THE USE OF GIS, REMOTE SENSING AND VIRTUAL REALITY IN FLOOD HAZARD MODELING, ASSESSMENT AND VISUALIZATION

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1. INTRODUCTION

Recently, the advancement of digital technology has driven interests in developing geovisualization to provide a spatial virtual environment, and at the same time to enhance user interactions within it (Hearnshaw and Unwin, 1994; MacEachren and Kraak, 1997; Rhyne, 1997; Unwin, 1997; Fuhrmann et al., 2000). Examples of these techniques include three dimensional (3D) visualization and virtual reality (VR). Displaying data in 3D shows patterns that are not evident in two dimensions (2D).

The concept of VR was introduced in 1929 when the first flight simulator was created by Edwin Link, but the term “Virtual Reality” was not coined until 1989 by Jaron Lanier (Heim, 1993). The most important feature of VR is to allow the user to immerse into the virtual environments (Schwertley, 2003). In geography, VR has brought the users of static maps a brand new approach visualizing the spatial environment, instead, it provides the user with “a sense of immersion and control over the spatial environment” (Schwertley, 2003). Researchers in cartographic mapping and VR have developed a variety of techniques for creating spatial environment for immersion (MacEachren et al., 1999a; MacEachren et al., 1999b; Fairbairn et al., 2001; Cartwright et al., 2001; Cammack, 2003).

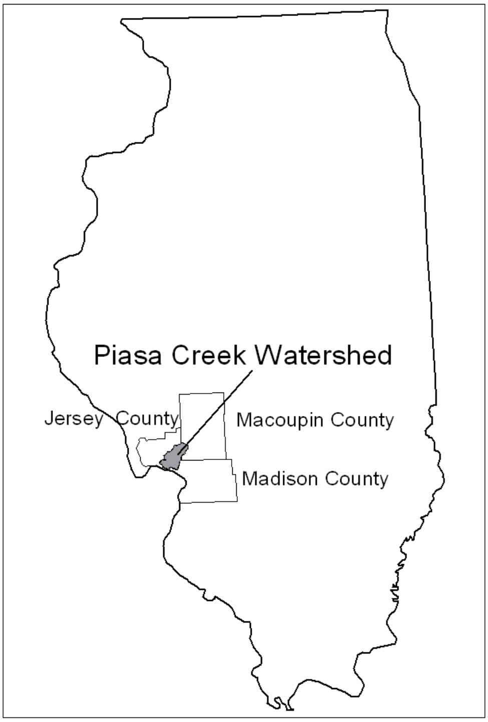
This paper demonstrates a new approach to modeling, assessing and visualizing flood hazard areas using a combination of geographic information system (GIS), remote sensing, and VR techniques. The study area is Piasa Creek watershed in southwestern Illinois northeast of St. Louis. The data sets include a 10-meter resolution digital elevation model, 1-meter resolution digital orthophotoquads, and a digital map of the 100-year flood zone. Procedures to develop the new approach are described, which involve the use of ERDAS Image 8.6, ArcView GIS 3.2a, Arc/Info Workstation, ArcView 3D Analyst, and Virtual Reality Macro Language (VRML) 2.0.

2. METHODOLOGY

2.1 STUDY AREA

The Piasa Creek watershed (PCW) is an area of approximately 312 square kilometers (77,000 acres), draining portions of Madison, Macoupin and Jersey counties of southwestern Illinois (Figure 1). Elevation in the PCW ranges from a low of 130 meters (430 feet) National Geodetic Vertical Datum (NGVD) at the mouth of Piasa Creek to a high of 226 meters (740 feet) NGVD on the bluffs along the Mississippi River. Elevations near the headwaters of Piasa Creek are approximately 220 meters (660 feet) NGVD (Shannon & Wilson Inc., 2002). The floodplain area in the PCW occurs in the Lower Piasa at the confluence of Piasa Creek and Mississippi River upstream to the confluence of Piasa Creek with Mill Creek.

FIGURE 1
LOCATION OF THE PIASA CREEK WATERSHED



2.2 DATA COLLECTION

The data sets included Illinois Geological Survey (ISGS) 1-meter resolution digital orthophotoquads (DOQ), U.S. Geological Survey (USGS) 7.5-minute quadrangles of 10-meter resolution digital elevation model (DEM), 100-year flood zone digital map, and 1:24,000-scale USGS digital raster graphics (DRGs) (Table 1). The DOQ and DEM data sets were all in Universal Transverse Mercator (UTM) coordinate system zone 15 with DOQ in North American Datum of 1983 (NAD83) and DEM in NAD27. The floodplain data set was in Illinois State Plane coordinate system west zone. The DRGs were in UTM zone 16 and NAD27.

TABLE 1
PROJECT DATA

Data Set	Original Coordinate System, Datum, and Zone	Data Source
1-m Digital Orthophotoquads	UTM, NAD83, Zone 15	www.isgs.uiuc.edu
10-m Digital Elevation Models	UTM, NAD27, Zone 15	www.mapmart.com
100-year Flood Zone Digital Map	Illinois State Plane, west zone	www.isgs.uiuc.edu
1:24000 Digital Raster Graphics	UTM, NAD27, Zone 16	www.isgs.uiuc.edu

Eight DOQs and six DEM quadrangles were required to cover the study area. The DOQs were downloaded from ISGS's web site, and they were in Mr.Sid image format (.sid). The DEM data were downloaded from Mapmart's web site free of charge, and they were all in USGS Spatial Data Transfer Standard (SDTS) format. The floodplain data were downloaded from the ISGS's web site, and in Arc/Info export interchange file format (.e00). Six USGS DRGs were also downloaded from the ISGS's web site, and in Tagged Interchange format (.tif).

2.3 DATA PROCESSING

In order for all the data sets to be used in the same spatial environment, they had to be transformed into a common reference system: UTM Zone 15, NAD83. Since the eight DOQs were already in the reference system as required for the project, no datum conversion was necessary. However, all DOQs were mosaicked using the MOSAIC tool of ERDAS Imagine. Also in Imagine, the area of interest (AOI) was generated using the Imagine's CREATE AOI tool and the ArcView shapefile of the watershed boundary (discussed below). And finally, the SUBSET module of Imagine was used to subset the mosaicked DOQ image for the entire watershed using the AOI.

The six DEM quadrangles were in USGS SDTS format. Therefore, the first step was to convert individual DEM files to Arc/Info's GRID format using SDTSIMPORT command available in Arc/Info Workstation. The second step was to transform the original DEM grids (NAD27) to the output DEM grids in NAD83 using the PROJECT command in Arc/Info. Then the six DEM quadrangles were mosaicked using the command MOSAIC in the Grid module of Arc/Info, the mosaicked DEM sunset using the SUBSET module of Imagine and the AOI, and finally triangulated irregular network (TIN) from the regular DEM grids constructed using ArcView's 3D Analyst.

The original 100-year flood zone data were in Illinois State Plane coordinate system. Therefore, a conversion to UTM coordinate system was required. This was done using PROJECT command of Arc module in Arc/Info.

The use of USGS 1:24,000-scale DRGs was primarily to create a digital map of the PCW boundary, which initially was not available for the project. The six DRG quadrangles were first mosaicked in ERDAS Imagine, the boundary was then delineated in ERDAS Imagine based on the PCW boundary drawn on a hardcopy map provided by the Great River Land Trust, Inc., saved as ArcView shapefile, and re-projected from UTM zone 16, NAD83 to UTM zone 15, NAD83. The accuracy of the delineation was verified by superimposing the ArcView shapefile of the watershed boundary on the DEM mosaic.

2.4. DATA VISUALIZATION

2.4.1 3D Visualization

Once the TIN data had been generated, a perspective view of the PCW was created. A perspective view is a 3D view of the terrain that has the same appearance as viewed with an angle from an airplane. The user can control the appearance of a 3D view by changing view azimuth, viewing angle, view distance, and vertical exaggeration factor or z-scale. The user also has the options to zoom in and out, pan, and fly through (Chang, 2002). The 3D Analyst Extension to ArcView provides graphical user interface for the user to change the parameters of the viewing. In addition, thematic layers such as roads, rivers, flood zone, and digital orthophotoquads can all be superimposed onto the 3D view of the terrain to make perspective views even more realistic.

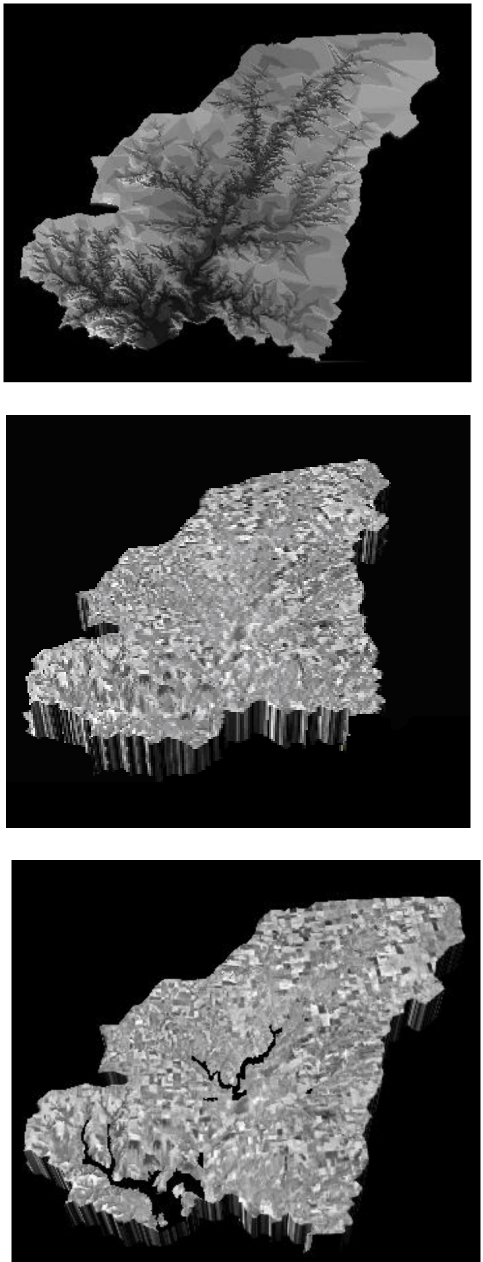
2.4.2 VR Visualization

In ArcView 3D Analyst, the 3D scenes can be exported to an exchange format called VRML. The benefit of creating a VRML file from the 3D scenes in ArcView is to disseminate the 3D representation of the spatial environment to a worldwide audience because VRML is now a standard browser for viewing 3D objects on the Internet. Interaction in a VRML-browser such as VRML 2.0 is usually achieved via the mouse and the control board of the browser.

3. RESULTS

Figure 2 is the 3D representation of the PCW in a 3D Scene Viewer of ArcView GIS. The user is easily able to rotate, navigate, or take a close-up view of the surface. Figure 2A demonstrates the effectiveness of 3D landscape with different gray shades corresponding to different elevations. Topography of the study area is distinctly revealed to the viewer, which is normally not an option in a 2D representation. In Figure 2B, the DOQ was draped over the TIN surface and displayed in 3D perspective. It reflects the photo-realistic, 3D representation of the spatial environment, which again is not an option to the viewer on a scanned aerial photograph. Figure 2C illustrates the impacted area of 100-year flooding using the 3D visualization approach. After the flood zone (after converted to 3D ArcView shapefile) is superimposed on the 3D DOQ, it looks as though the water level were rising from the nearby streams. This representation of floodplain contributes to the understanding of floodplain impacts or extent. If the parcel data or road data (converted to 3D ArcView shapefile) is available, the assessment of property values

FIGURE 2
3D REPRESENTATION OF THE PIASA CREEK WATERSHED: (A) 3D SCENE DISPLAYED IN ARCVIEW 3D SCENE VIEWER; (B) DOQ SUPERIMPOSED ON THE 3D SCENE; (C) 100-YEAR FLOOD ZONE SUPERIMPOSED ON THE DOQ (VERTICAL EXAGGERATION: 3)



(A)

(B)

(C)

that a flood impacts can be evaluated based on the water level of the flood event. For instance, the author did one survey on 27 single-family houses in Jersey County located in the100-year flood zone. The individual houses were digitized on screen directly from the DOQ and their current property values were entered as attributes. The total property value was estimated at $4,805,000. Figure 3 shows 2D representation of the surveyed area on which Piasa Creek, Highway 140, 100-year floodplain and surveyed houses are displayed. Figure 4 is a 3D representation of the same information as shown in Figure 3 but in different orientation for best viewing. It is clear that the 3D approach is more informative than the 2D representation.

FIGURE 3
A CLOSE-UP VIEW OF A PORTION OF THE PIASA CREEK WATERSHED SHOWING LOCATIONS OF SINGLE-FAMILY HOUSES INSIDE THE 100-YEAR FLOOD ZONE (2D REPRESENTATION)

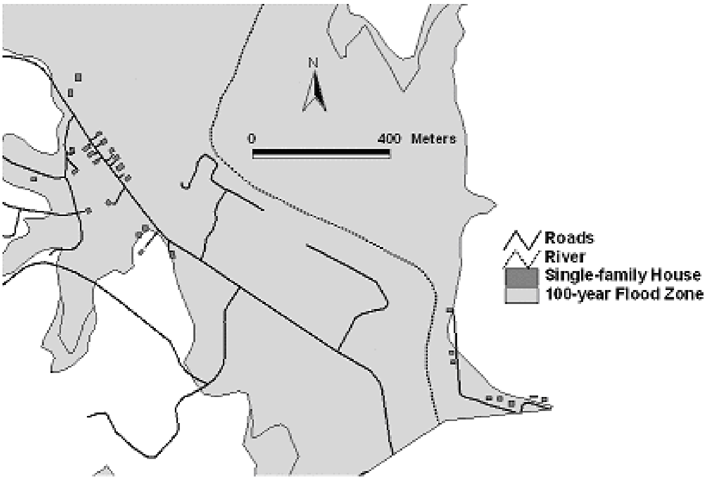


FIGURE 4
3D REPRESENTATION OF THE SAME PORTION OF THE PIASA CREEK WATERSHED AS SHOWN IN FIGURE 3 (NOTE: NORTH IS FACING TO THE LEFT)

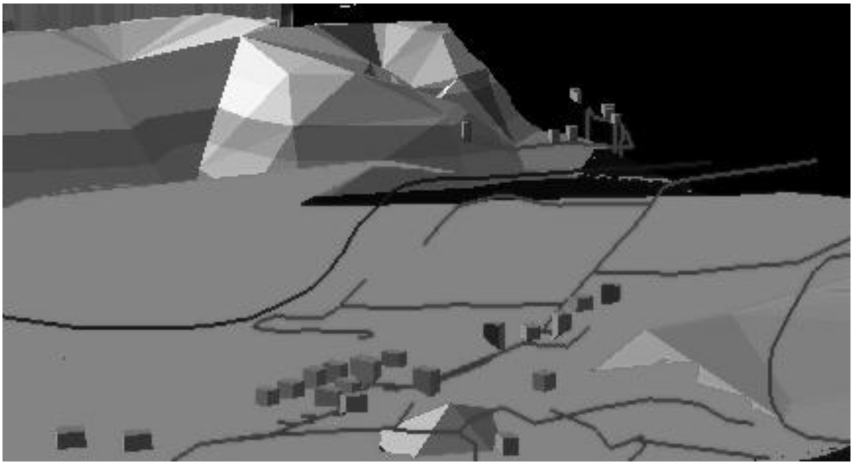
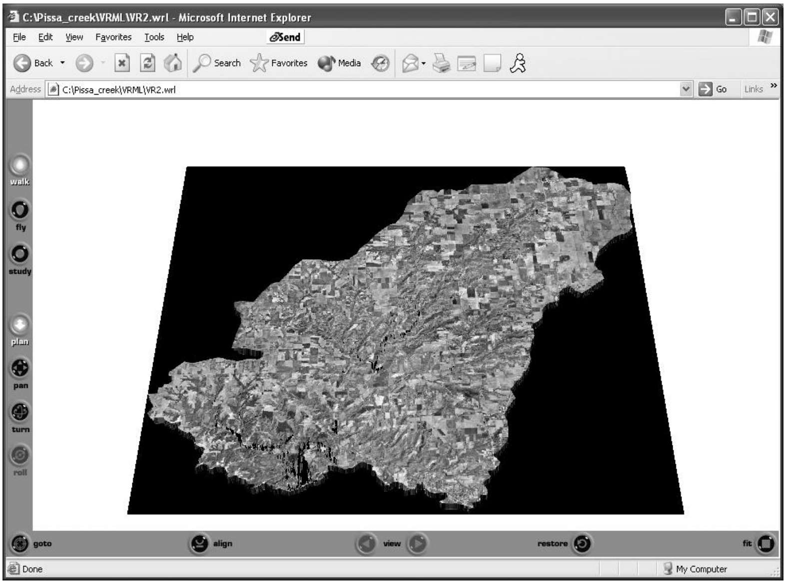


Figure 5 displays a screen-captured VRML 3D scene played back using VRML 2.0 as plug-in freeware for Microsoft Internet Explorer. The control board allows the user to perform walk, fly, turn, and roll on the 3D scenes. All these utilities make it possible to actually interact in three dimensions and the user feels immersed in such spatial environment.

FIGURE 5
VRML 3D SCENE PLAYED BACK USING MICROSOFT INTERNET EXPLORER (NOTE: THE 100-YEAR FLOODPLAIN IS DIPLAYED AS BLACK INSIDE PCW)



4. CONCLUSION

This paper has demonstrated the advantages of 3D visualization and VR techniques over 2D representation of the spatial environment under investigation. The new approach can be used for a large number of applications, such as navigation system in an urban environment, and 3D landscape visualization. In the future, it will be beneficial to incorporate ground photographs, digital video and sound within the 3D scenes.

5. REFERENCES

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