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Application of OpenMI interfacing to promote integrated modelling accross the water/environment sector, the FluidEarth Platworm

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APPLICATION OF OPENMI INTERFACING TO PROMOTE INTEGRATED MODELLING ACCROSS THE WATER/ENVIRONMENT SECTOR, THE FLUIDEARTH PLATWORM

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Abstract

Integrated modelling is an established procedure for the linking together of separate numerical models in a dynamic interactive manner. The models linked together (called a composition) are able to exchange data with each other on a timestep-by-timestep basis and allow feedback from interacting processes to update the calculation processes as they are carried out. This enables complex hydraulic and environmental situations to be more accurately simulated.

The paper describes FluidEarth; a community initiative that enables UK academics to gain access to suitably prepared (wrapped) software components and develop integrated model compositions using these components. The paper then continues by presenting an example of integrated modelling using FluidEarth tools. The example features how a model simulating building collapse can interact with a hydraulic model of the floods around it that cause its structure to fail.

FluidEarth has a web portal accessible at https:\\www.fluidearth.net. Thos portal provides a range of tools and guidance to support integrated modelling as well as repositories of wrapped and non-wrapped software components. Further work is planned in the near future to provide procedures and data for calibration and validation of software components and model compositions.

FluidEarth is able to provide a platform for compositions to be deployed and executed, whilst linked to the forcing data required to drive them. The aspiration is for FluidEarth to provide the UK node to a network of joined up computerised systems working in the water and environment sector.

FluidEarth was a medallist in the British Computer Society Annual Industry Awards in 2009 for research and innovation.

INTRODUCTION

FluidEarth is a community initiative established in response to the need for a change in modelling capability for the simulation of complex and inter-acting systems in the water and environmental domain. The increased demand for simulation complexity had reached a point where developing ever more large and complex software as a single piece of code did not provide a manageable solution. The alternative is to simulate complex systems by integrating multiple, smaller models that collectively simulated the problem in question.

Developing complex simulations in this way is possible. The OpenMI (Open Modelling Interface) Association has established a standard that when implemented allows models to communicate to each other and exchange values during execution. The main problem with the OpenMI standard is that it is requires the skills of a software engineer to implement and not a typical scientist or engineer writing a piece of simulation software. Recognising this knowledge gap, FluidEarth is being coordinated to develop the use of the OpenMI standard for linking hydraulic/environmental software together into integrated models. In particular this includes tooling and training to greatly simply the use and application of the OpenMI standard, eliminating the need to master software engineering skills. Furthermore it encourages cooperation and sharing of model components between members to establish a code library from which to build compositions and to deliver comparisons of different simulation approaches.

OpenMI

OpenMI has been developed from considerable cooperation and joint working by leading European hydraulic centres. The development of this standard has been a key response to more exacting needs that are developing, driven by factors such as:- the EU Water Framework Directive, the EU Floods Directive, concerns about Climate Change impacts, and the evolving needs for realistic modelling of complex catchment processes. The benefits that OpenMI brings to integrated modelling, amongst many others, is the ability to utilise established, accepted models as basic components and the avoidance of duplicating software.

The OpenMI standard has been designed (OpenMI Assoc., 2008) to allow data to be exchanged between independent models running simultaneously. Any models that are designed, or modified, to be OpenMI compliant will be able to exchange data. In providing *whole catchment modelling* as a key part of the *integrated water management* called for by the *Water Framework Directive* (WFD) requires 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. Facilities for integrated modelling developed by the OpenMI Assoc comprise the OpenMI Editor that provides the run environment for controlling the simultaneous running of linked models, and a guideline to assist modellers to write wrappers for their models (ie write the modifications to their code to become OpenMI compliant).

The aim of OpenMI is to provide a mechanism by which physical and socioeconomic process models can be linked to each other, to other data sources and to a variety of tools at runtime, hence enabling process interactions to be better modelled. Its specific objective is to allow the linking of models:

- from different domains
- from different environments
- based on different modelling concepts
- with different dimensionality
- working at different scales
- operating at different temporal resolutions
- operating with different spatial representations
- using different projections, units and categorizations;
- linking to other data sources
- running on different platforms
- running on different computers.

The Collaboration Website for the Openweb Community

Welcome

OpenWEB: Integrated Environmental Modelling 17/11/2009 14:45
by Sarah Boys

OpenWEB: Integrated Environmental Modelling

Welcome to the OpenWEB Portal, the official collaboration website of the OpenWEB community.

In order to understand how pressures such as climate change and developments impact the environment...

Contact the Openweb Administration Team 06/10/2008 10:52
by OpenwebAdm
You can contact the Openweb Administration Team on OpenwebAdmin@hrwallingford.co.uk

Welcome to Openweb Partners 06/10/2008 10:51
by OpenwebAdm
New Visitors
If you are a researcher / staff member at a partner organisation please contact the Openweb Administration team for a user name and password. This will need to be supported by the respective named representative.

Existing Members
...

Openweb Manual

Type	Name
	1. Introduction
	2. The Openweb Portal
	3. Business Guidelines
	4. Technical Guidelines
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Openweb Discussions

Subject	Created By
How to read data from files and write data to files?	Zhang

Announcements

OpenMI and HydroDesktop in the USA 06/01/2010 10:
by Quillon Harpham
CUAHSI (the Consortium of Universities for Advancement of Hydrologic Science) in the USA (http://www.cuahsi.org/) have made a range of US government hydrological databases accessible on-line as though they were one database. Their Hydrologic Information...

Pipistrelle and SDK 0.8 Releases 22/12/2009 10:
by Adrian Harper
Go to Openweb Portal (audited) > Openweb Manual > 4. Technical Guidelines > 4.1 Overview to see changes from 0.7

OpenWEB Business Plan Published 08/12/2009 13:
by Quillon Harpham
The OpenWEB Business Plan 2009 has been published. OpenWEB community members can view it from the "Business Guidelines" section of the OpenWEB manual (li on the portal home page).

Please note that it is not confidential, but is intended...

(More Announcements...)

Add new announcement

Openweb Community

New Actions

Company	Last Name	First Name
Company : BGS (1)		
Company : Birmingham University (2)		
Company : Bristol University (2)		
Company : Cardiff University (2)		
Company : CEH (1)		
Company : Exeter University (1)		
Company : Heriot Watt University (2)		
Company : HR Wallingford (7)		
Company : Imperial College (1)		
Company : Newcastle University (3)		

Figure 1 FluidEarth Portal (www.fluidearth.net)

Table 1 FluidEarth Partners

Universities	Plymouth, Exeter, Bristol, Oxford, Imperial College, Cardiff, Swansea, Birmingham, Newcastle, Heriot-Watt
Research Centres	BGS, CEH, HR Wallingford

FluidEarth

In order to take the OpenMI concept and procedures out into the research and industry sectors, FluidEarth has been implemented in the UK to *promote* integrated modelling for the water and environment sector. FluidEarth is a collaborative programme that brings academic researchers together with the water and environment user community in order to establish a development-to-delivery conduit. The aim is to develop ideas and enable them to progress through to solutions and products that can be pulled through to the user community. The multi-functional software platform that has been set up has enabled numerical modelling groups in the water and environment sector to link their models together, and will in future facilitate state-of-the-art development of integrated modelling.

Currently the members of FluidEarth include a number of the UK's leading HEI's and research centres engaged with managing the water environment these are listed in Table 1 above.

FluidEarth engages with its community through a web portal (See Figure 1). Access to the Portal is directly available to FluidEarth research partners and industry partners, but also at a general enquiry level. The portal provides a one-stop web-site for: tools download, wrapped components, information, membership details, technical specifications, FAQs and developers' discussion forum. Table 2 summarises the key software tools and software repositories that are accessible via the portal.

Table 2 FluidEarth Tools and Repositories

FluidEarth Editor, *Pipistrelle*	Provides the run-time environment in which software is linked together. This is freeware downloadable by partners and others from the portal
FluidEarth *SDK*	The Software Development Kit is an open source project and can be downloaded from the portal. It enables both new and existing software to be modified (wrapped) so that it can be linked to other software packages.
Development Platform	The repository in which different software are uploaded by the research partners for use within this community, providing the basic building blocks for integrated models
Demonstration Platform	The repository for completed software that is being made available for use in real applications.
Model Access Platform (*MAP*)	Provides users with access to details about model applications for given locations/situations

DEPLOYMENT AND USE OF FLUIDEARTH

Examples of Integrated Modelling in the scope of FluidEarth

Recent progress with FluidEarth has been to implement a series of actual use-cases for integrated modelling, taking advantage of the tooling available. These are listed below, although various partners are now also proceeding with their own integrated modelling initiatives.

- Infoworks RS – ZOOM3DQ – linking a river model with a groundwater flow model

This study has applied an integrated modelling approach to studying surface water and groundwater in Oxford by linking a groundwater model (BGS's ZOOM) with a river model (Infoworks RS). The study supports the Environment Agency's research strategy on integrated modelling and is providing new versatile modelling tools for developing an improved understanding of groundwater modelling and wetland flow processes.

- Integrated Wave, Shoaling / Refracting and Overtopping Modelling

Two existing numerical codes - one a wave shoaling and refraction engine, the other an overtopping model – have been wrapped to allow them to be integrated with the wave prediction model, *Swan*. A suite of generic tools that can be used to solve complex problems has been created. This has shown that complex simple underlying tools can be used in association to answer real-world questions and that the usefulness of a model can be greatly extended with a relatively small amount of effort.

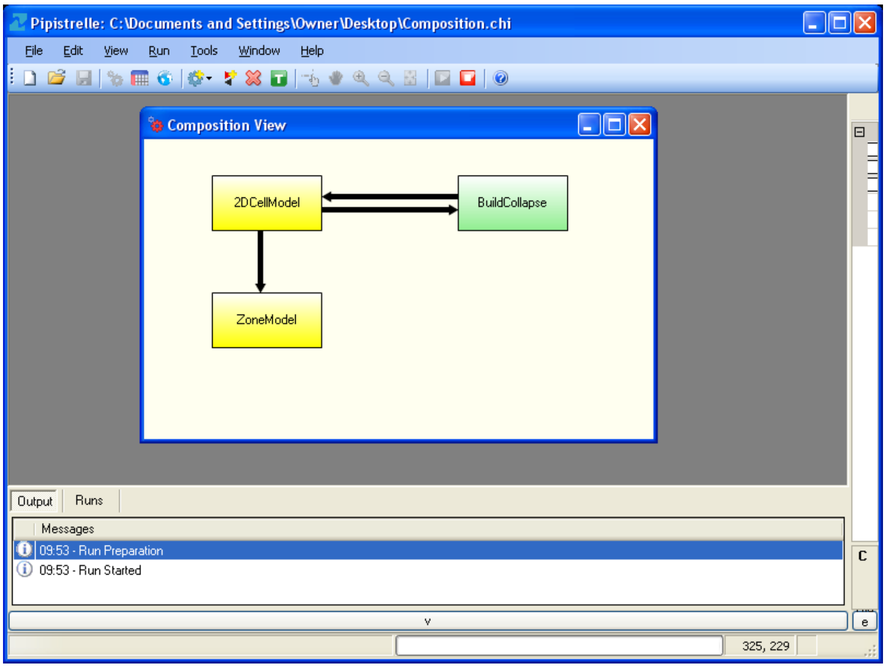
- Swan-Waqua – linking of a wave model with a marine flow model

HR Wallingford is supporting an EU FP6 OpenMI-Life initiative by Deltares to link the wave prediction model, Swan, with the tidal and storm surge model, Waqua, in order to study the impact of storms along the Dutch North Sea coast.

FLUIDEARTH USE CASE

Probabilistic Flood Risk Assessment

This case study considers the development of depth-velocity-damage relationships for use in probabilistic flood risk assessment. One of the more challenging aspects of probabilistic flood risk assessment is obtaining a credible estimate of the damage likely to be caused to residential and commercial receptors due to inundation by flood water. Such damages are likely to be a function of the characteristics of flooding (the depth, velocity, &c.) and an estimation of damage potential (Messner and Meyer, 2005).



09:53 - Run Preparation
09:53 - Run Started

Figure 2 **FluidEarth 'Numerical Flume' composition**

Within a high-level probabilistic methodology, for example RASP (Sayers et. al. 2002), meso-scale analyses of both flood-characteristics and damage-potential are used to quantify risk, which is aggregated at the system level. In such analysis, simplified hydraulic/flood spreading models are often used to predict flood depth across a domain, which are equated to damage by applying static depth-damage functions to a receptor database.

Despite the need for computational efficiency demanded by probabilistic flood risk assessment, it has been shown that the prediction of flood characteristics can be improved by coupling fine- and coarse-grid simulations (e.g. Neelz et. al., 2007) without incurring the typical computational overhead of high-resolution models.

While such an approach can allow flood characteristics to be better quantified, there are currently no analogous methods for improving the prediction of damage potential that go beyond the traditional depth-damage functions already in use. Outlined here is an OpenMI composition implemented entirely from models wrapped using the FluidEarth SDK, for the purpose of allowing depth-velocity-damage functions to be constructed using high resolution hydrodynamic and building collapse models. The intent of this composition is to inform the functions used to evaluate damage-potential, ultimately to improve the depth-damage functions currently used in system-level probabilistic flood risk assessment.

Implementation of a 'Numerical Flume' using FluidEarth wrapped component models

Given that flood velocity within real-world flood events will have high spatial variability, depending upon factors such as local topography or proximity to the source of flooding, the use of a single depth-damage function risks under-predicting the hazard to receptors in close proximity to sources of flooding. By concentrating a high-resolution study on that region where an under-prediction is likely to be made (i.e. where conditions will be closest to those of dam-break) an improved damage-prediction can be introduced to the current probabilistic models, without incurring the excessive run-time demands of high resolution models.

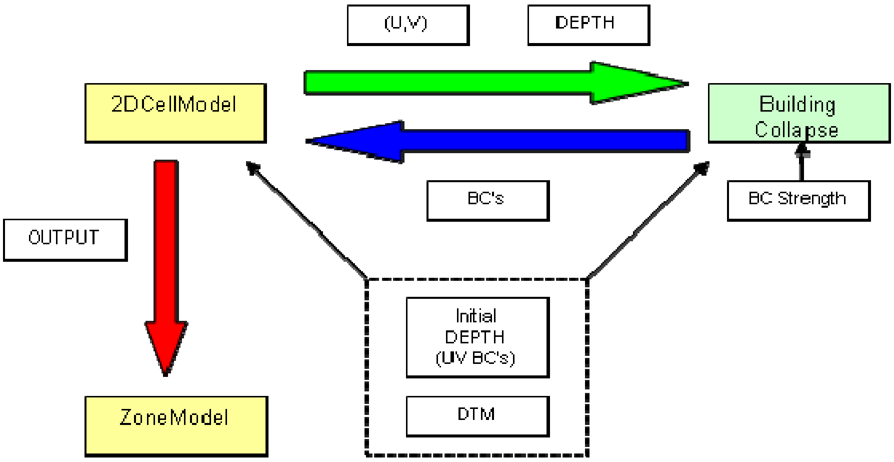


Figure 3 Movement of data within a composition

In an attempt to explore the damage potential close to the source of flooding, a 'numerical flume' (a simple test-bed, where different dam-break scenarios can be systematically tested for damage to different types of property) has been constructed from FluidEarth SDK wrapped modelling components (see Fig 2). These components are:

1. A high-resolution raster flood-spreading model ('2DCellModel').
2. A building collapse model (Bernoulli total-head model; 'BuildCollapse').
3. A model to spatially aggregate depth and velocity, &c, over areas of interest ('ZoneModel').

The composition is passed initial conditions at initialisation from simple plain-text steering files (DTM, boundary locations and types, total-head strength of BC's, initial water depths) and manages the exchange of data between the different model components to simulate interaction between structures and fluid.

Exchange of data between models in composition

A schematic indicating the passage of data between different models in the above composition is shown in Fig 3.

While performing a single timestep, calculations within the different models and data-exchanges between the models occur as indicated below:

1. The hydrodynamic model (2DCellModel) calculates depths and velocities based on local topography, boundary conditions and its state at the previous timestep and provides depth and a velocity vector to BuildCollapse (2a.) and ZoneModel (2b.) – a model that aggregates depth/velocity based on predefined zones of interest within a building.

2a. The Bernoulli total-head model (BuildCollapse) calculates the total-head across each length of the boundary within the domain by assuming a stagnation point at its base and using depths/velocities/bed levels at the boundary and at a short (user-specified) distance from it. Where the instantaneous total load exceeds the specified boundary strength for that type, the boundary is removed and the updated BC's passed back to the hydrodynamic model.

2b. The desired output (here, depth and velocity vector) are passed to a model where they are aggregated based on predefined zones defined within the building. In this way, the damage can be built according to different average room-class values – for example, based on information within the Multi Coloured Manual (FHRC, 2005).

Results

By using modular components within a composition, rather than a single model to calculate depth/velocity and building collapse, it is simple for any component to be removed and replaced. By including the dynamic response of structures to load, it is possible to account for the interaction between buildings and flood water, enabling improved depth-velocity-damage relationships to be explored, and for probabilistic flood risk assessment potentially to be improved. Fig 4 shows the predicted progression of the flood waters for a given situation. In this particular case the flow conditions are not sufficiently strong for the building walls to collapse.

CONCLUSION

Developing this capability is important for a wide range of users in the water and environment sector as various key drivers influence the way in which we manage and interact with our surroundings.

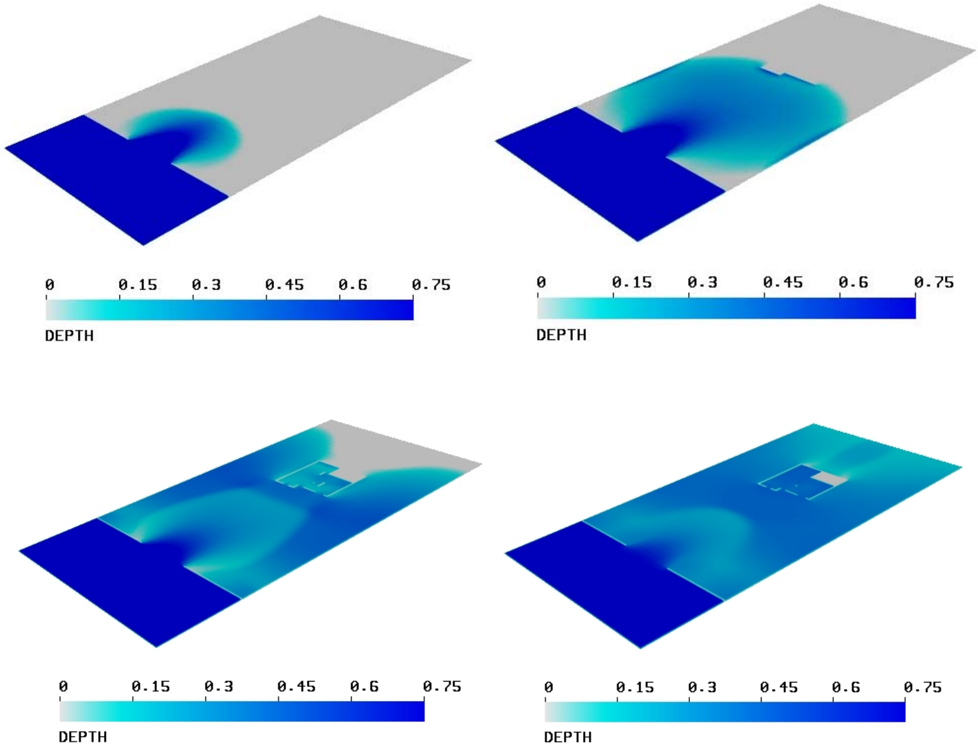


Figure 4 Results from FluidEarth building-collapse composition

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HR Wallingford provides world-leading analysis, advice and support in engineering and environmental hydraulics, and in the management of water and the water environment. Created as the Hydraulics Research Station of the UK Government in 1947, the Company became a private entity in 1982, and has since operated as a independent, non profit distributing firm committed to building knowledge and solving problems, expertly and appropriately.

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