COMP767 - Reinforcement Learning

Labeled RTDP: Improving the Convergence of Real-Time Dynamic Programming

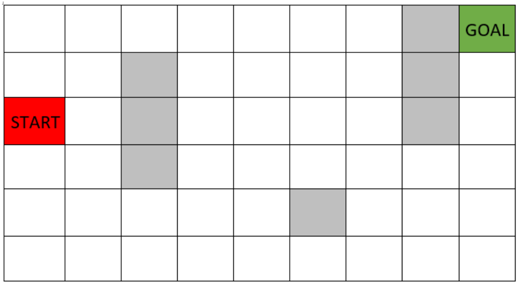
Claudio Sole

École polytechnique de Montréal

March 13, 2017

(Deterministic) Shortest Path Problem on a grid

- For each state the possible action are $\{up, down, right, left\}$
- If an action takes the agent out of the grid or against a wall, then the position on the grid remains the same (self-transitions)
- The reward is -1 for all transitions into non-terminal state and 0 for *Goal* state
- $V(s)$ initialized at 0 for every $s \in S$



1. The problem

2. DP algorithms seen so far
   - Synchronous DP
   - Gauss-Seidel
   - Real-Time Dynamic Programming (RTDP)

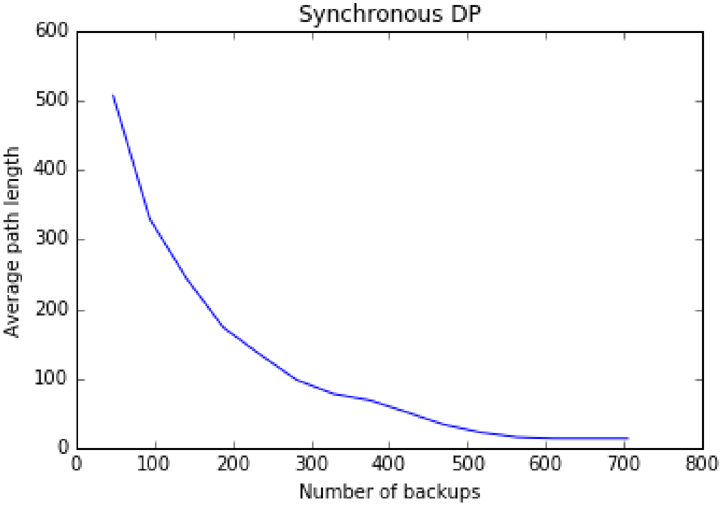
3. Labeled RTDP

4. References

Algorithm 1 Synchronous DP

1: Initialize V arbitrarily (e.g. V(s) $= 0 \; \forall s \in S$)
2: $\epsilon \leftarrow 10^{-4}$
3: $\Delta \leftarrow \epsilon + 1$
4: **while** $\Delta > \epsilon$ **do**
5: $\quad \Delta \leftarrow 0$
6: $\quad V_{old} \leftarrow V$
7: $\quad$ **for** $s \in S$ **do**
8: $\quad\quad V(s) \leftarrow max_a \sum_{s',r} p(s', r|s, a)[r + \gamma V_{old}(s')]$
9: $\quad\quad \Delta \leftarrow max\{\Delta, |V_{old}(s) - V(s)|\}$

Remark : states ordering has no influence


Synchronous DP
Average path length
Number of backups
0
100
200
300
400
500
600
700
800

Algorithm 2 Gauss-Seidel DP

```
Initialize V arbitrarily (e.g. V(s) = 0 ∀s ∈ S)
```

$\epsilon \leftarrow 10^{-4}$

$\Delta \leftarrow \epsilon + 1$

while $\Delta > \epsilon$ **do**

    $\Delta \leftarrow 0$

    $\cancel{V_{old} \leftarrow V}$

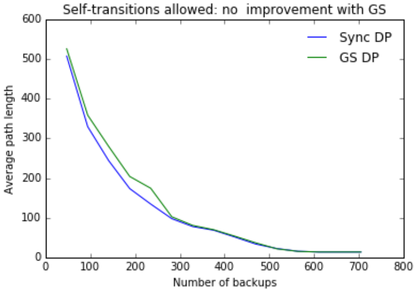
    for $s \in S$ **do**

        $v \leftarrow V(s)$

        $V(s) \leftarrow max_a \sum_{s',r} p(s', r|s, a)[r + \gamma V_{\cancel{old}}(s')]$

        $\Delta \leftarrow max\{\Delta, |v - V(s)|\}$

Remark: states ordering influences convergence rate



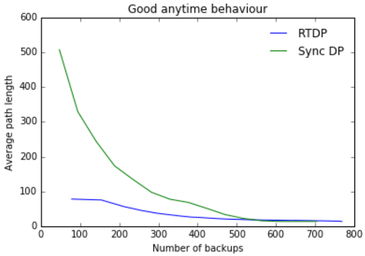
self-transitions	Yes		No	
	Sync	GS	Sync	GS
# sweeps	15	15	15	11
# backups	705	705	705	517

Remark: for the Gauss-Seidel implementation a random ordering for state backups has been chosen.

Algorithm 3 TRIAL-BASED RTDP

```
function RTDP( ):
    while not converged do
        RTDP_TRIAL(start)

function RTDP_TRIAL(s):
    while s is not goal do
        greedy_a ← argmax_a Σ_{s',r} p(s', r|s, a)[r + γV(s')]
        V(s) ← Σ_{s',r} p(s', r|s, greedy_a)[r + γV(s')]
        s ← s' with probability P(s'|s, greedy_a)
```


Good anytime behaviour
Average path length
Number of backups
RTDP
Sync DP
Slow convergence
Average path length
Number of backups
RTDP
Sync DP

Definitions:

- **Greedy graph(s):** graph made up of the states reachable from s following the greedy policy
- **Greedy envelope(s):** set of states in the greedy graph of s
- **Residual(s)** $= \left| V(s) - Q(s, greedy\_a) \right|$

Idea

We keep track of the states over which the value function has converged and avoid visiting those states again

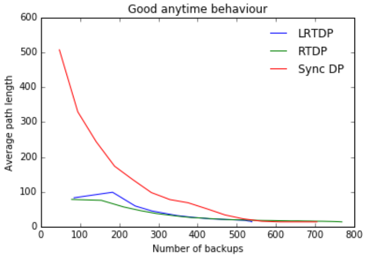
Algorithm 4 CheckSolved(s)

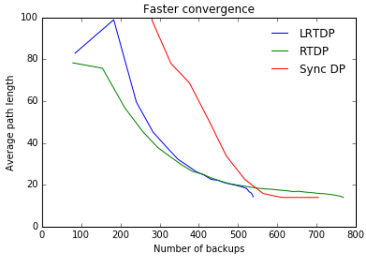
if $\nexists s' \in \mathit{greedyEnvelope}(s) : \mathit{Residual}(s') > \epsilon$ **then**
    mark as SOLVED s
    mark as SOLVED each states in the greedy envelope of s
    return TRUE
else
    backup states in the greedy envelope of s
    return FALSE

Algorithm 5 TRIAL-BASED LRTDP

function LRTDP( ):
  while *start* not SOLVED **do**
    LRTDP_TRIAL(*start*)

function LRTDP_TRIAL(s):
  visited = empty Stack
  while *s* is not *SOLVED* **do**
    visited.push(s)
    if *s* is *goal* **then**
      break
    $greedy\_a \leftarrow argmax_a \sum_{s',r} p(s', r|s, a)\left[r + \gamma V(s')\right]$
    $V(s) \leftarrow \sum_{s',r} p(s', r|s, greedy\_a)\left[r + \gamma V(s')\right]$
    $s \leftarrow s'$ with probability $P(s'|s, greedy\_a)$
  while *visited* $\neq$ EMPTY **do**
    $s = visited$.pop()
    if not checkSolved(s) **then**
      break


Good anytime behaviour
LRTDP
RTDP
Sync DP
Average path length
Number of backups
0
100
200
300
400
500
600
700
800


Faster convergence
LRTDP
RTDP
Sync DP
Average path length
Number of backups
0
20
40
60
80
100
200
300
400
500
600
700
800

Barto, Andrew G. and Bradtke, Steven J. and Singh, Satinder P.
Learning to act using real-time dynamic programming
Artificial Intelligence
1995

Bonet, Blai and Geffner
Labeled RTDP : Improving the Convergence of Real-Time Dynamic Programming
Proceedings of Thirteenth International Conference on Automated Planning and Scheduling
2003