Toward Visualization Methods for Interactive Improvement of MDP Specifications

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Motivation

- Complex software systems are often buggy or misspecified.
  - Does the policy exploit bugs in the MDP definition?
  - Does the policy balance disparate objectives in an acceptable way?
- Stakeholders lack a means of interrogating the intersection of simulator, values, and policies.
  - How can stakeholders believe the policy recommendation?
Examples of “Success”

- Debugging
  - Physics Bugs [0]
- Objectives
  - Vibrating Soccer Players [1]
  - Circling Bicycle [1]

[0] https://www.youtube.com/watch?v=STkfUZeR-Vs
Specific Motivation of Wildfire

- Immensely complex models with numerous potential integration points: vegetative growth, numerous fires spreading spatially, wood products markets, city encroachment, climate change, etc.
- Given a natural wildfire, SUPPRESS or LET-BURN

Figure 2: Left: Learning curve for DDV with and without incorporating Good-Turing confidence bounds. Right: Learning curves for MBIE, Q-learning, and DDV on a Tamarisk management MDP.
Solution: MDP Visualization

1. Control the rewards
2. Control the policy
3. Filter Initial State Distribution
4. View State Evolution
5. Filter Final States
6. View Results
Large MDP Visualization Requirements

- Have a basis in the MDP formulation
- **Scale well**
- Provide for *real-time interaction + exploration*
- Explore *distribution of outcomes* rather than single realizations
- Interactively **explore the policy space** – **Challenge**
- For rapid debugging, **generate new policies** based on changing rewards – **Challenge**
### MDP Formulation of Visualization

<table>
<thead>
<tr>
<th>Reward Definition: $R(s,a)$</th>
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<tbody>
<tr>
<td>Policy Definition: $\pi(s,a)$</td>
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<td>Initial State Distribution: $P_0$</td>
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<td>State Development Distribution: $P$</td>
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<td>Final State Examination: $S$</td>
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MDP Formulation of Visualization

Reward Definition: $R(s,a)$

- **Reward Specification**
  - $\uparrow \downarrow$ $10$ per board foot harvested
  - $\uparrow \downarrow$ $1,500$ fixed cost for suppression, per fire
  - $\uparrow \downarrow$ $500$ marginal cost per hectare for suppression
  - $\uparrow \downarrow$ $100$ per old growth hectare for habitat
  - $\uparrow \downarrow$ $10$ per mile of forested mountain bike trail

Update Visualization for New Rewards (Keyboard Shortcut "r")

Optimize a New Policy with these Rewards. (not implemented due to algorithmic issues)
## MDP Formulation of Visualization

**Reward Definition:** $R(s,a)$

**Policy Definition:** $\pi(s,a)$

### Initial State Distribution
- **Policy Definition:** 0.8 per kilometers per hour wind speed.
- **Policy Definition:** -0.12 per percentage humidity.
- **Policy Definition:** -0.15 per day in the fire season.
- **Policy Definition:** 9 Constant.

### State Development
- **Policy Definition:** Generate Monte Carlo Rollouts Under New Policy.
  (Keyboard Shortcut "g")

### Final State Examination

December 13, 2014
MDP Formulation of Visualization

Reward Definition: $R(s,a)$

Policy Definition: $\pi(s,a)$

Initial State Distribution: $P_0$

State Development Distribution: $P$

Final State Examination: $S$

Policy Definition: $\pi(s,a)$
MDP Formulation of Visualization

Reward Definition: \( R(s,a) \)

Final State Examination: \( S \)

Policy Definition: \( \pi(s,a) \)

Initial State Distribution: \( P_0 \)

State Development Distribution: \( P \)

December 13, 2014
MDP Formulation of Visualization

Reward Definition: $R(s,a)$

Policy Definition: $\pi(s,a)$

Initial State Distribution: $P_0$

Final State Examination: $S$

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Reward Specification
What are your personal values? Real world scenarios are subject to the political or personal preferences of the people affected. This layer allows the user to explore the effects of different preferences on the produced outcomes. Assign the financial gain (loss) for various outcomes and actions.

- $10 per board foot harvested
- $1500 fixed cost for suppression, per fire
- $500 marginal cost per hectare for suppression
- $100 per old growth hectare for habitat
- $10 per mile of forested mountain bike trail

Update Visualization for New Rewards
(Keyboard Shortcut: “r”)
Optimize a New Policy with these Rewards.
(not implemented due to algorithmic issues)

Policy Definition
What do you want to do? Here you can change the coefficients of a logistic regression policy determining whether wildfire should be suppressed. When the logit function evaluates to >.5 the fire is suppressed, otherwise the fire is unsuppressed.

- 0.6 per kilometers per hour wind speed.
- -.12 per percentage humidity.
- -.15 per day in the fire season.
- 9 Constant.

Generate Monte Carlo Rollouts Under New Policy.
(Keyboard Shortcut: “g”)
Summary

• As RL matures it needs new tools.
• Powerful tools require solving algorithmic challenges.

Algorithmic Challenges

Intelligent Caching of High Dimensional State Transitions

Generate Monte Carlo Rollouts Under New Policy.
(Keyboard Shortcut "g")

Quickly optimizing new policies

Optimize a New Policy with these Rewards.
(not implemented due to algorithmic issues)
Interactive Demo

AtlasOfLife.com/mdp
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Generating New Monte Carlo Rollouts

- Problem: Slow simulator prevents changing policies.
- Proposed Solution: pre-compute a database of transitions.

**Database “Hit” on \((s_0,a_0)\)**

\[(s_0,a_0) \quad \rightarrow \quad (s_{48312}, \cdot)\]

**Database “Miss” on \((s_{48312}, a_1)\)**

\[(s_{48312}, a_1) \quad \rightarrow \quad (s_{9248}, a_1) \quad \rightarrow \quad (s_{42999}, \cdot)\]

Updating Policy for New Rewards

- Simulator is still slow
- Optimizing in large MDPs is slow.

“It is important that the physical simulation be reasonably accurate... errors, will inevitably be discovered and exploited... Although this can be a lazy and often amusing approach for debugging a physical modeling system, it is not necessarily the most practical.” – Karl Sims

Make it practical in non-physical systems!