Hydrological modelling in the Brazilian Water Resources Information System (SNIRH)

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INTRODUCTION

Brazil has made several advances in the last 10 years regarding water resources planning and management. In terms of hydrological simulations, three distinct phases can be identified: development of models, integration of these models into Decision Support Systems (DSSs), and the coupling of Geographic Information Systems (GISs), as presented by Silva & Santos (2007). Nowadays, according to the demands of the Brazilian Water Resources Information System, the new challenge is to consolidate all the available knowledge into a Spatial Decision Support System (SDSS). This paper presents how part of the Brazilian Water Resources Information System (SNIRH) was developed and integrated into several hydrological models.

THE UNDERLYING BASIC SOFTWARE – AN OPENGIS

It was decided to adopt a free and open source GIS platform because the Brazilian National Water Resources Policy states that the code of this software should be accessible to everyone. In this situation, OpenGIS, i.e. an open source free GIS, was selected and OpenJUMP was chosen as the underlying program, which would be integrated with the hydrological models. This OpenGIS has been developed by the Geography Department of the University of Zurich in Switzerland, and it uses the JUMP core (JUMP, 2003). The OpenGIS has many advantages such as: (a) the OpenJUMP can access maps remotely through the standard services of the Open Geospatial Consortium. The SNIRH database can be directly accessed through web services; (b) it allows new applications (plug-ins) to be integrated into the system and this was how the selected models were integrated to OpenJUMP; and (c) OpenJUMP was developed in the Java language, based on concepts of Object Oriented Programming, which provides several additional advantages.

The design of SNIRH-hydrological model

The SNIRH-hydrological model was made up of a set of three applications: an access module to the Hydro database of the Brazilian National Water Agency (ANA, in Portuguese); hydrological models built as plug-ins; and a robustness analysis module. All applications of this system are based on the OpenJUMP software, since some of the applications work with spatial entities. The first module is the software to access the ANA database, in which the Web Services technology was used. This technology allows interaction between applications developed on different platforms. In addition, it is possible for newly developed applications to communicate with those that already exist without the need for major changes. Through Web Services, it is possible to get rainfall, runoff and other data. The application accesses the ANA database, returning a collection of objects with the required information, which are then available in a graphical-user interface.

OpenGIS is used to manage input information as well as to present the resulting simulations, in order to promote an integrated view of the basin and its elements. The chosen models were the hydrological lumped models IPH2 (Tucci *et al.*, 1981), MODHAC (Viegas Filho *et al.*, 1999) and SMAP (Lopes, 1982), and the distributed models MGBH (Collischonn *et al.*, 2007) and Kineros (Woolhiser *et al.*, 1990). Once the OpenGIS is opened, the user can select the SNIRH option in the main menu bar. The user chooses the option “models” and then they can click on the model that they want to use for their study. The integration between the OpenGIS and models was done through an interface for exchanging data, thus data stored in the GIS layers are converted into input files for a particular model. The interface is also responsible for the model execution, and again to transfer information to the GIS layers where the simulation results are presented. In this way, GIS plays an important role for the pre- and post-processing of data. After model execution, the user is able to compare all of the executed simulations within the same system. Several statistical parameters are available for this, and the user does not need another software program to analyse and compare the simulation results. Several statistical measures are available such as average, deviation, variance, covariance, minimum value, maximum value, autocorrelation, BIAS, MSRE, Nash coefficient, Pearson's correlation, and coefficient of determination.

Once the OpenGIS is opened, a plug-in will appear on the menu of the main program named SNIRH. Clicking on the icon, the user chooses the option "models" and then can click on the model that they want to use for the study. The "Basic data" function is used to open or save the basic information of the basin (name, area code and simulation title), and the chosen period for the simulation (start and end months, initial and final years). This option stores all the information, thus it avoids the issue of having to manually load the data each time the program is restarted. For each simulation carried out, a simulation counter is updated.

Once the input files are created, the model is run. By clicking on "Execute", the precipitation files and parameters are loaded automatically and all that is required is to fill the remaining fields on the screen. After the simulation is processed, observed and calculated runoff and sediment yield values are available within "Results", then figures will show the results of the simulation process for the runoff, and in the case of the Kineros model, the sediment yield and the sediment budget (input, output and deposition) for each element are also presented. For the distributed models, the user could analyse the results of each element separately. A careful analysis of the hydrographs (and sedigraphs) allows the user to estimate runoff generation (and sediment yield) in a particular section of the basin and to better understand the response of the basin to condition changes.

CONCLUSIONS

The integration of hydrological models within SNIRH allowed the development team to create an open source and free software that can be run on any operational system that has a Java Virtual Machine. The way that the hydrological models were integrated into the OpenJUMP software means that it was not necessary to implement them in Java language. Nevertheless, the use of an OpenGIS avoids the issue that new GIS functions need to be implemented. The distributed hydrological models allow separate simulation in each discretized element, and the system developed takes advantage of this to provide a graphical visualization of the results in order to facilitate the understanding of the spatial response of the basin to a rainfall event.

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