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Development of Interface for Daily Runoff Assessment from a Watershed

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ABSTRACT: Surface runoff is one of the major components in watershed hydrology. The amount of runoff generated from any watershed depends on the many watershed characteristics such as land use, soil type and its physical properties, topography, etc. These watershed characteristics are often spatial in nature. Besides these, rainfall in the form of time series is another major factor. An interactive interface for runoff assessment has been discussed in this paper, which combine the spatial and temporal data. An interface uses the NRCS CN method, which combine these both factors. The developed interface has incorporated in the DSS for operational water resources planning in a watershed, in which surface runoff is core component. The interface has been tested for small hilly watershed in western India. The estimated daily runoff depth for this watershed shows acceptable agreement with gauged daily runoff for the period of three years (2001 to 2003).

INTRODUCTION

Geographical Information System (GIS) has been used for spatial information processing and database management tool over the years. It has also been widely applied in most of the real-world studies that are spatial in nature. The usefulness of GIS in decision making problems has also been demonstrated in various studies (Loucks, 1995). The complex spatial and dynamic models can easily be applied with the use of GIS (Bertugila *et al.*, 1994). Hydrology is a complex science to deal with due to spatio-temporal variation of parameters involved. GIS has been found to be useful in hydrological studies (Walsh, 1993). Integration of GIS and hydrological model in ArcView GIS can be termed as approach of spatial modelling inside GIS (He, 2003). This is a commonly adopted approach in customization application which can be achieved by incorporating different models in GIS using software coupling methods. Another approach involves making model or software compatible to handle, read, manipulate and display the spatial data, which is termed as the modelling outside the GIS (Gar On Yeh and Qiao, 1999). Most of the hydrological models require both time and spatial information as input data. This requirement has brought a revolution in the field of spatial decision support systems, adding versatility to use GIS in diverse fields of hydrology (Singh and Forntino, 1996).

The first approach of modelling inside the GIS makes it difficult to handle time data with spatial layers, due to database management capabilities of GIS software. The database management in the second approach is convenient because the choice of database lies with the developer. Thus, the later approach is considered to be more appropriate in case of hydrological modelling. This paper demonstrates the use of this approach of modelling outside GIS for NRCS CN model, which requires both time and spatial information as input. The interface developed in the study has been tested for a small hilly watershed.

THE MODEL

The NRCS CN model is one of the most popular models used in simulation of runoff from the watershed. The model is divided into two parts; first part assigns Curve Number to specific land parcel depending on the land use and soil information. Second part takes rainfall data as input to decide the Antecedent Moisture Condition (AMC) and corresponding conversion of Curve Number to AMC. The first part can be related to spatial themes of soil and landuse, while the second part depends on time series rainfall data. The runoff is computed by the model in the form of time series.

THE INTERFACE

Any popular model or interface needs to have strong data analysis capabilities, model based analysis and visual presentation. In recent years, number of spatial information systems have been developed which provide resources upon which an integrated system infrastructure can be developed. With the support of object-oriented programming and system integration techniques, an interface has been developed, as shown in Figure 1, which incorporates essential functions of GIS, database systems and model management technique to provide overall modelling support. The Visual Basic programming language has been used for the development of this interface.

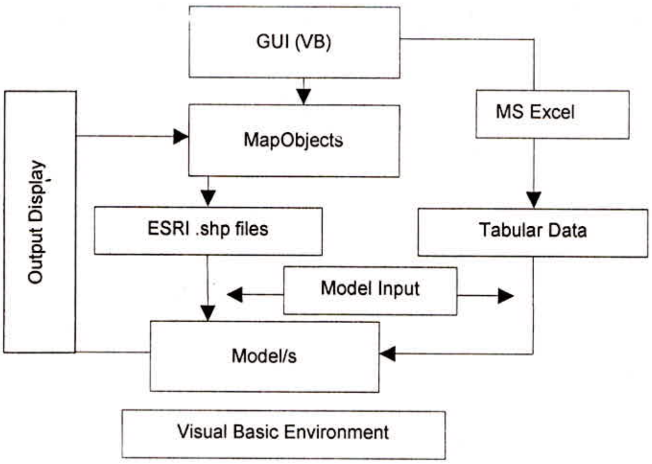

Fig. 1: Interface Architecture using MapObjects and Visual Basic

GIS FUNCTIONALITY

GIS is a functional tool kit to store and manipulate topographic, topological and thematic data. It is also helpful for cartographic display, spatial query, analytical modelling and results presentation. The present interface is based on MS Windows environment using ESRI's MapObjects as a tool for spatial data management and display. MapObjects is built upon MS's Object Linking and Embedding (OLE) standards, which consists of an ActiveX control (OCX) and programmable ActiveX automation objects. This is a collection of mapping and GIS components for application developers. Based on the object model diagram provided by MapObjects, MapObjects-based map display can be fully integrated with an individual interface to incorporate the functions of spatial data display.

THE DATABASE MANAGEMENT TOOLS

The database management is a key issue in the present interface, which uses the MS Jet database engine, Data Access Objects (DAO) programming interface to read and access the external time series data available in MS excel files. The spatial data is used in the form of ESRI shape files as specified in Table 1. This shape file is generated by digitizing landuse map provided by Department of Soil and Water Conservation, Government of Maharashtra and additional attributes of soil types in the respective polygon are added. The relational data associated with individual spatial object attribute is associated with DBASE IV file in structure of the shape file. Open Database Connectivity (ODBC), *RecordSet* of MapObjects and Visual basic with *TableDisces* properties have been used to bring the attribute data to Visual Basic environment. The data grid named *MSFlexGrid* has been used to display and perform the computation in Visual Basic. The database provides a user-friendly environment for data development and handling the model computation.

Table 1: Input Spatial Data

Name	*Description*	*Coverage Type*	*Attributes*
Landuse.shp	Land Use /Soil Type	Polygon	Object ID Shape Shape Area Shape Length Land Use Soil Type

THE MODEL BASE

The model base is important in an interactive spatio-temporal modelling. In recent years, a number of spatial models have been developed for different problem domains, which provide ample resource in this regard. The model base component in the present interface aims to handle spatial and temporal data in different formats. The model base functions in two steps; first the spatial data is called to display in the *MapLayer* of Visual Basic form, and second, the information generated from the spatial data is modified according to time series data to present the final output in time series. Model solver is developed with Visual Basic programming. The variables derived in the *MSFlexGrid* are directly linked other objects to be used further. The model execution sequence is important for an effective running of model for different data. In order to achieve this goal, model parameterization and computations are done in different forms of Visual Basic. The computing sequence of NRCS curve number model is given as follows:

1. ESRI shape file (polygon type) describing the landuse and soil type in each land parcel along with

its area is called to display in the *MapLayer* through MS Windows common dialogue box.

2. The spatial data related to land use and soil alongwith the area of each land parcel are displayed in the *MSFlexGrid* using the *RecordSet* and *TableDisces* properties of MapObjects.
3. The Curve Number values at AMC II are decided as per the standard norms of NRCS for each polygon unit, based on landuse and soil information.
4. The weighted Curve Number for each polygon is computed with respect to area of that polygon.
5. The weighted Curve Number for the complete area in the shape file is computed and displayed in the text box of same Visual Basic form.
6. In another form connected through the command button, rainfall data with date, month and year are displayed in *MSFlesGrid.* The Curve Number values at AMC II condition are also displayed which are later converted to AMC I or AMC III depending on five days preceeding total rainfall for the corresponding day.
7. The maximum potential abstraction (S) is computed for everyday using newly converted value of Curve Number.
8. The rainfall and maximum potential abstraction are used to compute the runoff in the form of time series data.

TESTING THE INTERFACE

The developed interface has been tested for Khadak Ohal watershed which lies at 73°16.5′ E longitude and 20°2.7′ N latitude in western Indian State of Maharashtra. The spatial data required for this has been prepared in ArcGIS. The description of shape file with its attributes is given in Table 1. Table 2 gives the different land use and their associated soil type with its area.

Table 2: Land Use and Their Associated Soil Type with Its Area

Sl. No	*Land Use*	*Soil Type*	*Area, ha*
1.	Agriculture	Clay	363.27
2.	Forest	Loam	1186.71
3.	Wasteland	Silty Loam Loamy Sand	10.07

Daily time series data regarding the rainfall and observed runoff are collected from the concerned authorities for monsoon period of year 2002. The rainfall data are arranged in MS Excel to call these in the interface. The ESRI shape file is prepared for the attributes as given in Table 1. The data display form of the interface with spatial data displayed in *Map Layer* is shown in Figure 2. The computed runoff for this data and monsoon rainfall of year 2002 are shown in Figure 3. The figure also displays the ETo values, a parameter which is computed by the modelling approach and use in the large study which has not been reported here. The regression coefficient of 0.7 is observed between the computed and gauged runoff from the watershed, which is quite acceptable. The plot of observed and computed runoff for the test watershed is shown in Figure 4.

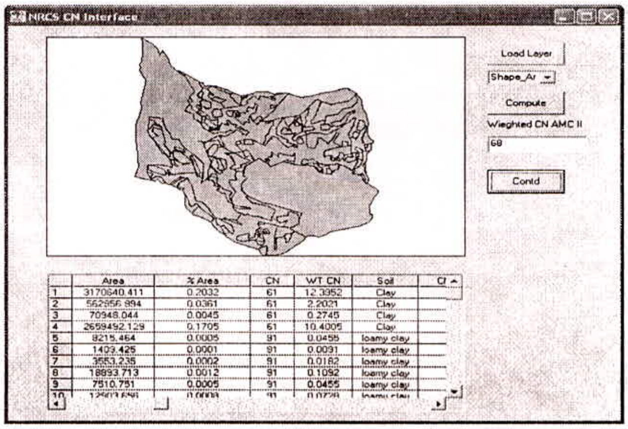

Fig. 2: Data Display Form of the Interface

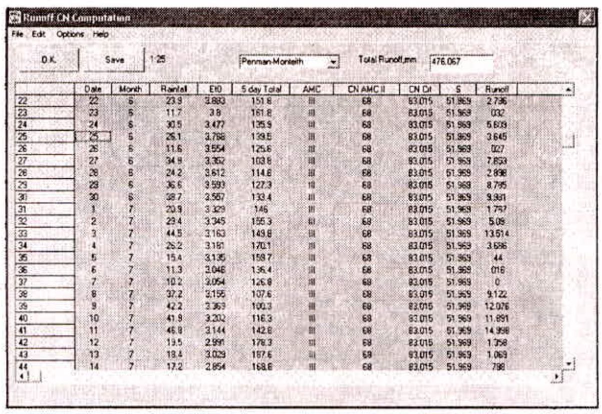

Fig. 3: Computation Form of the Interface

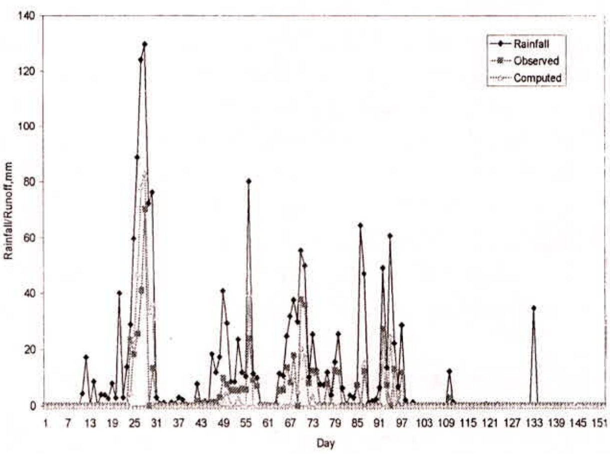

Fig. 4: Observed and Computed Runoff (Year 2002)

CONCLUSIONS

The study demonstrates the integration of spatial and temporal data for modelling and simulation of runoff. It demonstrates the concept of modelling outside GIS using object oriented programming language and ActiveX control. The developed interface is user friendly, and provides a convenient tool for handling spatial and temporal data. The results obtained from the simulation are in the acceptable range. The interface demonstrated here forms parts of a large study for developing the decision support system for water resources planning. The runoff obtained has been used for operational water resources planning at time step decided by the user.

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