Modelling Shallow Landslides within the context of a Distributed Framework for Multi-Risk Assessment of Forest Fire Hazards

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Abstract. The MEDIGRID project aims to use distributed GRID technology to integrate natural hazard models, maintained independently at different centres in Europe, into a single system, accessible to users over the internet. As an example, the SHETRAN hydrology, soil erosion and landslide model can receive input from a separate fire propagation model and in turn can provide data to a vegetation regeneration model. The individual models are located at process nodes while data relevant to forest fire impact modelling are provided at data storage nodes. Each node has been fitted with the Globus Toolkit, which provides the shared, specific computing environment required for the system construction. Users access the system through a series of portals and portlets, which provide a personalised interface to the Grid. Integration of the individual models required them to be modified so as to be run remotely over the internet as web services. As the models have different data characteristics, a common data format was created to allow exchange of data between the models. The MEDIGRID system marks an advance in the integration of independently constructed models to provide improved hazard assessment technology.

Key words: Shallow landslides, GRID, Multi-risk Assessment

1 Introduction

It has long been known that forest fires can significantly affect river basin response through their elimination of the hydrological and soil protection functions of the vegetation cover. Impacts can range from increased runoff, flashier runoff and accelerated soil erosion in the short term to increased landslide and debris flow incidence in the longer term (e.g. [13] [16]). Mediterranean-type environments are especially vulnerable to fire and there is interest therefore in the post-fire management of Mediterranean landscapes. However, while there is extensive literature on experimental studies of fire impacts, the field of impact modelling is less developed. In particular, models tend to refer to individual components of the overall impact, such as fire propagation, hydrological and erosion response and vegetation regeneration. Models have usually been developed in isolation from each other, so have different software architectures and data needs, and they may apply to different spatial scales or domains, e.g. plots, catchments and regions (e.g. [6], [2], [7], [4]).

The European Commission funded-MEDIGRID project (Mediterranean Grid of Multi-risk Data and Models) aims to use distributed Grid technology to integrate several, independent, pre-existing, natural hazard models into one single system. Models of forest fire behaviour and effects, erosion, floods, landslides and vegetation regeneration, which are individually maintained at centres throughout Europe, are linked through the internet such that the output of one model forms the input to another where appropriate. Major challenges in integration have included the identification of common data themes and links between the models, conversions between different spatial and temporal resolutions, and the development of a common data format for data exchange so that data can flow between the models. This paper describes in particular the integration of the SHETRAN hydrology, soil erosion and landslide model into the MEDIGRID system. SHETRAN can receive output (in the form of a vegetation map, and changes in soil properties) from a fire propagation model and can itself provide input (in terms of soil erosion and landslide data) to a vegetation regeneration model.

Integrating SHETRAN and other hazard assessment models into such a web-based system provides a modular decision support framework for multi-risk assessment of natural disasters, thereby helping users assess the links between, and impacts of, multiple hazards. In addition, the project will create a distributed repository of data of areas in Southern Europe that suffered recent devastating fires. Users will be able to use the shared disaster related data resources initially for test sites in France, Spain and Portugal.

2 The SHETRAN landslide model

SHETRAN is a general, physically based, spatially distributed modelling system that can be used to construct and run models of all or any part of the land phase of the hydrological cycle (including soil erosion and sediment transport) [7]. Through its integrated surface and subsurface representation of river basins, SHETRAN provides not only the overland and channel flows needed for modelling the transport of eroded soil but also soil moisture conditions. It is therefore a basis for simulating rain- and snowmelt-triggered landslides. The landslide component also models the erosion and sediment yield associated with shallow landslides at the basin scale [3]. The occurrence of shallow landslides is determined as a function of the time- and space-varying soil saturation conditions simulated by SHETRAN, using standard geotechnical infinite-slope, factor-of-safety analysis. Depending on conditions, the eroded material is routed down the hillslope as a debris flow. If the debris flow reaches the channel network, material is injected directly into the channel. In addition, material deposited along the track of the debris flow may subsequently be washed into the channel by overland flow. Material that enters the channel network is routed to the catchment outlet by the SHETRAN sediment transport component.

Within SHETRAN the spatial distribution of catchment properties, rainfall input and hydrological response is achieved in the horizontal direction through the representation of the catchment and the channel system by an orthogonal grid network and in the vertical direction by a column of horizontal layers at each grid square. The central feature of the landslide model is the use of derived relationships (based on a topographic index) to link the SHETRAN grid resolution (which may be as large as 1 or 2 km), at which the basin hydrology and sediment yield are modelled, to a subgrid resolution (typically around 10 - 100 m) at which landslide occurrence and erosion is modelled. That is, using the topographic index, the SHETRAN grid saturated zone thickness is distributed spatially at the subgrid resolution. Through this dual resolution design, the model is able to represent landsliding at a physically realistic scale while remaining applicable at basin scales (up to 500 km^2) likely to be of interest, for example feeding a reservoir.

SHETRAN data needs include rainfall and evaporation time series, a digital terrain model and soil and vegetation property maps. Examples of SHETRAN applications are given by [14] and [1].

3 The MEDIGRID system

The MEDIGRID project has the aim of providing a modular decision support framework for assessing multiple natural hazards based on Grid-enabled applications and distributed architecture. The key goals of Grid computing are to enable sharing, selection, and aggregation of a wide variety of geographically distributed computational resources (e.g. hardware, software, data and people), and to present them as a single, unified resource for solving internet-scale [15] computational and data intensive computing problems. The concept of Grid computing is not new. Past Grid-based projects have included computing performance, drug development, mathematics and cryptography. Environmental Grid computing (i.e. the application of Grid computing technologies and principles to environmental and Earth systems engineering computational problems) is, however, a relatively new field. Although some work has been carried out on environmental issues such as air quality monitoring [17], very little work has so far focused on natural hazards.

The natural hazard models considered within the MEDIGRID project are those based around forest fires and post-fire hazards, i.e. models of forest fire behaviour and effects, soil erosion, flash floods, landslides and vegetation regeneration. The different individual models or ‘process nodes’ are maintained at different partner sites in Portugal, France, UK, Slovakia and Greece. In addition, 'data storage nodes' are located in France, Spain and Portugal (see Figure 1a).

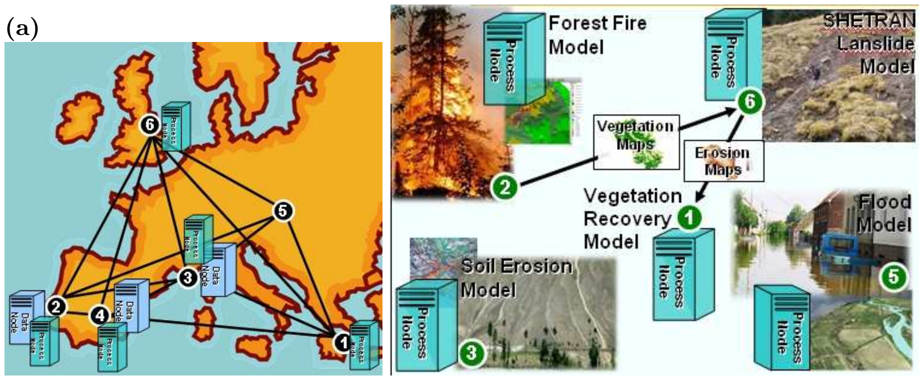

Fig. 1. (a) Locations of MEDIGRID data storage nodes: (1) Algosystems, Greece; (2) ADAI, Portugal; (3) CEREN, France; (4) Tecnoma (Spain); (5) IISAS, Slovakia; (6) University of Newcastle upon Tyne, UK. (b) MEDIGRID models including the links with SHETRAN.

The MEDIGRID partners (process and data storage nodes) form part of a Virtual Organisation and thus require a shared, specific computing environment. As part of the MEDIGRID project, each node has been fitted with the Globus Toolkit environment which works on any computing platform, including the Windows or Linux operating systems.

The Globus Toolkit 4+ [11] is an open source, open architecture, software project to produce a reference implementation of key Grid standards, specifications and protocols. It is currently being developed by the Globus Alliance [9] community. The project enabling the application of Grid technologies and concepts to scientific and engineering computing. The Globus Toolkit offers a detailed application development environment for building Grid services and systems that conform to both existing and emerging Grid/Web Service (WS-*) technology standards, architectural principles and best practices. Specifically, the Globus Toolkit is an implementation of the Open Grid Services Architecture (OGSA) [8] based on WS-Resource Framework (WSRF) [5] standards (e.g. communication protocols and formats) and architectural principles as defined by Grid standards bodies the Global Grid Forum [10] and OASIS (respectively). The Globus Toolkit provides a comprehensive collection of protocols, services, software libraries and documentation for developers to use when building a Grid system. This collection includes tools to support Grid Service resource (e.g. hardware, software and network) management, data management, security, communication, fault detection and portability.

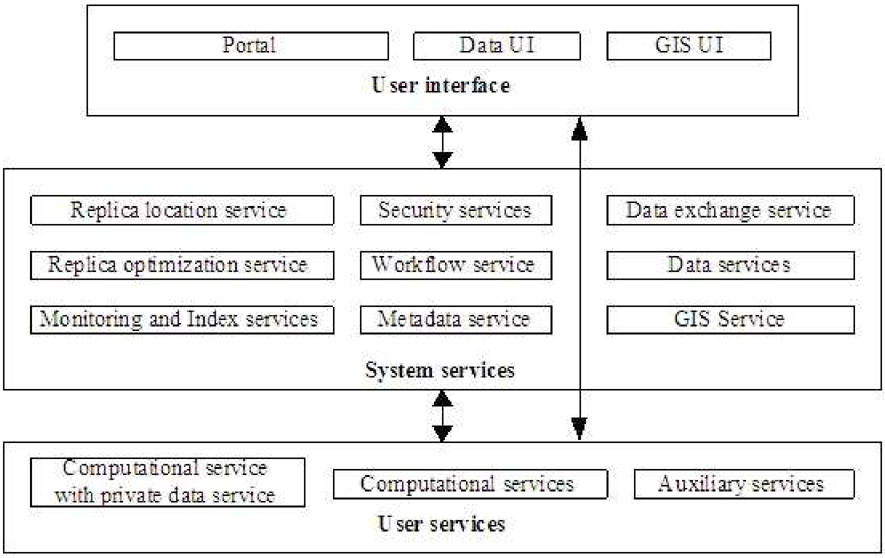

Fig. 2. MEDGRID System Architecture (Adapted from D1.2) UI = User Interface; GIS = Geographical Information System

An overview of the MEDIGRID system architecture is shown in Figure 2. The framework is logically divided to three layers: system services, user services and user interfaces (UI). The User and System service levels are built on top of and use many of the Globus Toolkits core services and software libraries.

The overarching role of the MEDIGRID software framework is to manage and support the interaction between a user of the system and the Grid services. Users access and use the system through a series of portals and portlets which provide a personalised interface to the Grid. Grid Portals are enhanced versions of Web Portals, themselves being web based applications that commonly provide functions such as personalisation, single sign on, content aggregation from different sources and host for the presentation layer of information systems. Web Portals, such as those used by Yahoo or Amazon, are in common use on the internet. In much the same way that these Web-portals deliver specific, targeted, mainstream services (e.g. email, calendar, search, mapping, file storage and visualisation) to large numbers of users through a single, integrated user interface, Grid Portals deliver a shared access point to Grid services and resources. A Grid Portal therefore communicates with, integrates and manages Grid applications, services and resources.

Portlets run within portals. They are reusable Web components that display relevant information to portal users. Common web applications include the display of email, weather reports, discussion forums and news. Portlet standards are such that portlets can be plugged into any portal supporting the standards. The portlet specification allows interoperability between portlets and web portals.

This specification defines a set of Application Protocol Interfaces (API) for portal computing, addressing the areas of aggregation, personalisation, presentation and security.

To facilitate user interaction and management of the MEDIGRID system, the Grid portal software, GridSphere [12] has been implemented. The GridSphere framework is an open-source portlet that offers many common Grid portal features and functionality (e.g. single sign-on, credential management, job submission, job monitoring, resources management, file transfer). GridSphere enables developers to quickly develop and package third-party portlet web applications that can be run and administered within the GridSphere portlet container.

SHETRAN and the other models are to be controlled via the MEDIGRID portal through a set of configuration portlets. These portlets will allow portal users to operate the models remotely and interact with them as if they were actually sitting at the machine on which the application is running. In addition, the portlets will allow users to specify model interconnectivities (i.e. how and which models are chained), required outputs and their display properties. Portlets to enable various stages of model setup from input dataset selection to individual configuration parameter adjustment are under development.

A standardised, distributed, data repository is also being created, populated with physical and climate data, plus field measurements, from countries that regularly suffer from forest fires. Although initial datasets are being provided by the project partners, users outside the consortium will eventually also be able to add to the datasets and run the models. Users will be able to access the service and run the system for selected sites in Spain, France and Portugal that are at risk from fire.

4 Incorporating SHETRAN into the MEDIGRID system

4.1 Conversion to web-service

The integration of the SHETRAN landslide model into the MEDIGRID system has mainly involved development work at the User services (partner site) level of the MEDIGRID architecture (Figure 2). For the model to be fully integrated into the system, it needed to be network enabled and accessible. Initially therefore, all the models, including SHETRAN, had to be modified so that they could be run remotely over the internet as web services. This required that each application be adapted to run as a standalone executable without the use of any graphical user interface. The SHETRAN model itself is a highly configurable piece of software, optimised to run in a standalone, non-networked, cross platform desktop PC/Workstation environment. It has never been developed to have a graphical user interface so only minor modifications to the code were required in order to enable it to run as a web service. Development work was carried out to alter the arguments that SHETRAN accepts at the command line level, in order to allow more fine grained specification of configuration files and input datasources.

Through SHETRAN specific portlets, the user will be able to:

- Select pre-defined SHETRAN configuration inputs and outputs
- Customise SHETRAN configuration parameters (e.g. vegetation type, precipitation)
- Submit a job to SHETRAN
- Monitor a submitted jobs progress and status
- List, view and download model outputs.

4.2 Integrating the models

As part of the larger Grid service, each model should be able to be configured, chained, and run as a single step process. There are, however, several barriers to integrating models which have been developed in isolation from each other, have been written in different languages and for different operating systems and which require different input and output data formats, structures and contents. Integrating models which have varying spatial and temporal resolutions, and different data needs and outputs has required work on the part of all partners to identify common links between model inputs and outputs and where necessary develop pre- and post-processing tools to translate data from and into a common format (Grass ASCII Grid) so that information can be shared between the models.

The aim of both pre- and post-processing is enable models to be chained together such that outputs from one model can flow into another model as input. In this way, the models work together as a single multi-risk assessment process, as opposed to in isolation of one another.

Certain models share a common natural link in terms of input/output components as is the case with forest fire, landslide (SHETRAN) and post-fire vegetation regeneration models. For example, changes in vegetation characteristics resulting from significant forest fires are output by the forest fire model, the resulting vegetation cover maps are a key input component to the SHETRAN model, which in turn generates amongst other outputs landslide, soil erosion and hydrological outputs, appropriate as input to the post-fire vegetation regeneration model (see Figure 1b). A user can therefore investigate the effect of different intensities and spatial occurrences of forest fire on hydrological, soil erosion and landslide response (for present and future climates) and can plan different strategies for vegetation regeneration accordingly.

4.3 Data

In addition to developing data transformation tools, conversions were carried out so that SHETRAN outputs are in formats suitable for visualisation and analysis through the MEDIGRID portal. For example, spatial data in the forms of maps (e.g. landslide incidence, catchment properties) are visualised in image (.jpg) formats, whilst other outputs (e.g. time varying river discharge, debris flow volumes) are available to the user to view or download either as ASCII text or as HDF5 (Hierachical data format) formats. Free HDF5 viewers are available as web applets for the user to download and use independently of the Grid system.

5 Conclusion

The prototype MEDIGRID system testbed provides the natural hazard impact assessment community with a functional environmental Grid computing platform capable of exploiting Grid computing standards and technologies. This leads to improvements in impact assessment and decision making processes focussed around the impacts of forest fire.

In addition, as an early real world example of a large scale environmental Grid computing system, MEDIGRID aims to document the implementation steps (e.g. installation guides, challenges encountered along the way) and to give advice suitable for use by other scientific communities that might be considering setting up a similar system in the future. The completed MEDIGRID system will also serve as a platform for future research and development into how members of both the academic and industrial environmental hazard/risk impact assessment communities can better collaborate through the sharing of vital (hardware/software/data) resources to improve the decision making processes and outcomes of environmental impact assessment.

The MEDIGRID portal implementation is currently under development. However, when complete it will serve as a demonstration access point for users to interact with the MEDIGRID system.

Virtual Organisations like the one formed by MEDIGRID project partners can improve collaboration and improve their processes through the sharing of resources essential to providing accurate assessments of environmental hazard impacts.

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