Large Scale, Spatial, Temporal Decision Making

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Introduction

- This is and isn't a practice talk
- Type of Project: Developing a general framework from a specific problem. Specific problem is from forestry.
    - want to create a solution that applies beyond this specific case
    - want to minimize the number of assumptions about the best policy
    - want the solution to be widely applicable
    - want a method that actually takes account of the complex spatial relationships involved but still provides a plan using a good approximation

Outline

1. Progression of Forest Planning Problems
   - Aspatial Forest Planning
   - Spatial Forest Planning
   - Spatial with Disturbances
   - Complexity of Disturbances
   - Software
2. General Problem
   - Definition
   - Data
   - Related Domains
3. Research Goals
   - Relevant Research
   - Opportunities
   - Problem Breakdown

Outline

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Definition

The smallest division of a forest is called a stand of trees. It is an area ranging from 1-50ha. Each stand has many features

- number of trees
- trees species dist.
- avg. age of trees
- terrain type
- presence of road
- presence of wildlife
- climate (temp, rainfall)

Aspatial Forest Planning

Definition

A planning problem is spatial if the decision about each spatial cell requires data specific to that cell's state and other cell's in its neighbourhood

- At the strategic level (whole forest) spatial concerns are often ignored
- At the stand level of modelling they often assume each stand is independant
- Simulate growth of trees over time
- Actions:*cut/don't cut a block of trees*

Spatial Forest Planning

Several types of planning requirements need spatial information

- maximum opening size
- road building
- ecological corridors/fragmentation
- visual impact
- water proximity

Solutions

Opening Size

unit restricted model (URM) - cells are predefined, need to decide which to cut so

area restricted model (ARM) - the restriction is on some amount of open area within a

Actions: cut/don't cut a block of trees, *build road to access stands, define optimal cut block polygons*

Solution Methods

- Simulated Annealing (Lockwood and Moore, 2993)
- Genetic Algorithms
- Mixed Integer Programming
- Hill Climbing

Spatial Forest Planning with Disturbances

A disturbance is a process, other than tree development cycles, native animal populations or weather that impacts some variable in the state of the forest system.

- The most important examples are
    - Human intervention
    - Insect/Disease infestations
    - Forest Fire
- A disturbance is not always negative
- Base forest system (without disturbances) is well understood, and predictable.
- Actions: cut/don't cut a block of trees, build road to access stands, define optimal cut block polygons, *actions that affect disturbance*

Disturbance Example

The Mountain Pine Beetle (MPB)

Life Cycle	1 year
Dispersal Distance	up to 40km
Source	naturally endemic
Trees at risk	lodgepole and other pine (18% of volume)
Method of Attack	burrows under bark and lays eggs
Current infestation	over 7 million ha (40% of BC pine)
Actions:	thinning, clearcut, tree treatment, fire

Disturbance Example

Disturbance Example

Spatial Disturbances Induce Spatial Decisions

- Most planning models ignore disturbances (Baskent, 2005)
- Global probability of disturbance is attached to all stands
- But disturbances need to be modelled since
  - Its big - dramatic impacts on many stands
  - The details matter - Particular shape of disturbance affects utility
  - Our actions matter - Human activities greatly influence development of disturbances

Software Solutions

- woodstock - aspatial planner
- Atlas/Simfor - planning simulator
- Prognosis BC - simulator
- Patchwork - spatial cut planning optimization
- Harvest - shape of cut areas optimized
- Westwide Pine Beetle Model - allows detailed simulation of MPB on medium landscape scale
- MPBSim - detailed stand level MPB simulator
- SELES-MPB - landscape simulator integrating MPBSim, customized to task

General Problem

State

- Space: The problem is fundamentally divided into a very large number ($> 10,000$) of spatial units or cells which have a limited number of neighbours. Cells are all roughly the same size.
- The state of a cell has several multi-valued dimensions.
- Each cell also has associated disturbances that affect its state (or are part of it).
- Time: Disturbances and Cells evolve over time and are influenced by the current state of the each other.

Action

- The number of available actions per cell is small and local to that cell only.

General Problem

Utility

- Defined over full state of cells in the long run but its cumulative, no ’end’ state to focus on
- Spatial constraints can be defined over different features of cells.

Planning

- The goal is to choose actions so as to maximize the utility of the model.

Available Data

- Provincial MPB studies
- Forest cover and infestation estimates for particular regions
- Terrain data for regions
- mpbsim - model of mpb behaviour
- fvs and other models of tree growth

Data comes in different formats (vector/polygon versus pixel/raster)

Related Domains

Other problems with this similar structure

- forest fire and mpb at least at this point
- fisheries management
- mining?
- urban planning

Some Relevant AI Work

- MDPs and POMDPs
- Augmented Probability Simulation (Beilza, 1996)
  - creates an augmented probability model across all variables, including actions and creates it such that using this model for simulation is equivalent to solving the original decision problem.
- BK Algorithm (Boyen and Koller, 1999)
  - Aggregate values may allow stands to be treated as weakly independant
- Particle Filters
  - Surprisingly haven't seen anyone using that. Although the use of the genetic algorithms sounds like PF
- Continuous Time Bayes Nets (Nodelman, 2002)
- Hierarchical spatial modeling (Wikle, 2001)

Opportunities

- This domain is *very* complex but has lots of unused structure (conditional, spatial, temporal)
- It is needed because practitioners in forestry are already pushing the limits of existing techniques
- There will always be more complexity to add
  - Open block constraints
  - Ecological spatial constraints
  - more stakeholders, more complex utilities
  - new layers for new disturbances
- Goal: Create general framework that allows more realistic models and requirements while using efficient approximiations to find a good plan.

Breaking Down the Problem

The Project has two major components

- decoupling the description of utility and the decision optimization
  - many constraints and requirements can actually be expressed as utility or cost functions
  - decision optimization searches for good policies relative to utility function
- finding efficient representations and algorithms for this structured domain
  - spatial - representative nodes, virtual neighbours, qualtitative representations, hierarchical regions
  - temporal - abstracting away gaps in time, selective memory
  - utility models - model constraints, broad definition
  - policies - hierarchical actions
  - feautures - hierarchies, abstractions, meta-features

The End

- What's missing?
- What would be an exciting direction to go?
- What's needed?

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