Project Reinforcement Learning (2023)

9 January 2023 - 3rd of February 2023

One of the main application of reinforcement learning is in operations research. Among the many domains of operations research, one of increasing importance is in the smart grids domain. Hydroelectric power, mostly from dams, supplies more than 10% of the world's electricity and is a significant source of renewable energy. One key challenge for dams is the daily operation of their storage levels. In this project you are in the role of the data science team and need to define a control strategy for a new dam that has been constructed.

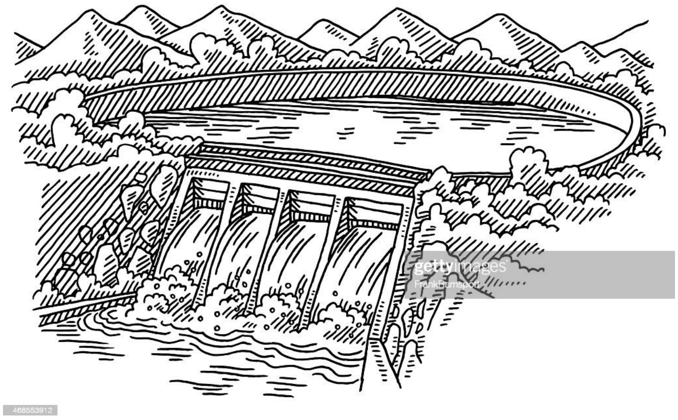

Figure 1: Illustration of a dam

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. Some dams have the possibility to work for both production of electricity (by letting water go from the upstream side to the downstream side) as well as storage (by pumping electricity from the downstream side to the upstream side). The dam can thus be considered as an energy storage facility

You consider a dam where the difference between the upstream side of a dam to the downstream side is $30m$ (considered as a constant for any storage level for simplicity). The quantity of water that can be stored on the upper side is 100.000 m^3 and there is no limit on the other side (e.g. there is a canal with unlimited water supply).

To calculate the total quantity of energy, that is stored/released, you can use the following formula that corresponds to the potential energy of the water from the upstream side as compared to the downstream side (energy that could be generated if there was 100% efficiency):

$$U = mgh, \tag{1}$$

where U is the potential energy, m is the mass ($1m^3$ of water is $1000kg$), $g = 9.81m/s^2$ and h is the difference in height ($30m$). At the beginning of a trajectory, the reservoir is half full.

The efficiency of the turbine is 90% for the production of electricity and 80% for the storage (by releasing 1 kWh of energy from the dam, you only generate 0.9 kWh of electricity and by using 1 kWh of electricity, you only store 0.8 kWh of potential energy with additional water for the upstream side). The hydro turbines can only let through $5m^3/s$ in both production of electricity as well as storage.

You need to suggest a control strategy for the operation (with unseen time series, i.e. next years of electricity prices) of the dam given 3 years of past electricity prices on the grid. These electricity prices (euros/MWh) are given on Canvas in the file *'spotmarket_data_train.xls'* that you can use to train/validate your model. You can assume that the price of electricity on the market is independent of the quantity of electricity that you trade with the market. Note that $1MWh = 3600MJ = 3.6 * 10^9 kg\ m^2\ s^{-2}$.

One important element is that the operation algorithm of your dam can only access the data up to the current time step. The future price is stochastic and unknown at the time of taking a decision because it depends on the offer and demand at the later time steps. This is also why RL is useful (otherwise an optimization formalization of the problem could solve this).

Presentation 1 (20th of January)

You need to make a presentation where

- you have implemented the environment (suggestion: you can do it as a gymnasium environment https://gymnasium.farama.org/),
- you have implemented at least one baseline algorithm (not necessarily RL),
- you can provide visualization of the operation of the dam as well as estimated performance (with the validation time series),
- you explain the key next steps to improve the model.

You need to make a presentation (5-8 minutes presentation + 5-8 minutes feedback/questions).

Report (2nd of February) and presentation 2 (3rd of February)

The final report and presentation need to show

- an RL solution that you have developed for the problem at hand,
- how you have validated the RL algorithm and what the estimated performance are,
- the code with a pre-trained model that can be run on new time series that will be provided. The additional data will be provided in the same format but possibly less days (e.g. with 1 year of data). The code should also have a README file that explains how to run the code for training the model and how one can use the pre-trained model.

You need to hand in a report (max 8 pages, appendix allowed) along with source code. You also need to make a presentation (5-8 minutes presentation + 5-8 minutes questions).

Additional research questions

As part of your final report and final presentation, you can also add variants to this problem and/or perform ablation analysis to highlight the key parts of your algorithm.

Additional avenues that you can investigate:

- Make the problem even more realistic by adding influx of water that reach the upper part of the hydrometric time series and investigate how you need to change the initial algorithm

- Run the same algorithm with less/more features and see how the performance is impacted.
- Explain different validation strategies and what are the pro and cons of using a given technique. You can also try to estimate how confident you are about the performance of the operation (e.g. by estimating the variance of the performance via for instance cross-validation).

Other

- Report and presentation (8 points)
  - Formalization (clarity)
  - Description of the results
  - Additional more open research questions that is investigated
- Code and its performance (2 points)
  - Details on how the required API that your code will need to have will be provided on Canvas such that your code can be tested with new unseen time series.