Software Frameworks for Integrated Modeling

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Important social issues in the management of rivers and coastal waters demand integrated modeling of all relevant aspects concerned. For instance in modeling of river floods such as in Germany and the Czech republic in August 2002, numerical simulation may involve rainfall, catchment, groundwater flow, river flow and evaporation. Thereby different regions may be modeled in more or less detail, and using different methods. For instance the amount of rainfall in an area may be estimated using weather predictions of a numerical model or using in-situ measurements. Also the inflow of water from tributaries may be estimated by a detailed hydrological model or by matching the weather situation against a database of previous occurrences.

The trend towards integrated modeling has been there for at least ten years and can be seen in many different areas. However, new possibilities for integrated modeling arise due to the rapid increase of computer speeds, for instance through parallel computing, and through the advent of new software development techniques. Whereas different models were integrated into single executables ten years ago, it is nowadays possible and required to construct larger models out of separate components in a flexible way. Also databases and other information sources may be treated as components and thus integrated into the simulation.

Although component based programming has been around for some years and has wide adoption in the business world, it is not trivially incorporated in large scale simulation models. Firstly this is because the standard solutions such as CORBA and .Net were not designed with the performance considerations of large scale modeling in mind. Consider for instance the coupling of two parallel simulation models that operate on partially overlapping regions and on different types of grids (e.g. numerical weather prediction and hydrological catchment models). In such a case special attention must be paid to the inter-model communication in order to achieve scalability towards larger numbers of processors. Secondly the coupling of different simulation models requires additional functionality, such as interpolation and accumulating data over multiple time steps. Therefore new software frameworks must be developed, to provide an infrastructure for easy integration of models and data from various sources.

A new system that we are working on in the Netherlands is the Dutch "Open Model System" (OMS). It is a public-private partnership between the Dutch Rijkswaterstaat and WL|Delft Hydraulics, and aims to replace both partners' currently operational shallow water flow modeling systems. An important goal of OMS is to define a software architecture that is based on modern software development methods and that allows for the separation and integration of different modules. Further the system should be open for developments in the outside world. One should be able to employ a turbulence model developed at a university in the proprietary flow model, as well as be able to connect to flow models of third parties for different domains in the global region of interest.

In this paper we highlight through the software architecture of OMS a number of key issues in the design of software frameworks for integrated modeling. These issues include:

- the definition of components, preferably in a hierarchic way, and the characterization of components' interfaces,

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- the communication model (e.g. data flow, tuple space), communication primitives such as put and get with particular semantics, and the use of transformation methods (e.g. interpolation),
- the configuration of different components into a compound application, which requires among others relating data structures of different components to each other,
- the execution model which includes sequential, multi-threaded and distributed execution.

Our current choices in these issues reflect our experiences from previous activities, concerning for instance the parallelization of 2D and 3D shallow water flow models, the extension of these models with domain decomposition with horizontal and vertical grid refinement, and the parallelization of the Kalman filtering version of the flow models. The latter parallelization effort is particularly relevant because of the approach that was followed: first breaking up the compound simulation software into different components (flow model, Kalman filter computations, linear algebraic computations), then parallelizing each of the components in their own most appropriate way, and finally coupling of the parallelized components into a single simulation.

In the description of these aspects we will also relate our choices to those made by other teams of researchers. Finally an overview of the OMS system is given in which the different parts are put together, for delivering the next generation shallow water models.