Modelling Environments and Use of Service Infrastructures

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EXTENDED ABSTRACT

Significant developments in both theory and application have been occurring in the areas of environmental information infrastructures and modelling environments for natural resource applications. These two areas share many common functions although, at present, coordination and integration of these has not occurred to any great extent. Models of environmental phenomena are a key tool for decision makers. However, if they are going to be used regularly and developed beyond their initial construction by a researcher or a consultant, they need to be integrated with the work environment of end users. This is where the integration with existing information systems and yet to be built cross-boundary information infrastructures comes in.

The needs of modelling systems for connection to data, connection to sensors and sensor networks, model and data updating, state updating and model deployment indicates an imminent need for integration of modelling environments and environmental models with day-to-day workflows of end users in environmental administrations, and with environmental information infrastructures under construction.

The proposed approach, shown in Figure 1, aims to broaden the concepts of modelling as a service via the use of service-based environmental information infrastructure. In this approach data retain their traditional position as base requirements for modelling, although access to data and updating of data sources (e.g. based on availability) and supply of data is done across a distributed information system. Sensors provide a key role in this as direct providers of data to models, and also as indirect contributors to the store of data available in an information system. In an extension of this concept, component models become another service that is provided, with modellers selecting models and creating model instances in application, or simply using models in a distributed mode via a service platform.

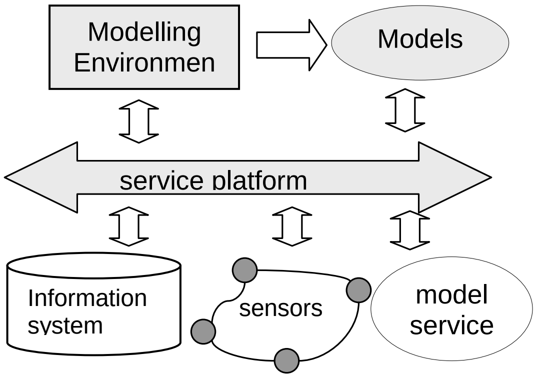

Figure 1. Modelling using environmental information infrastructure, via a service-based approach

Deployment of modelling services can be supported by the architecture shown in Figure 1, by either creation of integrated models using model instances that are then deployed via the service platform – similar to current deployment of integrated environmental models – or by providing model execution and reporting as services.

Together, the integration of sensors, models and information via a service based architecture offers the potential for more flexible and timely access to model and data services, tailored to meeting the needs of end users.

This paper concentrates on purely technical questions, and technical opportunities which have arisen from recent technological developments. It does not expand towards the social dimension, i.e. the vision of how these infrastructures will help humans to improve decisions, and how the Web will improve distributed collaboration.

1. INTRODUCTION

In recent decades the process of environmental modelling has moved somewhat from individual activities encompassing idiosyncratic design and coding practices to component- and environment-based approaches where researchers and developers contribute components to a code pool built around standard interfaces and shared concepts (Argent, 2004). These systems work with user-operated modelling environments (or frameworks) that recognise and give access to the available components, providing the space within which components can be linked to each other, and to data, to provide the desired modelling capabilities. Component capabilities encompass all aspects of environmental modelling from data repair and loading, through component model linking, model execution, and post-process analysis, reporting and exporting.

There are, however, a number of disadvantages in current systems, particularly with respect to the data and model serving capabilities of modern and near-future information networks. These include connection to data, connection to sensors and sensor networks, model and data updating, state updating and model-data fusion, and model deployment. This paper explores an approach to environmental modelling and the use of service infrastructures that aims to make the best use of the capabilities offered by combined systems.

2. EMERGING ENVIRONMENTAL INFORMATION INFRASTRUCTURES

In recent years, it has been more and more recognised that there is a need for environmental information and service infrastructures. This need also arises from the necessity to overcome regional and national boundaries. The largest investments of this kind are currently being made in Europe. Examples are the INSPIRE initiative (Infrastructure for Spatial Information in Europe; www.ec-gis.org/inspire) and the GMES program (Global Monitoring for Environment and Security; www.gmes.info). These large scale activities will be based on service infrastructures currently being developed under various R&D projects of the European Union, both under the EU IST program (Information Society Technologies) and the EU GMES program.

On a global level, the idea of a global system for earth observation (GEOSS, Global Earth Observation System of Systems; www.epa.gov/geoss) is drawing from various resources around the world, and will require a service platform as well.

In order to illustrate the emerging service platform, two typical projects are introduced in the remainder of this section.

2.1. ORCHESTRA – an open architecture for environmental risk management

The ORCHESTRA project is a 14 Million € R&D project under EU FP6 which develops a service platform for environmental and risk management. The project was started in September 2004 and will finish in Spring 2008. Its main technological result, the ORCHESTRA Architecture (OA), is published in the "Reference Model for the ORCHESTRA Architecture" (RM-OA; www.eu-orchestra.org), which is also an OGC (Open Geospatial Consortium; www.opengeospatial.org) discussion document. The main objective of ORCHESTRA is to help overcome all boundaries (geographic, organizational, system, technical boundaries) currently preventing integrated environmental information systems.

Detailed discussions of various aspects of ORCHESTRA can be found in the following sources: a) overview of the ORCHESTRA project and main project objectives (Denzer *et al.*, 2005), b) discussion of architecture requirements and design principles of the OA, c) an overview of the architecture approach (Usländer *et al.*, 2007), d) an overview on the use of semantics (Bügel *et al.*, 2007), e) an overview on meta-information modelling in the OA (Schimak *et al.*, 2007).

Figure 2 shows one of several different views of the ORCHESTRA Architecture. ORCHESTRA defines different service categories for service networks. Instances of such services are called OSI's (ORCHESTRA Service Instances) and are used for different functionality at different levels of the layer architecture shown in figure 2. In the integration domain, services focus on access, authorisation and integration issues (there is for instance a service for the integration / publishing of complete information systems). In the mediation and processing domain, the functionality includes discovery, schema mapping, geo-processing and so forth (including model instances). The source system domain is the domain of existing systems, and the user domain is the domain of end user applications. ORCHESTRA defines syntactic and semantic inter-operability through different types of services. The mediation domain may include semantic services (for instance the semantic search by means of a semantic catalogue). For details about ORCHESTRA service specifications, see Usländer *et al.* (2007).

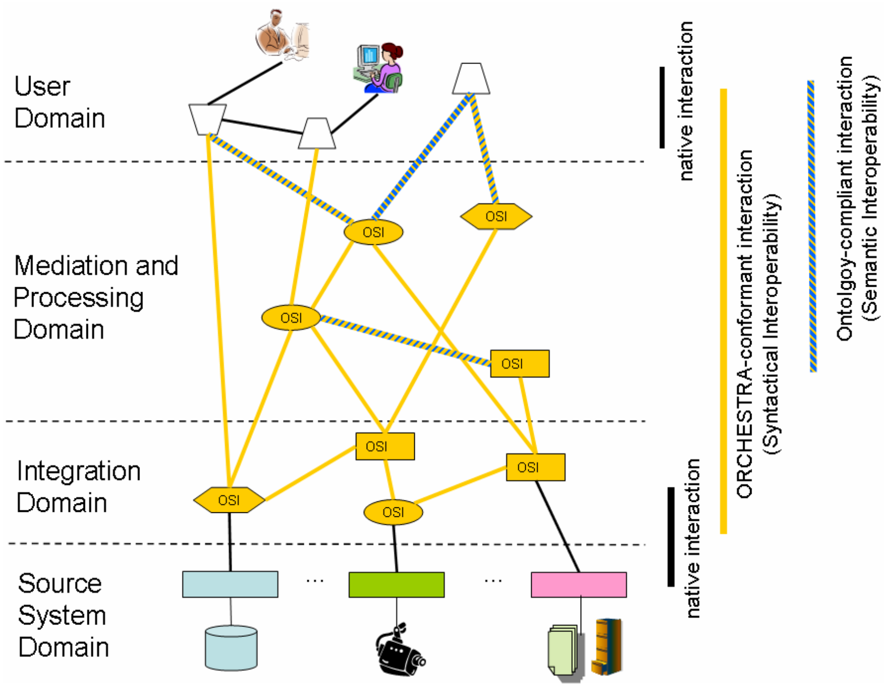

Figure 2 ORCHESTRA Integration Domains

2.2. SANY – Sensors Anywhere

The SANY project is a 12 Million € R&D project under EU FP6, started just over one year ago (September 2006). SANY has the intention to develop a service platform for environmental sensor networks. In the context of GMES, the contribution of SANY can be seen as sensor architecture for "in-situ" sensors (as opposed to remote sensors, which are covered by other projects, in particular by the HMA project; earth.esa.int/rtd/Projects/HMA).

In terms of an infrastructure and service platform, SANY has similar objectives as ORCHESTRA, only with a focus on sensors. In addition, SANY has a second focus on decision support environments which include support for fusion of sensor information. An overview of the project is presented in Havlik (2006).

3. A PERSPECTIVE FOR THE FUTURE

The broad investigation, analysis, decision making and operation roles of environmental modelling system require a suite of functions (Table 1), most of which are currently undertaken either manually via a variety of different systems, or as part of the functions of integrated modelling environments.

Functionality	**Performed By:**
Model building	Modelling environment
Model discovery	Modelling environment or service platform
Model linking	Modelling environment or service platform
Data connection	Service platform
Sensor connection	Service platform
Connection to external functionality	Modelling environment or service platform
Model execution	Service platform
Model calibration	Modelling environment
Result analysis	Application environment supported by service platform
Communication of results	Application environment supported by service platform

Table 1. Environmental modelling functions and options for service provision

Increasing the use of service infrastructures to support this functionality is envisaged via the architecture shown in Figure 1, and given in more detail in Figure 3. In this, broad service platforms including access to sensors provide the basic pool of resources (data, component models, other services) which can be used to develop integrated models. Execution is performed on instances of models constructed by the modelling environment, making use of functions from the service platform.

Each of these functions in Table 1 are examined in the following to consider how they may be implemented and provided through a service infrastructure based approach, including any differences that may occur if moving from a fixed environment to a service basis, and benefits that would accrue.

3.1. Model building

Construction of component models sits most logically within the realm of modelling environments, providing developers with flexibility to use construction tools appropriate to their needs and skill, and the flexibility to undertake iterative design, testing and development locally.

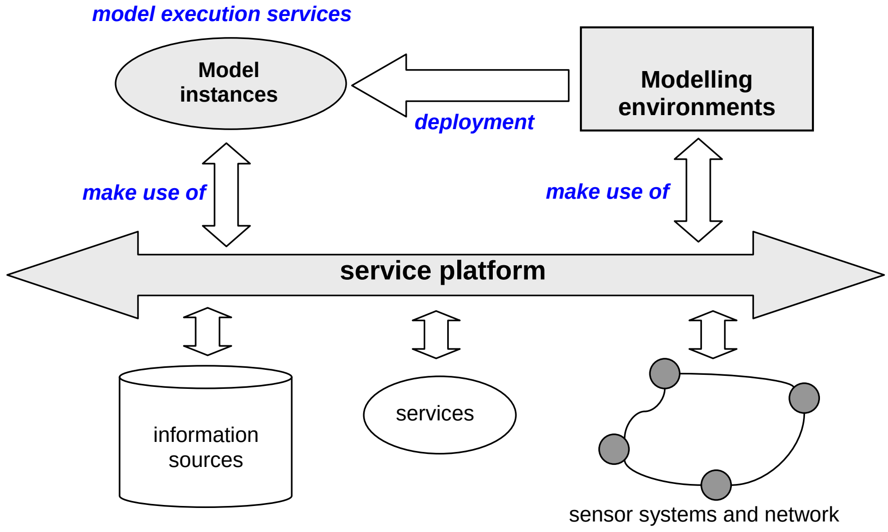

Figure 3. Modelling environments and service platforms

3.2. Model discovery

Discovery of models involves either manual or automatic identification of components that are compatible with the system and which can then be added or linked into a multi-component model. Although this process is currently done adequately via local modelling environments, the use of a service infrastructure to support this process would have the advantages of increasing the pool of developers and models available for any problem situation. The ability to find and download component models from a remote site would also improve the capacity of developers to distribute updated and improved models to users.

3.3. Model linking

Construction of integrated models relies not only on being able to find appropriate component models, but also to link these with other models, with pre-processing components, and with post-processing analysis, reporting and exporting components. This process is currently well handled by modelling environments, although use of a service-based approach would have a particular advantage when model linking was performed between served models, rather than creating local instances of models that re then linked. Linking could be, in some instances, an automatic part of the model discovery and selection process.

3.4. Data connection

Data provision and connection is one of the primary advantages foreseen from server based systems, as users will avoid storage of redundant or outdated data, will have access to a potentially wider array of data sources, and may also make use of transformation services (eg schema mapping, coordinate transformation) to manipulate data into appropriate forms (eg projection, time step) for modelling. Direct and near- or real-time data linking is essential to the data fusion or data assimilation approaches that will herald the next significant improvements in environmental modelling.

3.5. Sensor connection

The advantages of sensor network connection to environmental modelling are similar to those of data connection. An additional benefit would arise from the opportunity to run sensor-aware models, that used notification services to elicit model execution when needed, such as only performing a flow prediction run if it has rained more than 15 mm, or water level has changed by more than 5 cm, in any two-hour period.

3.6. Connection to external functionality

Development of a service-based approach to environmental modelling has the benefit that as more services become available, our models have the potential to connect to these and provide an increasing set of functions. In adopting standards across all services we avoid the task, common to many modelling environments, of having to implement individual services to connect with external functionality.

3.7. Model execution

Model execution follows logically from the arguments presented previously. Finding and linking models, and connecting to data providers, using service based approaches indicates that models be executed across service infrastructure. As with the previous functions, this will allow good use of local model knowledge and access to the latest models and data, as well as providing a flexible approach to modelling that can cross jurisdictional boundaries and allow flexible linking of models to meet needs. One down-side, however, is likely to arise if a given practical situation (for instance organisational policies) requires the passing of large amounts of data in mark-up fashion.

3.8. Common advantages and disadvantages

The previous sections have briefly provided an overview of some of the issues arising from adoption of service-based infrastructure approaches in environmental modelling. Overall, there are a range of common disadvantages to this approach, including:

- the need for a standard or reference model, adopted by the developer community,
- the requirement for models to be modified and possibly expanded to conform with the infrastructure, although this could be minimised by offering good tools for integration,
- the requirement for additional, and possibly substantial, meta information, although this may be offset by the increases in usage arising through better discovery, and
- the level of support, in terms of availability and dependability is currently not supported intrinsically.

The advantages are largely those mentioned previously, with more models able to be run by more people, better updating and access to current and new models, the ability to flexibly manage access and authorisation, the use of service monitoring services for auditing purposes, and finally, a significant reduction in the resources currently committed to seeking data and information from various providers.

One other issue, that of archiving data, parameters, models and results, is common to both modelling environments and service-based approaches, although the potential exists to create a service that provides this, based upon the information that is available during model execution.

4. RISK ASSESSMENT AND PREDICTION APPLICATIONS

As an example, the concepts outlined in the previous sections have been applied to a greater or lesser degree in a wildfire assessment and prediction application. The E-FIS (Electronic On-line Decision Support System for Forest Fires; www.e-fis.org) is a system designed to provide information and prediction services to national and regional fire-fighting authorities across southern Europe. E-FIS provides short term (7 to 10 day), daily and crisis risk assessment. For short term assessments, climate forecasts are combined with forest fuel load and state information to provide assessment of likely near-term fire risk. In daily mode, this information is enhanced by direct incorporation of conditions from the previous day, while crisis mode supports simulation of fire movement under predicted conditions, aimed at supporting decisions on the allocation and distribution of fire-fighting resources. Service delivery is undertaken using a multi-platform approach, including internet appliances, and Wireless Application Protocol (WAP) terminals such as mobile phones, two-way radios and smartphones.

Other example applications, where near- and real-time use of these sensor and modelling service concepts is applicable to environmental modelling, prediction and assessment includes a range of natural and humanitarian disasters, such as extreme climatic events, floods, tsunamis, disease spread and impacts of mass refugee movement.

5. CONCLUSIONS

This paper has offered an alternative approach whereby many of the services currently provided by modelling environments can be provided as services through adoption of a service-based architecture, and by taking up research on infrastructures currently carried out in Europe. The paper is based on recent work of the ORCHESTRA project, which has been deployed in several real-world situations.

It does not discuss the more general (and more important) vision of the Web becoming a collaboration tools for humans.

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