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A Software Architecture for Integrated Assessment Models
- Design and Implementation -

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Integrated assessment is widely used in global-change studies and aims to support „(i) the co-ordinated exploration of possible future trajectories of human and natural systems, (ii) the development of insights into key questions of policy formation, and (iii) the priorization of research needs in order to enhance our ability to identify robust policy options“ (IPCC, 1996). Current integrated assessment projects are largely utilising simulation models to combine knowledge from a wide range of disciplines – the so-called Integrated Assessment Models (IAMs). Performing a computer-model supported assessment involves four main tasks: 1) the development of a qualitative conceptual model of the system under consideration, 2) the quantification of the conceptual model to get a simulation model, 3) the simulation of the system dynamics, and 4) the analysis of the model system (Bossel, 1994).

To simulate the system dynamics the simulation model has to be realised as a computer program. This realisation can be done using only standard programming languages, like FORTRAN or C, or by utilising specific simulation libraries, special simulation languages, or simulation shells. Despite the fact that there are plenty of specialized utilities available, most of the current IAMs are implemented using standard programming languages. But the complexity of simulation models grows more and more due to more powerful computers, constant increase of available data needed for detailed models, and, last but not least, deeper insight into the processes under investigation. The implementation of a simulation model using standard programming languages requires a great deal of programming, where the share of source code specifying the actual simulation model makes only a few per cent of the total programming effort (Bossel, 1994).

The reuse of parts of IAMs could reduce the implementation efforts considerably: different sub-models of an IAM as well as different IAMs should be able to use the same modelling resources. A component based development is a good approach to increase the reusability of model

resources. The whole IAM should be viewed as one software-system – even if it consists of a collection of multi-disciplinary sub-models. The structure of the IAM then can be described by its software architecture, defining separated components, their responsibilities within the system and their interconnections.

To enhance the reusability the design of the components should be based on well-known principles and standards. The consideration of general software (architecture) patterns, e.g., described by Gamma et al. (1996) or Buschmann et al. (1998), and of more specific standards for simulation models, e.g., the high level architecture (HLA)(DMSO, 2002) or specifications of the Open GIS Consortium (OGC, 1999), is of importance for the development.

Several IAMs have been analysed to develop a software architecture. This architecture describes reusable components of an IAM and their responsibilities within the whole software system. Defined is, e.g., one component to manage simulation-runs and one component to manage metadata. The metadata managers responsibilities are to manage a metadata catalogue, to provide services for metadata generation and administration, to provide services for (semi) automatic metadata generation, and to provide services for basic consistency checks (Endejan, 2001a). The simulation-run manager is responsible for the mapping of simulation-run names to an unequivocal set of model options, and for providing these options at simulation run-time to the model. Other components provide, e.g., specialized GIS (geographical information system) functions (Endejan, 2001b) or services to interconnect different sub-models.

The paper gives an overview of the software architecture and the components identified to be important to increase the reusability of parts of IAMs.

The GLASS model, which is an integrated model for quantifying global-change induced influences on water and food security (Alcamo et al., 2001), serves as an example for the application of the architecture. Since the gathering of data necessary for IAMs and their preparation for the software is quite time consuming and expensive, data standards are also an important topic for the implementation of a simulation model. Therefore some aspects of data standards, like the usage of the ISO standard 3166 to encode country data, are also considered and round off the given principles to enhance the reusability of components of integrated assessment models.

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