Development of a Web-based Land Evaluation System and its Application to Population Carrying Capacity Assessment Using .NET Technology

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Abstract

The multi-disciplinary approach used in this study combines the state-of-the-art IT technology with an elaborated land evaluation methodology and results in a Web-based land evaluation system (WLES). The WLES is designed in such a way that the system operates both as a Web Application and as a Web Service. Implemented on top of the .NET platform, the WLES has a loosely coupled multi-layer structure which seamlessly integrates the domain knowledge of land evaluation and the soil database. The Web Service feature makes the WLES suitable to act as a building block of a larger system such as that of the population carrying capacity (PCC) assessment. As a reference application, a framework is made to assess the PCC on the basis of the production potential calculations which are available through the WLES Web Service interface.

Keywords: Land evaluation, Web-based computer model, Population carrying capacity, .NET technology, Multi-layer system design

Introduction

Environment and development issues and the quest for sustainability are at the center of the international attention today. The world is experiencing an unprecedented growth of human population, associated with rapid economic growth, industrialization, and urbanization (Uitto and Ono, 1996). The adoption and standardization of land evaluation methodologies are among the efforts of the international community to ease the population pressure and to achieve sustainable development. Since the *Framework for Land Evaluation* (FAO, 1976) established the conceptual approach and methodological orientation to the assessment of land suitability, successive guidelines explaining how the *Framework* can be applied to rainfed and irrigated agriculture, forestry and extensive grazing have been produced (FAO, 1983; 1984; 1985; 1991). They as a whole form the basis of the *knowledge domain* of land evaluation.

Land evaluation is the assessment of land performance when used for specific purposes (Sys *et al.*, 1991). There is today a high and worldwide demand for information in the suitability and productivity of land for a wide range of land uses. Connections have been made between land evaluation and sustainability, ecological, and environmental issues (FAO, 1993a,b; 1996) and human development (Uitto and Ono, 1996). The Web-based land evaluation system (WLES) presented in this study bridges the complexity of the domain knowledge of land evaluation and its proper use in above mentioned areas of interests in a user-friendly fashion.

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System Design

A *model* is a simplified representation of reality with which we can compute outcomes without having to perform actual experiments. Land evaluation models are computer programs that predict the performance of a land use on a given land area, with information on that area's land characteristics as inputs. Standalone land evaluation models are self-contained computer programs which apply the domain knowledge of land evaluation to local land-use conditions and produce qualitative or quantitative results. The term "*self-contained*" means the model is implemented with proprietary technologies, and the land evaluation subsystem itself is tightly coupled with a proprietary data engine. Standalone models have maintainability, availability, reusability and modularity disadvantages.

Layered System Structure

Standardized means of inter-subsystem communications are introduced to overcome the disadvantages of a standalone model. In other words, the land evaluation subsystem is *decoupled* with the data management and the user interface subsystems, and thus the resulting system has a 3-layer structure. Providing core functionalities of the system, the knowledge engine of land evaluation acts as the middle layer, with the browser-based graphical user interface (GUI) as the front-end, which presents the whole system to the client, and DBMS as the back-end, which keeps all data and results collected or produced by the middle layer (Figure 1).

Significant differences are observed between standalone models and multi-layer models. Firstly, the presentation logic and the data management functionalities are both achieved using standardized technologies. The front-end GUI is guaranteed to be compatible with all browsers, while the back-end can be any data engine with built-in SQL capabilities. Almost all commercial DBMS products support the structured query language (SQL). Secondly, request/reply style mechanisms are adopted for inter-layer communications. It is obvious that the well-known hyper-text transfer protocol, or HTTP (Fielding *et al.*, 1997), is used for transporting pages between the front-end and the middle layer. Between the middle layer and the back-end, SQL is in place for all database queries and updates. Lastly, inside the middle layer, the domain knowledge of land evaluation is encapsulated in knowledge containers which again are running on top of the Web server. In other words, the land evaluation subsystem is relieved from the low level networking tasks. In fact, every layer of the system is network ready. In a word, separating the middle layer from data management provides greater scalability and higher performance while accessing land, soil and social-economic data.

System Implementation

The evolvement of server-side computing falls into two leading architectures: Java 2 Platform Enterprise Edition or J2EE (Shannon, 2003), and the .NET Framework (Microsoft Corporation, 2003). Generally speaking, J2EE supports multiple operating systems and hardware platforms, but requires the Java language model, while .NET supports only one operating environment (MS-Windows family) but offers a choice of programming languages. Plenty of works have been done to compare these two architectures (Fricke, 2002). Among them, the benchmark tests conducted by the Middleware Company (2002) provide a significant reference in the context of this study. According to the benchmark, .NET's peak throughput of both Web Application and Web Service is significantly superior to that of J2EE (see Figure 2). We have also observed that Microsoft maintains an advantage in office automation for governmental, research institutional and individual uses, which coincides the potential audience of the WLES. Therefore, .NET is chosen as the implementation platform of the WLES.

Implemented using the .NET technology, the WLES is running inside the Web server on a Windows server machine. The WLES documentation is written in static HTML, the hyper-text mark-up language (Raggett *et al.*, 1999), pages and therefore is hosted directly by the Web server. The domain knowledge of land evaluation is encapsulated in namespaces and classes in ASP.NET pages, written in C#.NET programming language. ASP.NET pages are written in such a way that the code-behind philosophy is practised so that they are separated from the presentation logic which is conveyed in HTML pages. The data manipulation tasks are carried out by calling ADO.NET classes from inside the ASP.NET pages. The independent data engine behind the scene takes full responsibility of data integrity and consistency (Figure 3).

Framework of Population Carrying Capacity Assessment

The relationships between population and environment are extremely complex and defy a clear and comprehensive understanding (Ness *et al.*, 1993). Nevertheless, scientists believe that population is the leading factor concerning human impacts on the environment (Harrison & Pearce, 2001). The efforts to assess the population carrying capacity on Earth can be dated back as early as four centuries ago. Recent attempts had generated estimations with a wide range between 4 billion and 16 billion (Cohen, 1995).

For a given land utilization type (*LUT*), crop yield (*Y*) can be estimated by summing the land production potentials (*LPP*) on all mapping units (*MU*) with the same *LUT*:

$$Y_{LUT} = \sum_{MU}(LPP_{MU})$$

The LPP is the most comprehensive estimation of yields in quantitative land evaluation (Sys *et al.*, 1991), and it had been applied to PCC assessments in many countries (Higgins *et al.*, 1983) including China (Ye & Van Ranst, 2002). And the yield (tonnes/hectare) can be expressed in energy form (kilocalories) by multiplying with the energy content per unit yield (kcal/ton):

$$E_{LUT} = Y_{LUT} \cdot EC_{LUT} = \left[\sum_{MU}(LPP_{MU})\right] \cdot EC_{LUT}$$

where E_{LUT} is the energy produced for a given *LUT*, and EC_{LUT} is the energy content (Watt & Merrill, 1963; Higgins *et al.*, 1983) per unit yield of grain products corresponding to the *LUT*. The *PCC* is then assessed by the following formula:

$$PCC_D = \frac{E_{LUT}}{C_D} = \frac{\left[\sum_{MU}(LPP_{MU})\right] \cdot EC_{LUT}}{C_D}$$

where PCC_D is the PCC for a certain diet pattern (D), and C_D is the portion of energy provided by cereals in the diet pattern D.

As having already been discussed, the WLES has a build-in module of LPP estimation. Feeding data to it via the predefined WLES Web Service interface, a message containing the LPP calculation results is received though the network. In this way, the external PCC assessment system incorporates the LPP estimation capability and makes the WLES a building block of it.

Conclusion

The study demonstrates the feasibility of implementing a land evaluation system as a Web Application and a Web Service using .NET technology. A functional multi-layer system design is made and the system efficiency issues are gracefully addressed. The domain knowledge of land evaluation is seamlessly integrated into this state-of-the-art Web-based computer model. The WLES provides a sounder base for PCC estimation through its Web Service interface, and thus contributes to a better understanding of human-environment relationship.

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Figures

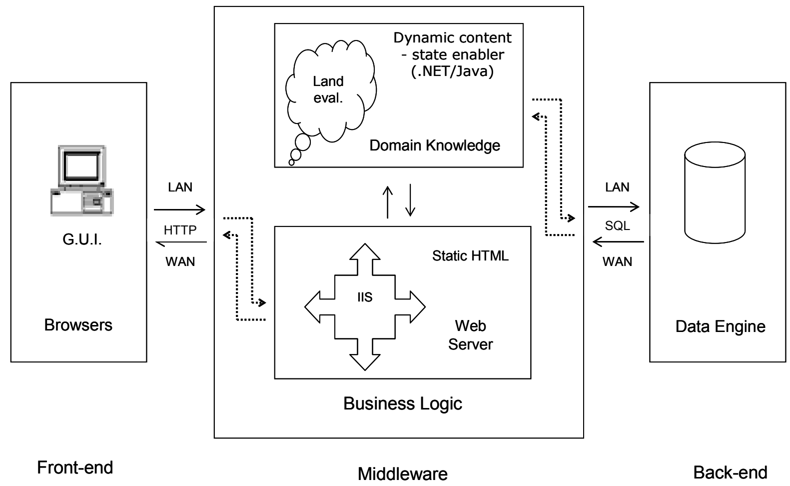

Figure 1. A 3-layer system structure of WLES.

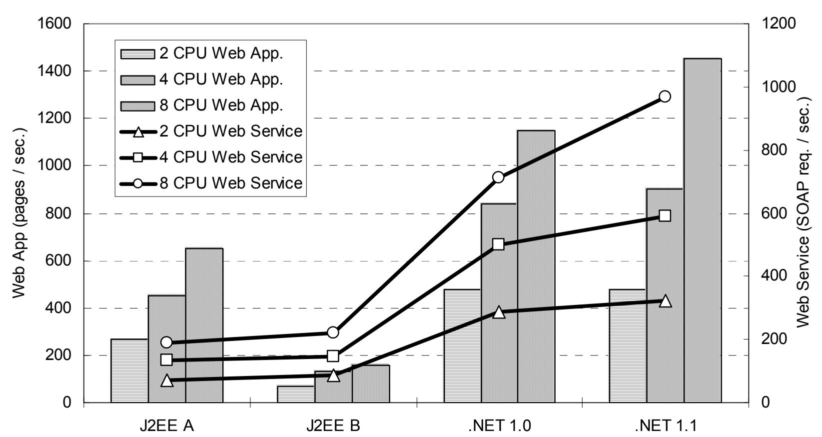

Figure 2. Web application and Web service performance benchmark on J2EE and .NET (after Middleware Company, 2002). Three hardware configurations (2, 4 and 8 CPUs) with two software installations (J2EE and .NET) were tested for two categories of performances (Web application and Web service). "J2EE A" stands for J2EE Application Server A; "J2EE B" for J2EE Application Server B; ".NET 1.0" for .NET Framework 1.0 with Windows 2000 Server; and ".NET 1.1" for .NET Framework 1.1 with Windows Server 2003.

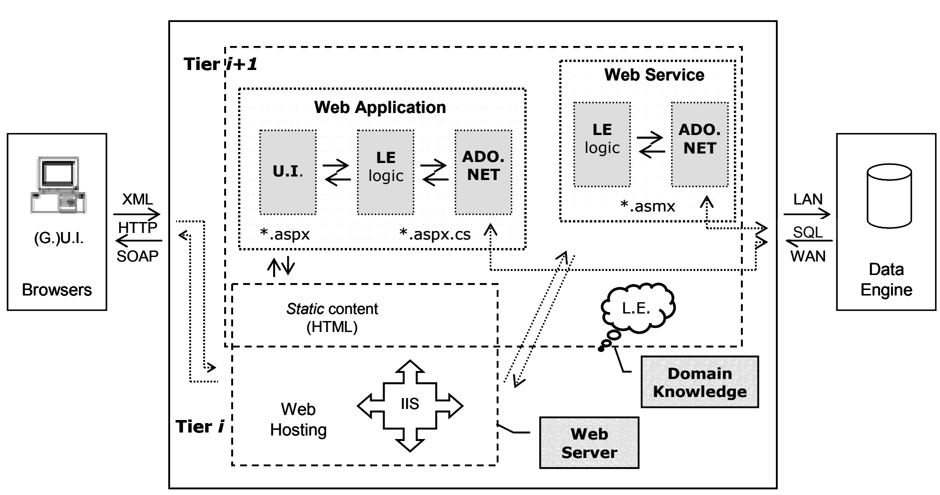

Figure 3. WLES Web Application and Web Service model.