

Point and Click GIS: ArcObjects Customization of Routine Business Processes

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Abstract

ArcMap is commonly recognized as ESRI's 2D ArcGIS platform, while ArcScene is ESRI's 3D GIS viewer. Normally, once an ArcScene project is created, it can then be viewed within an ArcMap customized project. However, this ArcScene project cannot be manipulated within ArcMap. This paper presents a method to switch between 2D and 3D viewers to perform complex queries and data processing in both 3D and 2D environments, within ArcMap, completely bypassing the ArcScene platform.

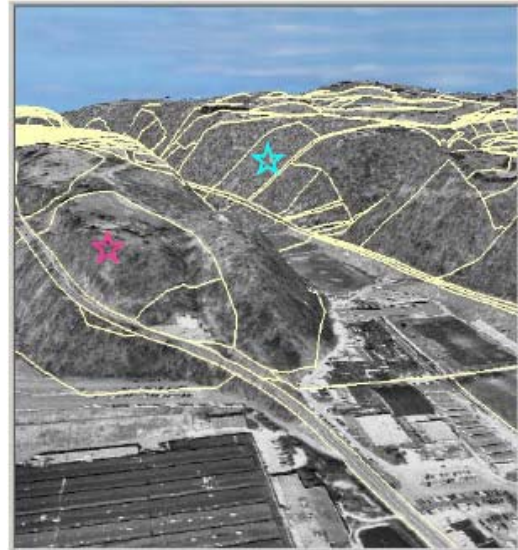
Layer files with elevation information are created in ArcScene, then loaded into ArcMap using ArcObjects' Scene Viewer. In ArcMap, these individual 3D layers are controlled (turned on and turned off) and analyzed simultaneously with the 2D view. An integrated, dynamic link between the 2D and 3D viewers provides more flexible viewing and analysis capabilities. Both spatial and attribute queries can be performed utilizing the linkage between these two viewers. Formatted reports can also be generated based on a user's request.

The 2D and 3D viewer customization was developed to model a routine business process for casual municipal desktop users. It combines many commonly used GIS functions into a few, easy- to-use forms.

Introduction

ArcMap has been a traditional GIS platform used to perform complicated spatial and non-spatial analysis on both vector and raster datasets. The analysis results are presented as a two-dimensional map that may not provide an intuitive representation of the true landscape to the casual GIS user. These results have the potential to be misleading. Depending on the purpose of the map, the 3D landscape shown in figure 1b can significantly enhance the analysis presentation to the casual GIS user, in lieu of the traditional 2D landscape shown in figure 1a.

ArcGIS 3D Analyst enables users to effectively visualize and analyze surface data, enhancing the user's understanding. With 3D Analyst, a surface may be viewed from multiple viewpoints to determine what is visible from a chosen location on a surface, and create a realistic perspective image by draping raster and vector data over a surface. Figure 1b illustrates the enhancement this adds to the visualization of the same area in 2D shown in Figure 1a.

**a. Landscape in 2D viewer****b. Landscape in 3D viewer****Figure 1. The same landscape in 2D and 3D viewers**

However, ArcScene must be used in conjunction with 3D Analyst to display the 3D representation so that the virtual reality of the landscape can be illustrated. The user must switch between 2D and 3D viewers to obtain the required views and effects, but cannot manipulate the viewers simultaneously. Setting the 2D and 3D views to the same map display scale can also prove to be a challenge.

This project integrates the 3D virtual reality capabilities of ArcScene into ArcMap through ArcObjects application programming interfaces. ArcObjects is based upon Microsoft's Component Object Model (COM) technology that allows developers to expand ArcGIS platforms and develop customized applications. It will be demonstrated by this research that both 2D and 3D viewers can be integrated into one common interface utilizing customized ArcObjects APIs that combine the strengths of different ArcGIS platforms and functionalities.

Study Area and Data Source

The study area is located in western Pennsylvania and includes approximately 800 parcels. The distinct elevation variations in this study area provide a 3D GIS model with distinct vertical dimension change. This is a significant factor to consider in municipal planning and development business processes. When developers and planners look at maps in this area, they need to see the true landscape behind the flat parcel maps to determine the development potential of the land.

The GIS data and source files used for this project may be summarized into four categories:

1. Vector-based Feature Dataset:

The study area is mapped with distinct spatial features, such as parcels, buildings, road centerlines, utilities, etc. This mapping represents the foundation of the spatial architecture in the study area and is critical for spatial analysis.

2. Raster Image Dataset:

Digital Orthophoto Quarter Quads (DOQQ) is a computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map. A 1-meter resolution DOQQ was used for this project and provides a real-world image of the study area, enhancing the understanding the vector dataset.

3. TIN-based Surface Data:

TIN (Triangulated Irregular Network) is a digital elevation model containing a network of triangles at randomly located terrain points. Irregularly spaced sample points are measured with more points in areas of rough terrain, and fewer in smooth terrain. For this project, a TIN file was created from the 5-meter contour line using ArcGIS 3D Analyst. The vector-based feature and raster image datasets are draped over the TIN data to illustrate the elevation information.

4. 3D Layer Files:

Normally, an ArcScene Document (*.sxd) is saved with all datasets to be displayed and used as the 3D virtual reality model. However, it can be very difficult to control and analyze the individual layer if the whole scene document is loaded into ArcMap as the 3D model. To create a more flexible and manageable 3D virtual reality model for the analysis, each dataset is saved as an individual 3D layer file after being draped over the TIN file.

Conceptual Design

To solve the problems illustrated in the introduction, the research objectives of this project are set up as follows:

1. ArcObjects and VBA are utilized upon the ArcMap platform to fully deploy the ArcObjects' functionalities as a prototype for further development.
2. 2D and 3D viewers are combined into the same windows form interface.
3. Layers in both 2D and 3D viewers can be manipulated (turned on and off) simultaneously by the same controls in the TOC (Table of Contents).
4. Both spatial and attribute queries are processed and the results presented in both 2D and 3D viewers simultaneously.

In this way, the user can perform common GIS functions without switching between 2D and 3D viewers to achieve a true representation of the work area landscape.

Interface Design

Figure 2 illustrates the interface design. It is composed of 4 sections:

- the toolbar on the top frame
- the TOC frame
- the 3D viewer (Scene Viewer Control)
- the 2D Viewer (MapControl).

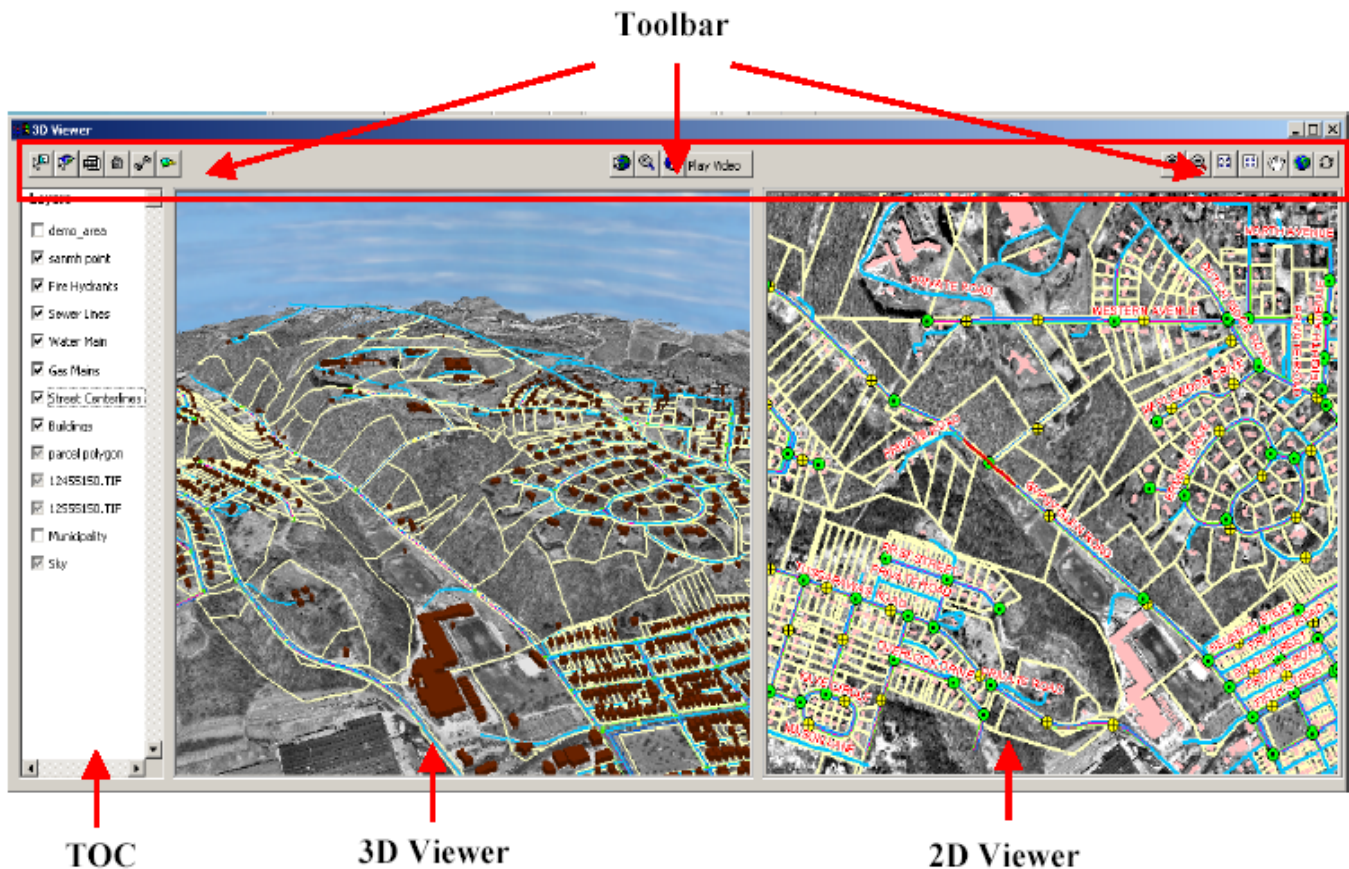


Figure 2. Interface Design

The toolbar provides a group of functional buttons to perform the complex spatial and attribute analysis, to manage the database, etc. The Table of Contents (TOC) frame shows the layers loaded into the project and provides a checkbox for each layer so that the user can turn on and off layers by changing the checkbox status.

The MapControl is the container for the 2D vector and raster datasets. It encapsulates many of the ArcObjects' co class with multiple properties, methods and events for managing the general appearance of the map. The SceneViewer Control is an ActiveX control for adding, displaying and managing 3D scene layers.

Main Functionalities

This research models a routine business process for casual municipal desktop GIS users. It integrates many commonly used GIS functions into a few, easy-to-use forms. The primary functionality explored for this project can be classified into the following nine categories:

1. Viewer Control Functions

The project interface provides some common functionality to manipulate the two viewers. The Zoom In and Zoom Out tools work in the similar way as “Fixed Zoom In” and “Fixed Zoom Out” in ArcMap. Users can use such tools to zoom into or zoom out of both viewers at the same time. The Full Extent tool will reset the 2D and 3D viewers to the full extent concurrently. Furthermore, the scene viewer control has some additional default functions, such as the navigate tool, which allows the user to rotate the data in the 3D viewer.

2. Layer Control Functions

The TOC frame provides layer control functions. The user can toggle on and off the map layers in both the 2D map viewer and 3D Scene Viewer simultaneously by checking and un-checking the layer checkboxes.

3. Spatial Query Functions

The spatial query is most commonly used for spatial analysis that evaluates the spatial relationship of the geo-features, such as “intersect”, “completely contain”, “completely within”, “are within a distance of”, etc. As a demonstration, this project performs complicated spatial query between parcel and the utility feature classes.

For example, the spatial query will select parcels that are located within a user-specified distance of various utility lines, such as water, gas, sewer, etc. A temporary graphic buffer is created around the utility lines at the user-defined distance. The buffer is then overlaid on the parcel layer to perform the intersection geo-processing and selection of the parcels that fall within the buffer. The analysis results are displayed both graphically (on the 2D MapControl and 3D Scene Viewer Control) and as a text list (either last name of the property owner, address of the property or the property ID). A specific parcel can be highlighted in the list box. The “Zoom to Selected” button on the Spatial Query form interface zooms both the 2D and 3D viewer to the selected property. The “Zoom to Previous” and “Zoom to Next” buttons zoom to the previous or next record of the highlighted property. In this way, the properties in the selection set can be viewed individually and incrementally.

Economic Feasibility

Dynamic Query:

Find a Parcel greater than acres, ☒ and

located within feet of public water supply, ☐ or ☒ and

located within feet of public sewer system, ☐ or ☒ and

located within feet of public gas line.

☐ 55-153-139 ---- Brighton Township
☐ 55-153-138 ---- Brighton Township
☐ 55-153-143 ---- Brighton Township
☐ 55-153-141 ---- Brighton Township
☐ 55-32-107 ---- Brighton Township
☐ 55-32-418 ---- Brighton Township
☐ 55-153-144 ---- Brighton Township
☐ 55-153-143 ---- Brighton Township
☐ 55-32-708 ---- Brighton Township
☐ 55-32-100.1 ---- Brighton Township

List by Parcel ID Zoom to Previous
List by Last Name Zoom to Selected
List by Address Zoom to Next

RecordCard

Locate Reset Selection Close

Figure 3a. Interface for Spatial Query

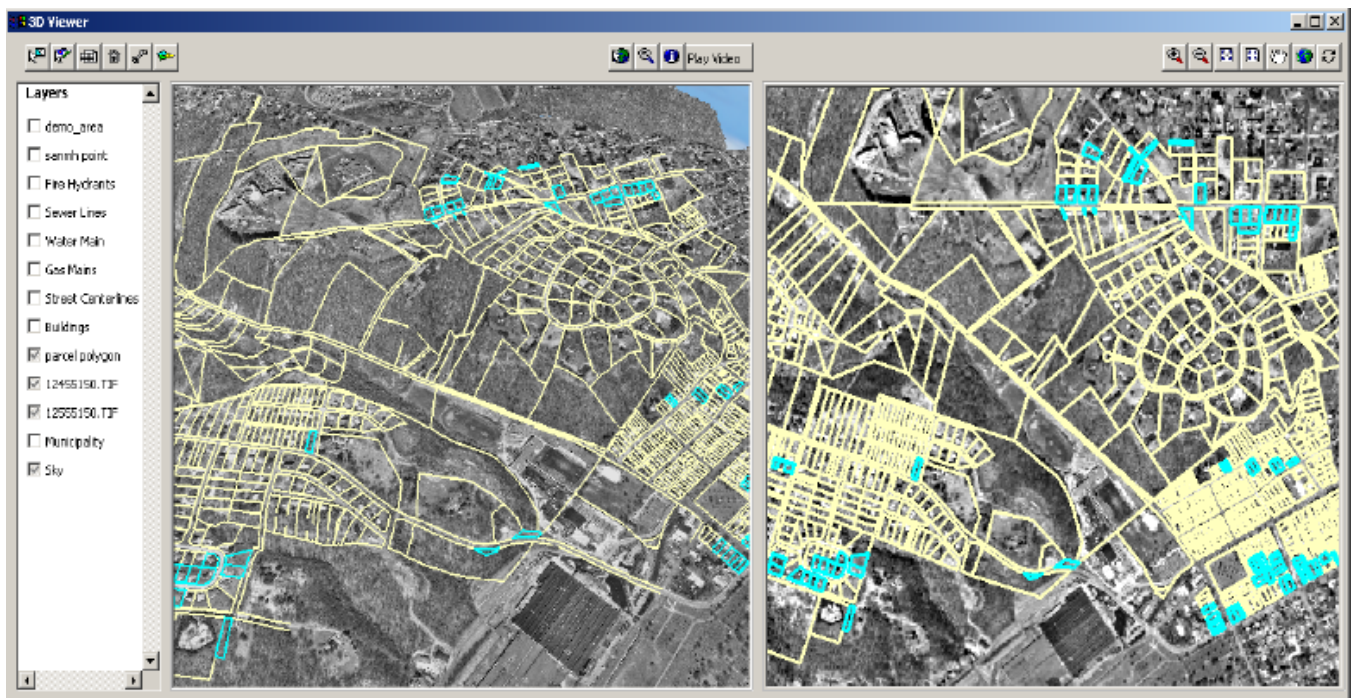


Figure 3b. Outcome of Spatial Query

4. Non-spatial Attribute Query Functions:

The attribute query generally selects records from a database containing information about features in the Geographic Information System. These geographic features or records are generally stored in a table and linked to the map feature by a unique identifier. For this project, complicated attribute queries are performed on the parcel, public utility and street centerline layers. Two templates of queries routinely used in daily planning and development processes are included in this project.

A routine task performed by a planner or developer is modeled by querying the parcel layer based on either a single, or a combination of attributes. For example, the query in Figure 4 is a combination query. The query selects all parcels that have two or three bedrooms, and one and a half bathrooms. The query results are displayed in the 2D parcel feature layer in the MapControl Viewer, the 3D parcel feature layer in the Scene Viewer Control, and in the textbox.

Beaver County GIS

Custom Query

1.) Select a Database Field: Char_Bedroom

2.) Select an Operand:

3.) Select a Database Value: 3

☐ AND ☐ OR

1.) Select a Database Field: Char_Bedroom

2.) Select an Operand:

3.) Select a Database Value: 2

☐ AND ☐ OR

1.) Select a Database Field: Char_Baths

2.) Select an Operand: =

3.) Select a Database Value: 1.5

- ☒ 734 ANDERSON AVENUE ---- Brighton Township
- ☐ 752 ANDERSON AVENUE ---- Brighton Township
- ☐ 776 ANDERSON AVENUE ---- Brighton Township
- ☐ 798 ANDERSON AVENUE ---- Brighton Township
- ☐ 1351 EIGHTH AVENUE ---- Brighton Township
- ☐ 303 DUTCH RIDGE ROAD ---- Brighton Townshi
- ☐ 1349 EIGHTH AVENUE ---- Brighton Township
- ☐ 132 CRANDON CIRCLE ---- Brighton Township
- ☐ 134 CRANDON CIRCLE ---- Brighton Township

Figure 4a. Form Interface for Parcel Attribute Query

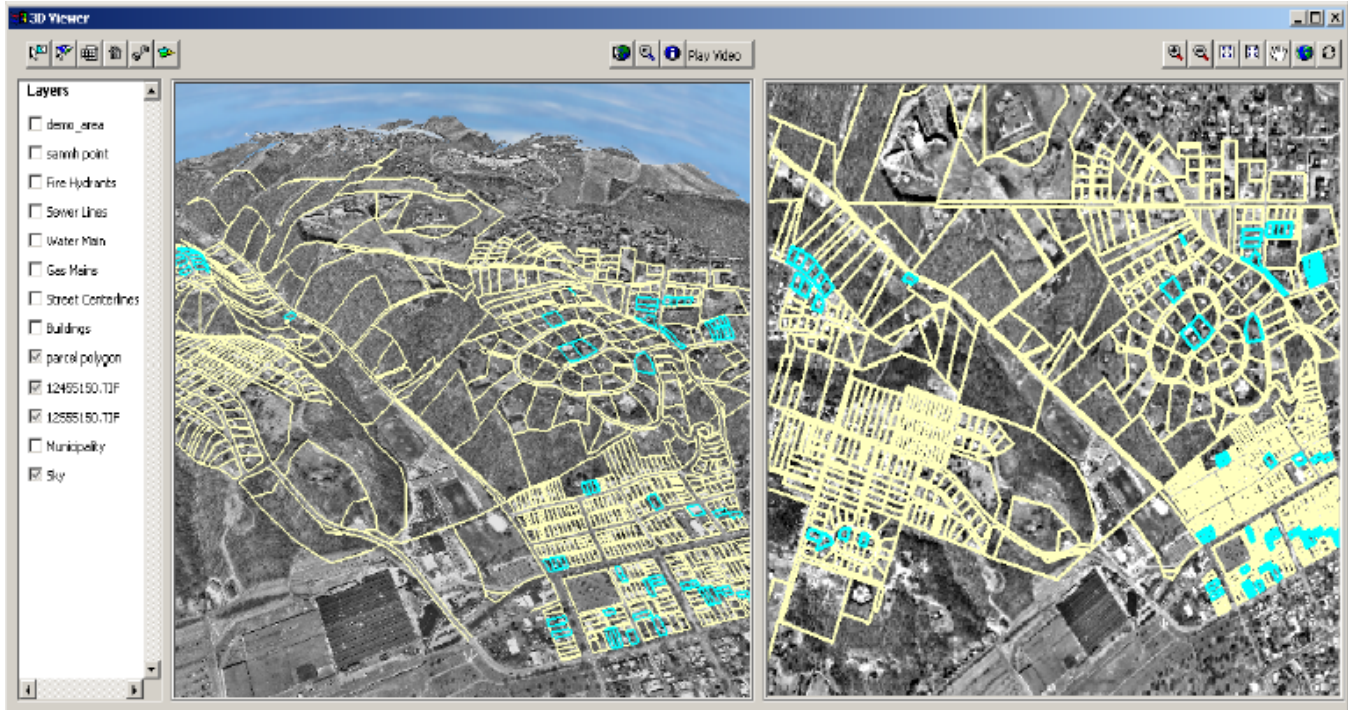


Figure 4b. Outcome of Parcel Attribute Query

Another example is a query on the utility features and street centerlines based on attributes such as material, installation date, etc. This query helps government or utility company employees maintain or upgrade public utilities and provide emergency services. For example, the query in Figure 5 selects all roads that were paved after 1972. The query results are sorted by the township in which the utilities reside and are displayed in both the 2D and 3D Viewers.

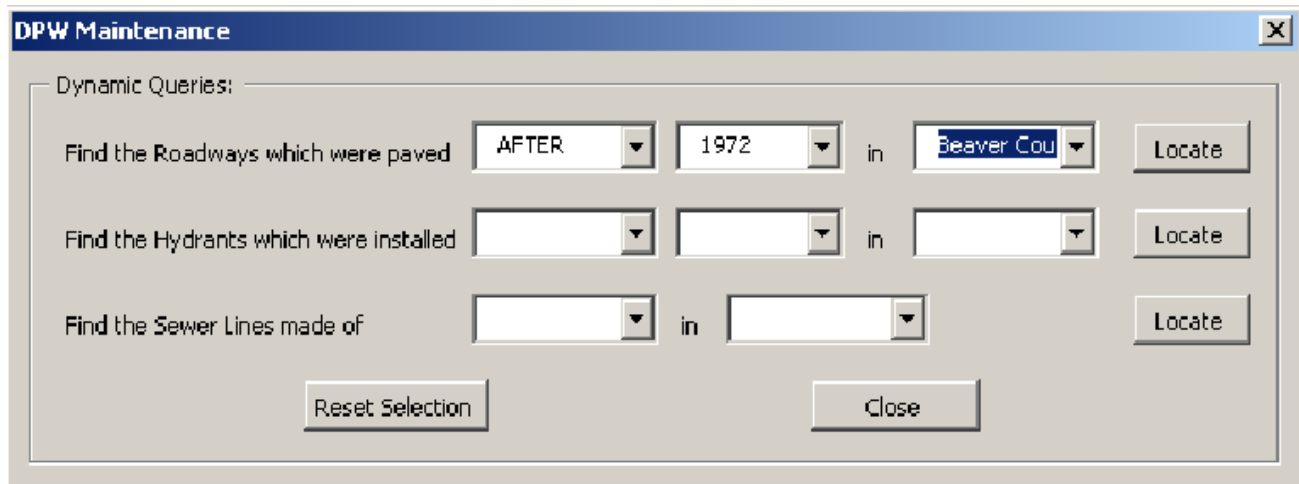


Figure 5a. Interface for Utility and Road Attribute Query



Figure 5b. Outcome of Utility and Road Attribute Query

5. Area Measurement Function:

A specific area of interest can be measured by tracing the area and generating a temporary polygon that is used to perform the Area Measurement Function. The Area Property of the IPolygon object is utilized to perform the measurement. The measurement result is reported in three different units: Square Feet, Acre, and Hectare. This tool is only available in the 2D MapControl viewer. Since the Z value (elevation) information is incorporated in the 3D model, it is pointless to take a measurement for the area of a flat polygon in the 3D Scene Viewer Control.

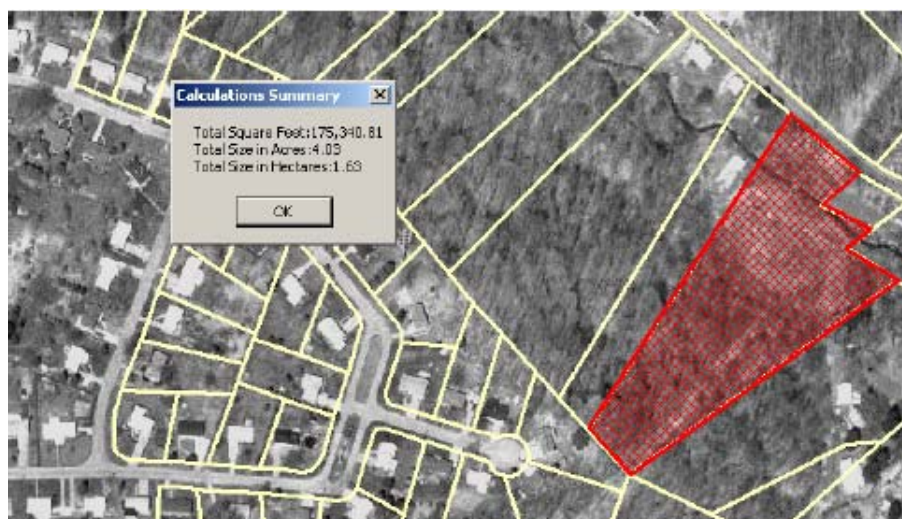


Figure 6. Outcome of Area Measurement

6. Database Management Functions:

When attribute tables contain many fields and records, it can be difficult for users to gain a clear understanding of the non-spatial properties of the geo-feature. The Property Attributes Review and Update function enables the user to select a parcel polygon by clicking on either the 2D or 3D viewer, and then edit or view the attributes for the selected parcel via a user-friendly form. Furthermore, a photograph of the parcel is also provided on the form, giving the user an even more intuitive view of the property without physically visiting the property. The user can perform database management functions via the form interface by reviewing, editing and updating the attributes of the parcel. The result can be posted back to the original database if desired.

Beaver County, PA - Property Record Card

OWNER Last Name: VAN DYKE First Name: WALTER S Address: 107 WINDY GHOU DRIVE City: BEAVER State: PA Zip Code: 15009		PARCEL IDENTIFICATION Parcels: 55-35-202 Map ID: 35 District ID: 55 Parcel ID: 202 Municipality: Brighton Twp House Number: 107 Street Name: WINDY GHOU DRIVE Description: 1.81 AC HS GR Lot ID: 3	
CALCULATED Area: 70937.9457924664 Parameter: 1093.39461564989		CHARACTERISTICS Design: PM Ext Fin: ST FC RMLD: Grade: 150 Int Fin: PN HR PHCO: 75 Occu: Floors: HR GART: ATTACHED RTNH: SUPERIOR Heat/AC: FA GS /Y GARC: 2 CAR YR Built: 1938 Baths: 3.5 Fire Place: 2 Roof: SL Kitchen: G ATTF: 829 FDTN: CN Bedrooms: 6 BAFS: Basemt: FULL Rooms: 12 CDUR:	
ASSESSMENT Year: 1982 Building: 49350 Code: 12 Total: 60850 Land: 11500		MARKET VALUE Land: 23000 Building: 98700 Total: 121700	
PROPERTY Deed Acreage: 0 Survey Acreage: 1.63 Taxes Paid: 2001 Loan Amount: 0		SITE Topo: RL Subb: 0 Street: PV Suba Rate: 23000 Utility: ALL A Act: F Acreage: 1.81 Subb Rate: 0 Frontage: 0 Sber: SQFT: 78844 t Land Value: 23000 Suba: 1.63	

Property Photo:

Buttons: START Editing, QUIT, Print

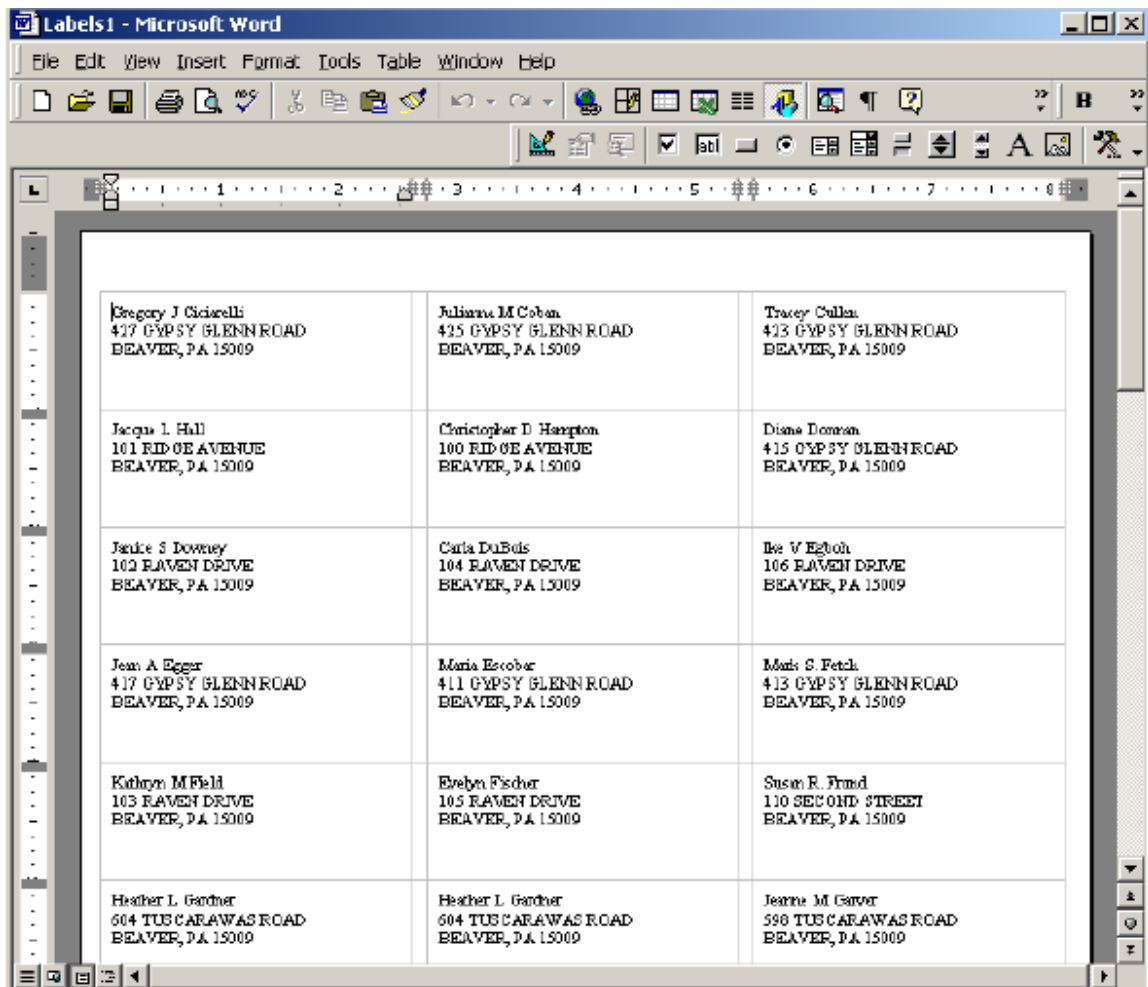
Figure 7. Property Attributes Record Card

7. Print Function

It is often helpful to generate a hard copy of the parcel attributes. The Print button on the Property Record Card form allows the user to print out a paper copy of the attributes for a specific parcel for reference, archive or distribution.

8. MS Word Document Generation

MS Word files are widely used in daily business processes to create official documentation and files. The following function was developed to demonstrate MS Word's document generation integration into GIS applications. In this example, notification letters are generated to inform a certain group of land/parcel owners of a proposed Public Works project. The address label creation tool retrieves the address information of the selected owners into a stand-alone table and merges the table with the MS Word mail label template.



Gregory J. Ciccarelli 427 GYPSY GLENN ROAD BEAVER, PA 15009	Julianne M. Cohen 425 GYPSY GLENN ROAD BEAVER, PA 15009	Tracey Cullen 423 GYPSY GLENN ROAD BEAVER, PA 15009
Jacques L. Hill 101 RIDGE AVENUE BEAVER, PA 15009	Christopher D. Hampton 100 RIDGE AVENUE BEAVER, PA 15009	Diane Dorman 415 GYPSY GLENN ROAD BEAVER, PA 15009
Jenike S. Downey 102 EAVEN DRIVE BEAVER, PA 15009	Carla DuBois 104 EAVEN DRIVE BEAVER, PA 15009	Ike V. Eglon 106 EAVEN DRIVE BEAVER, PA 15009
Jean A. Egger 417 GYPSY GLENN ROAD BEAVER, PA 15009	Maria Escobar 411 GYPSY GLENN ROAD BEAVER, PA 15009	Maria S. Fetch 413 GYPSY GLENN ROAD BEAVER, PA 15009
Kathryn M. Field 103 EAVEN DRIVE BEAVER, PA 15009	Evelyn Fischer 105 EAVEN DRIVE BEAVER, PA 15009	Susan R. Friend 110 SECOND STREET BEAVER, PA 15009
Heather L. Gardner 604 TUSCARAWAS ROAD BEAVER, PA 15009	Heather L. Gardner 604 TUSCARAWAS ROAD BEAVER, PA 15009	Jeanne M. Gerver 598 TUSCARAWAS ROAD BEAVER, PA 15009

Figure 8. Address Label

9. Multimedia Connection

The following fly-through animation file simulates the effect of flying through the featured landscape to help capture and visualize the whole study area. GIS animations can only be created once a 3D model has been developed. Such animation makes participatory presentations with non-GIS users more compelling

and can help visualize spatial data and information in a striking way. For this project, a Video Player button displays a form embedded with a Windows Media Player to play the exported Audio Video Interleave (AVI) file.

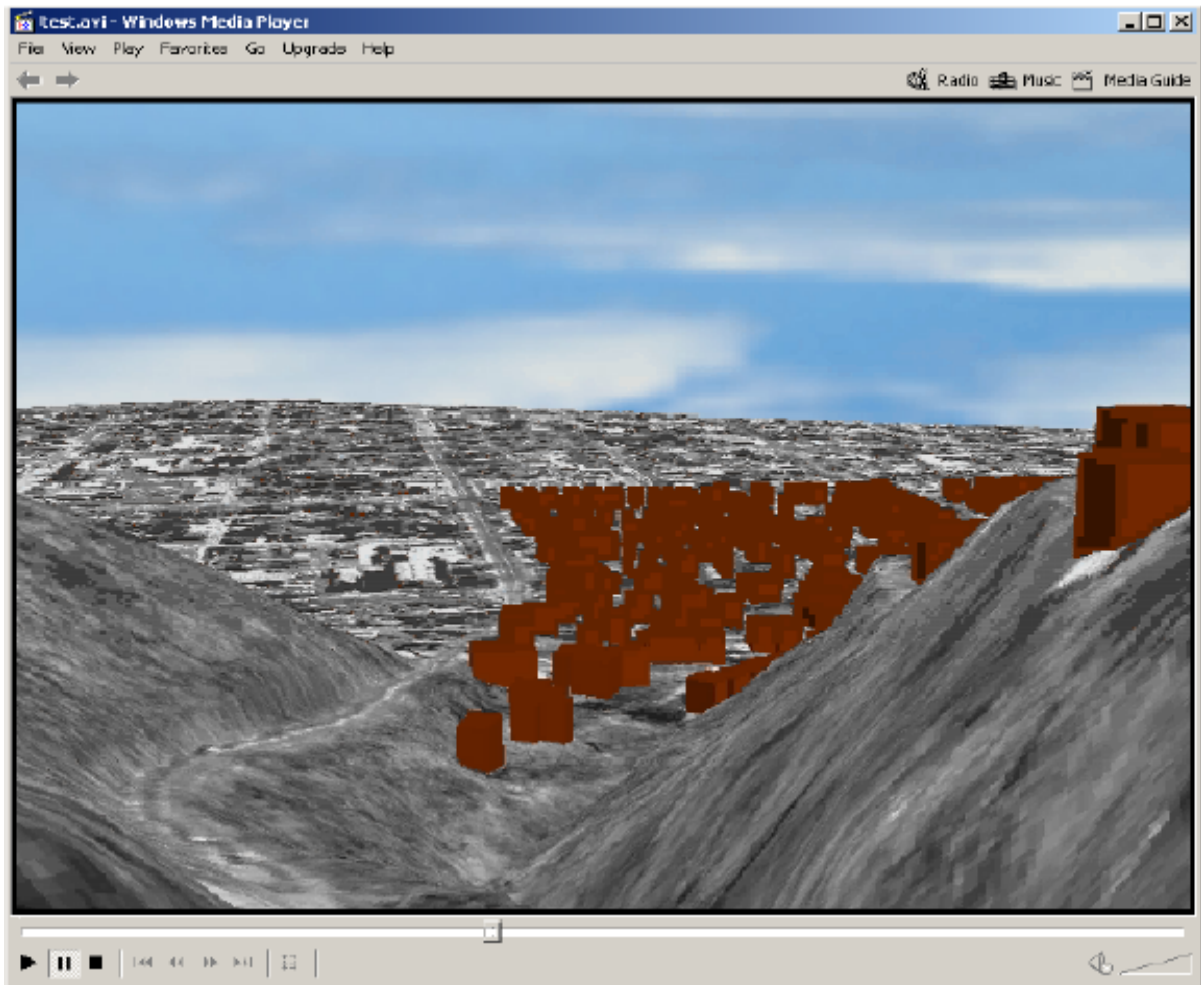


Figure 9. AVI File

Implementation

The project was developed and implemented utilizing the following methodology.

1. Database and Source File Preparation

The data sources for this project are in different formats, such as Microstation design files, and ESRI's shape and coverage files. All of these vector features were integrated into a geodatabase. The data is stored as "NAC_1983_StatePlane_Pennsylvania_South_FIPS_3702_Feet" using "GCS_Norh_American_1983" as the datum.

TINs are usually created from a combination of vector data sources. The point, line and polygon features can be used as input data for a TIN. For this project, the TIN file was created based on a 5-meter contour line shape file with elevation information using the “Create TIN from Features” method in the 3D Analyst function.

TINs and features with 3D geometries (pointZ, polylineZ, polygonZ, and multipatch shapes, for example) are automatically drawn in 3D. Since the vector data available for this project are 2D features, the z-value needed to be defined to create the layers in the 3D virtual reality model. The “Setting a feature layer’s base heights using a surface” method was used to define the z-value for the 2D vector files and the elevation information was derived from the available TIN file. After obtaining the z-value information, each feature layer was saved as a 3D layer file.

2. Form Design and Interface Implementation

The main interface of the project is composed of the Table of Contents View, the 2D MapControl (2D viewer), the 3D Scene Viewer Control (3D viewer) and the functional buttons. All application forms and components were built using VBA in an ArcMap project. The user form interface is used as the main container for all of the viewers, buttons, and checkboxes. ESRI MapControl object was used to create the 2D viewer, and ESRI SceneViewerControl was used to create the 3D viewer.

3. Class Modules and Functional Implementation

ArcObjects are extensively used for this project. The functional implementation was grouped into four major class modules – spatial query, attribute query, attribute update and the generic function module.

ISpatialFilter is the main COM object of the spatial query module. ISpatialFilter filters data based on a spatial relationship. The Geometry, GeometryField and SpatialRel properties are required to establish an ISpatialFilter. The Geometry property is the shape used to overlay with the feature layer to filter the data. Usually the GeometryField should be the “Shape” field. The SpatialRel property defines the spatial relationship such as intersect, contain, are completely within, etc., which determines the way features are selected. The spatial analysis is performed by applying the ISpatialFilter to the feature layer.

IQueryFilter is the main COM object of the attribute query module. Structured Query Language (SQL) is a powerful language used to define one or more criteria that consists of attributes, operators, and calculations. The WhereClause property of the IQueryFilter is an SQL statement that determines which features are to be selected. By defining the WhereClause property of the IQueryFilter object, the

standard to select features is set up. The feature selection can be accomplished by applying the IQueryFilter object to the specific feature layer.

The parcel attributes can be reviewed and updated in this application. When the updating request is processed, IFeature object is utilized to perform such functions.

Functions that are repeatedly used in the project, such as Clear Selection, Zoom to Selected Features, Refresh, Error Handle, etc., are grouped in the Generic Function Module.

The advantages for grouping code into class modules include:

- New functions can be added into the project without affecting existing functions. The application development is easy to expand.
- Developed functions can be re-used in other applications.
- Functions can be easily tracked and updated.
- Coding errors can be easily found and fixed.
- Conversion to the stand-alone applications can be well prototyped.

4. System Integration

Modulized functions can be easily integrated into the whole system. Initially, the map control functions were developed once both 2D and 3D viewers were created and added into the main interface. Other functional and class modules, such as layer control, spatial and non-spatial analysis, etc. and user forms, are then added-in seamlessly.

5. The Summary of the Keys

Spatial and Non-spatial Analysis: since the same layer files are used in both 2D and the 3D viewers, the same query function can process the request and present the outcome in the two viewers simultaneously based on the same spatial and non-spatial feature identifier.

Viewer Control: since the geographic boundary is the same in both 2D and 3D viewers, the spatial extent of two viewers can be controlled simultaneously and consistently when functions like Zoom In, Zoom Out or Zoom to selected are initiated. The z-value is important to ensure performing correct control functions in the 3D viewer.

Mouse Action on the Viewer: The (x, y) coordinates of the click point are the key to connect the 2D MapControl with the 3D Scene Viewer. When clicking in one viewer, the (x, y) value of the click point is retrieved and then used to perform the selection in the other viewer.

The code below shows how one click in the Scene Viewer Control results in the same selection results in both 2D and 3D viewers.

```
Set pScene = frm3Dview.SceneViewerCtrl1.SceneGraph.Scene
Set pViewer = frm3Dview.SceneViewerCtrl1.SceneGraph.ActiveViewer

frm3Dview.SceneViewerCtrl1.SceneGraph.LocateMultiple pViewer, xPos, _
yPos, esriScenePickGeography, False, pHit3dSet
Set pArray = pHit3dSet.Hits
Set pHit3D = pArray.Element(0)
Set pPoint = pHit3D.Point
Set pGeom = pPoint

Set pSelectionEnv = New SelectionEnvironment
pSelectionEnv.PointSelectionMethod = esriSpatialRelIntersects
pScene.SelectByShape pGeom, pSelectionEnv, True

pMap.SelectByShape pGeom, pSelectionEnv, True
pMxDoc.ActiveView.Refresh
```

Future Expansion and Potential Application

Developed with the modularized system architecture, this application can be easily expanded according other user's needs. This prototype built in the VBA development environment can also be upgraded and converted into stand-alone applications developed in VB 6.0 or VB.NET environment, which will enable the user to access and control the application more flexibly and naturally. With the release of ArcGIS 9.0, the new 3D symbol library will be incorporated into the 3D model to enhance the effect of the virtual reality presented in the project such as the simple building block. The realistic 3D building symbol and more symbols will be added to the model (such as traffic lights, trees, cars etc.), which will make the 3D display even more practical. The functionalities of the tool can be expanded according to the user's requirement. For example, new layer control functions like uploading and removing layers can be added to the interface and a different interface can be created for different feature layers. This will enable attribute review and updates for all kinds of features specified by the user.

Acknowledgement

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