A Knowledge-Based System for GIS Software Selection

Khalid Eldrandaly and Soad Naguib
College of Computers and Informatics, Zagazig University, Egypt

Abstract: *Building a new GIS project is a major investment. Choosing the right GIS software package is critical to the success and failure of such investment. Because of the complexity of the problem a number of decision making tools must be deployed to arrive at the proper solution. In this study a new decision making approach for solving GIS software selection problem was proposed by integrating expert systems and multi-criteria decision making techniques. To implement the proposed decision-making approach, a prototype knowledge-based system was developed in which expert systems and Analytic Hierarchy Process (AHP) are successfully integrated using the Component Object Model (COM) technology. A typical case study is also presented to demonstrate the application of the prototype system.*

Keywords: *GIS software selection, expert systems, AHP, knowledge-based systems, multicriteria decision making.*

Received September 26, 2010; accepted March 1, 2011

1. Introduction

Geographic Information Systems (GIS), a promising branch of Information Systems (IS), have achieved considerable success in recent years. This area of IS has concentrated on the construction of computer based information systems that enable capture, modeling, storage, retrieval, sharing, manipulation, analysis, and presentation of geographically referenced data [49]. GIS software packages provide a unified approach to working with geographic information. In the last few years, the GIS software market has undergone a remarkable change. The number of GIS software packages has increased significantly and prices have declined dramatically. Many of these packages were developed to fit different user needs and were designed to execute on a variety of hardware platforms [27].

Building a new GIS project is a major investment. Choosing the right GIS software package is critical to the success and failure of such investment, i.e., the impact of bad decision can be high not only in monetary terms but in terms of its impact on management attitude. The problem of selecting the most appropriate GIS software package for a particular GIS project is not a well-defined or structured decision problem. The presence of multiple criteria (both managerial and technical) and the involvement of multiple decision-makers will expand decisions from one to several dimensions, thus, increasing the complexity of the solution process [23]. However, a literature search did not find any thorough discussion of GIS software selection or comparison of selection methodologies except Eldrandaly [10] who developed an AHP decision model and applied it to a hypothetical case study to examine its flexibility in solving GIS software selection problem.

Reviewing IS literature indicated that ranking and scoring methods, goal programming, expert systems, fuzzy logic, and Analytic Hierarchy Process (AHP) are the most common used approaches for software selection. Detailed descriptions of these methods are reported elsewhere [2, 6, 10, 11, 13, 17, 21, 23, 33, 41]. However, existing methodologies for software selection fail to address all aspects of the problem and there is no framework currently exists to aid in the selection of GIS software packages [2, 10, 11, 17]. Thus, there is a need for developing a systematic GIS software selection process of identifying and prioritizing relevant criteria and evaluating the trade-offs between technical, economic and performance criteria. The approach should also reduce time and develop consensus decision making. This paper is primarily concerned with providing such a framework. In this paper a new decision making approach is presented in which expert systems, and Multi-criteria decision making techniques are integrated systematically in solving the GIS software selection problem. To implement the proposed decision-making approach, a prototype system was developed in which ES and a Multicriteria Decision Making (MCDM) method AHP were successfully integrated by using the Component Object Model (COM) technology to achieve software interoperability among the systems components. A case study is also presented to demonstrate the application of the prototype system.

2. GIS Software

GIS software packages provide a unified approach to working with geographic information. GIS software vendors-the companies that design, develop, and sell GIS software-build on the top of basic computer operating capabilities such as security, file management, peripheral drivers, printing, and display management. GIS software is constructed on these foundations to provide a controlled environment for geographic information collection, management, analysis, and interpretation. GIS software is a fundamental and critical part of any operational GIS.

The GIS employed in a GIS project has a controlling impact on the type of studies that can be undertaken and the results that can be obtained. There are also far reaching implications for user productivity and project costs. Today, there are many types of GIS software product to choose from and a number of ways to configure implementations. The main categories of generic software that dominate today are desktop, web mapping, server, virtual globe, developer, and hand-held [27]. One of the exciting and at times unnerving characteristics of GIS software is its very rapid rate of development. The GIS marketplace has four key vendors that deliver “generic” platforms: ESRI, Intergraph, Autodesk, and GE Energy. According to daratech annual analysis of GIS industry, the top three vendors for 2009 were ESRI with 30%, Intergraph with 16%, and GE energy (smallworld) with somewhere around 8% [9]. Other software leaders include IBM, Leica Geosystems, and mapinfo [3, 4, 5, 9, 14, 26, 27].

3. GIS Software Selection Criteria

After discussions with many GIS consultants, and operations manager, reviewing the literature for software evaluation and selection and studying the international standard ISO/IEC 9126 [16] which provides a framework for the evaluation of software quality, we identified five essential evaluation criteria to use in selecting the best GIS software: cost, functionality, usability, reliability, and vendor [3, 5, 6, 10, 11, 16, 17, 18, 23, 27, 34, 36].

3.1. Cost

Cost is an important factor in selecting software packages [18]. It is simply the expenditure associated with GIS software and includes product, license, training, maintenance, software subscription and support services costs [34, 43].

3.2. Functionality

Functionality refers to extent to which the software package contains all the features and functions specified in your Request for Proposal (RFP) which is generated based on the organization needs assessment [18]. A GIS is often defined not for what it is but for what it can do. A thorough examination of GIS capabilities is the critical step in how to pick GIS software, because if the GIS software does not match the requirements for a problem, no GIS solution will be forthcoming. On the other hand, if the GIS software has a large number of functions, the system may be too sophisticated or elaborated for the problem at hand [5]. Thus, functionality is usually considered when selecting software. Based on a review of the literature and on consultations with GIS experts, we identified eleven key functional elements of a GIS tool: operating system/network support, geographic data management, tabular attribute data management, GIS data import/ export utilities, GIS data entry and editing, map design and composition, basic geographic query and analysis functions, network analysis, terrain and 3-d data processing and analysis, raster image processing capabilities, and application development languages. detailed descriptions of these functions can be found elsewhere [5, 27, 38, 47].

3.3. Reliability

Software reliability is an important attribute of software quality. It is necessary that the reliability of software should be measured and evaluated, as it is in hardware. IEEE 610.12-1990 defines reliability as “The ability of a system or component to perform its required functions under stated conditions for a specified period of time” [18, 39]. ISO/IEC 9126-1991 defines three subcriteria of reliability: maturity, fault tolerance, and recoverability. Detailed descriptions of these subcriteria can be found elsewhere [16].

3.4. Usability

Usability is the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in particular environments [45]. ISO/IEC 9126-1991 defines three subcriteria of usability: understandability, learnability, and operability. Detailed descriptions of these subcriteria can be found elsewhere [16]. The process of assuring usability of a product is called usability engineering. From the web-pages of major GIS software companies there is hardly anything said about usability. Only on ESRI’s web-page it is clearly stated that the company practices usability engineering to ensure the productivity and satisfaction of the customers [45].

3.5. Vendor

The quality of vendor support and its characteristics are of major importance in the selection of software. Technically, vendor specific criteria include quality of support services, costs of support services, delivery lead time, vendor’s experience in related products;

vendor's experience in the application area, vendor's training capabilities, problem solving capabilities, and vendor's reputation [18, 34, 43].

4. New Decision Making Approach

A new decision making approach for GIS software selection is presented. The proposed approach integrates the capabilities of ES, and MCDM and provides an advisory system to assist the user during the tool selection procedure. Recommendations submitted by others, such as [9, 10, 11, 14, 17] regarding software selection considerations were observed in the design of the proposed approach Figure 1 depicts the three phases of the proposed approach (i.e., justification, screening and evaluation phases) and their procedural steps.

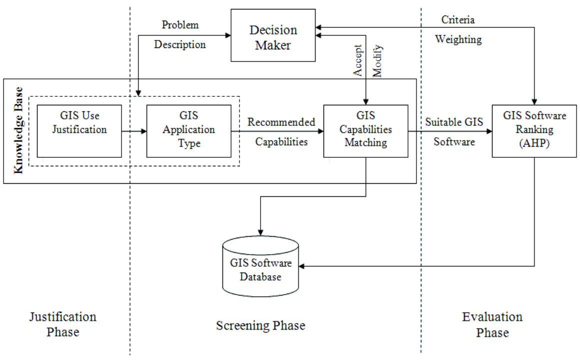

Figure 1. Framework of the proposed approach.

1. *Justification Phase:* In this phase an expert system is used to justify the use of GIS software for the application under consideration. That is, this phase will answer the question "Will GIS work for the considered problem?"
2. *Screening Phase:* In this phase an expert system is used to recommend the suitable GIS software packages/tools for a specific project. This phase consists of the following two steps:
   a. *Identifying the Application Type:* The expert system is used to assist the decision maker in defining the application type and to provide the recommended GIS software capabilities required for building the proposed application. The output of this step is a set of recommended GIS capabilities. The decision maker has the option of accepting or modifying these recommended capabilities.
   b. *Software Screening:* The expert system is used to identify candidate GIS software packages that meet the recommended capabilities. The output of this step is a list of candidate software for further assessment
3. *Evaluation Phase:* After identifying the GIS software packages that are suited for the considered application in the screening phase, selection of the most appropriate software package can be made. Comparing alternative software packages involves consideration of multiple criteria that have not been considered in the screening phase and may have conflicting characteristics. AHP, a MCDM technique, is used to address this multicriteria problem. The output of this phase would be a list of GIS software packages ordered by their level of suitability.

5. The Proposed Knowledge-Based System

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. The COM technology is a standard that enhances software interoperability by allowing different software components, possibly written in different programming languages, to communicate directly [11]. To implement the presented decision making approach, a prototype advisory system was developed using three COM-compliant commercially available software packages: Microsoft® Visual Basic 6.0, Visual Rule Studio®, and Microsoft® Access 2003. Microsoft® Visual Basic 6.0 was used to develop the MCDM (AHP) module, to provide the shell for the COM integration, and to develop the system's user interface. Visual Rule Studio® was used to develop the expert system module. Microsoft® Access 2003 was used to develop the database module.

The proposed system was developed as a three-tire architecture as shown in Figure 2.

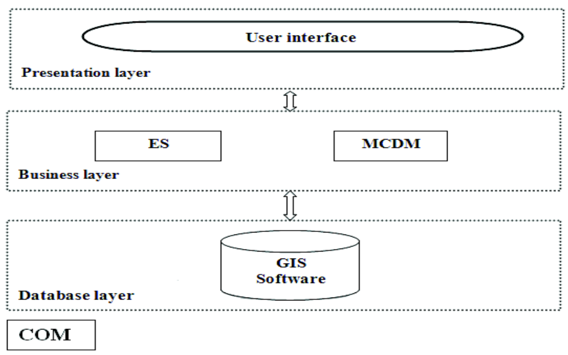

Figure 2. Three-tier architecture of the proposed system.

6. Development of the Prototype Expert System

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. Visual Rule Studio installs as an integral part of MS Visual Basic 6.0, professional or enterprise editions, and appears within the Visual Basic as an ActiveX Designer. This allows the developers to add rule objects to their existing or new Visual Basic application in much the same manner they would extend their application with a new form or ActiveX control. RuleSets can be complied within Visual Basic. EXE, .OCX, or .DLL executables and used in any of the ways the developers normally use such executables [40].

The knowledge base of the proposed expert system consists of three different RuleSets. Each one of them represents a separate Knowledge Source (KS). These KSs are independent chunks of knowledge and do not directly communicate with each other. Instead, they participate in the problem solving process by writing messages on a global database called blackboard and reading messages from other knowledge sources. This type of architecture is called blackboard architecture and is shown in Figure 3. The blackboard architecture is intended to support development of systems in domains characterized by interaction between diverse sources of knowledge and hence provides a framework for integrating knowledge from several sources. The blackboard serves as a global data structure, which facilitates this interaction. Usually, in typical blackboard architecture, the inference mechanism consists of the agenda and the monitor. The agenda keeps track of all events in the blackboard and calculates the priority of execution for KSs that were generated as a result of the activation of other KSs. The monitor takes the element with the highest priority and executes it. However, there is no fixed agenda and monitor in the current blackboard architecture. Since different solution steps of this system are explicitly seen on the main screen display, the sequences of the different processes are primarily selected by the user. Without fixed agenda, the user is free to change input data and check intermediate results given by the system during the consultation session. Detailed description of blackboard architecture is reported elsewhere [15, 35].

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 RuleStudio inference engine provides two primary problem-solving engines relevant to production systems: the forward chaining engine and the backward chaining engine [40]. 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.

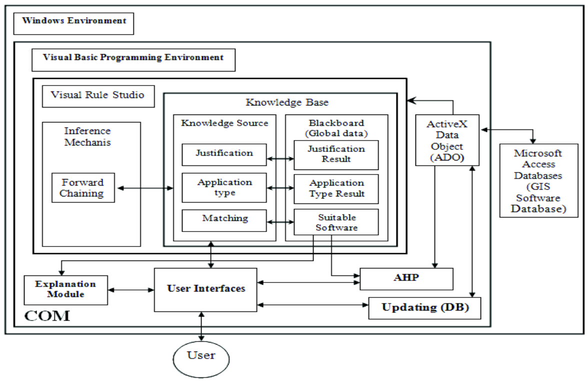

Figure 3. Blackboard architecture of the proposed ES.

7. MCDM (AHP) Module

A multicriteria decision problem generally involves choosing one of several alternatives based on how well those alternatives rate against a chosen set of structured and weighted criteria (the decision model). The criteria themselves are weighted in terms of importance to the decision maker(s), and the overall score of an alternative is the weighted sum of its rating against each criterion. The ordering of the alternatives by their decision scores is a prioritized ranking of those alternatives by preference. Over the last three decades, a number of MCDM have been developed. Among them, the AHP is perhaps the most prominent and successful method. AHP is a method that allows the consideration of both objective and subjective factors in ranking alternatives. Since its introduction in the mid 1970s by Dr. Thomas L. Saaty, AHP has been applied in a wide variety of practical applications in various fields including economics, planning, energy policy, health, conflict resolution, site selection, project selection, and budget allocation. It assists the decision making process by allowing decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model.

The AHP decision hierarchy involves a number of steps: Identification of the goal (e.g., to select the most suitable GIS software), use of a set of decision factors/variables/criteria (e.g., vendor support, cost, and easy of use), and determination of a set of alternatives/choices (e.g., software 1, software 2 and software 3). The levels of the hierarchy may be expanded as needed (e.g., cost could be considered in terms of initial, and maintenance). At the lowest level on the hierarchy we find the alternative solutions. Comparisons of the available choices/ alternatives are made on a pair-wise basis. For example in considering initial costs, AHP would determine whether software 1 is "better" (that is., has lower initial cost) than software 2 and if so, by how much? Similar comparisons are performed at each level on the hierarchy. This measure of importance/weight is done using a nine-point scale, which is widely utilized in the AHP technique. The AHP process synthesizes the alternatives' priorities into overall set of values that indicate the relative importance of each factor at the lowest level of the hierarchy. The AHP procedures are applicable to individual and group decision settings. Detailed description of MCDM and AHP is reported elsewhere [12, 31]. The application of AHP to the evaluation of software package has been successfully applied in many research studies [7, 8, 10, 11, 19, 20, 21, 22, 23, 30, 34, 36, 37, 41, 42, 44, 46, 48, 50, 51].

8. Database Module

Microsoft® Access 2003 was used to develop the GIS Software database module. The system gives the user the opportunity to update the database either by adding new packages or editing the current packages as shown in Figure 4.

Microsoft® ActiveX® Data Object (ADO) was used to read required information from the database. ADO provides consistent, high-performance access to data and supports a variety of development needs, including the creation of front-end database clients and middle-tier business objects, using applications, tools, languages or Internet browsers. ADO is designed to be the one data interface needed for one-to-multitier client/server and web-based data-driven solution development. ADO was implemented using a set of COM-based interfaces that provide applications with uniform access to data stored in diverse information sources [29].

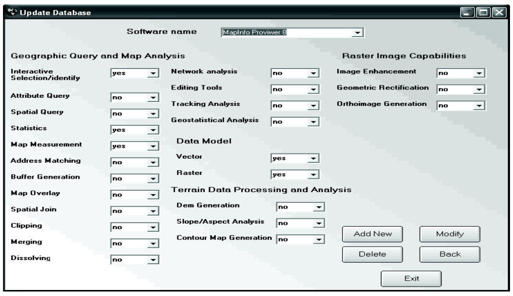

Figure 4. Updating GIS software database screen.

9. Verification and Validation

Verification determines correctness of the system, i.e., whether the product satisfies the specification standards set at the beginning of the project. In the expert system's context, verification ensures that the compile time and runtime errors are eliminated. The debugging utilities of the Visual Basic 6.0 and Visual Rule Studio were utilized throughout the development cycle to ensure error-free execution of the system. Different modules were evaluated individually by executing a series of predetermined test cases [24]. The complete system was then verified to ensure that the integrated modules behaved as expected. Verification aspects common to knowledge-based processing, as noted by Medsker and Liebowitz [28], were also applied.

Validation is the process of determining that the system completely and accurately represents the problem domain, and that it achieves acceptable performance levels [25]. Based upon their research methods approach, Ayel and Laurent [1] as well as Libetore and Stylianou [25] present a common procedure for establishing content validity. These guidelines were utilized throughout the development of the expert system. According to Medsker and Leibowitz [28], validation using independent experts reduces potential bias in the results, and lends credibility to the validation process. Content validity was established through face validation by several external experts. These experts were selected for their in-depth knowledge and experience in the field of GIS. All of the domain experts considered the system to be satisfactory, and that only some minor modifications were required. Any disparities between the evaluators' opinions were resolved, and their suggestions for modification were incorporated into the final version.

10. Example of Consultations Session

In order to demonstrate how the proposed system can assist the decision maker in selecting the suitable GIS software package for his/her application, a real test problem is demonstrated in this section.

The test problem utilized a real regional project (Integrated Coastal Zone Management (ICZM) in the area of Port Said-directed by the center of GIS Studies and Services, Zagazig University, Egypt). The goal of the test problem was to justify using GIS software in this project and to identify the most suitable GIS software packages to be used.

Upon execution of the system, it gives the user the option of either starting the program or updating the GIS software database as shown in Figure 5. Upon choosing to start the program, the system gives the user the opportunity to execute any phase of the three solution phases as shown in Figure 6 because the system is designed in modular form. If the user chooses to execute the first phase (justification phase), the system will help the user in answering the following question "Will GIS software work for my problem?" Figure 7 is a sample of screenshots during the justification phase.

Figure 5. Main screen.

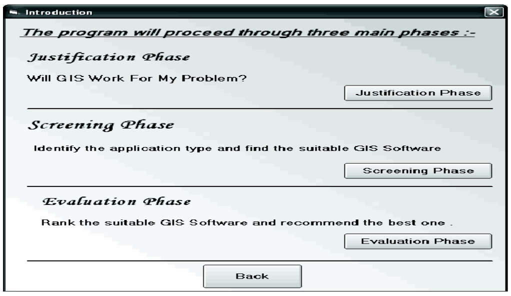

Figure 6. Different phase of the program.

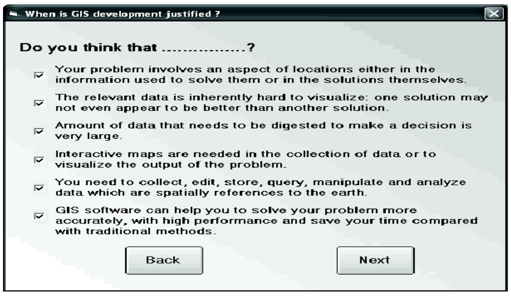

Figure 7. A sample of screenshots during justification phase.

After finishing the justification phase or if the user chooses directly the screening phase, during this phase the system will help the user identifying the proposed application type, and the required GIS software capabilities. The output of this phase is a list of candidate GIS software for further assessment. Figures 8 and 9 are samples of the screenshots during this phase.

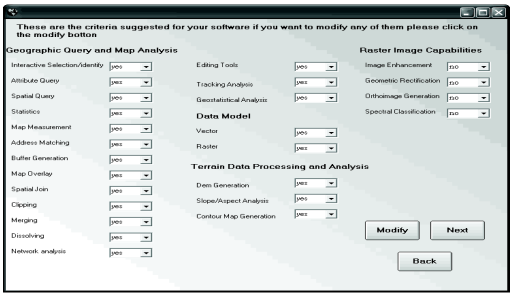

Figure 8. A sample of screenshots during screening phase.

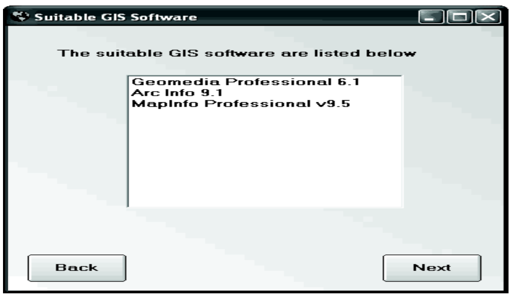

Figure 9. Results of the screening phase.

The final phase is the evaluation phase, in which the system will help the user in evaluating the suitable GIS software identified from the screening phase based on the AHP technique. Figures 10 and 11 are sample of the screenshots during this phase.

As shown in Figure 11, the system recommends ArcInfo 9.1 as the most suitable GIS software needed by the ICZM project; this result matches exactly the actual used GIS package and hence verified the validity of the proposed system.

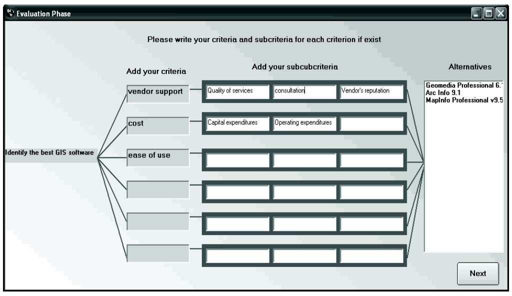

Figure 10. Identifying the evaluation criteria

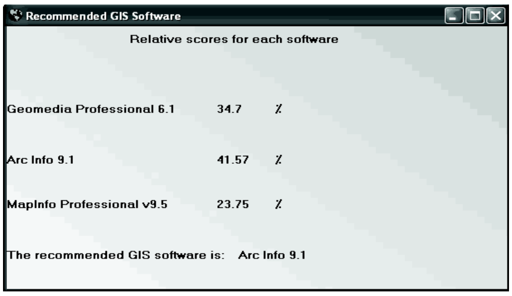

Figure 11. Output of the evaluation phase.

11. Conclusions

In this paper, a new decision making approach for GIS software selection is presented. This approach integrates the capabilities of ES, and AHP and provides an advisory system to assist the decision maker in selecting the most suitable GIS software for a particular GIS problem. The architecture, the development, and the implementation of the prototype advisory system are discussed in details. The use of Visual Rule Studio® (an object-oriented COM-compliant expert system development environment for windows) which runs together with Microsoft Visual Basic 6.0 is found to be very effective in producing the system under Windows environment. Also, software interoperability between the different components of the system is achieved by adopting the COM technology in designing the system. The GIS software package database could be updated easily to match the dynamic nature of the software market.

References

[1] Ayel M. and Laurent J., *Validation, Verification and Test of Knowledge-Based Systems*, John Wiley & Sons, Chichester, England, 1991.
[2] Bandor M., "Quantitative Methods for Software Selection and Evaluation," *Technical Report*, Carnegie Mellon University, 2006.
[3] Bernhardsen T., *Geographic Information Systems: An Introduction*, John Wiley & Sons, New York, 2002.
[4] Bolstad P., *GIS Fundamentals*, Eider Press, 2005.

[5] Clarke K., *Getting Started With Geographic Information Systems*, Prentice-Hall, 2003.

[6] Collier K., Carey B., Sautter D., and Marjaniemi C., "A Methodology for Evaluating and Selecting Data Mining Software," *in Proceedings of the 32nd Hawaii International Conference on System Science*, USA, pp. 1-11, 1999.

[7] Colombo E. and Francalanci C., "Selecting CRM Packages Based on Architectural, Functional, and Cost Requirements: Empirical Validation of a Hierarchical Ranking Model," *Requirements Engineering*, vol. 9, no. 3, pp. 186-203, 2004.

[8] Davis L. and Williams G., "Evaluation and Selecting Simulation Software using the Analytic Hierarchy Process," *Journal of Manufacturing Technology Management*, vol. 5, no. 1, pp. 23-32, 1994.

[9] Daratech Inc., "GIS/Geospatial Industry Worldwide Growth Slows to 1% in 2009," available at: http://www.daratech.com/press/releases/2009/091908.html, last visited 2009.

[10] Eldrandaly K., "GIS Software Selection: A Multicriteria Decision Making Approach," *Applied GIS*, vol. 3, no. 5, pp. 1-19, 2007.

[11] Eldrandaly K., "An Intelligent MCDM Approach for Selecting the Suitable Expert System Building Tool," *The International Arab Journal of Information Technology*, vol. 4, no. 4, pp. 365-371, 2007.

[12] Forman E. and Selly M., *Decision by Objectives: How to Convince Others That You Are Right*, World Scientific Publishing Company, 2001.

[13] George J., Batra D., Valacich J., and Hoffer J., *Object-Oriented Systems Analysis and Design*, Prentice-Hall, 2004.

[14] Heywood I., Cornelius S., and Carver S., *An Introduction to Geographical Information Systems*, Prentice-Hall, 2002.

[15] Hunt J., "Blackboard Architectures," available at: http://www.jadeetechnology.co.uk., last visited 2002.

[16] ISO/IEC 9126 "Information Technology-Software Product Evaluation-Quality Characteristics and Guidelines for Their Use," available at: http://www.techstreet.com/standards/iso_iec/9126_1991?product_id=863150, last visited 1991.

[17] Jadhav S. and Sonar R., "Evaluating and Selecting Software Packages: A Review," *Information and Software Technology*, vol. 51, no. 3, pp. 555-563, 2009.

[18] Keil M. and Tiwana A., "Relative Importance of Evaluation Criteria for Enterprise Systems: A Cojoint Study," *Information Systems Journal*, vol. 16, no. 3, pp. 237-262, 2006.

[19] Kim J. and Moon J., "An AHP and Survey for Selecting Workflow Management Systems," *International Journal of Intelligent Systems in Accounting, Finance, and Management*, vol. 6, no. 2, pp. 141-161, 1997.

[20] Kim C. and Yoon Y., "Selection of Good Expert System Shell for Instructional Purposes in Business," *Information and Management*, vol. 23, no. 5, pp. 249-262, 1992.

[21] Kontio J., Caldiera G., and Basili V., "Defining Factors, Goals and Criteria for Reusable Component Evaluation," *Conference of the Centre for Advanced Studies on Collaborative Research*, Canada, pp. 21, 1996.

[22] Kontio J., "A Case Study in Applying Systematic Method for COTS Selection," *in Proceedings of the 18th International Conference on Software Engineering*, USA, pp. 201-209, 1996.

[23] Lai V., Trueblood R., and Wong B., "Software Selection: A Case Study of the Application of the Analytical Hierarchical Process to the Selection of a Multimedia Authoring System," *Information and Management*, vol. 36, pp. 221-232, 1999.

[24] Laudon K. and Laudon J., *Management Information Systems: New Approaches to Organization and Technology*, Upper Saddle River, NJ, Prentice Hall, 2001.

[25] Libertore M. and Stylianou A., "The Development Manager's Advisory System: A Knowledge Based DSS Tool for Project Assessment," *Decision Sciences*, vol. 24, no. 5, pp. 953-976, 1993.

[26] Lo P. and Young K., *Concepts and Techniques of Geographic Information Systems*, Prentice-Hall, 2002.

[27] Longley P., Goodchild M., Marguire D., and Rhind D., *Geographic Information Systems and Science*, Wiley, 2010.

[28] Medsker L. and Liebowitz J., *Design and Development of Expert Systems and Neural Networks*, New York, Macmillan, 1994.

[29] Microsoft, "Microsoft Developer Network Online Documentation," available at: http://msdn.microsoft.com/en-us/, last visited 2003.

[30] Mohanty P. and Venkataraman S., "Use of Analytic Hierarchy Process for Selecting Automated Manufacturing Systems," *International Journal of Operations and Production Management*, vol. 13, no. 3, pp. 45-57, 1993.

[31] Mollaghasemi M. and Pet-Edwards J., *Making Multiple-Objective Decisions*, USA, IEEE Computer Society Press, 1997.

[32] Morera D., "COTS Evaluation Using Desmet Methodology and Analytic Hierarchy Process (AHP)," *in Proceedings of the 4th International Conference on Product Focused Software Process Improvement*, UK, pp. 485-493, 2002.

[33] Muralidar K., Santhanam R., and Wilson R., "Using the Analytic Hierarchy Process for

Information System Project Selection," *Information and Management*, vol. 18, no. 2, pp. 87-95, 1990.
[34] Ngai T. and Chan C., "Evaluation of Knowledge Management Tools Using AHP," *Expert System with Applications*, vol. 29, no. 4, pp. 889-899, 2005.
[35] Nii P., "Blackboard Systems at Architecture Level," *Expert Systems with Applications*, vol. 7, no. 1, pp. 43-54, 1994.
[36] Ossadnik W. and Lange O., "AHP-Based Evaluation of AHP-Software," *European Journal of Operational Research*, vol. 118, no. 3, pp. 578-588, 1999.
[37] Phillips-Wren G., Hahn E., and Forgionne G., "A Multiple Criteria Framework for Evaluation of Decision Support Systems," *Omega*, vol. 32, no. 4, pp. 323-332, 2004.
[38] Point of Beginning "2005 GIS Software Survey," available at: http://www.pobonline.com., last visited 2005.
[39] Rosenberg L., Hammer T., and Shaw J., "Software Metrics and Reliability," *in Proceedings of the 9th International Symposium,* Germany, pp. 1-8, 1998.
[40] RuleMachines, *Visual Rule Studio Developer's Guide*, Rule Machines Corporation, Canada, 2002.
[41] Sarkis J. and Talluri S., "Evaluating and Selecting E-Commerce Software and Communication Systems for Supply Chain," *European Journal of Operational Research*, vol. 159, no. 2, pp. 318-329, 2004.
[42] Shtub A., Spiegler I., and Kapaliuk A., "Using DSS Methods in Selecting Operations Management Software," *Computer-Integrated Manufacturing Systems*, vol. 1, no. 4, pp. 211-220, 1988.
[43] Tam M. and Tummala V., "An Application of the AHP in Vendor Selection of a Telecommunications System," *Omega*, vol. 29, no. 2, pp. 171-182, 2001.
[44] Teltumbde A., "A Framework for Evaluating ERP Projects," *International Journal of Production Research*, vol. 38, no. 17, pp. 4507-4520, 2000.
[45] Tiits K., "Usability of Geographic Information Systems in Internet," *MSc Thesis*, Tartu University, 2003.
[46] Toshtzar M., "Multi-Criteria Decision Making Approach to Computer Software Evaluation: Application of the Analytical Hierarchical Process," *Mathematics and Computer Modeling*, vol. 11, pp. 276-281, 1988.
[47] Tomlinson R., *Thinking About GIS*, ESRI Press, 2003.
[48] Wei C., Chien C., and Wang J., "An AHP Based Approach to ERP System Selection," *International Journal of Production Economics*, vol. 96, no. 1, pp. 47-62, 2005.
[49] Worboys M. and Duckham M., *GIS: A Computing Perspective*, CRC Press, 2004.
[50] Zahedi F., "Database Management System Evaluation and Selection Decisions," *Decision Sciences*, vol. 16, no. 1, pp. 91-116, 1998.
[51] Zahedi F., "A Method for Quantitative Evaluation of Expert Systems," *European Journal of Operational Research*, vol. 48, no. 1, pp. 136-147, 1990.

Khalid Eldrandaly is an associate professor of Information Systems, Faculty of Computers and Informatics, Zagazig University, Egypt. He is a certified GIS professional (GISP). He received his MSc degree in systems engineering AI and expert systems, and his PhD degree in systems engineering (GIS). He was a visiting scholar at Texas A&M University, USA, for two years. His research interests include GIS, expert systems, SDSS, MCDM, and intelligent techniques in decision making. He is a member of the Egyptian Engineers Syndicate, World Academy of Young Scientists, Arab Union of Scientists and Researchers, Texas A&M International Faculty Network, Egyptian Software Engineers Association and Association of Computing Machinery. He also currently serves as a member in the review committee of the International Arab Journal of Information Technology, Applied Soft Computing, Journal of Environmental Informatics, and The International Journal of Open Problems in Computer Science and Mathematics.

Soad Naguib is a lecturer of Information Systems, Faculty of Computers and Informatics, Zagazig University, Egypt. She received her MSc degree in Information systems and technology from Zagazig University in 2009.