An Information System for the Management of Ecological Simulations

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Abstract

Our paper deals with the information system Info-X. This software system aims at the management of ecological studies and provides a special functionality for simulation studies. In particular, Info-X can be seen as an approach to conserve the wealth of knowledge and experience, which manifests in models, simulation programs, and their practical applications. This knowledge/experience can broadly support research in theoretical and practical ecology. Info-X provides a state-of-the-art graphical user-interface to browse its database, select desired content, start simulation runs with suitable simulators, and check published results for plausibility/correctness. Furthermore, users can assess and rate the quality of existing content and are invited to submit new content.

1. Introduction and Overview

For recent years the Oldenburg Research and Development Institute for Tools and Systems in Computing Science (OFFIS) is working in close cooperation with the Center for Environmental Research Leipzig-Halle (UFZ). So far, this interdisciplinary cooperation results among others in three simulation tools: Meta-X (Lorek et al., 2000), Pop-X (the prototype was named ExiDLG; Köster et al., 2000), and AniTra-X (Köster et al., 2002). These tools are intended to enable users from landscape planning and conservation biology, to gainfully use simulation for their practical work. To support even users which are mainly familiar with the operation of usual office tools (e.g. word processing tools) Meta-X, Pop-X, and AniTra-X offer special (application specific) graphical user interfaces to simplify the parameterization, simulation execution, evaluation, and structured storage of simulation experiments.

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Among these simulation programs, many other models/simulations are developed and applied at the UFZ, as well as at other research institutes. These activities and the resultant models/simulations, their practical applications, and gained insights into the dynamics of ecological systems are a precious resource in the field of ecology. The wealth of knowledge and experience which, for instance, manifests in models and simulation programs, can broadly support further research and education in theoretical and practical ecology.

This observation motivates our activities to develop a software system to easily organize, maintain, and utilize such a resource: Currently, e.g. people who want to take an advantage of the knowledge/experience offered by simulation studies published in a journal or at a conference, often have to cope with the problem to find only incomplete information about such studies (e.g. incomplete or not very precise model descriptions). As a result, it is possibly difficult to validate and re-use research findings, and therefore it can be hard to learn from past studies.

To overcome some of these problems, we are developing a software system for the management of information about ecological (simulation) studies, practical applications of models/simulations, and research findings. The prototype of this information system is named Info-X. Info-X provides a state-of-the-art graphical user-interface to browse its database, select queried/desired content (documents, simulators, models, parameter settings etc.), start simulation runs with suitable simulators, and check published results for plausibility or correctness. Furthermore, users can assess/rate the quality of existing content and are invited to easily submit new content to be incorporated into the information system Info-X.

In the following, Sect. 2 gives a coarse survey of the basic requirements for the information system Info-X. Sect. 3 sketches Info-X’ architecture and Sect. 4 depicts some important aspects of the current implementation. Finally, a short conclusion and an outlook to future work is given in Sect. 5. As promised by the title of this paper, we will focus on the management of models/simulations which partially requires a special tool functionality to be provided by Info-X.

2. Basic Requirements for the Information System Info-X

Obviously, Info-X must be capable to handle different types of (complex) data or information. This heterogeneous content can be subdevided into six coarse categories: (1) simulators/models; (2) parameters; (3) simulation results; (4) additional documents and data sets which deal with an ecological system or study; (5) references to documents or data sets which are available via internet technology (virtual content); (6) additional metadata (see Sect. 4.1; Implementation).

The types 1 to 4 can be subsumed under the term materialized content, and type 5 can be seen as a kind of virtual content.
Besides this content-oriented perspective, Info-X must be designed to support multiple types of users (different roles). Each type of user has a particular focus while using the information system, and consequently has special requirements. Currently, we distinguish four categories:

→ A content provider considers Info-X as a tool to publish the already mentioned types of data/information. To support such users, Info-X should provide a simple mechanism to insert new data/information into its database.

→ An editor takes care for the database quality. Therefore, mechanisms must be provided to (stepwise) check, edit, and reject/approve newly submitted contributions.

→ A recipient explores the content of the information system. Ultimately, such an user wants to extract data/information of interest and desired quality, and must be supported by an adequate functionality for query formulation and result processing.

→ An administrator is responsible for technical aspects of the information system, and must be properly supported.

As mentioned above, in this paper we will focus on the handling of models and/or simulations: In the application context of Info-X, it is essential that an user has the possibility to deeply comprehend ecological simulations (e.g. understand how simulation results have been achieved, realize the models’ structure, check results for plausibility/correctness etc.). This is not only very valuable in scientific education programs, but also a necessary requisite to utilize previously published results as a foundation for further research activities. For this reason, Info-X, for example, should support a recipient to understand simulation experiments by allowing resimulation in an easy manner.

3. The Architecture of Info-X

The core of Info-X is based on a central database (server). To let multiple users access such a database from different locations, a widely applied approach in computer science is the client/server concept (Orfali et al., 1999).

Usually, the client is in charge of providing an user interface to formulate queries as well as to (pre-)process and present query results. The server manages the information systems’ content, processes queries, and delivers the queried data/information. Obviously, a client/server system can be realized by a 2-tier application architecture. Although this approach is much better than a monolithic approach (where all the functionality–client and server–is combined within one single program), there are different problems either: For example, a typically high network traffic, a limited number of client connections (in particular due to network traffic),
the maintenance and support of the clients, and requirements regarding the performance of the computer systems to run the client software.

A solution to these problems can be achieved by the realization of a 3-tier architecture, which we chose for the information system Info-X (cf. Fig. 1):

![3-Tier Architecture of Info-X](image)

**Figure 1: 3-Tier Architecture of Info-X**

In a 3-tier approach a middleware layer separates the front end of an application from its back end, and incorporates most of the application logic. Thus, a client only needs to provide a graphical user interface for the middleware services which, for instance, deliver pre-processed data to be displayed by the client. Due to the fact that most of the application logic is located in the middleware layer, it is possible to reduce the amount of data to be send to the client over potentially slow network connections (e.g. a modem connection to the internet). In particular, this attenuates the requirements regarding the bandwidth of a (wide area) network and facilitates the scalability of such a distributed system. Moreover, one has the possibility to develop a variety of special clients for different types of users which can be founded on the same middleware–identical (well-engineered) core functionality (application logic).

4. **Info-X**

This Section deals with the prototype of Info-X. Before we take a glance at the information system’s current graphical user interface in Sect. 4.2, some technical issues will be briefly sketched in Sect. 4.1.
4.1 Implementation

Currently, Info-X is being fully developed to a 3-tier architecture as sketched in the previous section. At present, we are using Interbase (Borland Inc., 2002) for the persistent storage of the information system’s content. CORBA (Siegel, 2000; OMG, 2002) is chosen as the basis for the C++-based backbone of Info-X (cf. Fig. 1).

As already pointed out in Sect. 2, Info-X had to be designed to handle very different kinds of data/information: For instance, on one hand we have models or simulation programs which should be accessible via Info-X; on the other hand we have to deal with parameter settings for single simulation experiments, or simple text documents which contain further information on ecological studies. To upload such heterogeneous content into Info-X’ central database and to process these data/information (organize, maintain, query), we implemented an approach based on metadata. For simplicity, these metadata are directly specified in XML (XML = eXtensible Markup Language; Box et al., 2000).

4.2 Application

In the context of Info-X, metadata are utilized, for instance, to exchange information on simulation studies, which are standardized, well-structured, and independent from their mostly proprietary representations for special simulation programs. Since XML is chosen as the base for the metadata description, these descriptions can easily be created either by a simulation program (a special functionality for the export must be implemented) or by using a simple text editor (manually). Currently, we integrated such a functionality into the simulation programs Meta-X, Pop-X, AniTra-X (see Sect. 1), and the simulation software i-EpiSim-2 (Köster et al., 2000; Köster et al., 2002).

In practical applications, first these metadata are imported by an Info-X client. Afterwards, Info-X generates a package which consists, for instance, of a proprietary parameter file and a suitable Info-X metadata description. This package can be transferred (via network) to a temporary storage, where it is usually stored until an editor rejects or approves it (cf. Sect. 2).

To enable a recipient to re-simulate and check the results of a simulation experiment for plausibility/correctness, a reference to the required simulation program is needed: An administrator must register such programs before they can be referenced. The process to register a simulation program is very similar to the already sketched registration procedure for a parameter setting. Again, a special XML-based description is used to provide Info-X with information about the name of the simulation program, its version, a reference to the executable etc. The simulation software itself can be stored within Info-X’ database (materialized or virtually) or must be installed on the client computer system.
Figure 2 shows the main window of an Info-X client intended to be used by content providers or recipients. This window is subdivided into two parts: On the left hand side the history and the results of already issued queries are shown in a simple tree view; on the right hand side one can see a map which visualizes the geographical locations referenced by query results.

Queries can be entered into the search field of the toolbar. Delivered query results are weighted and sorted depending on their relevance to the processed (complex) query. Their relevance is visually represented by colored dots which, for instance, are associated with each name of a simulation experiment in the results list.

An user can request more detailed information about a simulation experiment by selecting it either via the map or from the tree view. These information are displayed in a separate dialog which is shown in Fig. 3 (a). It is split up into different sections to support an user to easily browse through Info-X’ content: For instance, the needed simulation program, the project, all associated experiments and the scenarios. In this dialog an user has access to all information which are supplied to Info-X via metadata. Additionally, by this component of the graphical user interface an user can attach further documents related to a selected item, can make comments about it, and rate its quality.

In particular, the comment and ranking features could be important for establishing a scientific community for simulation and modeling in ecology, which wants to use Info-X as a kind of communication platform for exchanging (publishing/selecting) and discussing research results.
Beyond the selection of results of a study, members of such a community can easily re-simulate the study, if the administrator registered the corresponding simulation program in Info-X. Re-simulation can be done by using the Info-X functionality offered by the dialog shown in Fig. 3 (a). This dialog allows to launch a simulation program, and to load a simulation experiment of a study. In the example shown in Fig. 3, the simulation program Pop-X (see Fig. 3 (b)) is launched and the desired simulation experiment is opened automatically.

Figure 3: Reopening a simulation experiment

Thus, Info-X relies on the different simulation programs in order to use the most appropriate way for displaying simulation parameters or results, and processing simulations.

5. Conclusion and Future Work

In this paper, we first motivated the need for an information system for ecological (simulation) studies. Such a system requires the ability to handle complex and very different kinds of data as pointed out in Sect. 2. The short discussion on the principle software architecture in Sect. 3 yield good arguments for an advanced 3-tier architecture.

In Sect. 4 the existing prototype of Info-X has been presented. The insights into the technical implementation has shown, that Info-X uses an advanced yet easy to use metadata mechanism for submitting new simulation studies. This is important to gain a high acceptance of the system by the content provider and recipient. As Sect.
4.2 has shown, the prototype is already usable and has some nifty features like the geographical map reference and weighted query results.

Info-X has three main advantages for a community of scientists and practitioners: First, it provides context related search operations in all stored simulation studies. Secondly, the centralized storage system ensures that all information are available to verify and check studies—e.g. by re-simulation. Additionally, Info-X directly supports users to comment studies found in the database and discuss their value.

Based on our prototype, future work will concentrate on extending Info-X to a fully internet-based publishing system for ecological simulation studies, where users will always have access to the latest research activities. In addition, we plan to integrate advanced mechanisms into Info-X, which will support specialized information retrieval on ecological studies.

References