Planning Lab - Lesson 3

Markov Decision Process (MDP)

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Start Your Working Environment

Start the previously installed (lesson 1) conda environment *planning-lab*

```
> cd Planning-Lab
> conda activate planning-lab
> jupyter notebook
```

To open the assignment navigate with your browser to:
lesson_3/lesson_3_problem.ipynb

NumPy

What is it

NumPy is the fundamental package for scientific computing with Python. It contains among other things:

- *a powerful N-dimensional array object*
- *sophisticated (broadcasting) functions*
- *tools for integrating C/C++ and Fortran code*
- *useful linear algebra, Fourier transform, and random number capabilities*

What is it for

Fast array manipulation and mathematical operations. Think of it as a MATLAB like environment for Python: try to speed up the computations writing code in a vectorial fashion.

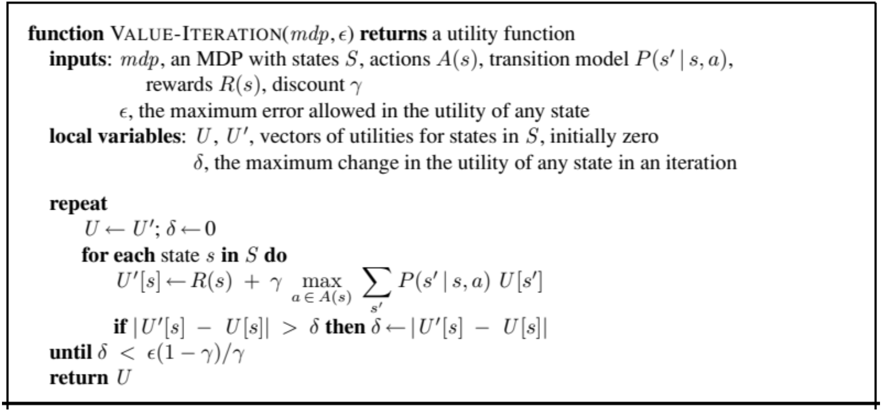
Where to find it

http://www.numpy.org

Assignments

- Your assignments for this lesson are at: *lesson_3/lesson_3_problem.ipynb*. You will be required to implement value iteration and policy iteration algorithms
- In the following you can find pseudocodes for such algorithms

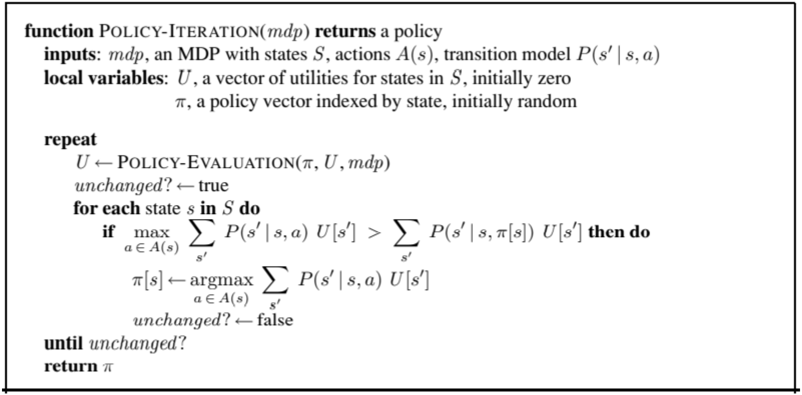
Value Iteration



```
function VALUE-ITERATION($mdp, \epsilon$) returns a utility function
  inputs: $mdp$, an MDP with states $S$, actions $A(s)$, transition model $P(s' \mid s, a)$,
            rewards $R(s)$, discount $\gamma$
          $\epsilon$, the maximum error allowed in the utility of any state
  local variables: $U$, $U'$, vectors of utilities for states in $S$, initially zero
                   $\delta$, the maximum change in the utility of any state in an iteration

  repeat
      $U \leftarrow U'; \delta \leftarrow 0$
      for each state $s$ in $S$ do
          $U'[s] \leftarrow R(s) + \gamma \max_{a \in A(s)} \sum_{s'} P(s' \mid s, a)\, U[s']$
          if $|U'[s] - U[s]| > \delta$ then $\delta \leftarrow |U'[s] - U[s]|$
  until $\delta < \epsilon(1 - \gamma)/\gamma$
  return $U$
```

Policy Iteration



```
function POLICY-ITERATION($mdp$) returns a policy
  inputs: $mdp$, an MDP with states $S$, actions $A(s)$, transition model $P(s' \mid s, a)$
  local variables: $U$, a vector of utilities for states in $S$, initially zero
                   $\pi$, a policy vector indexed by state, initially random

  repeat
      $U \leftarrow$ POLICY-EVALUATION($\pi, U, mdp$)
      $unchanged? \leftarrow$ true
      for each state $s$ in $S$ do
          if $\max_{a \in A(s)} \sum_{s'} P(s' \mid s, a)\ U[s'] > \sum_{s'} P(s' \mid s, \pi[s])\ U[s']$ then do
              $\pi[s] \leftarrow \operatorname{argmax}_{a \in A(s)} \sum_{s'} P(s' \mid s, a)\ U[s']$
              $unchanged? \leftarrow$ false
  until $unchanged?$
  return $\pi$
```

To implement the *Policy-Evaluation* step, use the following formula:

$$U_i(s) = R(s) + \gamma \sum_{s'} P(s' \mid s, \pi_i(s)) U_i(s') \,.$$