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TEACHING SPATIAL DECISION ANALYSIS WITH IDRISI ONLINE

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1. INTRODUCTION

This paper describes a Web-based tutorial for spatial decision analysis that is based on an online access to the Idrisi32 desktop geographic information system (GIS). The Idrisi GIS is briefly introduced with a focus on its programmability and its decision support capabilities. Specific attention is given to the multi-criteria evaluation (MCE) module. In a prototype implementation, Idrisi is been made accessible from standard Web browsers.

The tutorial data of the regular Idrisi installation are used for a sequence of four tasks in spatial multi-criteria decision analysis. The online tutorial makes parts of the problem solution from the Idrisi documentation accessible online in an interactive way. The architecture of the proposed application is described with an emphasis on the data flow between client-side browser input form, Web server, and the server-side CGI scripts that access Idrisi's Visual Basic API.

2. THE IDRISI GIS

Idrisi is a full-featured geographic information system. It is composed of so-called "modules" which can be accessed via the main window's menu system. Usually, modules require the input of parameters such as input and output file names and specific values for processing parameters. Modules can also be run through macros and accessed via Idrisi's application programming interface (API). In this case, parameters have to be provided by the external application that uses the modules.

Idrisi is one of the most popular GIS world-wide. It is maintained by Clark Labs, a spin-off of the department of geography at Clark University, Worcester, MA. The project has a low-cost approach, which gives it a high market share in academia and in developing countries. Clark Labs, headed by Dr. J. Ron Eastman, explicitly focuses on supporting research and development projects. A major research direction is spatial decision support.

2.1 Functions for Decision Support

Idrisi is likely to have the most advanced decision support functions available in GIS today. The "Decision Support" submenu contains fourteen individual modules for different steps in spatial decision support. The online tutorial developed in this paper uses two core decision support modules (MCE and FUZZY), three additional GIS analysis modules (BUFFER, RECLASS, and ASSIGN), and an export function (JPGIDRIS). Table 1 shows how these modules are used in the tutorial.

2.2 The MCE Module

Multi-criteria evaluation in Idrisi offers three variants for aggregating multiple constraints and factors. In this context, *constraints* are criteria that reduce the set of feasible decision alternatives by excluding locations based on specified categories or threshold values, while *factors* describe the degree of suitability of a location with respect to a criterion. Factors can be weighted against each other.

MCE	Performs multi-criteria evaluation by Boolean intersection, weighted linear combination, or ordered weighted averaging (described in more detail in the following section)
BUFFER	Creates buffer zones around features in a raster map
RECLASS	Re-classifies cell values in raster maps by equal interval or user-defined mapping of new to old values
ASSIGN	Re-classifies integer cell values (categorical data)
FUZZY	Converts image to fuzzy membership values (0..1, or 0..255); used for score range standardization
JPGIDRIS	Converts Idrisi raster maps to JPEG images

Table 1 Idrisi modules used in the online spatial decision analysis tutorial

Boolean intersection in the MCE module is a logical AND operation on Boolean constraint maps. Only locations that are characterized as suitable (value 1) on all maps will be suitable in the result.

Weighted linear combination (WLC) assesses the suitability of image cells by weighting and combining factor maps. WLC multiplies cell values in standardized factor maps by the corresponding factor weight, and then adds weighted values across images. Due to conditions on the weights (all positive or zero, sum equal to one), the resulting cell values are in the same range as those of the factor maps.

Ordered weighted averaging (OWA) is a family of multi-criteria aggregation operators based on WLC that allows the user to specify a decision strategy through an additional set of weights. These "order weights" influence the amount of tradeoff between criteria, and the decision risk. Solutions using the logical AND operator are characterized as risk-averse, those using the logical OR are defined as risk-taking. OWA re-orders weighted standardized values for each cell of factor maps in descending order. Re-ordered values are then multiplied by the order weights and added across factor maps. This way, order weights increase or decrease the influence of good or bad criterion outcomes for individual cells.

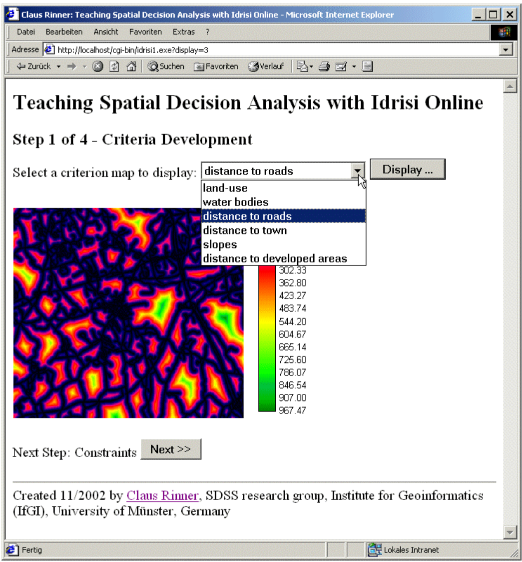

Fig. 1 Inspection of original data

To accommodate these three aggregation variants, the MCE module requires two parameters, the output file name and a decision support file (*.dsf) name. Further parameters are contained in the decision support file: the number of constraints and factors, the file names of constraint maps, the file names of factor maps together with the corresponding importance weights, and, for OWA, the order weights. The *.dsf file is created by Idrisi's MCE dialog with the parameters entered by the user. In the case of macro or API access to the module, the *.dsf file has to be created by the client application.

3. AN INTERACTIVE ONLINE TUTORIAL

The Web-based tutorial developed in this paper uses the decision problem and related data from the regular Idrisi32 desktop tutorial. The scenario is about finding suitable areas for residential development around a town. The problem solution described in Eastman (2001a) is partially made available here in an interactive, online context. It consists of data inspection, criteria development, and multi-criteria evaluation. Eastman (2001b) provides detailed information on some of the methods used.

3.1 Data Inspection

The tutorial first offers users the option of inspecting the available data sets to be used as decision criteria. The raw data consists of the following maps from the MCE folder of the Idrisi32 tutorial:

- land-use categories
- location of water bodies
- distance to roads
- distance to the town centre
- slopes
- distance to developed areas

In the first step of the online tutorial, these maps can be displayed in the Web browser one at a time (see Figure 1).

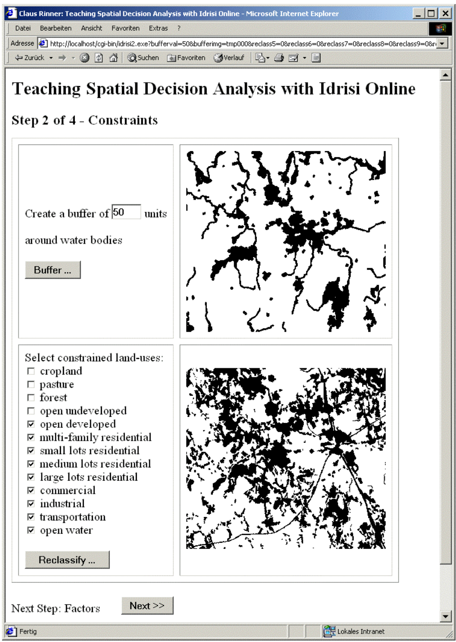

Fig. 2 Development of Boolean constraint maps

3.2 Development of Constraints

Step two of the tutorial allows users to specify constraints on water bodies and land-use categories. Water bodies can be protected by a buffer zone that is defined as non-suitable for residential development. Land-use categories can be classified into suitable and non-suitable. Figure 2 shows the input form for constraint development with user-specified water buffer and land-use suitability maps.

3.3 Development of Factors

All six data sets in the tutorial are used as factors. That is, distance to water bodies and categories of land-use are used as factors in addition to the related constraints described before. The additional data sets are used as factors only.

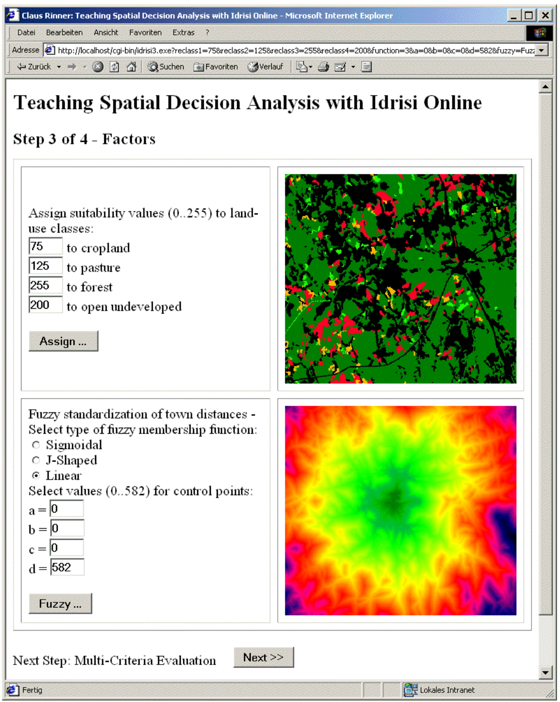

Fig. 3 Development of factor maps

In order to demonstrate the development of factor maps, the online tutorial provides support for two tasks: definition of suitability levels for land-use categories, and fuzzy re-classification of values for distance to the town centre (see Figure 3). For the remaining factors, standardized factor maps of the Idrisi32 tutorial are used to keep the online tutorial as simple as possible.

3.4 Multi-Criteria Evaluation

The last step of the online tutorial provides users with an overview of the previously defined factor maps and constraint maps. It uses weighted linear combination to evaluate suitability for the residential project. Users have to provide weights of relative importance for each of the factors, and specify whether constraints should be used or not (see Figure 4).

The final suitability map is calculated according to user input and displayed using the default Idrisi 256 colour palette with green values indicating highest suitability.

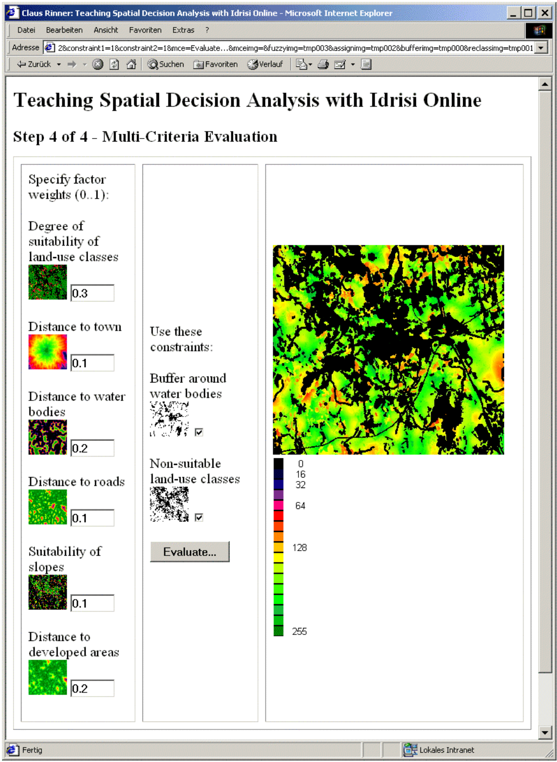

Fig. 4 Multi-criteria evaluation

4. ONLINE ACCESS TO IDRISI'S DECISION SUPPORT MODULES

Steps two through four described above make use of a server-side Idrisi for criteria standardization and multi-criteria evaluation. A classical, server-side approach (Plewe 1997; Green & Bossomaier 2002; Rinner & Jankowski 2003) has been used to connect Idrisi to the Web. Clients display a HTML page that contains static map images and a form. When submitting user input, data in the form is sent to a HTTP server via a POST request. The server software used here is the Sambar server.

The HTTP server calls an executable CGI script on the server PC and transfers to it the CGI parameters from the HTML form. The tutorial was developed with scripts written in Visual Basic, one for each of the four steps. These scripts receive the parameters as a string via the standard input stream and parse the string for key/value pairs. Then, they use the input to access decision support modules with custom parameters through Idrisi's RunModule API function.

For example, a CGI script stores parameters from user input in a decision support file, and uses RunModule to call the MCE and JPGIDRIS modules for evaluation and conversion of the resulting raster map into a Web-compliant JPEG image. Result images are stored on the server with temporary file names.

Finally, a new HTML page is generated including a form and references to the temporary image files. The HTTP server forwards the standard output of the script to the client. When the client displays the new HTML page, it loads the result map image directly from the server (see Figure 5).

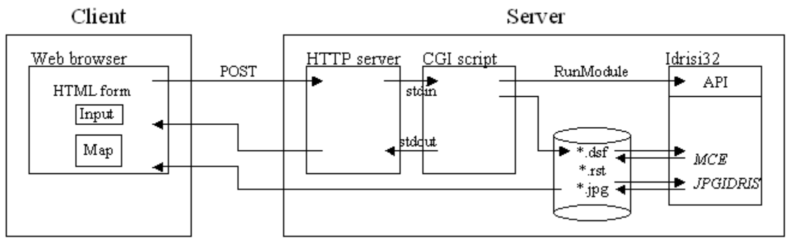

Fig. 5 The architecture of the online tutorial

5. CONCLUSION AND OUTLOOK

This paper proposes an interactive online tutorial for spatial decision analysis. A classical Internet map server approach with a thin client was implemented as a prototype.

Despite of the fact that online access has been provided in the past to GIS packages such as GRASS or Arc/Info, the application presented here provides novel aspects for WebGIS: 1) Earlier applications have not been presented as *tools for distance learning* (of spatial decision support concepts). However, a tutorial provides a context in which interactive access to GIS for a potentially broad audience of non-experts is very useful. The option to review user preferences and re-do tasks to explore the consequences can be assumed to increase learning outcomes. 2) *Advanced GIS analysis functions* required for decision analysis have rarely been made available online. Instead, most WebGIS applications are confined to using map generation and information retrieval functions of server-side GIS (Rinner 1998). 3) Usually, GIS functions are hidden from Internet users in WebGIS applications. In a teaching environment however, *making step-by-step data processing explicit* is part of the mission.

The Idrisi32 GIS has one of the most powerful spatial decision support toolkits available today. It also provides comprehensive documentation for its decision support capabilities. Therefore, Idrisi was chosen for server-side data processing. To the author's knowledge, Idrisi has not been made available on the Web before. The vendor, Clark Labs, was contacted in order to check compliance with the available license types. Currently, Clark Labs request that clients of an Idrisi server have to be licensed users of Idrisi32. A tentative authorization procedure was included in the prototype implementation of the online tutorial.

Two critical technical issues have been identified in an ad-hoc user test: The system stalls on incorrect user input, and response times are unpredictable and generally too long. The Idrisi programming API does not support error handling. Instead, error messages appear on the screen of the server computer. Therefore, detailed consistency checks are required for user input on the client side. The Javascript language can be used for this. Performance issues are more difficult to tackle and will require additional, detailed user studies.

The online access to some of Idrisi's decision support functions is also a test for Web-based spatial decision support in general. It is implemented using server-side techniques and a thin, viewer client in contrast to client-side techniques (Rinner & Jankowski 2003), and Web services (Bernard 2002). In the interoperable Web services approach, each individual task should be managed by its own service. Due to the lack of specialized Web services, the traditional approach of a comprehensive, server-side GIS is still required today for demanding applications such as spatial decision support. However, the author is involved in research aiming at broadening the scope of Web service specifications to more complex geo-processing tasks.

6. ACKNOWLEDGEMENTS

Niklas Panzer provided valuable support in processing the Idrisi tutorial data sets.

7. ONLINE RESOURCES

Online tutorial described in this paper: http://cyclone.uni-muenster.de (authorisation required)

Idrisi homepage: http://www.clarklabs.org

Sambar Web server documentation and download: http://www.sambar.com

8. REFERENCES

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