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AN OVERVIEW OF GEOGRAPHIC INFORMATION SYSTEM AND ITS ROLE AND APPLICABILITY IN ENVIRONMENTAL MONITORING AND PROCESS MODELING

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Abstract

The geographical information system (GIS) is a tool used generically for any computer-based capability for manipulating geographical data. The hardware and software functions of GIS include data input, data storage, data management (data manipulation, updating, changing, exchange) and data reporting (retrieval, presentation, analysis, combination, etc.). All of these actions and operations are applied to GIS as a tool that forms its database. The paper describes the types of the GIS data formats (vector, raster), database object definitions, relationships, geometric features, and the data organization structure. Some GIS applications and examples are given for better understanding of how GIS data can be used in GIS applications, with the respect to data formats, including surface elevation and slope from digital elevation model data (DEM), with the applicability in water industry.

Key words

Geographical Information System (GIS), data vector, data raster, GIS data management, digital elevation model (DEM)

Introduction

Geographical Information System (GIS) is a computer based tool for collecting, storing, transforming, retrieving and displaying spatial data from the real GIS world. GIS provides facilities for data capture, data management, data manipulation, analysis, and the presentation

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of geographical data. GIS is not simplya system for making maps (although it can create maps at different scales, in different projects), a GIS is an analysis tool as well.

The geographical (or spatial) data represent phenomena from the real world in terms of their position with respect to a known coordinate system, their attributes that are unrelated to position (such as color, pH, incidence of disease, etc.) and their spatial interrelations with each other. The spatial relations describe how they are linked together (this is known as topology and describes space and spatial properties such as connectivity, which are unaffected by continuous distortions) [12].

Application of GIS

GIS occurs in almost every industry. It is used for education, land management, natural resource management, environmental and aeronautical applications (data on rocks, water, soil, atmosphere, biological activity, natural hazards, and disasters collected for wide range of spatial levels of resolution) [12].

Although it is easy to purchase the parts of GIS (hardware and software), the system functions only when the requisite expertise is available, the data are compiled, the necessary routines are organized and the programs are properly modified to suit the application, and/or organization’s needs. GIS system suitability chain is shown in Fig. 1 [5].

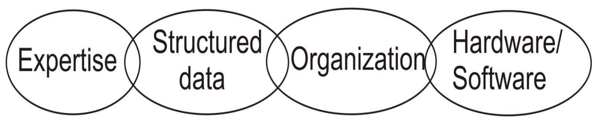

Fig. 1 *GIS system suitability chain*

Geographical information attaches a variety of qualities and characteristics to geographical locations. These qualities are physical parameters such as ground elevation, soil moisture, atmospheric temperature, as well as classifications according type of vegetation, ownership of land, zoning, floods, environmental accidents, water sources, wastewater, storm water, air quality, etc.

GIS are powerful and cost effective tools for deigning intelligent maps for water, wastewater, and storm water systems. Below, we will describe a storm water system management, and give some examples of system application as well.

The practice of storm water management reduces the quantity and/or quality of water being discharged into a land or water area.

Effective storm water management requires the linking of specialized computer models to the GIS. Also, integration of engineering, environmental, and socioeconomic objectives into storm water management could be included.

In local storm water management, different areas of a watershed implement different storm water management plans locally to solve the problems as flooding, sedimentation, erosion, etc.

Most of the physical, social and economic problems associated with storm water are attributable to unwise land use, insufficient attention to land drainage in urban planning, and ineffective updating of existing storm water control systems. An effective solution to storm water management is the watershed wide approach. This approach implements a comprehensive storm water plan throughout the watershed to prevent the adverse effects of storm water, both at a particular site and anywhere downstream where the potential for harm can be reasonably identified [10].

Typical applications of GIS for storm water systems include: (1) Watershed storm water management; (2) Floodplain mapping and flood hazard management; (3) Hydrologic and hydraulic modeling of combined and storm sewer systems (Fig. 8), including estimating surface elevation and slope from digital elevation model data (DEM) (Fig. 2); (4) Documenting field work; (5) Planning, assessment of the feasibility and impact of system expansion; (6) Estimating storm water runoff from the physical characteristics of the watershed, e.g., land use, soil, surface imperviousness and slop [4], [6].

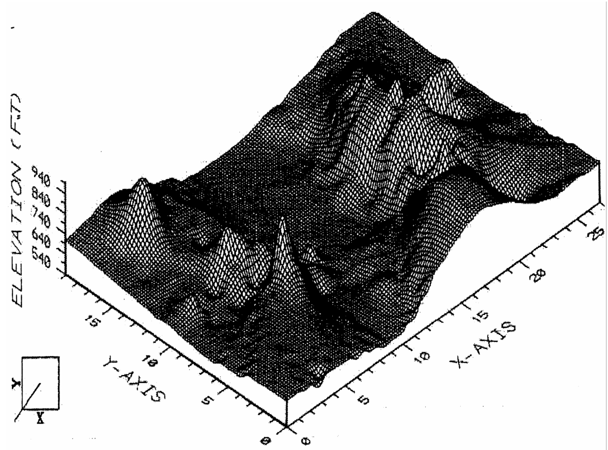

Fig. 2 *Digital elevation model data (DEM) [1]*

Topography influences many processes associated with the geography of the Earth, such as temperature and precipitation, GIS application professionals must be able to represent the Earth surface accurately because any inaccuracies can lead to poor decisions that may adversely affect the Earth environment.

A DEM model (Fig. 2) is a numerical representation of terrain elevation. It stores terrain data in a grid format for coordinates and corresponding elevation values. DEM data files contain information for the digital representation of evaluation values in a raster form. Cell-based raster data sets (or grids), are very suitable for representing geographical phenomena that vary continuously over space such as elevation, slope, precipitation, etc. Grids are also ideal for spatial modeling and analysis of data trends that can be represented by continuous surfaces, such as rainfall and storm water runoff.

Regardless of the data structure, DEM models can be defined in terms of (x, y, z) data values, where x and y represent the location coordinates and z represents the elevation values. Grid DEM model consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals. This data structure creates a square grid matrix with the elevation of each grid square, called a pixel, stored in a matrix format.

Fig. 2 shows a 3D plot of the grid-type of digital terrain models (DEM) data. Usually, some interpolation is required to determine the elevation value from a DEM for a given point. The DEM based point elevations are most accurate in relatively flat areas with smooth slopes. DEM models produce low-accuracy point elevation values in areas with large and abrupt changes in elevation, such as cliffs and road cuts [1], [12].

Major DEM applications include: delineating watershed boundaries and streams, developing parameters for hydrologic models, modeling terrain gravity data for use in locating energy resources, determining the volume of proposed reservoirs, calculating the amount of material removed during strip mining, determine landslide probability. DEM can be used for automatic delineation of watershed and sewershed boundaries. DEM data can be processed to calculate various watershed and sewershed characteristics that are used for Hydrologic and Hydraulic model (H&H) modeling (Fig. 3) of watersheds and sewersheds [1].

DEM can create relief maps that can be used as base maps in a GIS for overlaying vector layers such as water and sewer lines. DEM files may be used in the generation of graphics such as isometric projections displaying slope, direction of slope (aspect), and terrain profiles between designated points. The aspect identifies the steepest down-slope direction from each cell to its neighbors.

Raster GIS software packages can convert the DEM into image for visual display as layers in a GIS. DEM data may be combined with other data types such as stream locations and weather data to assist in forest fire control, or they may be combined with remote sensing data to aid in the classification of vegetation.

Possibility to use GIS to modify the configuration of the water distribution network, compile model input files reflecting those changes, run the hydraulic model from within the GIS, use the GIS to map the model results, and graphically display the results of the simulation on a geo-referenced base map. The integration method of interrelationships among the user, the Hydrologic and Hydraulic model (H&H), and the GIS software is shown in Fig. 3 [1]. A detailed description of H$H model can be found in [1].

GIS is intended to be a means of improving everyday life. Geographical information attaches a variety of qualities and characteristics to geographical locations. These qualify for physical parameters are such as ground elevation, soil moisture, atmospheric temperature, as well as classifications according to type of vegetation, floods, environmental accidents, water sources (wastewater, storm water), ownership of land, etc.

We described common geographical data model structures - a grid-based structure (raster), and a coordinate point structure (vector). Also, we gave a view at a database management system DBMS as a program (or collection of programs formalized description of real world phenomena, database structures and methods of database organization) that enables the user to save, modify, classify, select, and extract information for a central database.

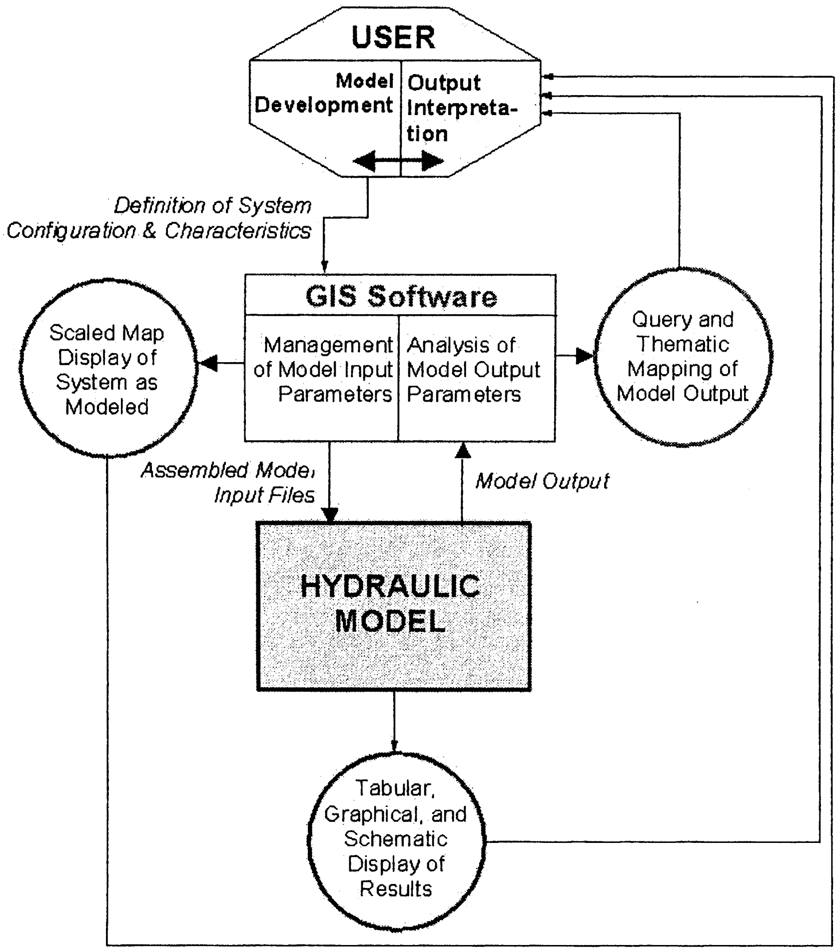

Fig. 3 *Integration of GIS Software, End User, and H&H model [1]*

Conclusion

We showed the GIS system as the powerful and effective tool for creating intelligent maps for, e.g., water, wastewater, and storm water systems. Although it is very easy to purchase the constituent parts of GIS (hardware and software), the system functions only when the requisite expertise is available, the data are compiled, the necessary routines are organized, and the programs are modified to suit the application, and/or the organization's needs.

GIS integrates all kinds of information and applications with a geographic component into one manageable system. Therefore, a benefit of GIS applications is their ability to integrate and analyze all spatial data to support a decision-making process. A GIS system has to be built up within an organization. The integration capability of GIS technology empowers organizations to make better and informed decision based on all relevant factors.

We must be aware of the fact that the digital representation of geography is not equal to the geography itself. Any digital representation involves some degree of approximation. It is therefore important that the information that results from data processing be applied to guide the real world in the right direction.

References:

[1] SHAMSI, M. *GIS applications for water, wastewater, and stormwater systems*. 2005. ISBN 0-8493-2097-6

[2] BERNHARDSEN, T. *Geographic Information Systems:* An Introduction. Publisher: John Wiley. 1999. ISBN 0-4713-21923

[3] GOROKHOVICH, Y., KHANBILVARDI , R., JANUS, L. GOLDSMITH, V., STERN, D. Spatially Distributed Modeling of Stream Flow During Storm Events. In *Journal of the American Water Resources Association*, 2000, Vol. 36, No.3, pp. 523-539.

[4] SHAMSI, U.M. *GIS tools for water, wastewater, and stormwater systems.* ASCE Press, 2002. ISBN 0-7844-0573-5

[5] LONGLEY, Paul. *GIS – Principles and Technical Issues.* Volume 1. Publisher: John Wiley, 1999.

[6] LONGLEY, Paul. *GIS – Management Issues and Applications*. Volume 2. Publisher: John Wiley, 1999.

[7] Self Teaching Student's manual for GIS. http://infosys-law.canberra.edu.au/gismodules/index.html

[8] Brian KLINKENBURG, Holly DICKINSON. The Vector GIS Capabilities, The Vector or Object GIS.1996 http://www.geoplan.ufl.edu/giseducation/vector.html http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/u13.html

[9] FOOTE Kenneth E., HUEBNER Donald J. The *Geographer's Craft Project. Department of Geography*. University of Texas at Austin, 1996. http://www.colorado.edu/geography/gcraft/notes/datacon/datacon_f.html

[10] POERTNER, H.G. *Stormwater Management in the United States. Stormwater Consultants*. Bolingbrook, IL. 1988.

[11] Ladislav VIZI, Gejza M. TIMČÁK, Peter BLIŠŤAN. GIS for geological survey data and geostatistical model of the Kišovce-Švábovce Mn deposit. In *GIS Ostrava 2003 : GI/GIT teorie a praxe ruku v ruc*e : 10. ročník konference, 26.-29. ledna 2003. Ostrava: VŠB-TU, 2003. - 1 elektronický optický disk (CD-ROM). 13 p. ISSN 1213-239X

[12] GIS standards and interoperability. In *Arc News. The Environmental Systems Research Institute (ESRI)*, 2003, Vol. 25, No.1.

[13] Jozef HALÁSZ, Roman CHOVANEC. *Informačné systémy pre životné prostredie*. 1. vyd. Žilina: STRIX, 2008.130 p. ISBN 978-80-89281-21-3

[14] BURROUGH, P. A, McDONNELL, R. A. *Principles of Geographical Information Systems*. Oxford, University Press, 2000. ISBN 0-19-823365-5

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