EMDS Has a GeNIe With a SMILE

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Abstract

The Ecosystem Management Decision Support (EMDS) system has been further enhanced with an analytical engine—BayesFusion's SMILE (Structural Modeling, Inference, and Learning Engine) that comes with the GeNIe (Graphical Network Interface) software—for creating Bayesian network (BN) models. BNs are graphical networks of variables linked by probabilities, that have proven useful in decision-aiding for risk analysis and risk management.

Keywords: Ecosystem Management Decision Support, EMDS, Bayesian network models, probability networks, decision analysis.

Introduction

The Ecosystem Management Decision Support (EMDS) system has been serving the needs of natural resource land managers in the United States and beyond for over 20 years now (Reynolds et al. 2014). First released in 1997, and recently updated to version 7, EMDS is a freely available framework for spatial decision support; it is composed of a suite of analytical engines tied to geographic information systems (GIS) to help researchers and managers evaluate landscape conditions for use in strategic and tactical planning.

The classical notion of a decision support system includes a "problem processing system" that reads and interprets data to draw conclusions and perhaps make recommendations to a system user (Holsapple 2003). A shorter alternative name for a problem processing system is an **engine**. GIS analysts often use simple overlay operations to analyze how data affect some outcome of interest (e.g., habitat suitability), but overlays are, in effect, extremely simplistic models, whereas engines can process deep, complex knowledge captured in various kinds of models (e.g., logic or Bayesian models).

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EMDS is essentially a spatially referenced decision support system that can integrate empirical data, geographic information, and knowledge-based reasoning. Its analytical engines include a fuzzy logic engine (NetWeaver); multicriteria decision analysis (Criterium DecisionPlus, CDP); Prolog-based decision trees (VisiRule); and now Bayesian networks (BNs).

The BN component consists of BayesFusion's SMILE engine (https://www.bayesfusion.com). The addition of a BN component is particularly useful for EMDS applications pertaining to the adaptive management element of ecosystem management by explicitly representing degrees and implications of uncertainties. SMILE (Structural Modeling, Inference, and Learning Engine) comes with the GeNIe (Graphical Network Interface) software, an interactive graphical user interface (GUI) for BN application development, written for the Windows™ operating system[2] but working also under iOS™ and Linux.

The GIS component of EMDS runs in ArcMap™, QGIS, MapWindow, and DotSpatial, making EMDS a highly flexible system for environmental analysis and planning at any geographic scale (or multiple scales). The EMDS core component manages the interoperability of the analytical engines with each other and the GIS environment, and is built on the open source Windows Workflow Foundation (WWF). A workflow is an organized collection of activities (often, but not necessarily, sequential) that are executed to accomplish some overall analytical task (Chappell 2009).

Owing to its WWF architecture, EMDS applications can invoke complex sequences of analytical tasks, using any or all of its analysis engines in any order that makes sense to the application at hand. In EMDS version 7, system users can incrementally build a workflow, invoking the engines one at a time, or (and this is the real power of workflows) the task sequencing can be programmed in a graphical workflow editor that is integrated into EMDS. Thus, programmed workflows enable automation. For example, one might run an analysis, and then want to explore 40 alternative scenarios that represent either variations in data inputs or model specifications, or both. This is easily automated in a workflow editor.

Example of Workflow Sequence

Because the focus of this report is the addition of BN processing, the following is an example of a workflow sequence that illustrates how the SMILE Engine might fit into a larger, more complex decision support project for ecosystem restoration (see fig. 1):

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.
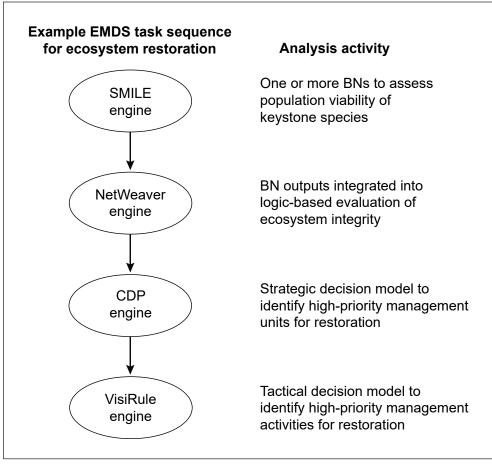
Example EMDS task sequence for ecosystem restoration

Analysis activity

SMILE engine → One or more BNs to assess population viability of keystone species

NetWeaver engine → BN outputs integrated into logic-based evaluation of ecosystem integrity

CDP engine → Strategic decision model to identify high-priority management units for restoration

VisiRule engine → Tactical decision model to identify high-priority management activities for restoration

Figure 1—Workflow stream in Ecosystem Management Decision Support (EMDS) using a Bayesian network (BN) model. SMILE = Structural Modeling, Inference, and Learning Engine; CDP = Criterium DecisionPlus.

1. BNs, created by the user through the GeNIe interface and processed by the SMILE engine, are used to assess population viability of a few to several keystone species.
2. BN outputs are integrated into the biodiversity component of a NetWeaver logic model that evaluates the broader question of ecosystem integrity.
3. NetWeaver outputs (and additional external logistical considerations) are passed to a strategic CDP model that prioritizes landscape elements for restoration activities.
4. Finally, VisiRule could be invoked to recommend optimal tactical management actions in high-priority landscape elements.

In this example, SMILE outputs flow through steps 2 to 4, influencing the logic evaluation, and strategic and tactical decisions for ecosystem restoration.

Application of BN Components

Several applications of the BN component of EMDS are currently proposed for aiding resource management decisions in a GIS environment in the U.S. Pacific Northwest. For example, one application would use a published BN model (Marcot et al. 2019) that determines the potential injuriousness of invasive species. Integrating this model in a GIS framework would produce regional maps showing probabilities of invasive species establishment, spread, and harm among subbasins (catchments), which could help prioritize locations and guide targeted management activities to dissuade such species introductions.

Many other applications are possible and await development. In EMDS, these BN applications could either be stand-alone or integrated into an analytical sequence as described above.

EMDS information and free downloading can be found at http://emds.mountain-viewgroup.com/. Further information and links to applications can be found at https://en.wikipedia.org/wiki/Ecosystem_Management_Decision_Support.

Acknowledgments

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