Better Generalization with Forecasts

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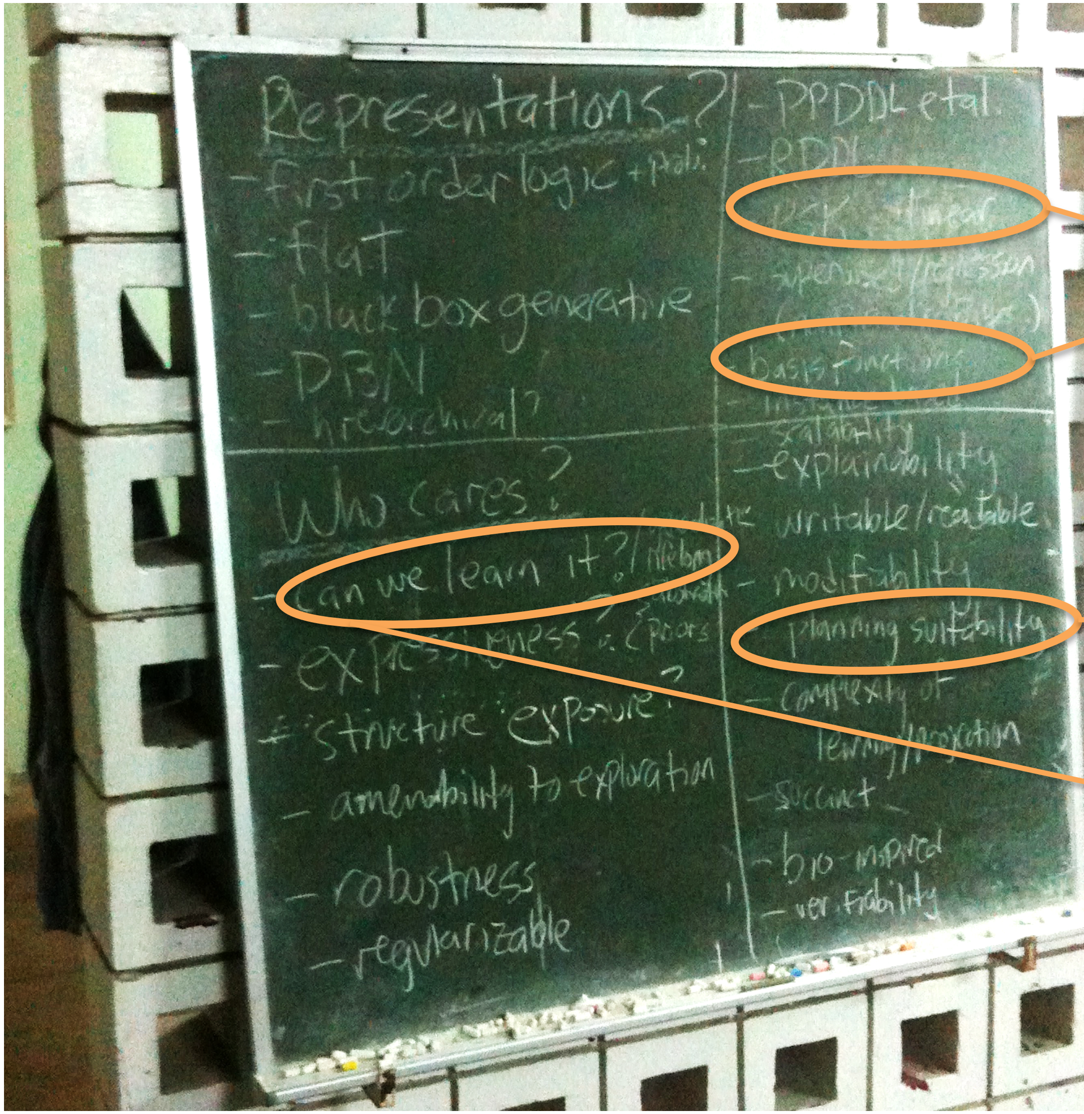
Which Representations?



Type: Feature-based representations (state = feature vector)

Quality 1: Usefulness for linear policies

Quality 2: Generalization

Outline

✓ Motivation

- Representation
  - Predictive State Representations
  - General Value Functions, aka "Forecasts"
  - Simplified subclass of Forecasts
- Evaluating Generalization
- Results

Predictive State Representations

- Question/test: “Will I hit the wall if I take a step left and then a step back?”
- Expected answer = feature ϕ
- Defined as a set of testable predictions
  - Observable quantities (wall sensor)
  - Conditional on action sequence (step left, step back)
  - Open-loop (ends at *t+2*)

General Value Functions

- ϕ = "After how many steps will I encounter a door if I head to the the wall in front of me, and follow it clockwise?"
- General Value Functions
  - More general questions
  - Closed-loop: arbitrary length sequences
- We call them "Forecasts"

Forecast Components

- Conditional on an option: following a policy (straight+clockwise) until termination (door)
  - *I*: states of interest
  - β(s): termination probability
  - π: policy

- Target value (expectation): any function of the state, cumulative
  - *c*(s): accumulated value before termination
  - *z*(s): final value upon termination in s

Simplified Forecasts

- Constant components:
  - $c(s) = 0$
  - I = all states
- Defined by only a target set of states **T**
  - $z(s)$: 1 if s in **T**, 0 elsewhere
  - $\beta(s)$: 1 if s in **T**, $1-\gamma$ elsewhere
  - π: implicitly defined: maximizes the expected z

→ Only one free parameter: **T**

→ Output: feature vector $\phi(s)$

Outline

- ✓ Motivation
- ✓ Representations
- Evaluating Generalization
  - Ideal vs. estimated forecast values
  - Canonical forecast ordering
  - Quality measures
- Results

Forecast Values

- Distinguish:
  - Forecast definition (“question”)
    - From target set **T**
  - Ideal forecast value (true “answer”)
  - Forecast value estimate (approximation)
    - can be learned

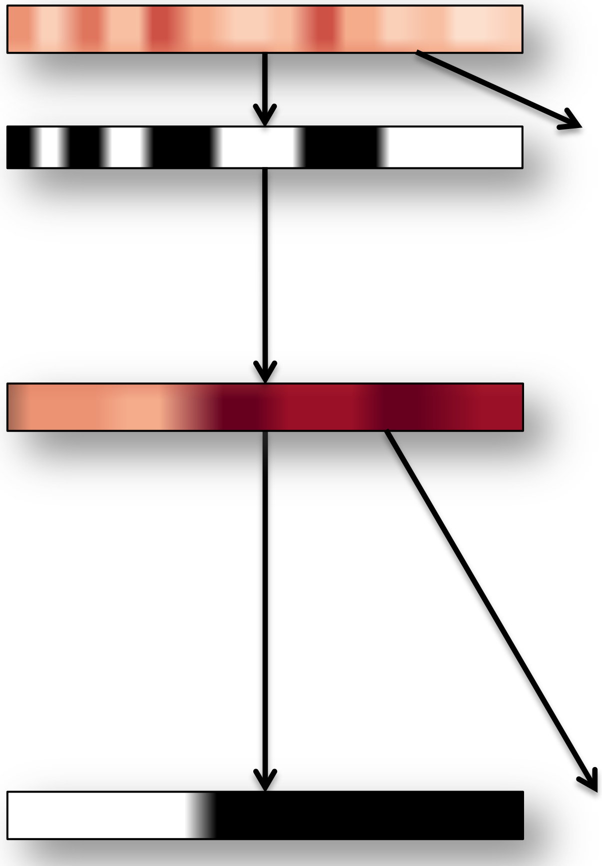
- Focus: quality of representation
  - Use ideal forecast values as features
  - We can ignore the learning issues (i.e., we can cheat!)
  - Namely: policy iteration with transition model

Forecast Generation (1)

- Canonical (breadth-first) exhaustive generation
  - First layer based on observations
  - Forecasts can build upon other forecasts
  - Unique ordering (lexicographic tie-breaking)

Forecast Generation (2)

1. Initially: observations define target sets **T**
2. Compute ideal forecast values ϕ from **T**
   - Cheat 1: transition model (infinite experience)
   - Cheat 2: knowledge of state
3. Threshold ϕ for new candidate **T** sets
4. (Ignore redundant sets)
5. Go to step 2, until no **T** is left



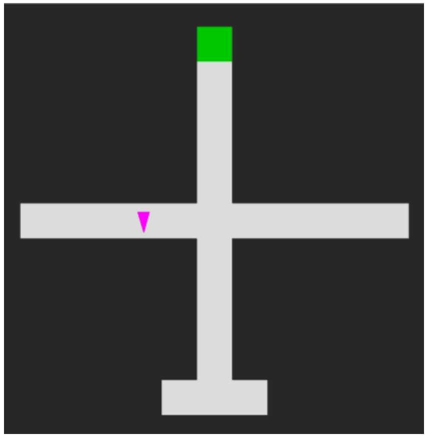
Evaluation of Feature Sets

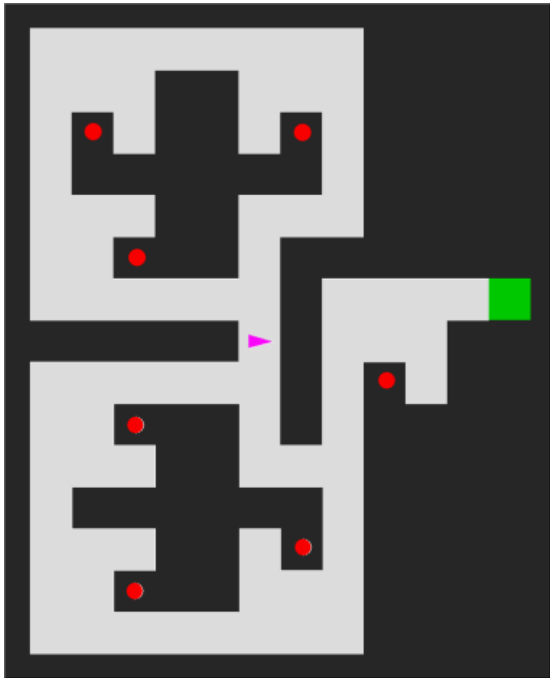
- Quality measures:
  1. Optimal policy using linear function approximation (LFA) on features (LSTD+PI)
  2. Distance between estimated external value *V'* (using LFA on features) and true *V** (MSE)

- Generalization:
  - consider random subset of states (e.g. 50%)
  - train the LFA based on this limited experience
  - see how that *V'* generalizes to the remaining states

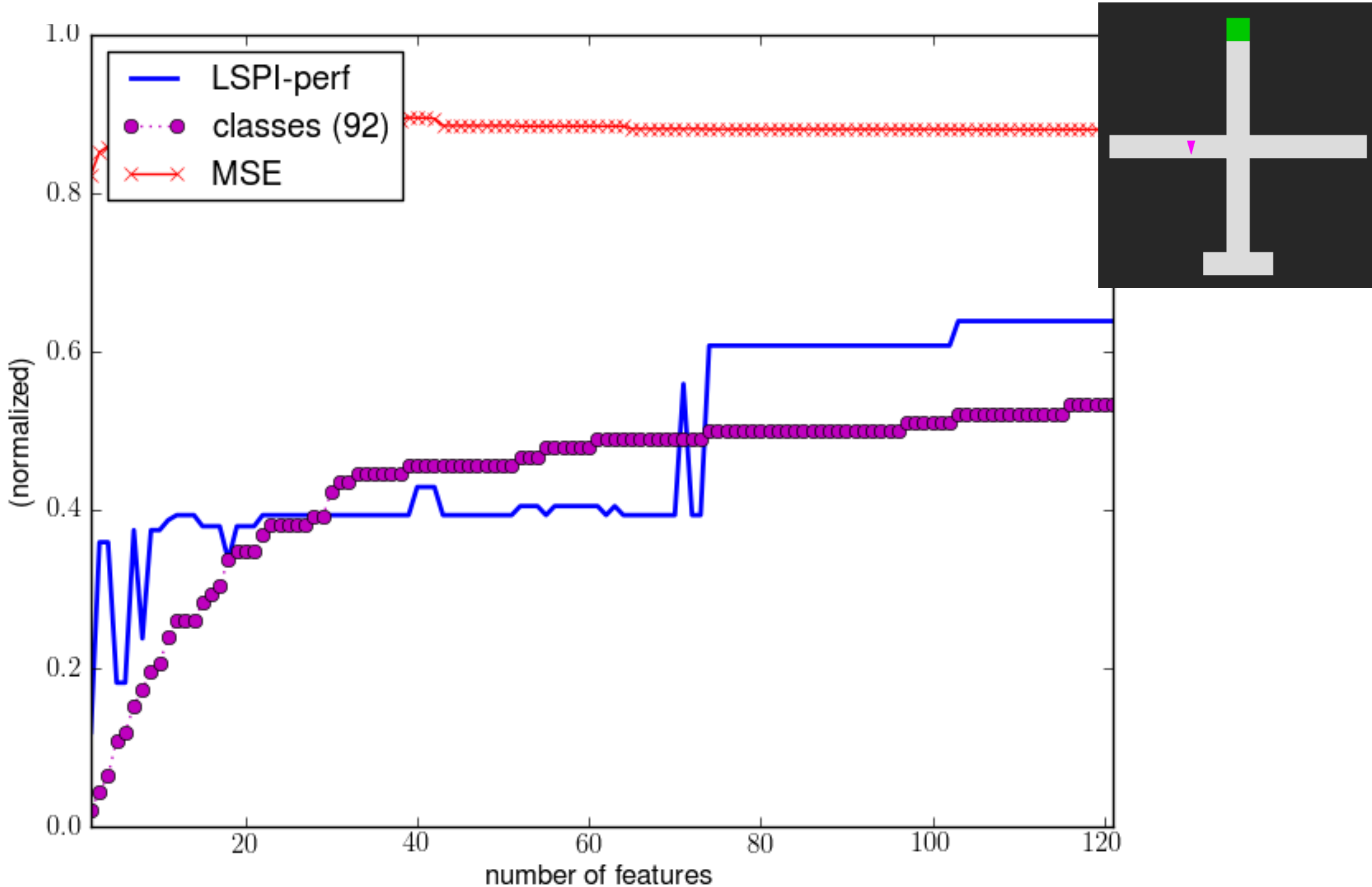
Outline

- ✓ Motivation
- ✓ Representations
- ✓ Evaluating Generalization
- Results
  - Two mazes
  - Simplistic agent
    - 1 binary observation (wall sensor)
    - 1 binary action (forward/rotate left)
  - Comparison to PSRs as baseline

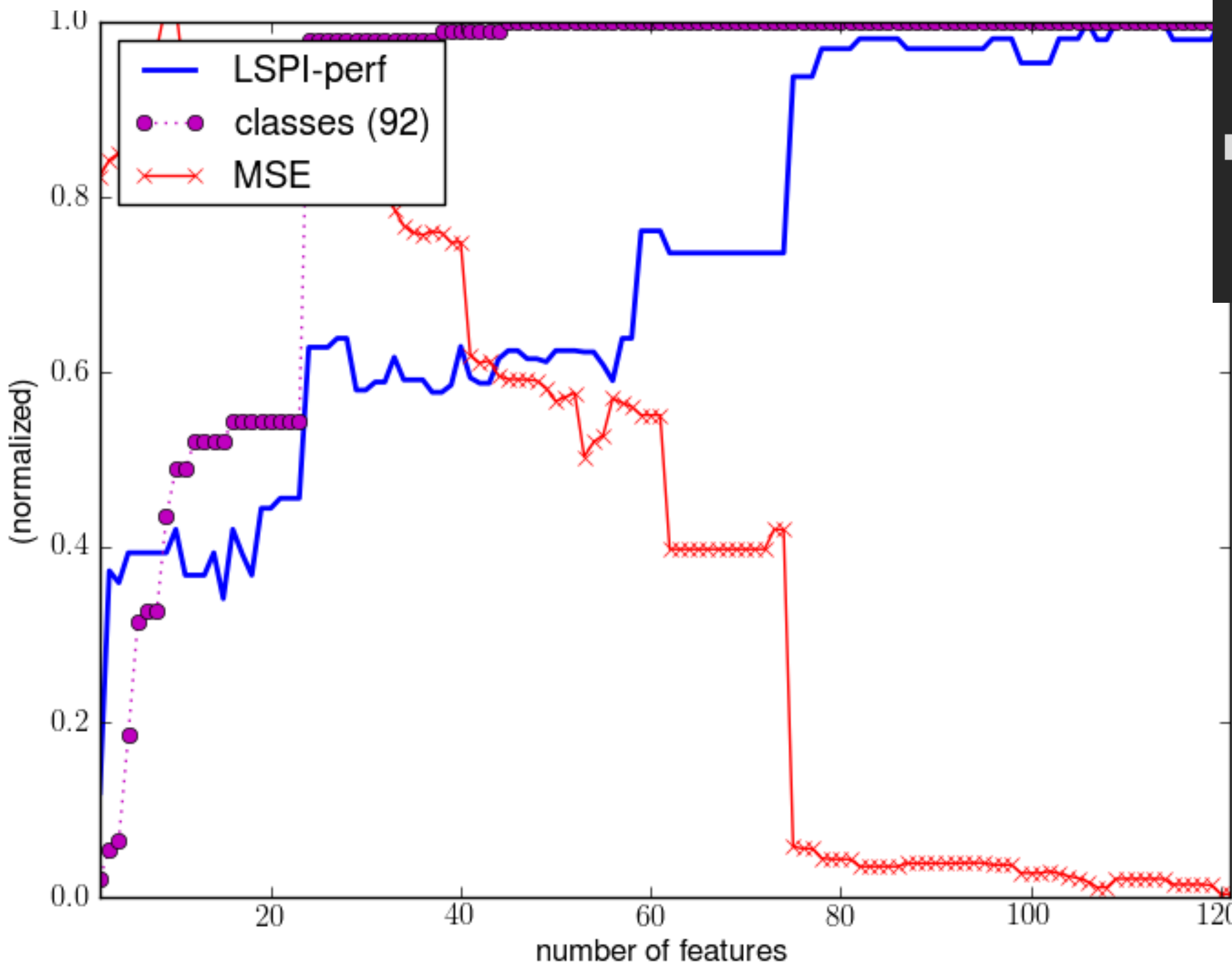


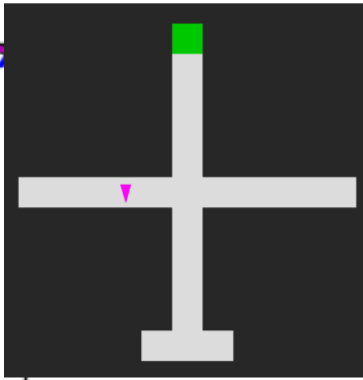


4-Arm-Maze: PSRs

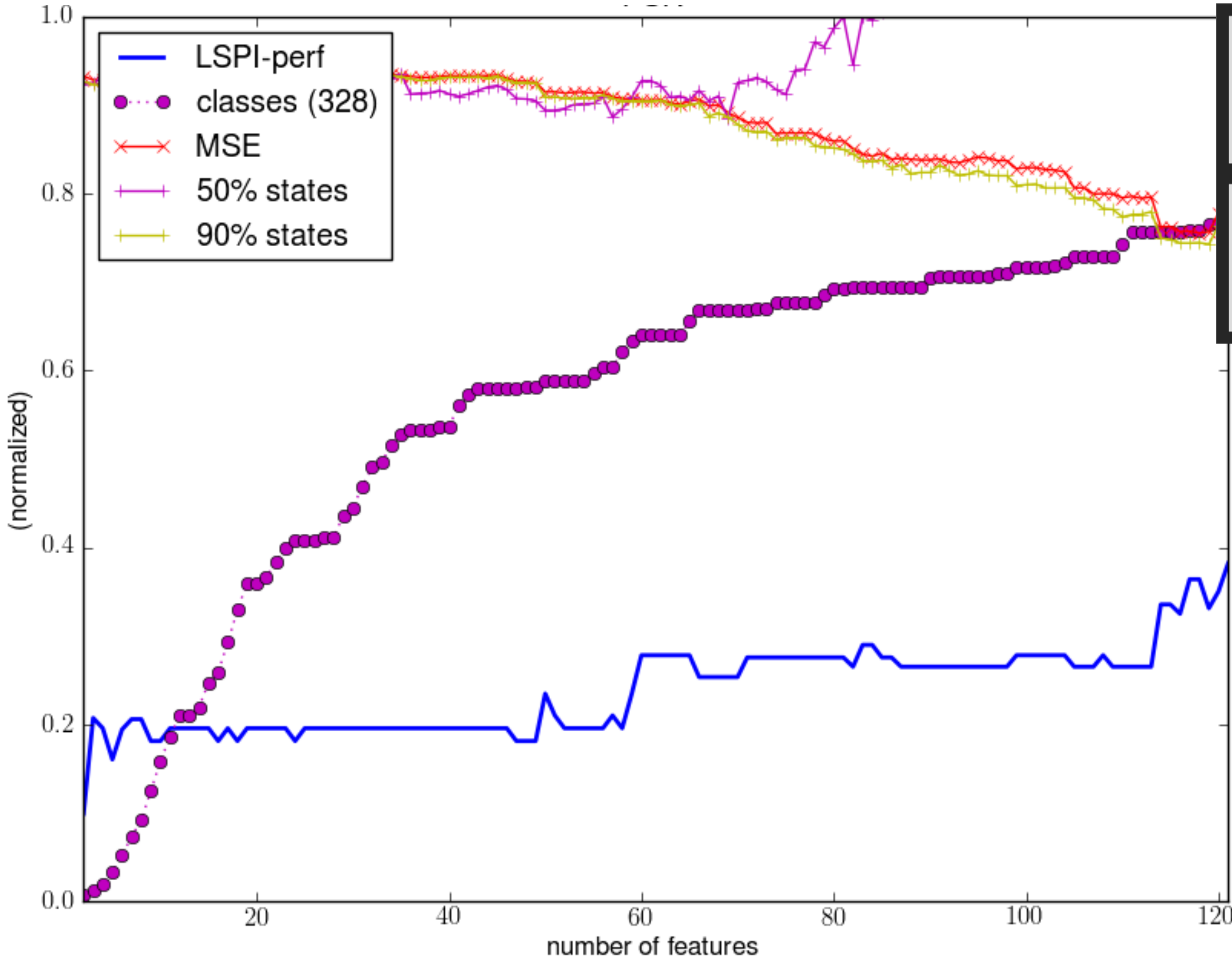


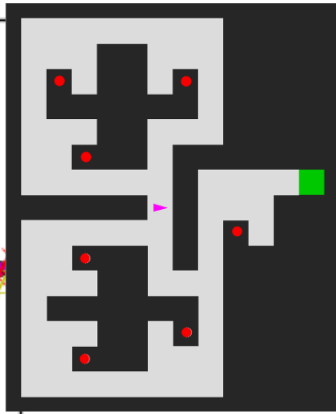
4-Arm-Maze: Forecasts



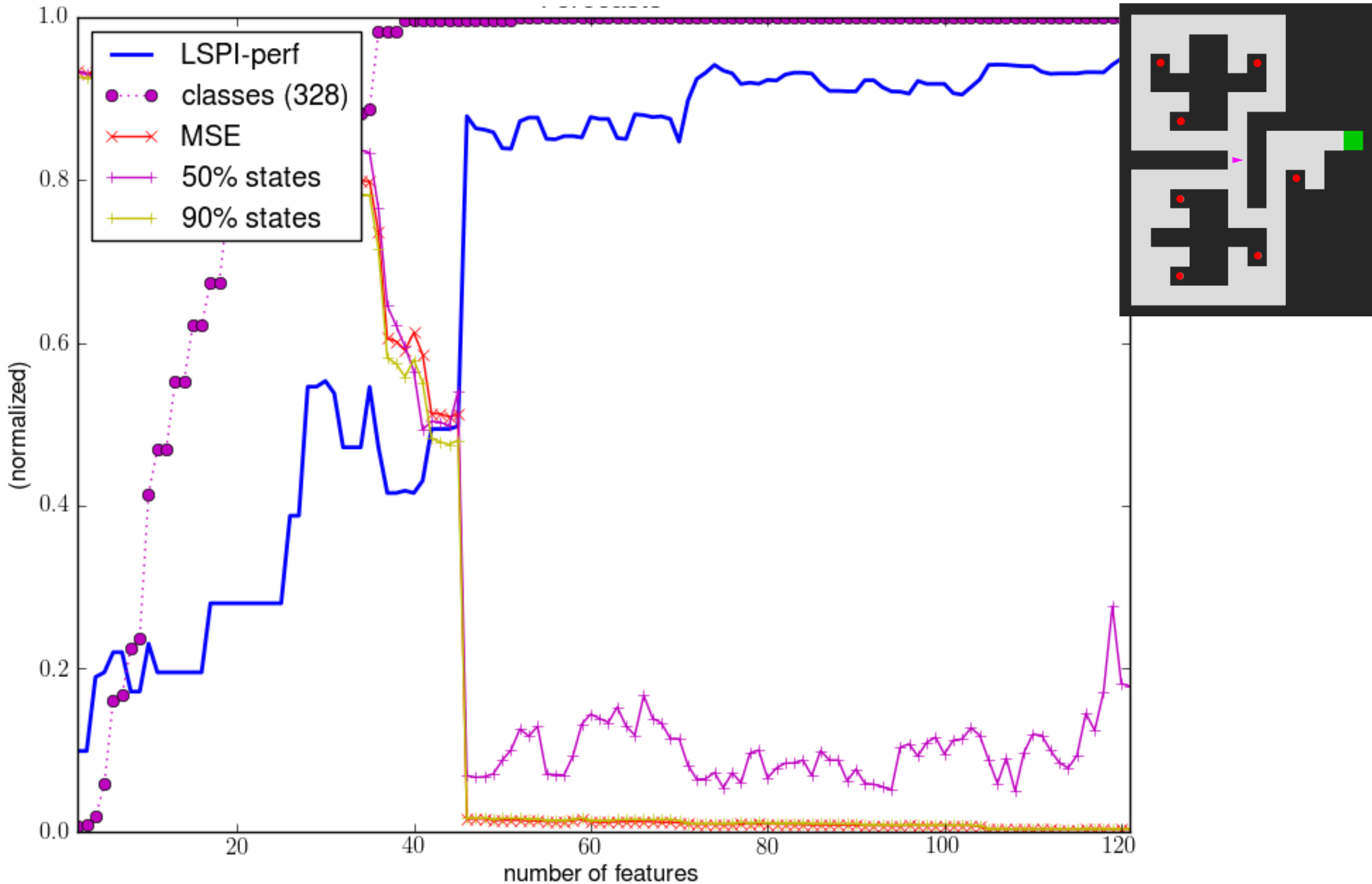


7-Rooms-Maze: PSRs

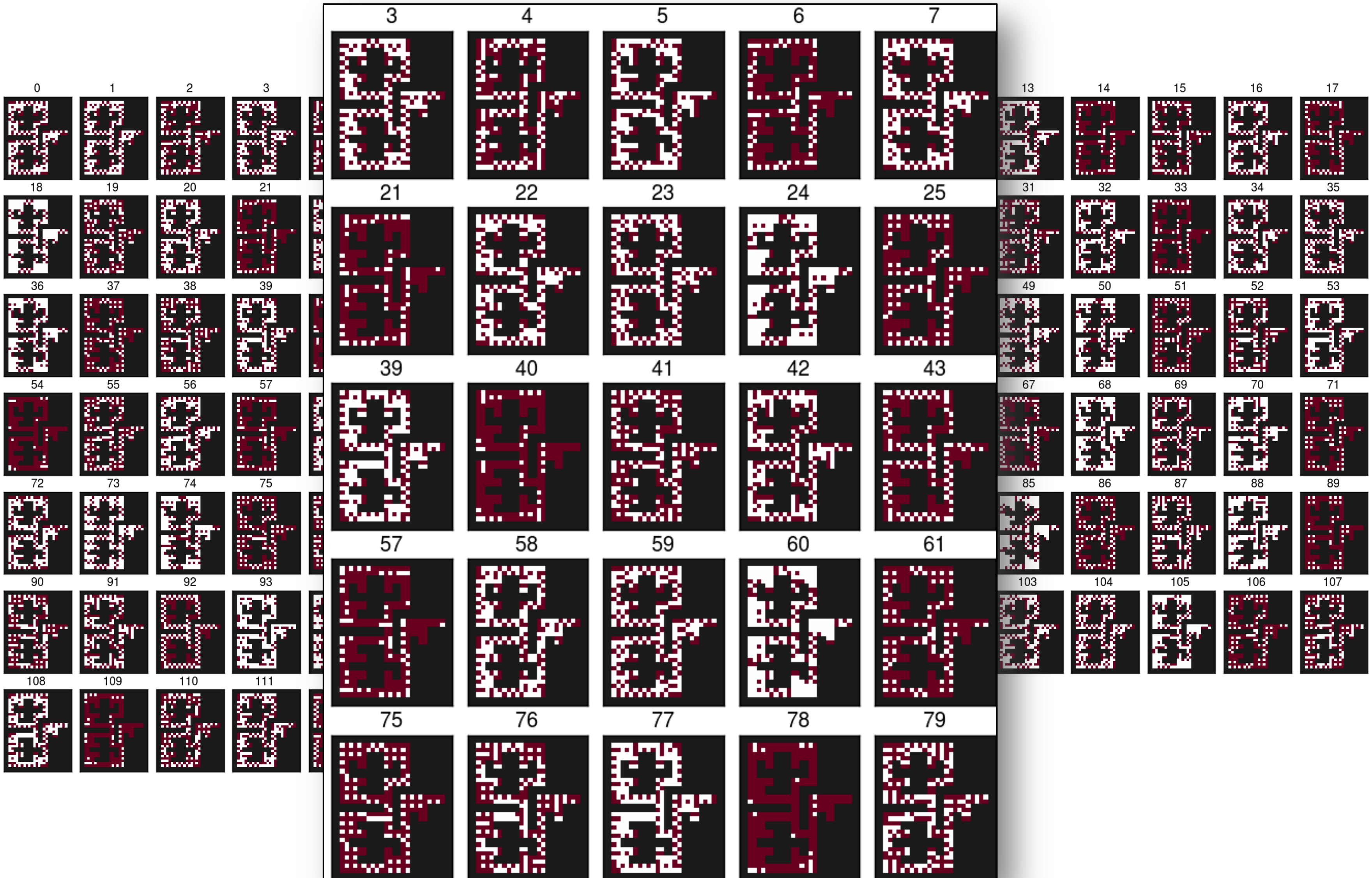




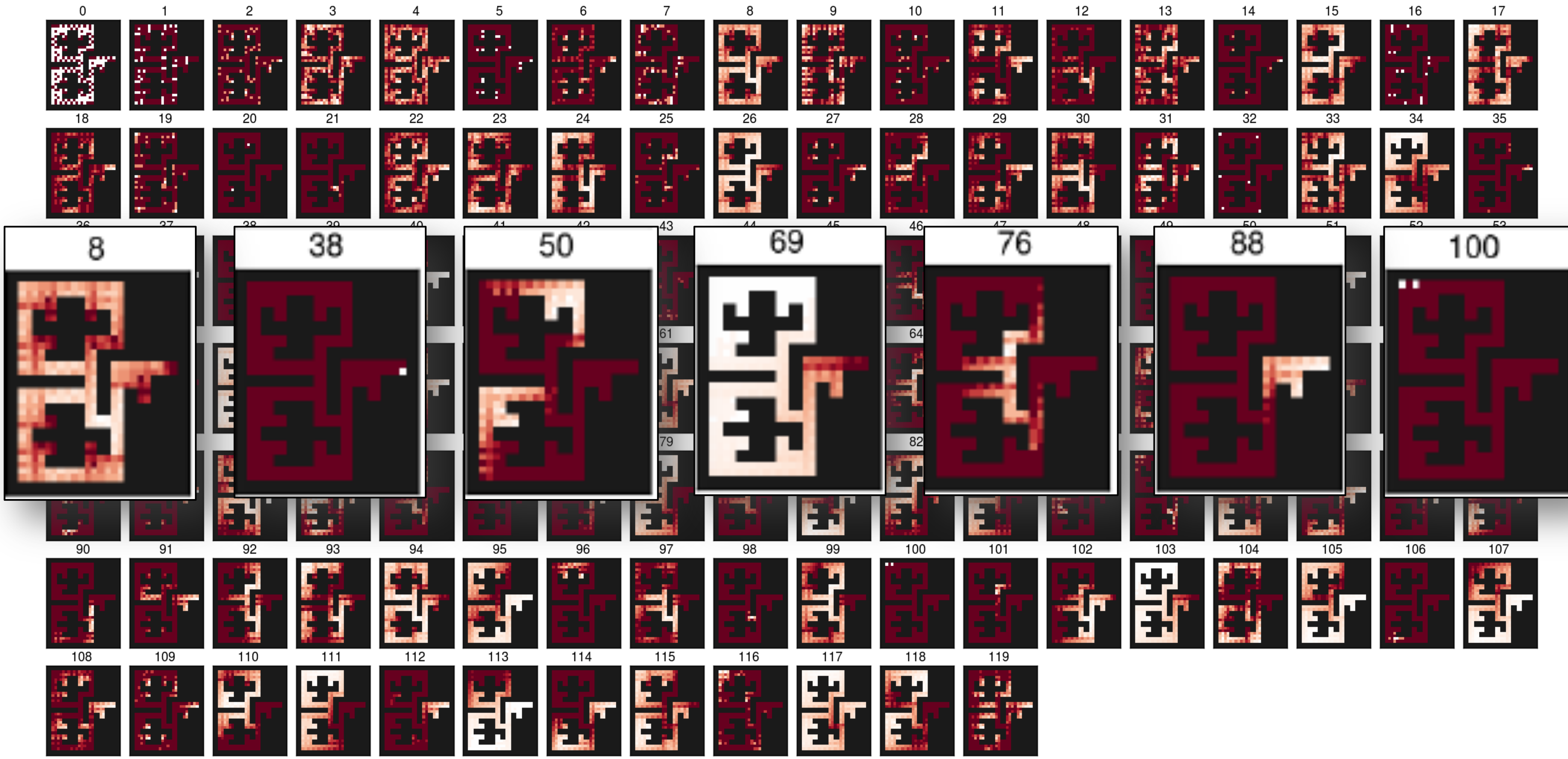
7-Room-Maze: Forecasts



PSR Features



Forecast Features



Summary

Forecasts as representations:

- Temporal abstraction (closed-loop)
- Simple structure
- Useful features for linear evaluation and control
- Good generalization with linear FA

Future work

1. Removing the cheats: using learned estimates instead of ideal forecast values
2. Smarter forecast generation than exhaustive