The Use of OpenMI in Model Based Integrated Assessments

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EXTENDED ABSTRACT

Integrated policy assessments are tools to find out whether, why and how policies are developed and what the possible options for these policies are. Performing an integrated assessment involves determining the economic, social and environmental impacts of these options. In model based integrated policy assessments, there is a need for linking models and data from different domains.

The OpenMI (Open Modelling Interface and Environment) provides a blue print captured in a standardized set of interfaces to describe, link and transfer numerical data between models on a time step basis. It is an interfaced based open standard that enables simulation models of environmental and socio-economic processes to be linked.

Although the original focus of the OpenMI was on hydrological models, it could (and wishes to) grow into a standard for the mentioned environmental and socio-economical domain. Having a single standard for model integration, instead of inventing new "standards" all the time would be beneficial. Using OpenMI in some of the EU 6th framework program projects for integrated assessment can serve as catalyst for the further development of OpenMI into these other domains.

To successfully use the OpenMI standard for these integrated assessment projects, requirements from the applicable other domains need to be included. This paper will describe some of those requirements both from a modeller's and a policy evaluator perspective.

Based on an internal working copy of the Java version of OpenMI the required conceptual and technical changes have already been implemented and tested. At the moment an organizational process is taking place to see how the OpenMI Association, that governs the development of the OpenMI standard, can support these modifications. This is ongoing and beyond the scope of this paper.

1. INTRODUCTION

The Open Modeling Interface and Environment (www.openmi.org) has been developed from the need to answer integrated hydrological catchments management questions within the EU 5th framework program project HarmonIT. The main objective of the HarmonIT project was to provide a widely accepted unified method to link models, both legacy code and new ones (Gijsbers *et al*, 2002). The Open Modeling Interface and Environment (OpenMI) provides a standardized interface to define, describe and transfer data between software components that run sequentially, based on a *pipes and filters architecture* (Gregersen *et al*, 2007) .

Since the release of the OpenMI in early 2006 the environmental domain adopted the OpenMI within several European Projects. For example:

- SEAMLESS – assess agricultural and agro-environmental policies;
- SENSOR – assess sustainability impacts of land use related policies;
- NitroEurope – assess the effects of reactive nitrogen in the environment;
- EFORWOOD – assess sustainability impacts of European forest wood chains, which are influenced by policy, market drivers and technological innovations.

These projects have a strong integrated character: environmental, social and economic dimensions are taken into account to do an ex-ante integrated assessment. An integrated assessment (IA) can be defined as an interdisciplinary process of combining, interpreting and communicating knowledge from diverse scientific disciplines in such a way that the whole cause–effect chain of a problem can be evaluated from a synoptic perspective with two characteristics: (i) it should have added value compared to single disciplinary assessment; and (ii) it should provide useful information to decision makers (Rotmans and Dowlatabadi, 1997).

The European Commission provides guidelines on impact assessments. An impact assessment is an EU tool to find out whether, why and how the EU should develop policies and what possible options for these policies are (figure 1). Doing an IA involves answering a number of basic analytical questions: What should be the objectives pursued by the Union? What are the main policy options for reaching these objectives? What are the likely economic, social and environmental impacts of those options? What are the advantages and disadvantages of the main options? (European Commission, 2005).

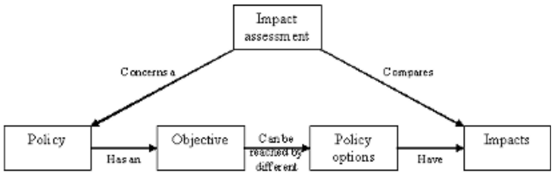

Figure 1 – Impact assessment

Progress towards a policy objective is measured by indicators, where indicators are tools that synthesise or simplify relevant data relative to the state or evolution of certain phenomena. They are tools for communication, evaluation and decision making that can take quantitative as well as qualitative form depending on the purpose of the indicator (Gallopin, 1997). E.g. when the objective is to increase the share of renewable energy the policy option could be to increase the subsidy on bio-fuels. The impact could be measured by: i) economical growth in rural areas; ii) loss of habitat due to land use change from fallow land to rapeseed and iii) decrease of the unemployment rate.

The nature of these projects and the models and tools involved are (partly) different from the ones the OpenMI was originally designed for. The following gives an overview of the current OpenMI standard, the additional and specific requirements from the environmental projects mentioned, and a proposed adapted design of parts of the OpenMI to meet them.

2. OPENMI (VERSION 1.2)

The OpenMI is constantly under development under supervision of the OpenMI Association. The OpenMI Association is the organisation responsible for the development, maintenance and uptake of the OpenMI. The OpenMI standard described within this paper concerns the current 1.2 version which is available for the Microsoft .Net and SUN Java programming environments.

The OpenMI provides a standardized interface to define, describe and transfer (numerical) data between software components. The data definition concerns what the data is about (*quantity*) and where (*element set*) and when (*time*) it applies. Each component (*LinkableComponent*) has a meta data description of its exchangeable data in terms of a *quantity* and an *element set.* Each unique exchangeable *quantity* is registered and published in a so-called *ExchangeItem*. Connections between *ExchangeItems* of *LinkableComponents* are defined by a *Link* and exist as a separate entity (Figure 2). For more information see http://www.openmi.org.

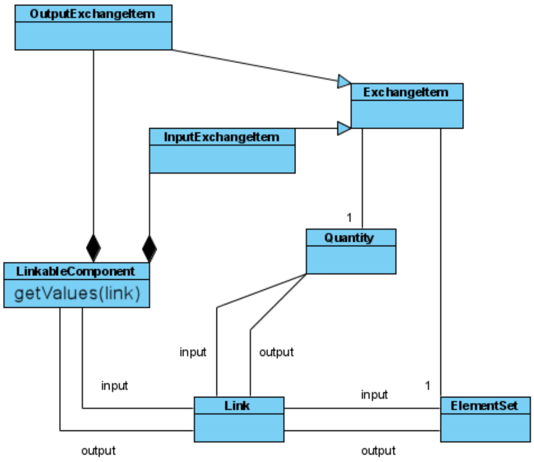

Figure 2 – simplified class diagram of LinkableComponents and Links

The OpenMI is a pull-based system (a pipes & filters architecture). Figure 3 shows how the chain of *LinkableComponents* is triggered (step 1) by a successive call of the *LinkableComponent* method *getValues()* (step 2 and 3) after which values are returned to the original caller (step 4 and 5).

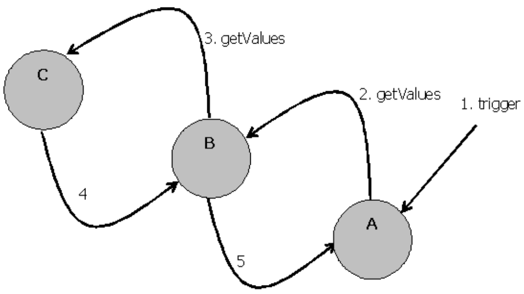

Figure 3 – Call chain of LinkableComponents

3. ENVIRONMENTAL MODELS

The environmental projects concern the calculation of indicators based on drivers, such as: market drivers, technological innovations, policy, or management measures (figure 4). Indicators concern both quantitative and qualitative level of measurement.

3.1. Types of Data

The level of measurement of a variable in mathematics and statistics is a classification to describe the nature of information contained within numbers assigned to objects and, therefore, within the variable (Wikipedia: level of measurement, 2007). An example of a quantitative indicator is 'gross domestic product' expressed in euros. Qualitative indicators distinguish between nominal and ordinal units of measurement. Examples of nominal respectively ordinal indicators are: i) 'land use' in terms of {agriculture, urban, forest} and ii) 'social cohesion' in terms of {decrease, stable, increase}.

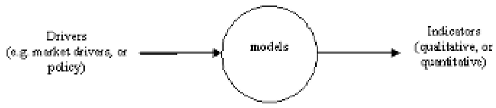

Figure 4 – Driver based indicator calculation .

The nature of the models within these projects vary from complex simulation models like Capri for agri-economics (Britz *et al*, 2003), Clue for the conversion of land use (Kok and Veldkamp, 2000) and EfiScen for forest resource projections (Lindner *et al*, 2002) to the Integrator meta model for nitrogen related measures and their effects (de Vries et al., 2007) and knowledge rule based models (Roos-Klein Lankhorst *et al*, 2004).

3.2. Transparency and Back Tracking

The European Commission stresses the importance of transparent assessments. Model transparency is often realized by documentation and publications. Within some models, however, back tracing of calculations can be realized within the software itself. Back tracing shows how and with which assumptions calculations have been carried out.

3.3. Higher Order Links

The amounts of *links* between two models vary; from a single up to hundreds of *links*. A *link* describes one semantic connection concerning what variable is exchanged between the models and at what (real world) location the exchange takes place (Gregersen, 2007). Variables that logically fit together need to be split as a link concerns a single variable. In many cases the different connections concern the same (real world) location and are often used in conjunction with each other in the calling model. To get any number of variables from a model, it needs to be called for each of these variables. It is up to the internal intelligence of the model to avoid unnecessary (re)calculations (e.g. by using some caching system).

Allowing a *link* to concern multiple variables simplifies the use of that *link* within a call for variable values. Links could also be given more functionality, but there should stay a clear distinction between functionality of a *link* versus that of a *LinkableComponent*.

3.4. Keep Location with the Result

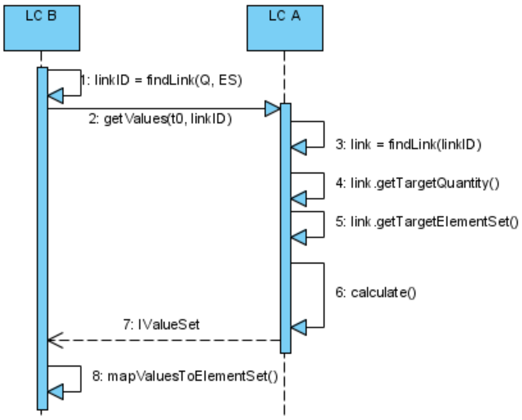

Figure 5 – Use of getValues method

Figure 5 shows how the *getValues()* method is used to acquire calculated variable values from a *LinkableComponent*. Here the target linkable component (LC B) needs results from the source linkable component (LC A). With the current OpenMI, first it needs to determine which link provides the required quantity (Q) and element set (ES). The ID of the link can then be used to request the data from LC A. This source linkable component can in turn determine what values are requested by retrieving the link and examining it to get the variable and (real world) locations again. After calculation the component returns the result as a list of values. Each value relates to one (real world) location (matching the elements in the element set). The value list itself, however, does not hold a reference to the (real world) coordinates and the variable concerned. If the caller model wants to have this information it needs to take care of this administration itself (again, step 8). Including both the (real world) location (where) and the variable (what) information within the returned list of values (e.g. as metadata) would simplify the use.

3.5. Multiple Outputs to one Input

An *ExchangeItem* (chapter 2) holds meta information concerning what can be exchanged. An input gets its values from a single output, while an output can go to multiple inputs. Within the EFORWOOD project (EFORWOOD, 2005) *LinkableComponents* represent processes that transform wood products into other wood products (e.g. pine timber into pieces of furniture). The *InputExchangeItems* of the *LinkableComoponent* define the required different types of wood products, while the *OutputExchangeItems* define the different produced wood products.. Different products can not only come from different sources, but equal input products can come simultaneously from different delivering processes: a single input can get its values from multiple outputs.

3.6. Additional Requirements

The following list sums up the additional requirements for the OpenMI derived from the environmental projects, as illustrated in the previous paragraphs:

- Support for qualitative data description.
- Support for qualitative data exchange.
- Allow exchange of complex data over a single link, have higher order links.
- Be able to describe complex data for a single exchange item (not only a single quantity).
- Support for multiple input links on a single input exchange item.
- A standard (supplemental) interface for linkable components that support back tracing.
- Inclusion of the data description (‘what’) and location (‘where’) in the calculation results (‘values’).

4. PROPOSAL FOR CHANGE

Alterra, in cooperation with partners of the mentioned EU projects, has already implemented many of the requirements outlined in the previous chapter in its Java “incubator” version of the OpenMI. Some workable designs and solutions exist, however they need further detailing and hopefully be made part of the official OpenMI standard.

4.1. Qualitative Data

To enable the meta information (‘what’) to store qualitative information the abstract notion of *DataType* is introduced (Figure 6). With this abstraction also future extensions such as stochastic and fuzzy data can be designed and implemented.

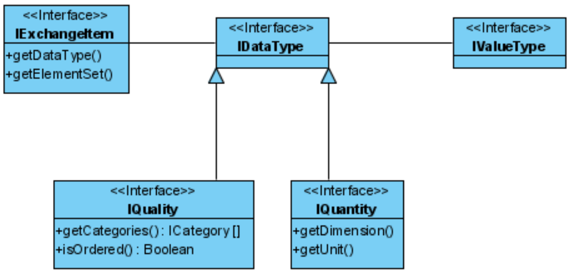

Figure 6 – Qualitative data description

This could even be taken a step further by "externalizing" the notions of qualities and quantities and just describing how this semantic information is to be retrieved. To illustrate this (based on current SEAMLESS development) a class could be annotated (a programming concept of the Java language) with a reference to meta data stored in an ontology.

```
@ConceptURI("http://localhost/ontologi
es/crop.owl#Crop")
public class Crop …
```

Exchange items could then directly use these annotated classes and retrieve the meta data by reflection, like:

```
type.getAnnotation(ConceptURI.class)
```

For qualities and quantities existing ontology could be used, instead of hard coding own definitions into the OpenMI standard.

4.2. Multiple Outputs to one Input

A *Composition* (from the OpenMI Java Edition Version 1.2) is a chain of *LinkableComponents*, which are connected via *Links* (Knapen *et al*, 2006). A composition has a method *canConnect* to decide whether a connection between pairs of *quantity – element set* can be made. The behaviour is generic for all *LinkableComponents* and *Links*. To be able to support multiple input links on an *InputExchangeItem* this functionality has to be moved to the *InputExchangeItem* itself (figure 7). The default implementation of the *canConnect* method in the *ExchangeItem* class behaves like the current implementation from the *Composition* class, but can be overridden for specific implementations like the support of multiple input links in an *InputExchangeItem*.

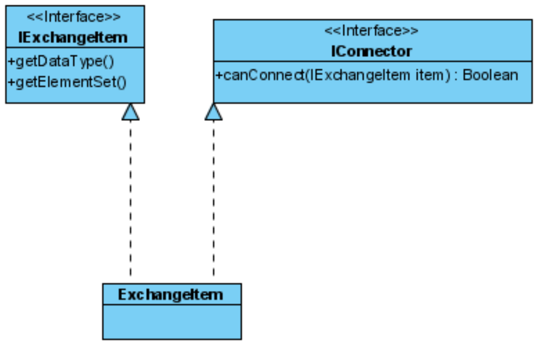

Figure 7 – Connector interface

4.3. Keep Location with the Result

A calculation result is returned as a *ValueSet*. Within OpenMI version 1.2 a *ValueSet* is a container for a list of values. This container does not hold any descriptive ('what') and location ('where') information, but is expected to contain as many values as the caller requested. Figure 8 shows how descriptive and location information can be added to a *ValueSet*.

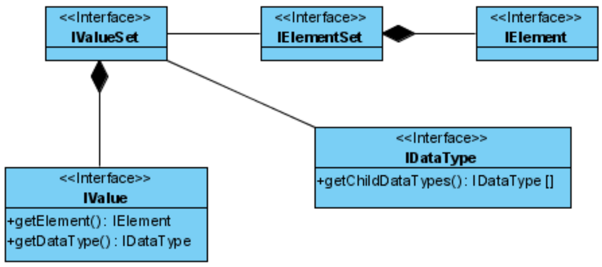

Figure 8 – Descriptive and location information within a ValueSet

4.4. Complex Data

Each *value* corresponds to an *element*, in which a value can be a composite data structure (Gamma *et al*, 1998) as implemented in the OpenMI *ResourceSet*. In theory each value has a different data structure. E.g. if a model would calculate indicators per region, the indicators could vary per region. Then to be self descriptive a value needs a reference to its composite *DataType*.

5. CONCLUSION

The OpenMI is constantly under development under supervision of the OpenMI Association. For the use of OpenMI in Model based integrated assessments in the agricultural and environmental domain, there is a need to change and extend the standard. The main additional requirements are:

- Support for qualitative data exchange.
- Be able to describe complex data for a single exchange item (not only a single quantity).
- Support for multiple input links on a single input exchange item.
- A standard (supplemental) interface for linkable components that support back tracing.

Alterra, in cooperation with partners of the mentioned EU projects, has implemented many of these requirements and brings this in the OpenMI association to discuss whether this can become part of the official OpenMI standard.

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