The OpenMI Document Series

Scope

For the OpenMI (Version 2.0)

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Preface

This document provides an overview of the OpenMI – the Open Modelling Interface – which aims to deliver a standardized way of linking environmental related models. The OpenMI is supported and maintained by the OpenMI Association.

This is the first document in the OpenMI report series, which specifies the OpenMI interface standard, provides guidelines on its use and describes software facilities for migrating, setting up and running linked models.

Titles in the series include:

- **Scope** (this document)
- The OpenMI 'in a Nutshell'
- OpenMI Standard 2 Reference
- OpenMI Standard 2 Specification

The OpenMI is maintained by the OpenMI Association and this document, along with other more detailed documentation, can be obtained from www.openmi.org.

The official reference to this document is:

The OpenMI Association (2010) *Scope for the OpenMI (Version 2.0)*. Part of the OpenMI Document Series

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Acknowledgement

The OpenMI Association's members would like to acknowledge the contribution of the European Commission in co-funding the HarmonIT and OpenMI-LIFE projects. In particular, we would like to thank the Commission's staff for their sustained encouragement and support over many years.

Further information

Further information on OpenMI-LIFE can be found on the project website, www.OpenMI-Life.org.

Information on the OpenMI Association and the Open Modelling Interface (OpenMI) can be found on www.openmi.org.

Contents

1 Introduction

The OpenMI standard defines an interface that allows models from different vendors to exchange data at run-time. When the standard is implemented, existing models can be run simultaneously and share information as required. This is the key to making model integration feasible at the operational level. Model integration helps the understanding and prediction of process interactions and is an essential capability for the achievement of the integrated approach to environmental management, including integrated water management as called for in the Water Framework Directive.

1.1 The need for the OpenMI

The *Water Framework Directive* (WFD) calls for *integrated water management* to be put into practice and identifies *whole catchment modelling* as a key part of integrated management. The challenge that this presents is not only that individual catchment processes be modelled but also their interactions. Constructing a single model of all catchment processes is not a feasible option, does not make good use of existing models and doesn't provide the flexibility to try alternative models of individual processes. The only realistic mechanism for whole catchment modelling is *integrated modelling*. This approach links models of different processes and hence allows process interactions to be simulated.

Until a few years ago, no generic operational linking mechanism had been developed. However, technological advances in computing, the impetus provided by the Water Framework Directive, co-funding from the European Commission and support from the leaders of earlier attempts enabled the FP5 project *HarmonIT* to develop the *Open Modelling Interface* (the *OpenMI*). The *OpenMI* is a standard interface that enables OpenMI-compliant components to exchange data as they run. The *OpenMI Environment* comprises a set of software tools. They help make new and existing model code *OpenMI-compliant* and they offer facilities to combine OpenMI-compliant components into integrated modelling systems and then run them.

A linkage mechanism, such as the OpenMI, is the key to moving single domain modelling to integrated modelling and integrated modelling from a research exercise to an operational task. It will allow for integrated water management to be put into effect and, hence, the objectives of the WFD to be achieved.

However, the OpenMI architecture does not limit its applicability to the water domain. It can be applied in many more domains, although its base will remain the environmental domain where temporal and spatial variability are key issues in understanding and managing systems.

After six years' development work, testing and review, the OpenMI is now widely accepted as the way forward. Evidence for this view can be found in the number of FP6 projects that use the OpenMI, the interest in and use of the OpenMI by universities and software developers in Europe and the US, and the competent authorities that use, intend to use or are interested in using the OpenMI. Hence, the founders of the OpenMI believe they have created a software architecture that, by its high quality, will become the European and global standard for linking models from the water domain and, later, other environmental domains.

However, adopting the OpenMI requires model developers to make a commitment. Most organizations cannot afford to make that commitment until the OpenMI is widely available in a number of implementations and is properly supported – in other words it becomes a well-maintained standard. Therefore, the OpenMI Association has being created to support the user community and sustain the OpenMI into the future.

1.2 Aims and objectives

The aim of the OpenMI is to provide a mechanism by which physical and socio-economic process models can be linked to each other, to other data sources and to a variety of tools at run-time, hence enabling process interactions to be better modelled.

Specific objectives are that the mechanism's design should:

- Be applicable to new and existing models
- Impose as few restrictions as possible on the modeller's freedom
- Be applicable to most, if not all, time-based simulation techniques
- Be capable of accepting different data sources, e.g. databases or GIS data
- Require the minimum of change to the program code of existing applications
- Keep the cost, skill and time required to migrate an existing model to a minimum so that these factors are not a deterrent to the OpenMI's use
- Be easy to use
- Not unreasonably degrade performance

1.3 Why should organisations adopt the OpenMI?

The discussion above has explained the need for the OpenMI that has been created by the adoption of the WFD. What benefits does it bring to the designated authorities, basin managers, regulators, consultants, modellers and model developers responsible for implementing the WFD? Some of the arguments for adopting the OpenMI put forward by organizations that have already adopted or are considering adopting the OpenMI are:

- Protection and enhancement of existing investment in model development (i.e. it is not necessary to rewrite them completely in order for them to become OpenMI-compliant)
- The simplification of the model-linking process, leading to an improved ability to model process interactions
- The ability to use appropriate model combinations and to swap between different models of the same process, assisting sensitivity analyses and benchmarking
- A reduction in development time and hence cost for decision support systems
- An increased choice for model users, in that they will be able to 'mix and match' models from different sources
- Increased opportunities for model developers, in that individual models become more saleable because they can be linked to established systems, enhancing the value of both
- Increased opportunities for the creation of Small and Medium Enterprises (SME), especially from the academic sector

- Increased opportunities to contribute to the implementation and evolution of EU policies
- The opportunity for model developers to concentrate their core business (e.g. computational cores) because they will be able to buy in OpenMI-compliant tools such as GUIs and post-processing tools
- The availability of the OpenMI Environment tools for migrating and linking models and monitoring linked model runs (which are available free under an Open Source licence and would otherwise have to be written by the developer)
- The small cost of conversion compared with the cost of writing a whole catchment model from scratch or redeveloping existing models
- The ability for model users to run third-party computational cores in their own environments
- No need to understand other organizations' I/O procedures
- The ability to change a model's code without affecting the linking process or interface

1.4 The development process

1.4.1 The HarmonIT project

The first version of the OpenMI was developed by a team drawn from 14 organizations and seven countries co-funded through the European Commission's Fifth Framework programme under contract number EVK1-CT-2002-00090 (the HarmonIT project). Led by the Centre for Ecology and Hydrology, the team comprised the Institute for Inland Water Management and Waste Water Treatment RIZA, DHI Water and Environment, WL Delft Hydraulics, HR Wallingford Group, Universitat Dortmund, Instituto di Ricerca Sulle Acque, the National Technical University of Athens, WRc plc, DHI Hydroinform a.s., Povodi Labe s.p., Hydroprojekt a.s., Alterra B.V. and the Centre National du Machinisme Agricole, du Genie Rural, des Eaux et des Forets.

Design and development was conducted in an incremental way taking use cases as a basis for iterative development. The development was primarily been undertaken by the three major commercial model developers, DHI Water and Environment, Delft Hydraulics and HR Wallingford. The role of the other organizations was to manage the project, to support the design and development, and to test the standard and environment rigorously.

To ensure that the work met the standards required by the Commission and the scientific and user communities, a panel of experts comprising leading scientists from around the world reviewed all key documents and advised the Steering Committee. The project's quality assurance plan established procedures for the critical areas of work and covered document and code version control.

1.4.2 The OpenMI-Life project

To turn the OpenMI from a research outcome into a sustained standard for operational practice, a second project was initiated under the policy area "Sustainable management of ground water and surface water management" of the European Commission's LIFE Environment programme (Contract no: LIFE06 ENV/UK/000409). Led by the Centre for Ecology and Hydrology, the team comprised the Institute for Inland Water Management and Waste Water Treatment DHI Water, Environment and Health, WL Delft Hydraulics, Wallingford Software Ltd., National University of Athens, RIKZ, Aquifin, Vlaamse Milieu Maatschappij, MM, Flanders Hydraulics, Université de Liège, and University of Thessali.

The objective of this project was to set up a structure for support, maintenance and dissemination of the OpenMI (i.e. the OpenMI Association), and to apply the OpenMI in the Scheldt and Pinios basins to prove that OpenMI can assist competent water authorities in joint model integration to achieve the objectives of the Water Framework Directive.

The technical work concerning the maintenance and improvement of the OpenMI has been being conducted by many of the same team as in the HarmonIT project, and carried out in a similar way to that project.

1.4.3 Other projects

The OpenMI is being used by various other projects, both EU funded and nationally funded. So far, few projects (e.g. Seamless) provide feedback to improve the OpenMI technology, although all contributions are welcome.

2 Overview of the OpenMI

This section describes the main requirements of the OpenMI, the scenarios against which the standard was tested and the functions of the OpenMI interface.

2.1 Requirements

To be useful, the OpenMI must be able to link any models whose interactions need to be simulated in carrying out the requirements of the Water Framework Directive. Therefore, the key requirements of the OpenMI are to:

- Link models from different domains (hydraulics, hydrology, ecology, water quality, economics etc.) and environments (atmospheric, freshwater, marine, terrestrial, urban, rural etc.)
- Link models based on different modelling concepts (deterministic, stochastic, static etc.)
- Link models of different dimensionality (0, 1, 2, 3D)
- Link models working at different scales (e.g. a regional climate model to a catchment runoff model)
- Link models operating at different temporal resolutions (e.g. hourly to monthly or even annual)
- Link models operating with different spatial representations (e.g. networks, grids, polygons)
- Link models using different projections, units and categorizations
- Link models to other data sources (e.g. databases, user interfaces, instruments)
- Link new and existing (legacy) models with the minimum of re-engineering and without requiring unreasonably high level IT skills
- Not impair performance, especially of large models
- Be based on proven and available technologies (and, in particular, the architecture must be component-based and multi-layered)
- Link models running on different platforms (e.g. Windows, Unix and Linux)
- Be ‘open’ (the interface specification should be placed in the public domain)
- Allow components to be developed using at least the following programming languages: C/C++, C#, Fortran, Delphi/Pascal, Java and Visual Basic.

The remainder of this section shows how these requirements have been met.

2.2 Use cases

To check that the requirements were correctly expressed and to ease the development of an architecture for the OpenMI, a range of scenarios or 'use cases' were identified. Some examples from the full list of cases are shown below:

- Connect two 1D hydrodynamic river models.
- Connect a 1D hydrodynamic model with a water quality transport model.
- Connect a 1D river model with a 3D groundwater model.
- Connect a 1D hydrodynamic river model to vegetation and habitat models.
- Connect a 3D coastal model to a 1D river model.
- Connect a 2D polygon-based root zone model to a 3D regular grid groundwater model.
- Calibrate a rainfall runoff model linked to a hydrodynamic sewerage model.
- Model the propagation of uncertainty through a chain of models.
- Use different units of measurement for the data to be exchanged between models.
- Connect to an agent-based model.

For version 2.0 development, a new set of use cases was defined to prove extension of the functionality and usability:

- A constant value provider (e.g. the value 7.1) .
- Zero-dimensional component (typically a time series or a collection of time series). Such components may or may not have any spatial location.
- GIS-type components (e.g. a polygon and associated values). Such components may or may not have a time dimension.
- Analytic function – f(x,y,z,t). Components based on analytic functions may have both time and space or only one of these. However, what makes such components special in relation to the OpenMI is that data is not represented beforehand on any discrete geometry (e.g. grid) or at any specific timestamps or time spans.
- Database or other simple data providers. These are different from models because access is available to all data at any time, compared to models where it may not be possible to request data earlier than the current timestep.
- Optimizers and scenario managers.

2.3 Terminology

A number of terms are used when describing the OpenMI standard.

As shown in Figure 1, the term *model application* encompasses all parts of the modelling system software that is installed on a computer: for example Mike11, PHABSIM and InfoWorks-RS.

Typically, such systems consist of a *user interface* and an *engine*. Usually, the engine is a generic representation of a process and this is where the calculations for simulating or modelling that process take place. The user supplies information through the user interface and this is converted into the input data for the engine.

The data describes a specific scenario in which the process is to be simulated: for example the Rhine during a time of extreme rainfall. The user runs the engine by selecting an option or pressing a button on the user interface. The engine reads the input, performs the calculations and outputs the results to files or displays.

When an *engine* has read its input it becomes a *model*. For example, an engine may represent the generic process of water flowing in an open channel. When it has read in the data describing the channel network of the Rhine, along with any boundary conditions and rainfall data, it becomes a model of the Rhine in the scenario to be simulated.

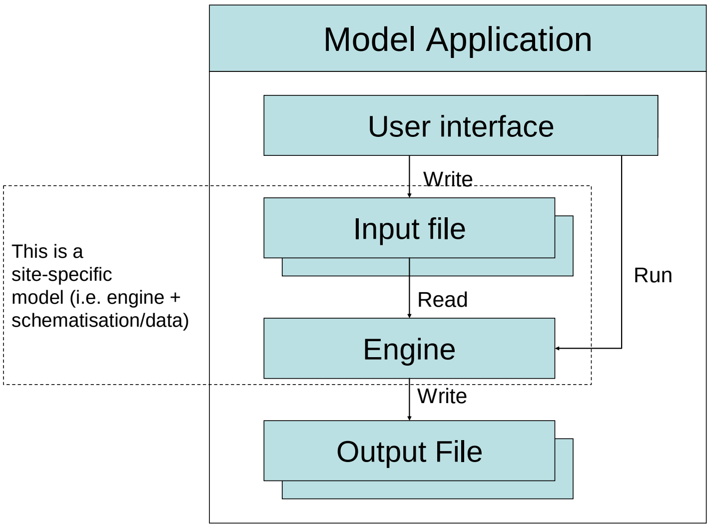

Figure 1 The general structure of a model application

If the code for an engine can be instantiated separately and has a well-defined *interface* through which it can *accept* and *provide* data, then it is an *engine component*. (The engine's *interface* is the part of the code that handles the transfer of data to and from the engine; it should not be confused with the *user interface*, which is the part of the application that the user sees.) The key to enabling models to exchange data lies in standardizing the design of the engine interface. When an engine component implements such a standard interface, it becomes a *linkable component*. An engine that implements the OpenMI interface is called *OpenMI-compliant.*

2.4 The OpenMI standard interface

The OpenMI defines a standard interface that has three functions:

- *Model definition*: To allow other linkable components to find out what items this model can exchange in terms of quantities simulated and the locations at which the quantities are simulated.
- *Configuration*: To define what will be exchanged when two models have been linked for a specific purpose.
- *Run-time operation*: To enable the model to comsume or provide data at run time.

Figure 2 shows two model applications whose engines have been made OpenMI-compliant. Their overall structure remains unchanged but each engine is now a component with an OpenMI interface and one component can now get values from another.

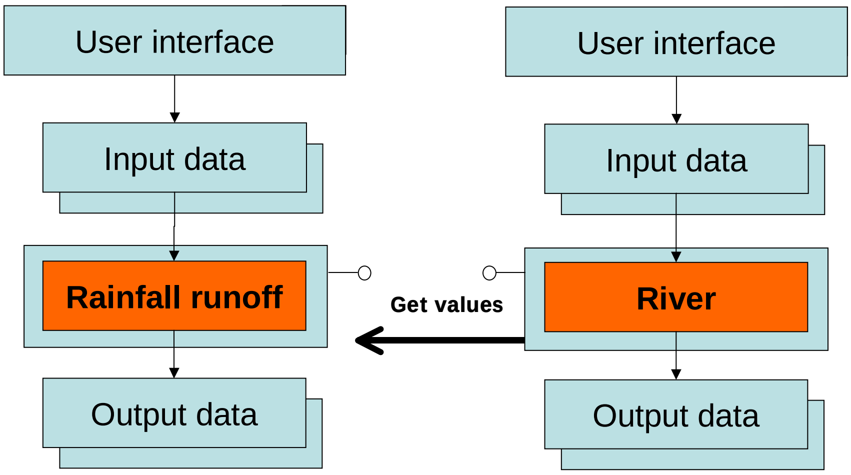

Figure 2 Two applications after migration to the OpenMI standard

Figure 3 illustrates some of the information held in the model definition about the quantities that two models can either accept or provide. The arrow represents a link between the two models and indicates that, in this particular case, runoff produced by the Rainfall Runoff Model will be used to represent lateral inflow in the River Model. There is no requirement to harmonize the terminology; the linking process creates the appropriate cross-reference table.

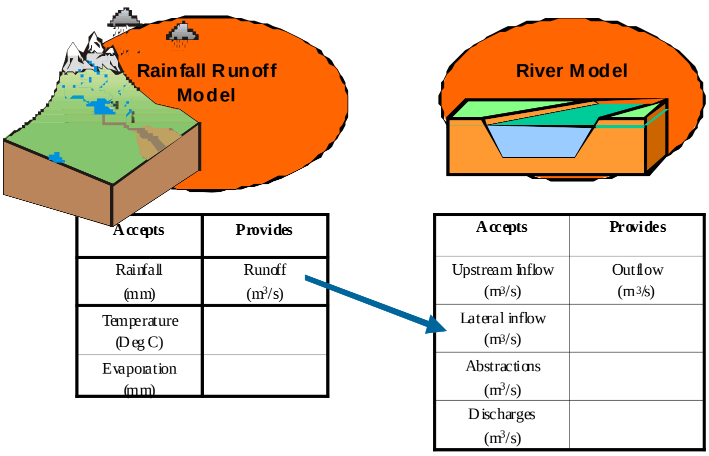

Figure 3 Showing and linking quantities

Figure 4 shows the geographical matching of elements in a river model to those in a groundwater model. The river model is a vector model and each single stretch represents an element; the groundwater model is grid-based, each node in the grid being an element. Therefore, in order to link the two models, each element in the river model will usually be linked to several elements in the groundwater model. In any non-trivial situation, this will require the matching of thousands of elements and therefore the process is automated.

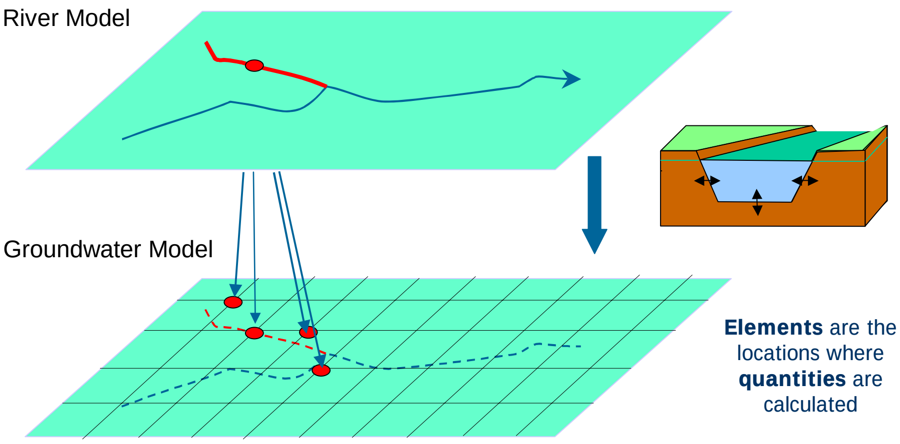

Figure 4 Linking element sets

2.5 An interface-based open standard

The OpenMI provides an intelligent mechanism whereby models running simultaneously can exchange data at runtime. It thus enables process interaction to be represented more accurately than is possible by sequential linkage. It is important to explain that the OpenMI is *neither* a common data-model specification *nor* is it an integrated modelling system.

The OpenMI is 'interface-based':

- Its ‘standardized’ part is defined as a software interface specification.
- This interface acts as a ‘contract’ between software components.
- The interface specification is not limited to specific technology platforms or implementations.
- The interface implementation may be limited by the technology supported in a specific release[1].
- By adopting the implemented interface a component becomes an OpenMI-compliant component.

The OpenMI is ‘open’:

- Its specification is publicly available via the Internet (www.openmi.org).
- Its source code is open and available under Lesser GPL licence conditions.
- It enables linkages between different kinds of models, different disciplines and different domains.
- It offers a complete metadata structure to describe the numerical data that can be exchanged in terms of semantics, units, dimensions, spatial and temporal representation and the conversions that are available.
- It provides a means to define exactly what is linked, how and when.
- Its default implementation and software utilities are available under an open source software license.

The OpenMI is a ‘standard’:

- It standardizes the way data transfer is specified and executed.
- It allows any model to talk to any other model (e.g. from a different developer) without the need for co-operation between model developers or close communication between integrators and model developers.
- Its generic nature does not limit itself to a specific domain in the water discipline or even in the environmental discipline.

Note that the OpenMI enables validation by dimension checks on the quantities linked. However, the OpenMI cannot guarantee that the representation of the process in the component or the link to another component is scientifically valid. That is the responsibility of the modeller, model integrator and user.

[1] The technology chosen for Release 2.0 is version 3.5 of the .NET framework, and version SE 6 of Java.

3 Products

A range of products is available for the OpenMI. Products have been developed and delivered within the HarmonIT project, the OpenMI-Life project and various other EU research projects.

3.1 OpenMI software releases

The official release of the OpenMI is Release 2.0 (November 2010). A variety of other releases exist in .NET and Java. They are not considered official releases as incompatibility problems exist when using those releases in combination.

The official release consists of the items below.

3.1.1 The OpenMI standard interface

The OpenMI standard interface defines the interface that an engine component must provide for it to be OpenMI-compliant. Both the paper specification and a software implementation have been placed in the public domain and may be found on the OpenMI website at www.openmi.org.

The OpenMI standard interface version 2.0 is available as a compiled .NET assembly with namespace OpenMI.Standard2, for.NET framework version 2.0. The assembly is compiled with Microsoft Visual Studio 2008 and protected by a private signature file.

This .NET assembly is leading over any other implementation based on the paper specification.

3.1.2 The OpenMI Software Development Kit

The OpenMI 2.0 Standard release will be followed by the release of the OpenMI Software Development Kit (SDK), software that assists in the implementation of the standard. The OpenMI 2.0 SDK includes the compiled .NET assemblies, the source code of all packages and their documentation. The software will be released under Lesser GPL license conditions and will be available on www.openmi.org and www.SourceForge.net/projects/OpenMI.

The Software Development Kit contains:

- a base implementation of various interfaces in the standard
- functionality for buffering and interpolating data
- different kind of spatial representations
- tools for easing development

3.1.3 The OpenMI Graphical User Interface

The OpenMI 2.0 Standard release will be followed by the release of the OpenMI Graphical User Interface, software that supports the configuration of linked components. The OpenMI version 2.0 GUI release includes the compiled .NET assemblies, the source code of all packages and their documentation. The software will be released under Lesser GPL license conditions and will be available on www.openmi.org and www.SourceForge.net/projects/OpenMI.

3.1.4 The OpenMI documentation

All aspects of the OpenMI are documented in the OpenMI report series, comprising the following titles:

- **Scope** (this document)
  A decision maker's document: describes the scope of the OpenMI architecture and the organization behind it.

- **OpenMI 'in a Nutshell'**
  A developer's manual: describes how to migrate, link and run OpenMI-compliant models. The document includes sample code and tutorial examples.

- **OpenMI Standard 2 Reference**
  A software technical document: describes the interfaces of the OpenMI.Standard2 namespace. The specification is expressed in Universal Modelling Language (UML) and in API terms. This specification has to be adopted for a component to become OpenMI-compliant.

- **OpenMI Standard 2 Specification**
  A software technical document: describes the SDK content and its default implementation (i.e. the classes that implement the OpenMI.Standard2 interface). This implementation is the basis of the OpenMI environment.

3.2 Future services

The OpenMI is on its way to becoming a global standard for model linkage and data exchange in the environmental domain. To support and maintain the OpenMI, and to stimulate development and increase its wider use in practice, an association has been established under Dutch law: the OpenMI Association.

The association is a membership-based organization that manages the future maintenance and development of the OpenMI as a worldwide-applied software standard for model linkage in the water and other environmental domains.

In addition, the Association stimulates the use of the OpenMI and it disseminates information on the OpenMI through its website.

More information on the OpenMI Association, and its membership, is available at www.openmi.org.