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OpenMI – Opportunities For Integration

Author: David Fortune (Wallingford Software) *david.fortune@wallingfordsoftware.com*

ABSTRACT

OpenMI is a standard for data exchange between interacting models, designed to enable integrated modelling. With the release in 2005 of the standard and the first implementation, should we expect a major shift from single-issue modelling to integrated modelling? What opportunities does OpenMI offer to wastewater planners?

The case for integrated catchment management has been well made, and has become a core part of initiatives such as the EC Water Framework Directive. Most water and environmental professionals expect that integrated modelling will take a necessary role in decision support for catchment management, in both planning and operations. Indeed, there is a common assumption that such modelling exists and is regularly carried out. Yet a closer examination reveals that where model integration does exist, it is in a hard-wired or entirely proprietary way.

The widespread implementation of integrated modelling depends on the availability of a sufficiently flexible and powerful linkage mechanism for data exchange between models, and indeed between models and user interfaces, databases and other data-hungry processes. Until now, no such linkage has existed, and easy availability of integrated modelling has remained a dream. Under the EU Framework V HarmonIT Project, a remarkable collaboration between rival commercial software specialists, with the help of some excellent academic, research and operational partners, has developed the OpenMI standard for data interfaces. It is anticipated that this standard will have far-reaching consequences for water modellers and managers.

An implementation of the standard has also been developed, along with sufficient utilities to allow the standard to be tested to the point of scientific proof or proof of concept. The main tests have involved the incorporation of the OpenMI data interface in a range of model source codes, from widely-used commercial codes to specialist research models. Various combinations of populated models were then built and the data transfers tested.

This paper presents an overview of the technical details of the OpenMI standard and a description of some of the testing that has been carried out. The full specification can be downloaded from the OpenMI-website www.openmi.org or can be downloaded from the documentation section of the OpenMI environment software installation package (incl. source code) available from the CVS-repository on sourceforge.net/projects/openmi.

The author acknowledges that the availability of a suitable integration mechanism is just the beginning. OpenMI now exists as a freely-available, open-source standard, but its long term future needs to be secured for it to have lasting impact on catchment management. Much research and development needs to be done to understand how best to implement integration between different sorts of models with a variety of linkages. Should we expect

a major shift from single-issue modelling to integrated modelling? Does OpenMI offer new opportunities for wastewater modellers and planners? The author expects that the answer to both questions is "Yes", in time, but we will have to wait and see if OpenMI really does stimulate lasting change and afford new opportunities for wastewater professionals.

1. INTRODUCTION

Integrated Water Management requires an understanding of catchment processes and the ability to predict how they will respond under different management policies. Most traditional modelling systems have not been able meet these requirements as models have tended to represent individual processes and have been run independently. Hence, their output may not reflect the interactions between different aspects of the environment. Clearly, it is not practical to construct a single model that could simulate all catchment processes and to do so would be wasteful of the large number of existing models. A better solution is to couple models and hence enable them to exchange data as they run, thus allowing interactions to be represented in the simulation.

In response to the need created by the Water Framework Directive from its introduction of integrated water management, the HarmonIT project has developed the Open Modelling Interface and Environment (the OpenMI) to allow models to exchange data. This has been developed with the following objectives in mind: (i) the standard should be applicable to new and existing models, requiring the minimum of change to the program code; (ii) the standard should impose as few restrictions as possible on the freedom of the model developer; (iii) the standard should be applicable to most, if not all, time-based simulation techniques; and (iv) implementation of the standard should not unreasonably degrade performance.

Wastewater collection systems dictate the flow through a small part of the wider catchment flow. But their performance immediately affects the public through waste removal and prevention of local flooding. Any meaningful analysis of behaviour of wider catchments should include analysis of collection systems. Also, it is becoming increasingly evident that analysis of the performance of collection systems should take account of the impact of the collection system on the catchment as a whole. Regulators and operators want to compare impacts, not only on flow, but also on water quality, ecology, agriculture and economics.

It looks as if moves towards integrated water management will have impact on wastewater managers. Wastewater modelling processes were developed to serve the needs of stand-alone wastewater management. It seems likely that if integrated water management becomes an actuality, then not only wastewater management, but also wastewater modelling will need to change. The OpenMI standard for data exchange now makes integrated modelling possible on an economic scale. The technology exists. This may well change current working practices that were based around stand-alone models. Procedures may need to be changed. This brings some risk to modellers that are fixated with single models to answer isolated, single questions. Surely there is also opportunity for wastewater modellers to bring their high standards and professionalism to the broader field of integrated catchment modelling?

It is hoped that modellers will challenge the accepted limitations imposed by single-models, and allow them to define the best ways in which wastewater models can be integrated with models of rivers, treatment works, groundwater, ecology, agricultural activity and economic activity. This in turn should lead to new opportunities for wastewater modellers.

This paper briefly describes the OpenMI concepts. It is not necessary to understand these concepts to appreciate the possibilities for integrated modelling. So please feel free to skip Section 2. However, for those that want to know more about the mechanics of OpenMI, there is a wealth of information, including guidelines for programmers, on www.openmi.org. The software implementations are available as Open Source, please also refer to the OpenMI website.

Section 3 describes the released state of OpenMI and some of the modelling systems in which it has been incorporated. Section 4 describes some of the testing of OpenMI. There has been very little testing of integrated modelling itself to solve real-world problems. This may lead to major changes in the future, but we are only at the beginning of the testing of integrated modelling. The rate at which it will be adopted in real life will depend largely on the speed of response, acceptance and take-up by environmental regulators.

2. OPENMI CONCEPTS

The majority of model applications that are the result of a design process (as opposed to those that just evolved over time) have a common structure comprising a user interface, input files, a calculation engine and output files. Typically, the *user interface* enables the user to create or point to *input* files and allows the visualization of the *output* or *result* files. The calculation *engine* contains the model algorithms and becomes a *model* of a specific process, e.g. flow in the Rhine, once it has populated itself by reading the input files. A model can compute output. If an engine can be instantiated separately, it is an *engine component*. If, further, it supports a well defined interface, it becomes a *component.* Finally, if the engine supports the OpenMI Linkable component interface, then the engine is said to be *OpenMI-compliant*. An engine component populated with data is a *model component*.

The OpenMI focuses on the run-time exchange of data between populated components. These components can be data providers (e.g. models, databases, text files, spreadsheets, pre/post-processors, data editors, in-situ monitoring stations etc.) and/or data acceptors (e.g. models or on-line visualization tools). Thus, the OpenMI potentially allows the development of a complete integrated modelling system consisting of GUI, engines and databases. When this level of system integration will be achieved, depends on the adoption of OpenMI as *a component linkage standard* by the environmental model and software development community.

At the start of HarmonIT, the components were foreseen as running within a framework, but gradually this concept was replaced by standardizing the run-time interface of linkable components, thus allowing direct communication between components. The linkable component interface, described in the namespace org.OpenMI.standard, can be implemented in a variety of ways, of which the OpenMI environment, developed by the HarmonIT project, is just one.

Essential to OpenMI is the distinction between quantities, element sets, time and values. Elements can be non-geo-referenced or geo-referenced in 0/1/2/3D. The entities are supported by meta-data interfaces describing what the data represent, to which location it refers, for which time (time stamp or time span) they are valid and how they are produced.

The developers of OpenMI created a full software implementation, called the OpenMI environment, in C# (.NET) and a less extensive one in Java (soon to be released). The focus of development was primarily oriented to data exchange issues. Hence a wide range of utilities is provided to enhance the implementation of the OpenMI interfaces from typically legacy code. E.g. a wrapper package provides facilities for book keeping of links and data handling such as buffering and spatial and temporal mapping. Simple tools are available to define links, to run the system and to display results.

OpenMI is based on the request-reply architecture concept. The basic workflow is the following. At configuration time, meta data of a component is inspected to identify and define the links between the components. At run-time a component is requested by another component for values at a specific time and location (element set) using the GetValues-function call (see Figure 1). This providing component is obliged to reply to this request and provide the data at the time and location as requested. In order to reply, he may need to do internal computations to progress in time. This computation may require external data that can be requested from other components by a GetValues-call. Once the internal time progressed at or past the requested time, data transformations can be applied to return the values at the exact time, element set and units as requested.

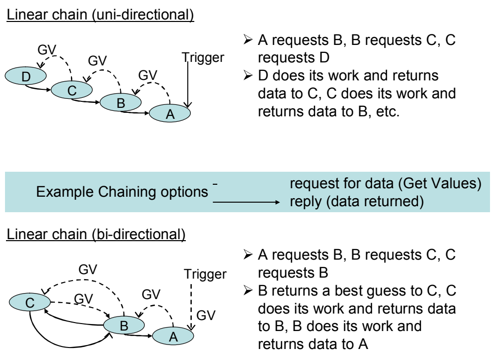

Figure 1 The basis of OpenMI: the request-reply concept

The interface orientation of OpenMI does not prescribe the use of the OpenMI environment. Hence OpenMI can also be used to glue model engines with existing modelling frameworks through the OpenMI interface. OpenMI is expected to satisfy the modeling requirements of a wide group of users in various engineering domains, such as model coders, model developers, data managers and end users. The expected impacts are the simplification of the model linking process, the ability to represent feedback loops and process interactions, the establishment of a communication standard for modelling and a reduction in development time for decision support systems.

3. OPENMI NOW AND IN THE FUTURE

The first full release of the OpenMI standard and an implementation (Version 1.0) was made in September 2005. OpenMI is currently being applied by a range of software developers in the catchment domain (sewers, open channels, hydrology, groundwater, waste water treatment, water quality, socio-economy) and is starting to be adopted by the estuarine and marine domain. These applications have highlighted how little is known about how best to implement integration between different models using a variety of linkages. There is much more work for the water modelling community to do to really understand integrated modelling.

Initially, much of the research and development was carried out by software developers, but specialist model builders are now taking a larger role. New opportunities for modellers have been identified in building and running sets of integrated models, without needing constant input from software developers. It is hoped that this will lead to growth in the activity of integrated modelling, to satisfy the requirements to better represent cause and effect in catchments and other complicated processes.

The concepts of the OpenMI have been shown to be very powerful, but the experiences also have indicated the desire for further refinement of the interfaces. It is foreseen that updates of the OpenMI will be desirable to obtain a mature standard and to maintain it in use. A thread is started on the sourceforge.net/projects/openmi forum to stimulate the development discussion on the OpenMI.

Nonetheless, confidence in the OpenMI concept is high enough, even with the initial release, for a number of commercial system developers to incorporate the interface in releases of their modelling products. And OpenMI is starting to be specified as an essential element in the architecture for software systems being built under contract. To support this growing family of users, the core partners of the HarmonIT consortium have committed themselves to set up an open organisation (the OpenMI Association) that will maintain the OpenMI and stimulate its development, support and uptake by the modelling software community. The founders are now defining the constitution and rules of the OpenMI Association, after which membership will be made available.

One of the limitations to the widespread take-up of integrated modelling using OpenMI is the need for a better user interface for configuring and running integrated sets of models. Such a user interface was developed for the HarmonIT project, and was entirely suitable for the purposes of testing the OpenMI interface. However, the user interface has limitations and becomes tedious under frequent use. It is not regarded as being a full industrial application as demanded by professional modellers for commercial contracts. It is anticipated that more functional and efficient user interfaces will be produced by commercial software developers in the future.

4. INTEGRATED MODELLING TESTS

Wallingford Software released Version 7.0 of InfoWorks CS (wastewater modelling) and InfoWorks RS (river modelling) in December 2005. Other manufacturers have made versions of their modelling systems available with the OpenMI interface. Before these releases, numerous tests of the interface were carried out using these modelling products. While these were tests of the interface itself, the software developers and modellers carrying out the tests found that they immediately learned much about integrated modelling itself. They also realized that there is a lot more to learn !

The very first tests involved splitting a simple Isis flow channel (a river) in two and passing a wave up and down the channel. While in some ways this is a simplistic test, it immediately shows up any errors in the implementation of the interface. The wave should move smoothly and continuously back and forward across the boundary between the two sub-models: and indeed it did, across the two-way OpenMI boundary.

One major test was to simulate the analysis of a "typical" water framework directive problem. The catchment had several upstream rural areas, feeding into a river. A major city drained through its wastewater treatment plant into the river, and the river flowed into a lake. Another city drained to the lake and the lake had outflow into another river. The test was to integrate models that might be used to analyse the causes of intermittent fish kills found in the lower river. It should be possible to use an integrated set of models to help track down whether the cause of the kills was water quality problems that stemmed from the lake, the river itself, the urban areas, or from upstream diffuse pollution.

The test incorporated eleven different models, of six different processes, from four different suppliers: Wallingford Software (InfoWorks CS, InfoWorks RS), Delft Hydraulics (Sobek) and WRc (STOAT). The models represented flow and water quality through the upstream areas, the rivers, the urban areas, the treatment works and the lake. It was important to integrate models from different manufacturers, in case any one manufacturer had made erroneous assumptions in their use of the standard interface. This would show up as data errors across the interfaces.

Wallingford Software has made further tests by integrating InfoWorks CS sewer models with InfoWorks RS river channel models. They have also integrated quasi-2D (flood cell) and 2D finite difference models of urban flood flow with InfoWorks CS sewer models.

It is clear that there would be much to learn by incorporating gridded groundwater models in the wide-area catchment test and in the urban flood tests. A suitable groundwater model with an OpenMI interface was not available at the time of these tests. There is now an OpenMI-compliant version of the MODSIM groundwater modelling software. It is anticipated that this will be incorporated with other model types in the future.

The tests described here, and the many others carried out, were all aimed at ensuring that OpenMI was fit for purpose and ready to be released. A European partnership has now applied for EU funding to go way beyond this, and to test the whole concept of integrated modelling as part of integrated catchment management within two river basins: the Scheldt in Belgium and Holland, and the Pinios in Greece. Models that were created for singular use will be integrated via OpenMI and put to use to answer common catchment planning problems. This will include InfoWorks CS sewer models and InfoWorks RS river models. The decision on funding for this project is expected shortly.

5. CONCLUSIONS

The OpenMI standard and initial implementation has been released and is freely available. Numerous modelling system developers have already incorporated it to make their systems OpenMI-compliant. The OpenMI interface has been tested by linking different combinations of models that were built using these systems. OpenMI has been specified as a standard for integration by some European organisations. Some major projects are actively using it for integration. The OpenMI Association has been formed and is already planning future releases of OpenMI. Yet the author asserts that we are only at the beginning of the introduction of integrated modelling: we still have a lot to learn and commercial tools for professional modellers are not yet fully developed. However, it is fully expected that wastewater modellers will be able to use integration as a means of bringing their own professionalism to the broader field of integrated catchment modelling, so opening up new opportunities.

6. ACKNOWLEDGMENTS

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