A Generalization of Automated Planning Using Dynamically Estimated Action Models

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Introduction

- Main idea: postpone (part of) the modeling process to the planning phase
- Avoids early commitment to (unnecessary) modeling computation
- Allows ad hoc modeling choices –> Planning with reacher, more realistic, models
- Lets the planner trade-off model uncertainty vs. computational effort –> Improved reliability, supports scaling
- Generalizes important existing efforts (e.g., semantic attachments)

First Implementation

- Planning with dynamically estimated action costs
- A novel planning problem definition:
  - Multiple cost estimators per action
  - Planning with cost bounds
  - User-supplied target sub-optimality
- A novel graph-search algorithm (ASEC):

Algorithm 1: A^* with Synchronous Estimations of Costs

Input: Problem $\mathcal{P} = (\Sigma, \Theta_\Sigma, s_0, S_g)$, target ϵ
Parameter: Procedure GetEstimator$(\cdot)$
Output: Plan π, bound η_{eff}

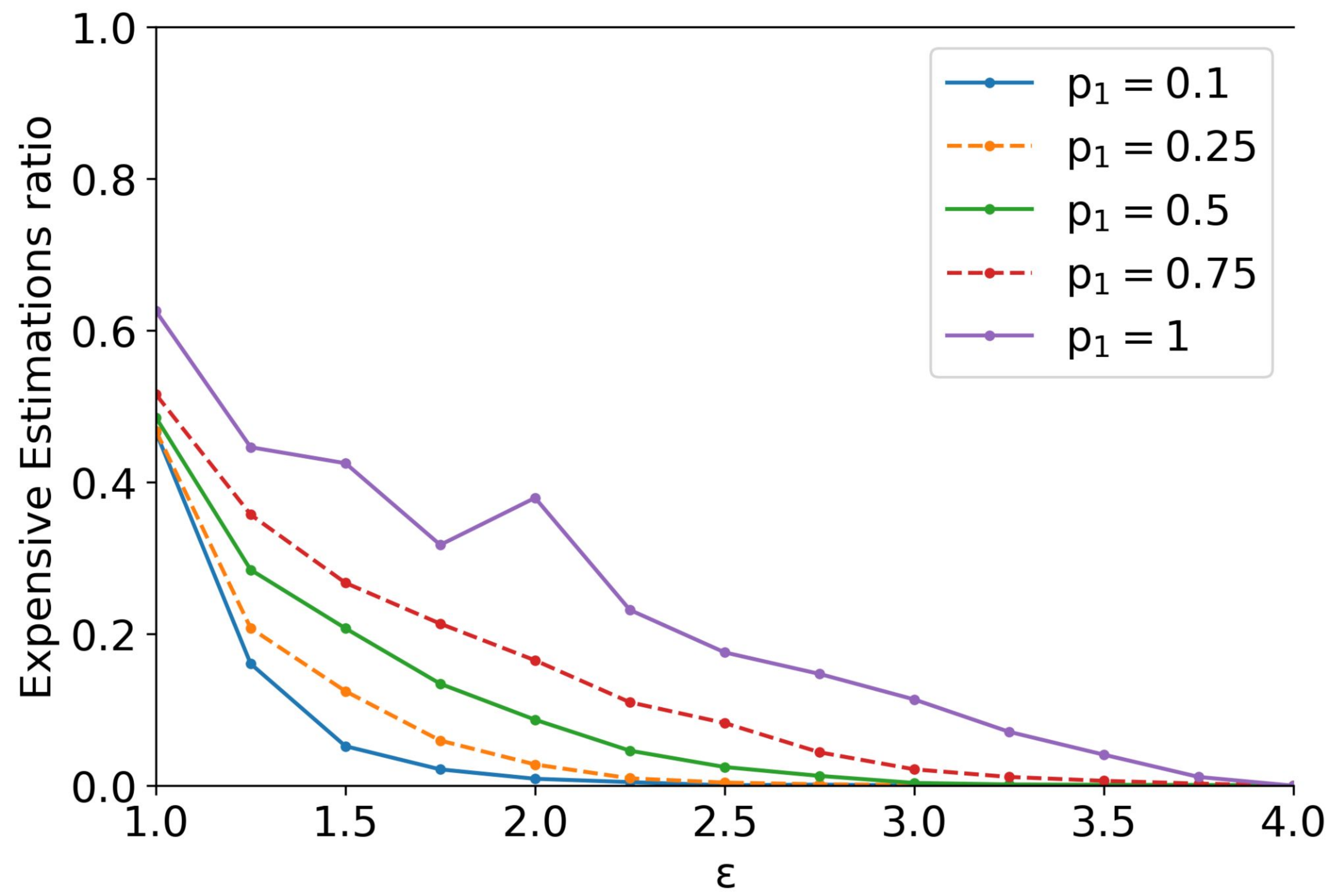
$g_{min}(s_0) \leftarrow 0$; $g_{max}(s_0) \leftarrow 0$
OPEN $\leftarrow \emptyset$; CLOSED $\leftarrow \emptyset$
Insert s_0 into OPEN with $f(s_0) = h(s_0)$
while OPEN $\neq \emptyset$ **do**
  $n \leftarrow$ best node from OPEN
  if $Goal(n)$ **then**
    return $trace(n), g_{max}(n)/g_{min}(n)$
  Insert n into CLOSED
  for each successor s of n **do**
    if s not in OPEN $\cup$ CLOSED **then**
      $g_{min}(s) \leftarrow \infty$
    $\eta_{eff} \leftarrow \infty$; $\underline{g} \leftarrow 0$
    $\theta \leftarrow$ GetEstimator((n, s))
    while $\eta_{eff} > \epsilon$ **and** $\underline{g} < g_{min}(s)$ **and** $\theta \neq \emptyset$ **do**
      $\underline{c}, \bar{c} \leftarrow$ apply(θ)
      $\underline{g} \leftarrow g_{min}(n) + \underline{c}$; $\bar{g} \leftarrow g_{max}(n) + \bar{c}$
      $\eta_{eff} \leftarrow \bar{g}/\underline{g}$
      $\theta \leftarrow$ GetEstimator((n, s))
    if $\underline{g} < g_{min}(s)$ **then**
      $g_{min}(s) \leftarrow \underline{g}$; $g_{max}(s) \leftarrow \bar{g}$
      if s in OPEN $\cup$ CLOSED **then**
        Remove s from OPEN and CLOSED
      Insert s into OPEN with $f(s) = g_{min}(s) + h(s)$
return $\emptyset, \infty$

Summary

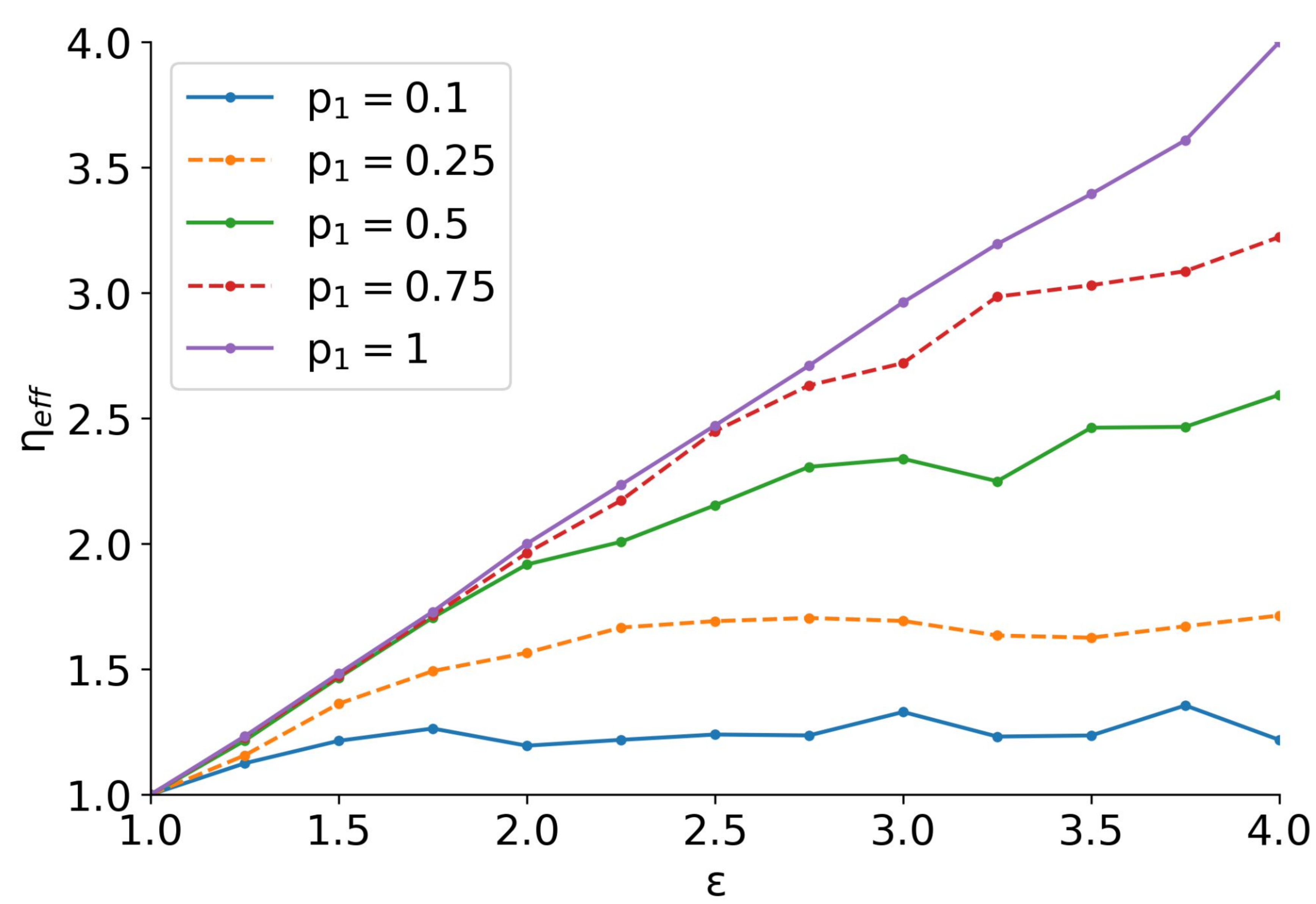
- Planner controls modeling choices
- Initial results for using dynamically estimated action costs provide empirical support for the efficacy of the approach
- Future work aims to expand dynamic modeling

Preliminary Results

- ASEC is ε-sound, and under special circumstances also ε-complete
- Extensive experiments based on modified (IPC) planning problems demonstrate considerable savings in modeling effort:



- ASEC tightly meets target sub-optimality without wasting resources:



Papers (RDDPS Workshop)

- Position Paper: Online Modeling for Offline Planning
- Planning with Dynamically Estimated Action Costs

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