A Methodological Framework Focused on Integrating GIS and BBN Data for Probabilistic Map Algebra Analysis

Framework

Introduction
Bayesian Belief Networks (BBNs) provide a graphical (and automated) way to display and interact with probabilities of related event information (Pearl 1988). Integrating spatial data with BBNs at the resolution of pixels, allows for the opportunity to perform probabilistic map algebras (Taylor 2003; Ames & Anselmo 2008). Belief maps (or probability maps) can be created by transferring the results of probabilistic map algebra back into GIS. The methodological framework presented in this paper proposes a set of structured techniques for utilizing GIS and BBNs to inform spatial decision making and analysis. The methodological framework proposed in this paper progresses a set of structured techniques for integrating GIS and BBNs to inform spatial decision making based on belief about causally related datasets. The end result is the ability to produce belief maps based on exploratory analysis of BBNs. Finally, a case study is discussed to put this framework into context.

Bayes' Theorem can be read that the probability of A (hypothesis) given B (evidence) is equal to the probability of B given A multiplied by the probability of A divided by the probability of B.

P(A|B)=P(B|A) × P(A)/P(B)

Integrating GIS and BBNs
The cartographic model presented here shows the steps required to prepare both vector and raster datasets for the probabilistic map algebra format.

Geopixels and Belief Maps
Central to the framework presented in this paper is the concept of the geopixel which provides an explicit spatial context to the BBN. The geopixel is simply a taxonomy for each raster cell of the prepared datasets. This taxonomy can be created by utilizing a scripting language (e.g. python) with access to the spatial and attribute data (e.g. GDAL). From the output of a raster dataset, we can create a belief map based on belief about causally related datasets. These maps are resultant of the probabilistic map algebra approach and BBN exploration.

Exploratory Analysis with BBNs
BBNs correspond well to MacEachren’s (1995) presentation of geovisualization where the user is not presented with a single passive static view but rather an active process where map data, imbued within the BBN, goes beyond simple information communication to that of an enabler of knowledge construction.

Case Study

Essential Attributes and Data
Data were collected from each essential attribute to represent the values of each SENRLG agency. Datasets selected for the Albemarle-Pamlico region included land cover, habitat, longleaf pine, environmental justice and historic places, to name a few.

Belief Network
SENRLG used a belief network to apply probabilistic map algebra to the essential attribute data. Each node of the network represented criteria, which were queried then used to determine areas in the Albemarle-Pamlico region that fit that criteria. These criteria were used to create “stories.”

Stories
The SENRLG “stories” described different themes and indicated which areas in the AP met the criteria.

Criteria for Natural Story
Distance to Roads: HIGH
Ownership: NON-FEDERAL
NLCD: NATURAL
NDVI: HIGH

Criteria for Drinking Water Story
Environmental Justice: YES
First Order Streams: YES
Priority Watersheds: YES
SEF: YES
Public Water Supply: YES

Criteria for Biotic Habitat Story
Waterfowl: YES
SN Heritage Areas: YES
SEF: YES
NLCD: NATURAL

Criteria for Tourism Story
SEF Recreation: YES
National Register of Historic Places: YES

Sea Level Rise
40cm

References

J.D. Morgan, M.W. Hutchins, J. Fox, K.L. Rogers
UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC)
One University Heights Asheville, NC 28804
Email: {jdmorgan;mwhutchi;fox;krogers}@unca.edu