Spatial Analysis in Forest Protection using the visual modelling tool MapModels

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Abstract

Serious risk assessment and pest management in forestry need practicable tools based on profound knowledge about triggers of insect outbreaks. At the Institute of Forest Entomology a rating system was established which facilitates the evaluation of a given region with respect to its potentials for bark beetle development. The practical and empirical work has been carried out mainly with MapModels – a graphical modelling language based on ArcView® which supports easy development of analysis procedures by means of flowchart representations.

1. MapModels

MapModels is a new and flexible tool for explorative spatial data analysis and decision support (SRF 2002). It has been developed at the Institute of Regional Science of the Vienna University of Technology to bridge the gap between spatial decision analysts and computer programmers (Riedl et al. 2000). MapModels is a visual programming language based on the widespread geographical information system ArcView®. It supports the development and implementation of analysis procedures based on flowchart representations in a very intuitive and user-friendly manner.

Flowcharts are used for the visualization of models and analysis processes in a wide range of applications. Normally this kind of graphic representation is simply focused on the illustration of the model structure and information flow but doesn’t directly control the underlying processes.

Within MapModels the nodes of a flowchart are in fact active elements of the model. They provide a visual encapsulation of real analysis procedures and data

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objects where input data and analysis operations are represented by labeled icons connected by edges which characterize the dataflow (Fig. 1).

![Flowchart Diagram](image)

**Fig. 1:** A simple spatial query: "find all relatively flat areas with an elevation higher than a given threshold" (center: MapModel; left: slope<10% and elevation>1100m; right: slope<40% and elevation>1700m with corresponding results)

Since MapModels flowcharts contain executable code, the specification and the implementation of the analysis model is just one single step. It is kind of a drawing-process where flowchart elements are inserted into the model environment and connected by means of drag-and-drop operations with the mouse.

Currently a basic function library is available which contains a steadily increasing number of flowchart elements for a wide range of analysis operations including e.g. the application of fuzzy logic (see Benedikt et.al. 1999 and 2002). Standard MapModels-users usually will apply functions out of this set. Users with basic Avenue™ programming skills can extend and/or customize the existing set according to their specific needs with low effort (for details see SRF 2002).

The recently implemented option of “nesting” models enhances the flexibility of MapModels (Riedl and Kalasek 2002). This concept is very similar to the routine-subroutine design of conventional programming languages. A submodel is defined as a collection of MapModels-functions which act as a single flowchart element when used within other models. An input/output interface has to be defined for each submodel in order to address the submodel on other model-levels (fig. 2).
Fig. 2: Concept of submodels: the flowchart inside the dark box (left model) is merged by means of a specialized dialog box (model interface generator, upper right picture) in a single node (lower right model).

This modular design enables users to build customized basic analytical units for their applications and reuse them wherever they want and need. Compared to “All-In-One” concepts (i.e. the whole analysis model is represented within a large single model) the modular approach in the recent version 2 of MapModels helps to keep models small and self-explanatory and avoids redundancies within the whole analysis-structure as well (i.e. duplication of programming code).

2. Application to Forest Protection

A sophisticated rating system regarding the hazard of bark beetle mass outbreaks was applied and evaluated at the IFFF by means of MapModels. The analyses were carried out within the scope of the EU Inco-Copernicus project “Integrated risk assessment and new pest management technology in ecosystems affected by forest decline and bark beetle outbreaks”. This project was launched, since spruce dominated forests in mountainous areas are increasingly endangered by infestations of the 8-toothed spruce bark beetle *Ips typographus* (Coleoptera; Scolitidae). Not only severe economical losses for forest proprietors may be caused by this major pest, but also significant ecological changes may be brought about. The dieback of spruce stands puts at risk diverse functions of mountain forests demanded by human
society, such as avalanche protection, water supply or recreation. Consequently, the identification of hazardous situations and damage prevention are essential aspects of forest management, especially in zones of nature conservation. Basing on profound knowledge about triggers of bark beetle mass outbreaks, the developed rating system was intended as practicable tool for risk assessment. Hazard rating was realised for areas at the eastern rim of the High Tatras National Park, which is situated at the border between the Slovak Republic and Poland. The nature reserve is characterised by high structural diversity, the altitudes in the research area range from 900m to more than 1600m above sea level.

The hazard assessment system was based on the concept of predictable susceptibility (predisposition) of forests to a certain disturbing agent, assuming that the probability of damage is influenced by the occurrence of specific site and stand related characteristics (Nopp, 1999). Hazards regarding site and stand level are separated, since a distinction between naturally given danger spots and conditions changeable within the scope of silviculture is aspired. The complex system consists of several sub-models, comprising input parameters regarding soil, terrain, stand composition and structure as well as predisposition to and previous damages by several biotic and abiotic factors (see Fig. 3).

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**Fig. 3:** Site and stand related parameters of the rating system. In the following the procedure of modelling is demonstrated by means of the sub-model “Terrain” (marked area) for assessing predisposition to storm damage.
Each indicator of the assessment system (e.g. status of water supply) was weighted according to its relevance and contribution to an overall predisposition. The scoring between 0 and 1 followed empirical approximation based on a thorough review of respective literature and was approached by Fuzzy Logic. In order to evaluate the predisposition pattern of the study area, the spatial distribution of each parameter was analysed. The relevant topographic and stand related data were derived from a digital elevation model (DEM) and a digital forest map. Subsequently, the appropriate scores of included indicators were summarised for each locality and related to the maximum total – most unfavourable - amount.

The procedure of modelling is demonstrated by the sub-system “Terrain” for assessing the site related predisposition to storm damage (Fig. 4). The availability of breeding substrate is essential for bark beetle development and may be supplied on a massive scale after windfall. A complex checklist for assessing the probability of wind damage (Nopp 1999) was very much simplified for its implementation in the research area. Slope gradient, slope position and exposure towards the prevailing wind direction (Aspect) were considered the main terrain-related indicators. Depending on slope orientation to wind (Windward, Leeward, Angular and Parallel) lower, middle and upper slopes are weighted by different fuzzy functions (Fig.5). Intermediary results such as the spatial distribution of weighting classes for single parameters and indicator combinations (e.g. sub-model “Terrain”) may be illustrated by maps (Fig.6).
Fig. 4: In order to assess terrain characteristics of the research area the single indicators “Aspect” (exposure of slopes to wind) and “Slope Position” are calculated by subordinate models.
Fig. 5: Model node for weighting “Angular” slopes basing on respective fuzzy function.

Fig. 6: Illustration of intermediary results.
For system verification, the predominant scores of indicator weighting and of predisposition classes were extracted for each forest compartment. The selectivity of the predisposing criteria was analysed by computing relative frequencies of damage categories (areas recently infested or not infested) within both the different indicator weighting classes and levels of predisposition. These distributions were interpreted as measures of predication quality of the assessment system and showed a strong correlation between the deduced probability and actual status of infestation.

Bibliography


