The Generic Framework – An Open Framework for Model Linkage and Rapid Decision Support System Development

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Abstract: In the Netherlands all major players in the field of modelling in integrated water management have joined forces to develop an open, broadly supported IT framework for efficient integrated model systems development. Summer 2001 the first version of this framework has been implemented and some legacy models have migrated to work together within the framework. This paper describes the background and current status of the project and the two cases used for proof of concept of version 1. Finally the paper discusses the future expansion of the framework and some very closely related projects.

Keywords: Framework; Integrated modelling system; Model linkage; API; Component Based Design

1 INTRODUCTION

The past decades have shown an increase in the use of information technology (IT) in water resources management. The development of IT applications at different institutions in The Netherlands and over a long period of time has resulted in major difficulties in technically linking applications and dealing with uncertainties in model chains. However, combining the models and data from different disciplines is considered a prerequisite for effective integrated water resources management and implementing the EU Water Framework Directive. These and other findings are the driving force in the current activities within the Generic Framework (GF) Program. The GFA Program's main aim is to improve the contribution of models in policymaking, management and research. Within this program several projects are carried out , one of which is the development of an IT-Framework for modelling: the Generic Framework Water Application (GFA). This paper describes the development and current status of the framework.

2 BACKGROUND AND OBJECTIVES OF THE GFA PROJECT

The linking of stand-alone (legacy) models to form integrated modelling systems (IMS's) and decision support systems (DSS's) and maintaining such systems is usually very time and budget demanding. However, many activities in developing such systems appear to be repetitive in the various system development projects. Some examples: (I) Input and output of individual models need modification in order to be exchanged. (II) Schematic representation of the object of study must be matched, e.g. 1 dimensional river flow schematisations to 2 dimensional ground water flow schematisations. (III) Geographic and temporal points need to be defined on which data flow between the individual models takes place, including data aggregation over time and space. (IV) If coupling on a time step basis is a necessity, including two-way data-dependence major modifications in the original models may not be prevented. This is for example the case if the interaction between river flow and aquatic plant growth is modelled. (V) Finally, tools for data editing, parameter editing, presentation, etc often-times need to be disabled in the individual programs and frequently new tools and control software needs to be developed or redesigned to meet the demands. As a result building an IMS frequently results in multiple versions of underlying models which are integrated, resulting in increasing resources for maintenance and updates.

Besides the technical problems in linking models these also result in scientific problems. For example, it is difficult to carry out research on linkage concepts. Currently consensus based on experience rather than on sound scientific work and concept comparison leads to the choice of the linkage concept.

The objective of the GFA project is to solve these problems and achieve high efficiency and flexibility for future IMS development. The tangible aim is to develop an open IT framework in which models, tools and data (bases) may easily be linked to form IMS's. Since models for integrated water management originate from different specialist institutes and companies and cooperation between specialist institutes is becoming more and more vital the problem to solve is not purely technical: The large number of involved parties (see e.g. the acknowledgement) all have in-house traditions of modelling and model development. The IT framework development must account for these differences and allow any type of existing models to function within the framework.

The basic principles stated in the Terms of reference (TOR) [Werkgroep Generieke Tools, 1998] are: (1) For any set of models that needs to be linked, the user only needs to define the linkage properties: Additional adaptation of the model or it's interface shall not be required. (2) Another important principle is that non-model specific functionality is generally available as re-usable 'tools', that may be linked to models. (3) The third important principle is that ultimately models may easily use the same basic data, such as land use maps, digital terrain models and river cross section data, allowing swapping models in the system without the necessity to rebuild the geographic schematisation. These basic principles lead to the necessity to strictly separate models, tools and data and adopt a component-based design approach. This is represented by the well-known three-tier representation in Figure 1.

It should be noted that in this context, a model is just a set of algorithms implemented. A model is not a full representation of a tangible environment. On the other hand linking models requires geographical links - a set of linked models, called a model system or model application, thus includes data. In this paper the phrase "A model of X" is a model of tangible environment X, thus including data etc.

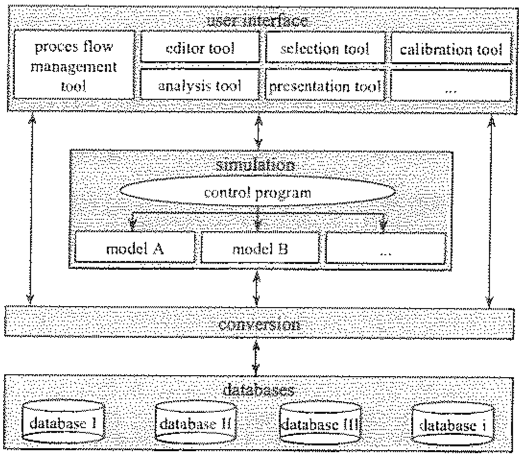

Figure 1. Three-tier representation in software engineering.

3 ARCHITECTURE

Based on the TOR the software architecture of the framework has been defined [van der Wal, 1999; van der Wal and Elswijk, 2000]. Following state of the art IT it was clear that a component-based (CBD) approach should be adopted. Components may be viewed as large objects which internally are not necessarily object oriented. Furthermore the three-tier representation appeared to be not fully appropriate: Data should be handled as components and a large data-layer and data-standardization seemed to be restrictive and limit the flexibility towards the future. However, as a representation of the concept of separating functionality Figure 1 remains valid.

A domain analysis of the field of modelling in integrated water management formed the basis of elaborating the architecture. In the first place such a domain analysis is necessary to create a common understanding of the domain between all parties involved. In the second place the domain analysis is necessary to elaborate a high level IT-abstraction on which to base further designs. Three angles of approach were taken: the physical domain, the mathematical simulation domain and the 'environment for integrated model application development' domain.

The physical domain analysis resulted in a subdivision of the domain in sub-domains (Figure 2).

Individual models in the framework should cover one or more of the domains, and only interface where the domains connect. Although further subdivision of the domains is necessary to make optimal use of modularity, this has not yet been elaborated.

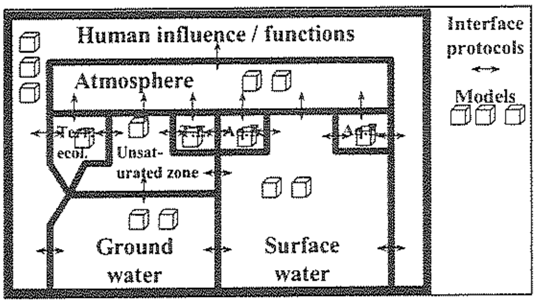

Figure 2. Result of the analysis of the physical domain ("Terr. Ecol" and "Aq.E" are the domains of terrestrial and aquatic ecology, respectively)

The mathematical simulation domain resulted in a class diagram suitable for a variety of mathematical solutions and schematisation methods (1D schematisations; 2D/3D grids; analytical elements).

The 'environment for model system development' domain resulted in a class diagram relating the various model components and tools to form a fully operational integrated model system.

To facilitate the (geographical) linking and flexibility, 'in-process tools' were defined. These tools act as (virtual) models: However, they do not change data like a model but prepare incoming data for input into the next model. Re-scaling data from e.g. different grids or from grids to 1D schematisations is an example of an in-process tool.

Though not desired from the viewpoint of performance, in-process tools may also serve as unit-converters. Thus the necessity for a priori data standardization is limited and flexibility is enhanced.

The architecture has been the point of departure for implementing the GFA. Based on the architecture a functional design and a technical design have been developed.

4 GENERIC FRAMEWORK VERSION 1

4.1 Description

Basic components shape the GFA. They deliver the fundamental functionality of the framework, like the ability to link the building components (models and tools) with each other in place and in time, to manage the flow of data and processes and to manage (the definition of) cases. Because they define the framework, an instance of these components always needs to be present. Or, to put it more precisely, each component is required to deliver a minimum service or functionality. This minimum set needs to be implemented. Additional services make life much easier for a user, but are not strictly necessary.

The foremost important component is the framework itself, providing the functionality to add, register, manage and delete individual components, thus creating a platform for integration. Figure 3 shows one of the functionalities of the framework, the overview of registered components and un-register functionality.

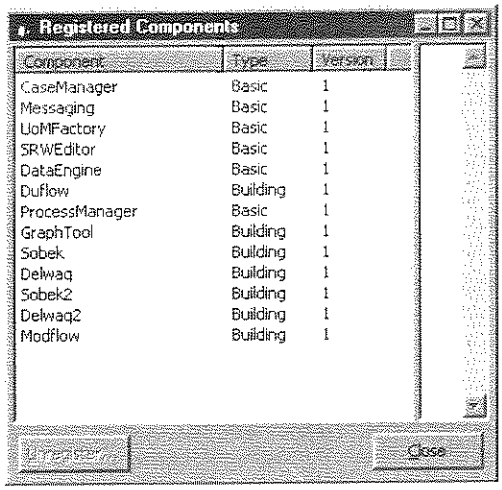

Figure 3. The registered components overview.

When using the GFA the building components shown Figure 3 are visualised and ready for use as is shown on the left hand side of Figure 4. Using drag & drop these components may be added to a case, like the model component 'SOBEK' in Figure 4. The case 'Demo 1' in Figure 4 is built with the help of the case manager component: It is independent of the generic framework application and thus may be replaced by any other preferred case manager as long as it fulfils GFA interface requirements.

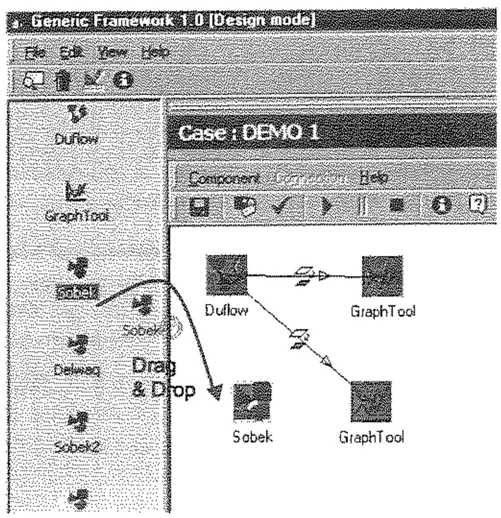

Figure 4. Drag & Drop to place models within a case.

Of course, one may need to change specifics of individual models. By double-clicking on the component some functionality becomes available, as is shown in Figure 5 for the DUFLOW (1D open channel flow) model.

Currently, not all functionality available in the models is accessible within the framework. For the time being models (including their data) are developed and calibrated in their original modelling environment. Within the framework such a model may be used by for example changing the paths to files as is shown for DUFLOW in Figure 5.

To link models one simply 'clicks' on both models pressing the shift button. This results in a line between the two components as is shown between DUFLOW and the Graph tool in Figure 4. By clicking the icon on this line the GF-editor (SRWeditor) is started and the "Connection Viewer" pops up. Figure 6 shows this for the linkage of a DUFLOW and SOBEK (1D open channel flow) model. The black lines and the darker grey area approximately in the middle of the map actually represent spatial points on which data may be provided and/or required by the models. The "Connection Viewer" facilitates the geographical linking process. The Connection Viewer is used to (roughly) select connection points of both models.

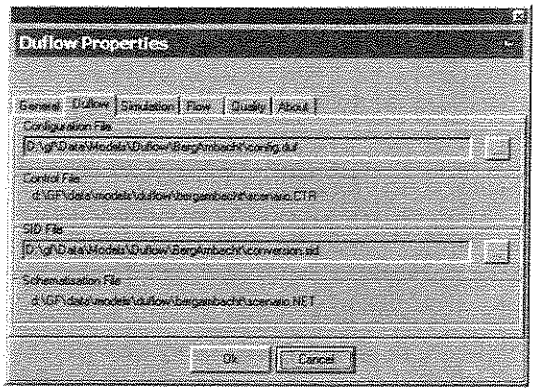

Figure 5. Property editor for DUFLOW.

The GFA editor saves the linkages in an XML based file. As such it is an excellent example of additional user oriented functionality: a XML editor would be sufficient to create the linkage file!

The current tool makes life easier, but in future some additional automation will be provided for example for linking different grids. Manual connection for grids is currently a time consuming task.

The tab 'connection editor' allows finalization of the linking process. Figure 7 shows in it's upper half the geographical points that were selected in the Connection Viewer: 1 for DUFLOW and 5 for SOBEK. Now the final selection of connecting points may take place by selecting the appropriate geographical points and the attributes that need to be exchanged.

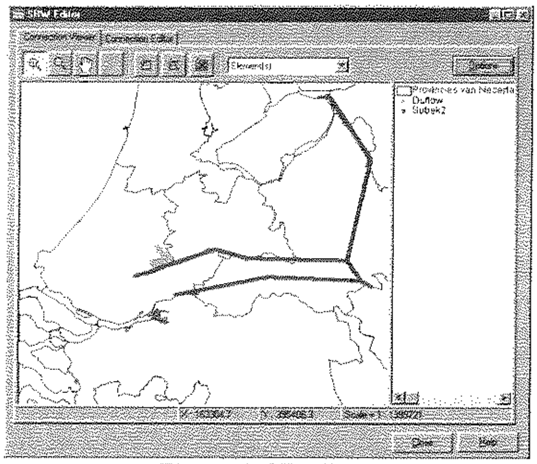

Figure 6. GF-editor.

Having connected the models the case is ready to run.

The current case-manager is only capable of defining, saving and opening one case at a time, future case-managers will be able to handle several cases simultaneously, thus providing a mechanism to compare different results of different cases (together with tools to visualise the results).

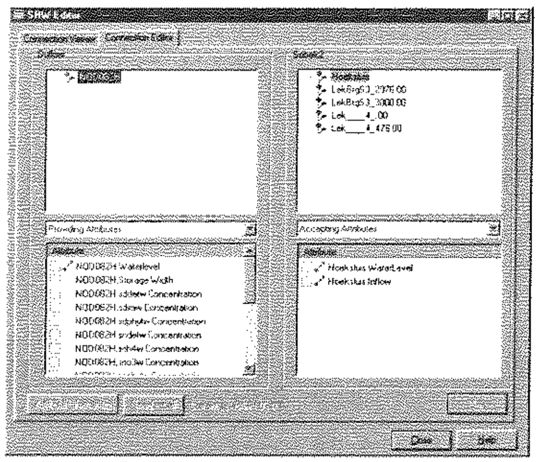

Figure 7. GFA editor – Connection Viewer.

Besides the components described above four other components have been implemented. The process manager is responsible for the time-component of linking models. It can schedule when a model should start its calculation, and provides the interface to control and manage that calculation. Note that, because the GFA provides in a linking on a time step basis, this control requires that several models, each waiting for input from other models will be active simultaneously. In the current version, models requiring input do so each time step, using the last value available from the providing model. In future other time integration functions will be available for exchange, such as average values over the last interval. The component "Data engine" manages the dataflow and provides a generic storage-facility to manage and store (meta-) data related to a particular case. Be aware that in general data transfer between models is via rapid access memory (RAM). The data engine also invokes the component "Unit of Measurement Factory (UoMfactory)" in case the units of attributes do not match.

The last component is the "Messenger". This tool "catches and reports" all messages that are tossed from individual components.

4.2 Migrating legacy models

Getting a legacy model to work within the framework is called migration. This is a straightforward task. The model needs to be wrapped in a shell which adhere the GFA specification on one side, and link to the model on the other. Given a default "wrapper" this task is quite simple.

The original model however may need some more complex modifications. Besides possible adaptations to link to the "wrapper" the model needs to be able to exchange data and pause on a time step basis. Also generic functionality and user interfaces need to be detached from the computational core if these are entangled in the code.

4.3 Technicalities

The current implementation of the framework and the basic framework components is platform dependent (Windows 9X, WinNT/2000 ©). At the current time it was felt that this platform is most commonly in use, and the extra investment in platform independence was not desired for version 1.0 and proof of concept. The concept for utilizing tools and models on other machines and platforms is implemented in such a way that it is independent of the choice for middleware (COM/CORBA etc.).

5 PROOF OF CONCEPT - CASES

As proof of concept of the first version of the GFA two case studies have been carried out. The first case study considers the linking of two 1D flow models. It proves that individual models within the same domain, such as 1D flow models of adjacent basins, may be linked to form a valid new model. The advantage of this type of linking is that detailed large scale models may be developed by linking instead of integrating detailed models of adjacent sub-basins. As a result a change in a sub-basins model only needs to be dealt with in the sub-basin model. The different sub-basin models may even be implemented in different software packages, allowing to use the most appropriate model in each sub-basin. In this case the first model is a SOBEK (http://www.sobek.nl) model of a large part of the main Dutch river system (rivers Rhine, Waal, IJssel, Lek). The model, which is linked to this 'national' model, is a DUFLOW (http://www.duflow.nl) model of an adjacent small regional water system. Both hydrology and water quality are included. The connection points presented in Figure 6 represent the geographical location of the case.

The second case considers mainly the linking of groundwater flow to surface water flow on a regional scale. The regional groundwater flow model MODFLOW (http://www.modflow.com) is linked to the 2D SWAP model for water budgets at the ground surface and soil moisture flow in unsaturated zone (http://www.alterra.wageningen-ur.nl). Both models are linked to either the 1D surface water flow models SOBEK or DUFLOW. This case is used to proof that groundwater, unsaturated zone and surface water may be adequately modelled by a consistent set of models developed by different modelling groups. It is also used to proof that a river flow model in an integrated modelling system may be exchanged by another river water flow model without any further IT investment and assistance.

6 GFA - RELATED DEVELOPMENTS

6.1 Frameworks

Several projects are currently carried out or planned for the near future which are closely related or complementary to the GFA application development. The Institute of Coastal zone and Sea Management (RIKZ) and WL|Delft Hydraulics combined forces to develop a modular open modelling system (OMS) for complex three dimensional modelling. This project will use GFA knowledge and produce amongst others knowledge about how to link models which need to transfer large amount of data without loss of performance.

Within the Delft Cluster Research Institutes, extension of GF's architecture to the 'dry' part of civil engineering is researched. Additionally research is carried out for calibration tools within the GF.

RIZA is studying the migration of the models for the policy evaluation and development. Other institutes are undertaking similar activities.

Within the European community a large project is co-funded by the European Union: HarmonIT. This project aims to develope an open standard for model communication and implementation of a framework. Amongst many others, the three large software vendors, DHI Water and Environment, Wallingford Software, and WL|Delft Hydraulics are participating. The need for a common interface definition is felt throughout Europe.

6.2 Quality Assurance in Modelling

Though IT frameworks support many aspects of modelling, the process of modelling is still an expert's job. In order to guide the process of modelling a Good Modelling Practise Handbook has been developed in the Netherlands (STOWA/RIZA, 1999). In the project HarmoniQuA, a common European handbook and supporting tools will be developed for quality assured modelling studies.

7 CONCLUDING REMARKS

Almost three years after the kick-off of the multi-stakeholder GFA project the first version of the framework has been produced. All major players in the water management field in the Netherlands support the program and finalizing the first version the developments gain valuable momentum.

The cases have proved that the concepts and solutions chosen are applicable. Though three years is a long period for a software development project it was time well spent: all institutes agree on the framework and the framework appears to be well equipped and sufficiently flexible for the future, without imposing complete rebuilding of legacy systems. However, major tasks still lie ahead. Given the questions in integrated water management raised recently, the framework is just in time to form the basis for new integrated model systems.

Some of the major tasks that lie ahead are:

- The development of advanced generic tools.
- Allowing all user functionality, that is all parameters and data, to be approached by the user.
- Migrating additional models.
- Parent schematisations: In version 1.0 models still work with model dependent geographic schematisations. It is foreseen that these schematisations will be based on a common parent schematisation, making swapping of e.g. 1D models much easier.

Though the framework is currently geared towards experts in integrated modelling it will be beneficial for domain specific research and enhance research on the interaction of domains. Researchers may easily co-operate and may for example quickly test new algorithms in combination with other models. The different linkage concepts may be compared, laying the foundation of scientifically sound linkage of models.

The generic framework also presents an opportunity to develop decision support systems for non-modellers. Given the development of dedicated interfaces the generic framework may be the platform to link the underlying models and tools. Since this may be done rapidly, the system may easily be adopted to fulfil the end-users wishes during the entire process of discussion and decision.

For up-to-date information on GFW refer to www.genericframework.org.

8 ACKNOWLEDGEMENTS

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