Interactive Environmental Software: Integration, Simulation and Visualization

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Abstract

Environmental planning and management require comprehensive and interdisciplinary information as the scientific and technical information basis for what are, ultimately, political decisions. The volume and complexity of this information, uncertainty in the data and the understanding of processes, as well as the often very large number of alternatives to be considered require specific data processing tools.

Electronic data processing and in particular, the simulation and analysis of environmental problems and possible measures of environmental management require the development and implementation of the required data and numerical models, but also of appropriate user interfaces.

The user interface allows interactive control of the software, the graphical display and visualization of results, and the integration of models and data bases, multiple models, or expert systems components. It also facilitates customization of the system for specific institutional applications.

Important components are graphical and symbolic user interaction, the graphical display of results that are dynamic or spatially distributed, the integration of geographical information systems as a source of data, but also as a tool for further analysis, and the use of AI components that allow efficient systems behavior and easy, error-free use of the software.

The role of integrated systems is not only to model selected aspects of the environment, but to offer a broader view of the overall problems, and to provide tools and methods of analysis that distill the most critical features of decision-oriented information bases and explicit decision support.

Using a number of practical examples from application domains such as air quality, ground and surface water, hazardous chemicals, technological risk and environmental impact assessment, a number of interactive and integrated information and decision support systems, implemented in a number of countries for environmental planning and management, are described and discussed together with the architecture of their implementation and the basic approach.

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1 Introduction

Human activities, and in particular large scale industrial, energy, construction, or agricultural projects adversely and considerably affect the natural environment. Consumption of natural resources, including space, water, air, and biota, and the generation of wastes, including the dissipation of energy, usually lead to a degradation of the natural environment. Environmental problems, including climatic change and ozone depletion, acid rain and forest die-off, marine pollution and eutrophication, groundwater contamination, or regional and local air pollution, are increasingly reaching alarming proportions.

Environmental considerations are, however, becoming important components of planning with many countries introducing legislation calling for the explicit consideration of environmental impacts in the planning and decision making process for large projects. More and more national and international legislation and agreements are designed to revert past and stop current environmental degradation.

The basic components of Environmental Impact Assessment (EIA) as the basis for the design and evaluation of any management or control options are a description of the current environment, of the proposed project or activity, and a description of the expected impacts. Obviously, the prediction of future impacts is the most difficult part. Approaches range from purely qualitative checklist-based matrix approaches (for a recent overview see Fedra, 1989a), and any combination of these approaches. However, most of the accepted and routinely used tools of EIA, and environmental planning and management in general, are not based on the use of computers, but on rather more-or-less formalized qualitative assessment procedures.

The availability of increasingly powerful and affordable computers is rapidly increasing (Fedra and Loucks, 1985; Loucks and Fedra, 1987), and so has computer literacy among technical professionals. New technologies such as expert systems, interactive modeling and dynamic computer graphics allow more powerful, more accessible and more directly useful environmental models to be built.

2 Integration, Interaction and Visualization

The new approach to modeling environmental impacts, made possible by these advances in computer technology, is based on the concepts of integration, interaction, and visualization (Figure 1). To make complex simulation models and tools of analysis more accessible and easy to use, models can be integrated with data and knowledge bases that provide input data, parameters, but also domain-specific knowledge, by integrating expert systems technology in simulation models.

Clearly, a model that "knows" about the limits of its applicability, what kind of input data it needs, how to estimate its parameters from easily available information, how to format its inputs, how to run it, and how to interpret its output will require not only less computer expertise from its user, it will also make less demands on his domain expertise. Environmental impact assessment usually deals with rather complex problems that touch upon many disciplines, and rarely will an individual have all the necessary expertise at his disposal. The expert systems component of an EIA system can help to fill this gap and at the same time take over the role of a tutor. For recent surveys of the role and potential of expert systems technology in environmental planning and assessment see Ortolano and Steineman, 1987; Gray and Stokoe, 1988; Beck, 1990; Fedra 1989b.

The same line of argument holds for data base integration. A forecast of likely consequences and impacts has to be based on some kind of model. Whether that is a mental model, a set of "rules of thumb" or heuristics an expert might use, or a formal mathematical model, the necessary informa-