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Expert Systems with Applications 31 (2006) 94–100

Expert Systems with Applications

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A COM-based expert system for selecting the suitable map projection in ArcGIS

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Abstract

A map projection is a systematic rendering of locations from the curved earth surface onto a flat map surface. It is impossible to make spherical maps into perfectly flat papers without some distortion. There are many projections, each with its own advantages and disadvantages. No single projection can maintain all of the important spatial variables such as shape, area, direction, and distance. A successful Geographic Information System (GIS) depends in large part on using map projections correctly, and a person's skills in managing and converting projections can dictate the value of a database. GIS software packages such as ArcGIS provides GIS analyst with many projections from which the analyst must choose the one suitable for his project. Map projection selection is a complex process involving an evaluation of map projection alternatives based on a set of characteristics that describe these projections and the types of analysis to be performed. This paper presents a prototype expert system for selecting the suitable map projection. The component object model (COM) technology is used in designing and integrating the prototype expert system with ArcGIS to achieve software interoperability.

Keywords: Map projection; Expert systems (ES); COM; GIS

1. Introduction

Geographic Information Systems (GISs) are different from other information systems because they contain spatial data. These spatial data include the coordinates defining the location, shape, and extent of geographic objects (Bolstad, 2002). In order to locate the positions of objects on the earth's spherical surface, three-dimensional coordinate reference system has to be developed that takes into account its shape. The Spherical Coordinate System in use for over 2000 years is known as the Geographic Coordinate System, which makes use of a network of latitude and longitude (known as graticule) to fix the positions of points on the earth (Lo and Young, 2002). While latitude and longitude can locate exact positions on the surface of the earth, they are not uniform units of measure; only along the equator does the distance represented by one degree of longitude approximate the distance represented by one degree of latitude. To overcome measurement difficulties, data is often transformed from three-dimensional geographic coordinates to two-dimensional projected coordinates. Because the earth is round and maps are flat, getting information from a curved surface to a flat one involves a mathematical formula called a map projection, or simply a projection.

Map projections are a systematic rendering of points from the curved Earth surface onto a flat map surface. While there are many purely mathematical or purely empirical map projections, the most common map projections used in GIS are based on developable surfaces onto which the network of latitudes and longitudes is projected (Bolstad, 2002). A developable surface is a surface that can be laid out flat without distortion. Cones, Cylinders, and Planes are the most common developable surfaces (Lo and Young, 2002). A map projection is constructed by passing rays from a projection center through both the Earth surface and the developable surface. Points on the earth are projected along the rays and onto the developable surface. This surface is then mathematically unrolled to form a flat map (Bolstad, 2002). This process of flattening the earth will cause distortions in one or more of the following spatial properties: Distance, Area, Shape, and Direction. No projection can preserve all these properties; as a result, all flat maps are distorted to some degree. Fortunately, we can choose from many different map projections. Each is distinguished by its suitability for representing a particular portion and amount of the earth's surface and by its ability to preserve distance, area, shape, or direction. Some map projections minimize distortion in one property at the expense of another, while others strive to balance the overall distortion.

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doi:10.1016/j.eswa.2005.09.008

As a GIS analyst, you have to decide which properties are most important and choose a projection that suits your needs.

Map projections can be generally classified according to what spatial attribute they preserve as follows (Kennedy and Kopp, 2000):

- ☐ Equal area projections preserve area. Many thematic maps use an equal area projection. Maps of the United States commonly use the Albers Equal Area Conic projection.
- ☐ Conformal projections preserve shape and are useful for navigational charts and weather maps. Shape is preserved for small areas, but the shape of a large area such as a continent will be significantly distorted. The Lambert Conformal Conic and Mercator projections are common conformal projections.
- ☐ Equidistant projections preserve distances, but no projection can preserve distances from all points to all other points. Instead, distance can be held true from one point (or a few points) to all other points or along all meridians or parallels. If you will be using your map to find features that are within a certain distance of other features, you should use an equidistant map projection.
- ☐ Azimuthal projections preserve direction from one point to all other points. This quality can be combined with equal area, conformal, and equidistant projections, as in the Lambert Equal Area Azimuthal and the Azimuthal Equidistant projections.
- ☐ Other projections minimize overall distortion but do not preserve any of the four spatial properties of area, shape, distance, and direction. The Robinson projection, for example, is neither equal area nor conformal but is aesthetically pleasing and useful for general mapping.

A successful Geographic Information System (GIS) depends in large part on using map projections correctly, and a person's skills in managing and converting projections can dictate the value of a database. GIS software packages provide GIS analyst with many projections from which the analyst must choose the one suitable for his project. For example, ArcGIS contains more than 60 map projections. Map projection selection is a complex process involving an evaluation of map projection alternatives based on a set of characteristics that describe these projections and the types of analysis to be performed. Knowledge about map projection selection has been discussed extensively by many authors (Nyerges and Jankowski, 1989). This paper presents a prototype expert system for selecting the suitable map projection from the many ones available in ArcGIS. The component object model (COM) technology is used in designing and integrating the prototype expert system with ArcGIS to achieve software interoperability.

2. Software interoperability and COM technology

Interoperability is the ability of two or more software components to directly cooperate/communicate despite of their differences in programming language, interface, and execution platform (Finkelstein, 1998). Interoperable systems, therefore, are systems composed of autonomous, locally managed, heterogeneous components that cooperate to provide complex services.

The development and deployment of successful interoperability strategies require standardization that provides the communication channels and format needed for direct exchange and integration of information (Vckovski, 1998). The GIS community has recently embraced well-known standards to develop specifications for GIS' data and functionality exchanges. Examples of these standards include Microsoft-COM® and Object Management Group-CORBA® (Common Object Request Broker Architecture) (Bian, 2000). COM is a standard that enhances software interoperability by allowing different software components, possibly written in different programming languages, to communicate directly (Microsoft, 2000). COM specifies an object model and programming requirements that enable COM objects to interact with other COM objects. These objects can coexist in a single procedure/process, in independent procedures/processes, or even on remote machines. COM allows these objects to be reused at a binary level and thus third-party developers do not require access to source code, header files, or object libraries in order to extend the system (Zeiler, 2001).

3. The proposed expert system

A prototype expert system was developed to assist the GIS analysts in selecting suitable map projection for their application. The output of the proposed system is a set of recommended map projections that are suitable for the GIS application under consideration.

Visual Rule Studio® (an object-oriented COM-compliant expert system development environment for windows) was used to develop the prototype expert system. Visual Rule Studio solves the problem of software interoperability by allowing the developers to package rules into component reusable objects called RuleSets. By fully utilizing OLE and COM technologies, RuleSets act as COM Automation Servers, exposing RuleSet objects in a natural COM fashion to any COM compatible client (RuleMachines, 2002).

The Visual Rule Studio's object-oriented rules technology is a new adaptation of rule-based expert system technology. It is based on the Production Rule Language (PRL) and Inference Engines of LEVEL5 Object®. Rules in a production system consist of a collection of If Condition–Then Action statements. Each rule has a left-hand-side, or IF part, and a right-hand side, or THEN part. The IF part of a rule comprises the conditions or antecedents of the rule. The THEN part is the action part of a rule and is often called the rule's consequent or conclusion. The rule language of Visual Rule Studio is a high-level grammar for business problem representation and abstraction designed specifically for the specification and processing of business rules. A RuleSet may contain class declarations and methods, forward-chaining rules, backward-chaining demons, and an agenda. The grammar of the PRL uses an object-referencing notation that is the same as that of all popular language environments, such as, C++, Java, and Visual Basic. Visual Rule Studio objects are used to encapsulate knowledge structure, procedures, and values. An object's structure is defined by its class and attributes declarations within a RuleSet. Object behavior is tightly bound to attributes in the form of facets, methods, rules, and demons (RuleMachines, 2002). Fig. 1 shows the breakdown of a Visual Rule Studio object's structure.

The RuleSet of the proposed expert system was developed using Visual Rule Studio RuleSet (PRL) Editor. RuleSets developed with PRL Editor can be used directly by web applications or client applications developed in any COM-compliant development environment such as Visual Basic. The PRL Editor allows you to update the RuleSets used by applications without having to modify the client application. The RuleSet of the proposed system consists of two Classes and 64 Rules; the following gives a typical example of the classes and rules used in the map projection RuleSet:

- CLASS Projection
- WITH Projection_Name MULTICOMPOUND
- WITH Projection_Type MULTICOMPOUND
- CLASS Map
- WITH General_Purpose COMPOUND
- Topological, Geologic, Thematic, Presentation, Navigation, USGS
- WITH Location_or_Shape COMPOUND North, South, East, West, Oblique, Equatorial, Midlatitude, Polar, Circular
- WITH Suitable_Extent COMPOUND World, Hemisphere, Continent, Ocean, Region, Sea, Medium Scale, Large Scale
- RULE 1 for Aitoff Projection
- IF Map.General_Purpose Is Presentation AND Map.Suitable_Extent Is World
- THEN Projection.projection_name Is Aitoff
- AND Projection.projection_type Is Modified
- Azimuthal

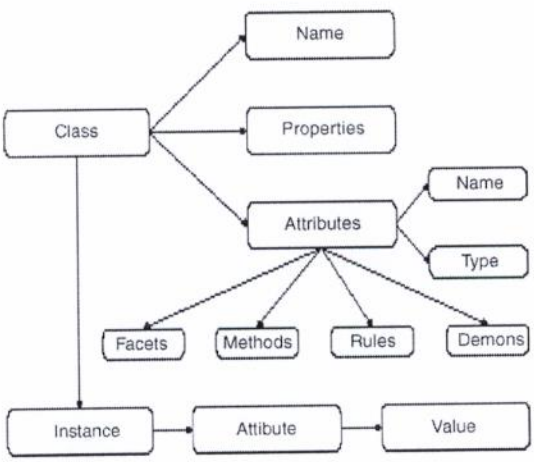

Fig. 1. Structure of a Visual Rule Studio Object (adapted from RuleMachines, 2002).

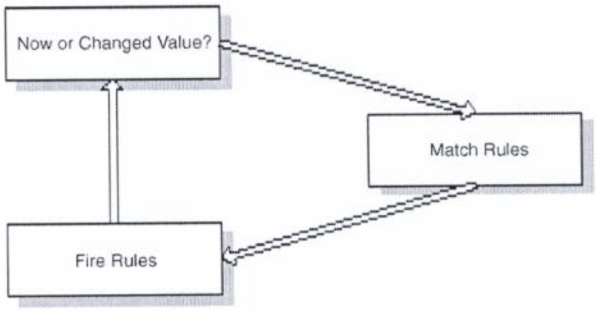

Fig. 2. Forward-chaining inference processing (adapted from RuleMachines, 2002).

The inference engine of Visual Rule Studio's production system acts as the 'unseen hand' or executor which causes processing to take place. Processing here is defined as the combining of supplied data with rules to create inferred data. It is the inferred data that is the desired end result of the production system processing. The Visual Rule Studio inference engine provides two primary problem-solving engines relevant to production systems: the forward-chaining engine and the backward-chaining engine. In the proposed expert system forward-chaining engine is used. Starting from an initial or current set of data, the forward-chaining inference engine makes a chain of inferences until a goal is reached. In forward-chaining the data values of the context are matched against the IF parts, or left-hand-sides, of rules. If a rule's IF side matches the context, then the inference engine executes the Then part, or right-hand-side of the rule. If the execution of the Then part of a rule changes the data values of the context, then the inference engine repeats the entire match-execute cycle again using the new state of the context data values as a new initial set of data (Fig. 2).

4. Integrating the proposed expert system with ArcGIS

The coupling strategy presented here is based on employing the COM technology for integrating the proposed expert system with ArcGIS. ESRI-ArcGIS® 9.0 is a COM-complaint GIS software package. Its built in macro language, Visual Basic for Application (VBA), was used to develop the Map Projection application that implements the proposed expert system using Automation Technology.

Microsoft-Automation is a COM-based technology that allows an application to programmatically manipulate another through a set of well-defined interfaces. A COM component that makes Automation objects available to other applications is known as an Automation server. An Automation object is just an application's object that is exposed for access by other applications. The application or programming tool (such as Visual Basic) that accesses the Automation objects provided by the Automation server is known as the Automation controller (Lewis, 1999). To call the proposed expert system Automation server, the first thing that should be done is to set a reference to the VRMS RuleMachines Type Library (Type libraries are files that describe an object in a standardized format so that COM

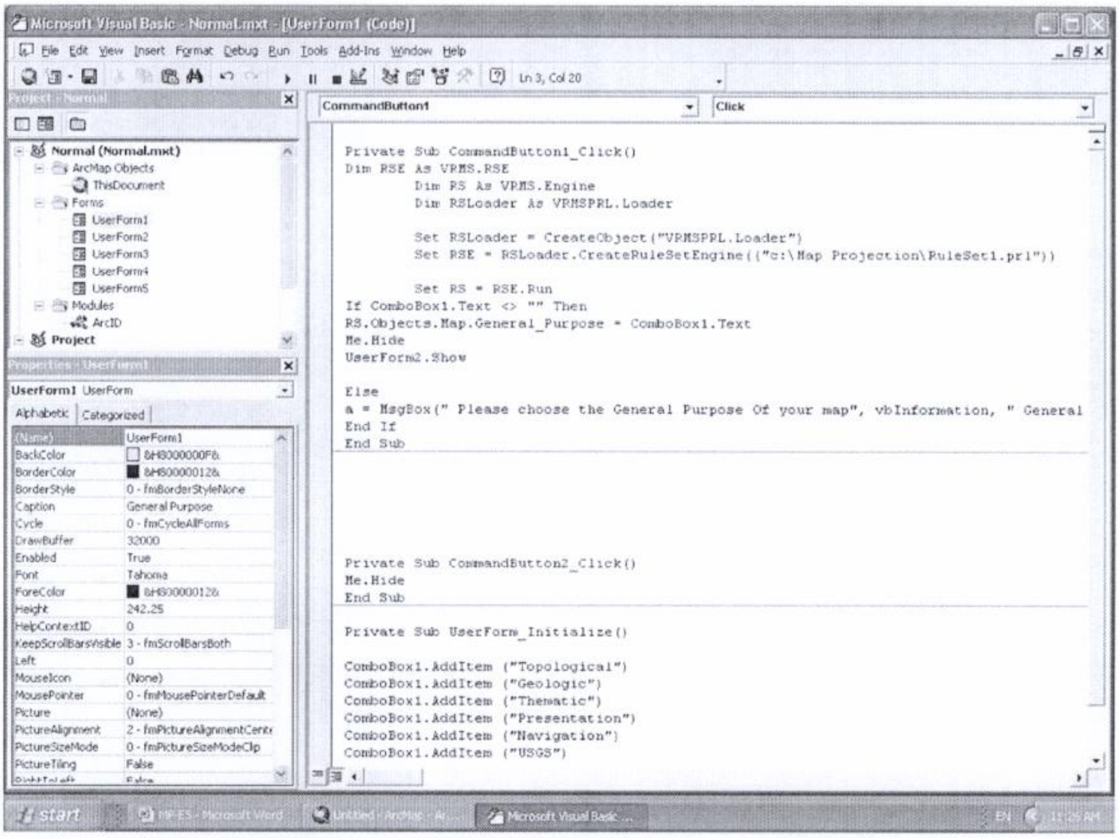

Fig. 3. Sample of the used VB code.

clients can find which properties and methods of an object are supported). Then the VRMSPRL Loader, an ActiveX DLL, and the CreateObject function are used to read the RuleSet source file (RuleSet1.PRL) and create an instance of the RuleSet Engine server. As the entire object variables were declared as variables of a specific class, then the object references are early bound. Early binding dramatically reduces the time required to set or retrieve a property value, because

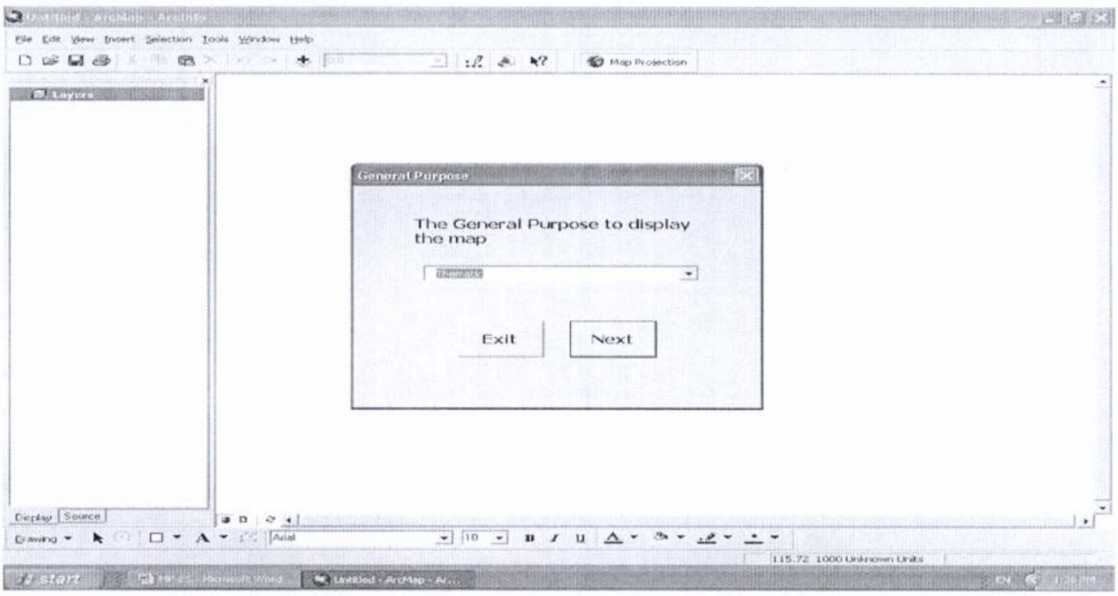

Fig. 4. Defining the general purpose of the map.

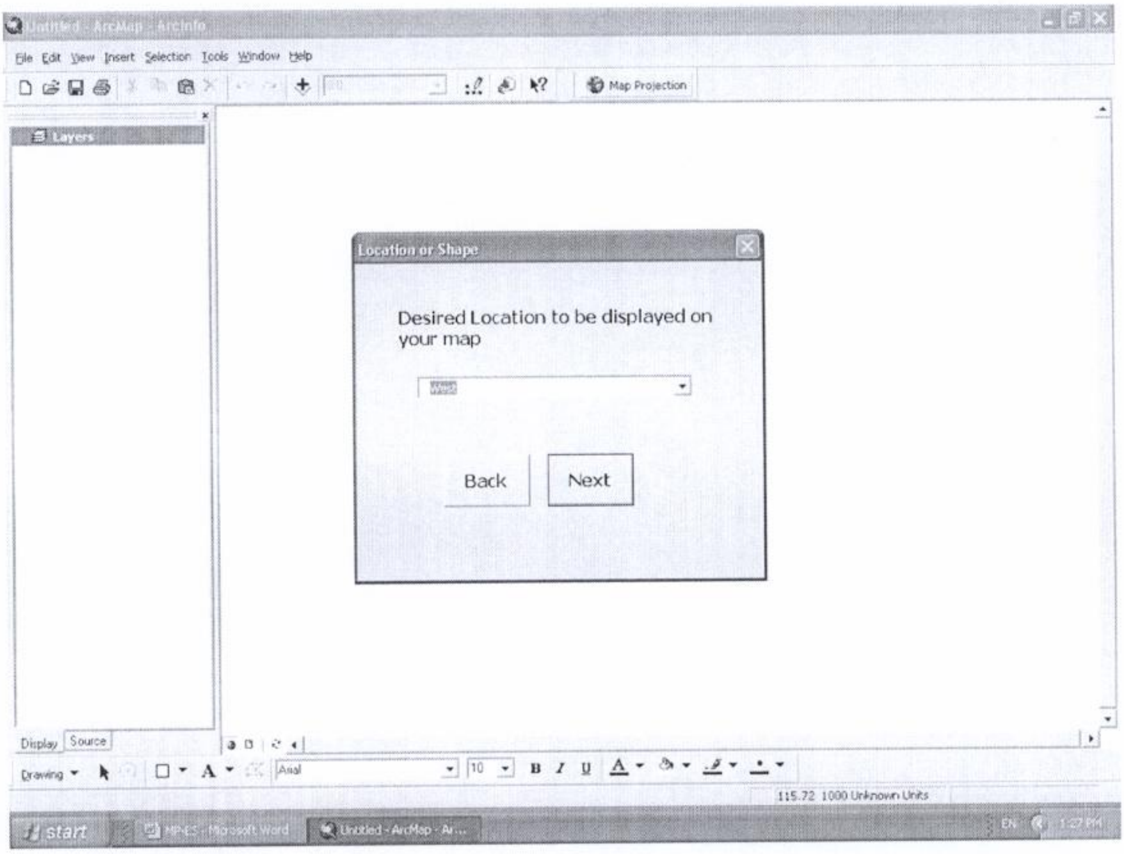

Fig. 5. Defining the desired location to be displayed.

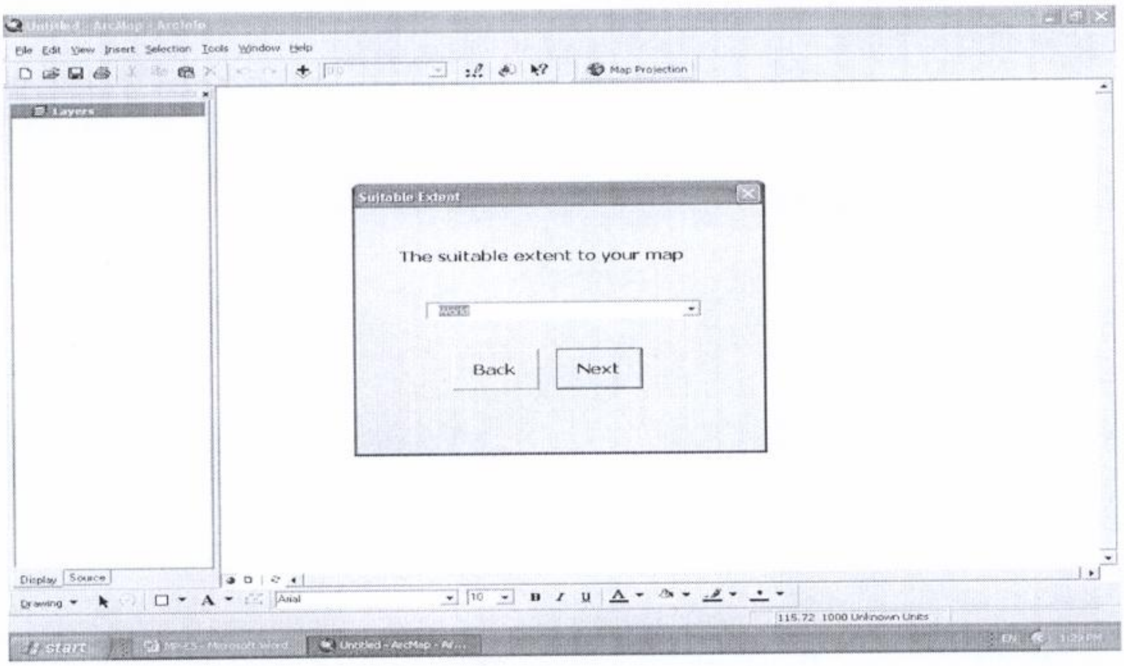

Fig. 6. Defining the suitable extent of the map.

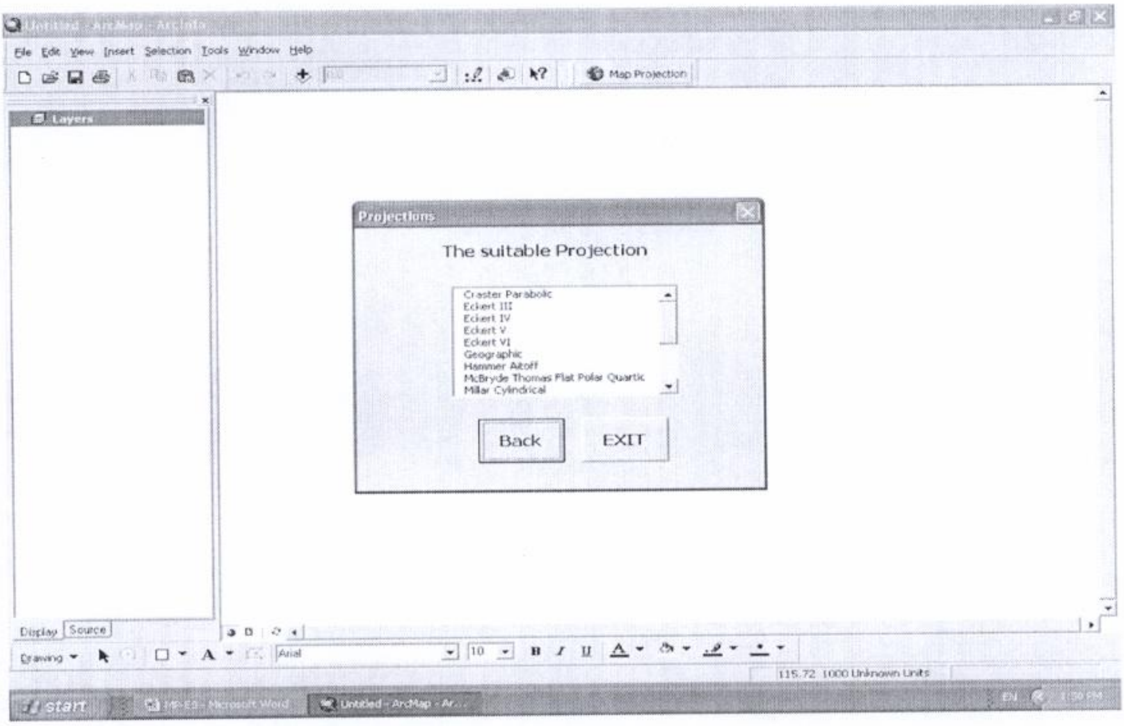

Fig. 7. Recommended projections.

the call overhead can be a significant part of the total time (Microsoft Visual Basic 6.0 Programmer's Guide 1998).

Fig. 3 shows a sample of the used visual basic code.

5. Example of consultation session

In order to demonstrate how the proposed system assists GIS analyst in selecting the suitable map projection for his GIS application, a sample run is demonstrated in this section. Upon execution of Map Projection Expert System by clicking on the Map Projection button on ArcMap, the expert systems begin asking the GIS analyst some questions related to his application. After answering the entire questions, the system presents the recommended map projections for the application under considerations. The user can get more information about any of the recommended map projection by double clicking on

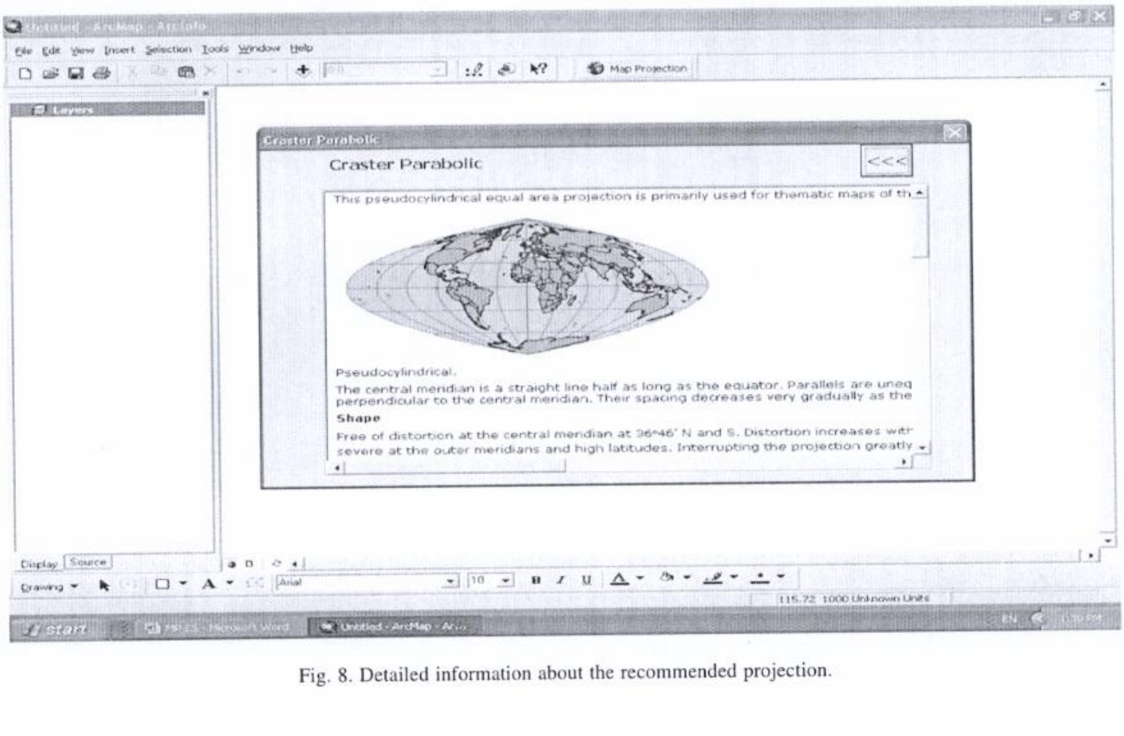

Fig. 8. Detailed information about the recommended projection.

it. Figs. 4–8 give a typical example of a complete consultation session.

6. Conclusions

A successful Geographic Information System (GIS) depends in large part on using map projections correctly. ArcGIS software package provides GIS analyst with many projections from which the analyst must choose the one suitable for his project. Map projection selection is a complex process involves an evaluation of map projection alternatives based on a set of characteristics that describe these projections and the types of analysis to be performed. A prototype expert system was developed to assist the GIS analysts in selecting suitable map projection for their application. The output of the proposed system is a set of recommended map projections that are suitable for the GIS application under consideration. The component object model (COM) technology is used in designing and integrating the prototype expert system with ArcGIS to achieve software interoperability.

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