Fast Simulation for Computational Sustainability Sequential Decision Making Problems

Sean McGregor, Rachel Houtman, Hailey Buckingham, Claire Montgomery, Ronald Metoyer, Thomas Dietterich
Sequential Optimization in Wildfire Suppression Decisions

Simulate 100 Years of Decisions
Two Tasks

1. Optimizing policies
2. Validating policies
How do We Validate?

1. The optimization algorithm produced acceptable results
2. Simulation specification is correct
How do We Validate?

1. The optimization algorithm produced acceptable results
2. Simulation specification is correct
Visualization

Connect simulator to a visualization
1. Manually change parameters
2. Generate trajectories
3. Explore trajectories
How do We Validate?

1. The optimization algorithm produced acceptable results
2. Simulation specification is correct
Wildfire Reward Function

\[ \text{Timber Price} \times \text{Timber Harvest} \]

\[ \text{Reward} = \text{Timber Revenue} + \text{Ecology “Revenue”} + \text{Suppression Expenses} \]

\[ \text{Ecological “Price”} \times \text{Ecological State} \]
Wildfire Reward Function

Suppress Everything!

Reward = Timber Revenue + Ecology “Revenue” + Suppression Expenses

Let Everything Burn!
Wildfire Reward Function

Selecting ecological reward selects policy
Visualization

Connect simulator to a visualization
1. Manually change parameters
2. Generate trajectories
3. Explore trajectories

Connect optimizer to visualization
1. Manually change parameters
2. Optimize policy
3. Generate trajectories
4. Explore trajectories
Problem

CompSust problems are (often) expensive to simulate

100 Years of Wildfire Simulation: several hours
Optimizing to 100 year horizon: many days!
Solution

Trajectory Synthesis: Creating trajectories from a database of pre-computed state transitions

Benefits:
• Perform database queries at visualization time instead of expensive simulations
• Very sample efficient for exogenous variables

Constructing Database
Constructing Database

1. Suppress
2. Let Burn
3. Suppress
4. Let Burn
5. Suppress
6. Let Burn
7. Suppress
8. Let Burn
9. Suppress
10. Let Burn
11. Suppress
12. Let Burn

Constructing Database
Fast Simulation

Draw Initial State
Fast Simulation

Switch to the most similar state in the database
Fast Simulation

Apply Current Policy
Fast Simulation

Get Result State
Fast Simulation

Get Most Similar State From Database
Fast Simulation

Apply Current Policy
Fast Simulation

Get Result State
Fast Simulation
Fast Simulation

1. Optimize Over Many Sets of Trajectories

2. Generate a Final Set of Trajectories

3. Visualize!
Results
Modeling Trajectory Synthesis

Much simpler than learning a full predictive model

Step 1: Sample a policy space to create a dataset
Step 2: Create a similarity metric for states
Similarity Metrics

State
- Weather
- Ignition

Action
- Suppress or Let Burn

Simulate
- Fire Spread
- Growth
- Harvest

Sample

Eliminate Exogenous State!
S: Weather, Ignition Location, and Landscape

W₀: Weather and Ignition Location
X: Landscapes
Thanks!

Collaborators: Rachel Houtman, Hailey Buckingham, Claire Montgomery, Ronald Metoyer, Thomas Dietterich

Funder: NSF

Contact: CompSust@seanbmcgregor.com

Questions?