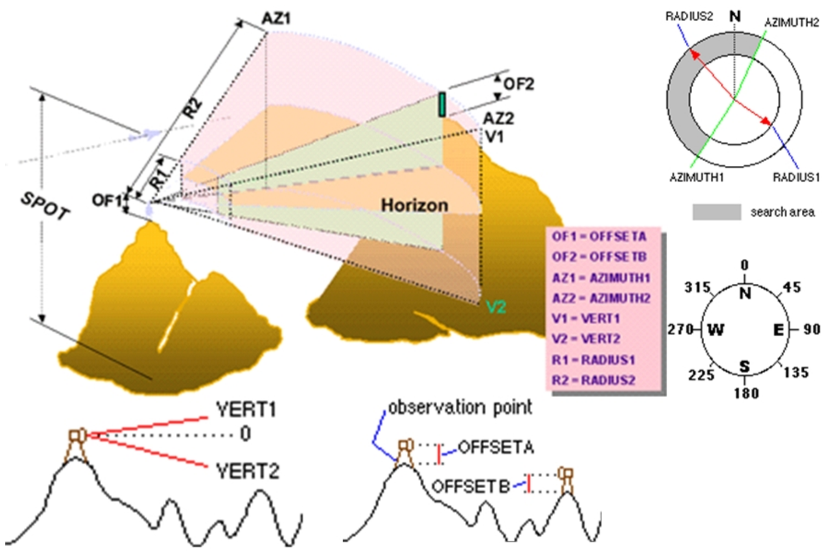

Figure 4. The 9 controllable characteristics of the viewshed tool. [10]

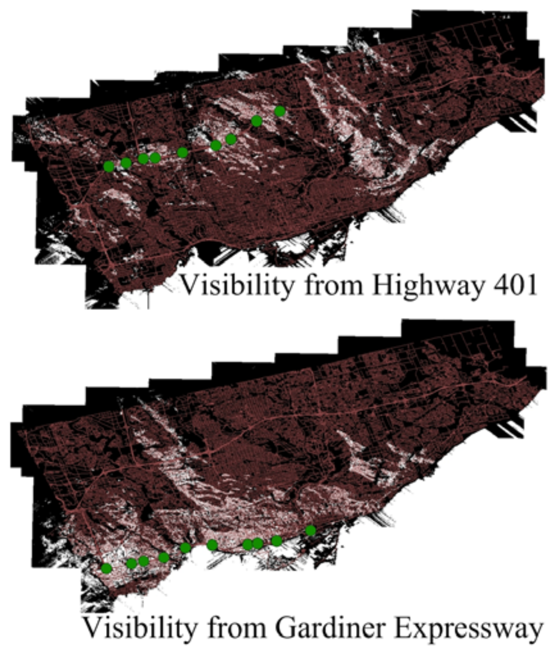

Figure 5. The visibility from Highway 401 based on the 10 observation points (top) and the visibility from the Gardiner Expressway based on 10 observation points (bottom). [8]

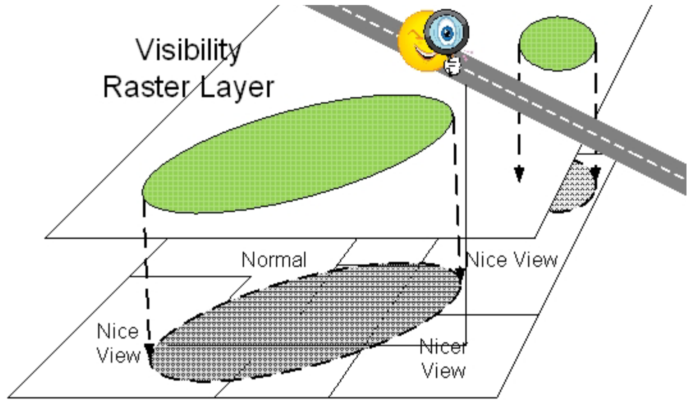

Figure 6. Computation of the scenic value of a particular link. [8]

7 CONCLUSIONS AND FUTURE WORKS

This paper reviews related works in 3-D GIS in the context of intelligent transportation system. Some of the key features of ArcGIS from ESRI including Viewshed function for computing visibility information, Slope function for producting raster map of spatially distributed slope by using DEM layer in GIS; are found to be effective tools in computing scenic route and bike routes. In the future, transportation engineers can explore further about the influence of drivers having access to the additional height information.

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