Project 1 – Battery Management

The electrical grid is getting more crowded and crowded in the following sense: not only is the demand for electricity rising from the consumer's side but also – and consequently – the peak consumption rises as well. A high peak puts excess load on the wires, potentially leading to blackouts/brownouts, and thus it is penalized by the energy provider.

As a resident of a remote, totally non-fictitious island, New Delft, you regularly experience said blackouts/brownouts in your home due to limited power generation on the island. Your plan to reduce your peak consumption is to use the brand new battery system provided by the totally non-fictitious company, MARKOV Inc., that your friends were telling you about.

Being an engineer, you want to (optimally) control the battery system such that it can help lowering the peak. At any moment in time you can charge/discharge the battery up to some maximum rate, that is, you cannot (dis)charge the battery instantaneously. Further, for every kWh you want to store/use only a portion (α) is available to you due to inefficiencies. The battery has some finite capacity, meaning it can only store a certain amount of energy and not more. The (incomplete!) dynamics of the battery looks something like this:

$$c_{t+1} = c_t + \begin{cases} \overline{\alpha} u_t & \text{when charging} \\ \underline{\alpha} u_t & \text{when discharging} \end{cases},$$

where c is the remaining charge of the battery, α's are (dis)charge coefficients, and u is the amount of charge to be moved to/from the battery which can never exceed u^{min} and u^{max} (see Table 1 for numerical values).

Additionally, you have collected some data of your home's electrical demand throughout the years (will be available from Brightspace[1]). Your main goal is to find when and how fast to (dis)charge the battery so that the peak load is lowered. Intuitively, you want to charge the battery when the demand is low and discharge when the demand is high. However, doing so blindly may actually increase your peak consumption! For example, you may end up with no charge left in your battery when the peak increases. That is why you have to put your engineering knowledge and what you (will) have learned during the course to "smartify" the system.

1. At first sight, the problem seems to have memory (and is thus not Markovian). Why is that? How can you eliminate this memory and make a truly Markovian model? What is the state space and action space?
2. Modelling the dynamics:
   (a) Identify the sources of uncertainty in your model. What is random and where does it come from?
   (b) Write down your dynamics $x_{t+1} = f(x_t, u_t, w_{t+1})$.
3. You pay a price for the peak usage seen from the energy supplier. How can you model this in terms of cost? (*Hint: Think in terms of* $g(x, u)$ *and* $G(x)$.)
4. By now, you should be able to put your model into the machinery of dynamic programming and solve the problem. Before you start, it is important to analyse the model from the perspective of implementing it on a computer.
   (a) Discretization: How many discrete states do you have? How many discrete actions do you have? How do you discretize randomness?
   (b) Interpolation: $J(f(x, u, w))$ may not be a point in your $J(x)$ database. How do you deal with that? What kind of interpolation/extrapolation makes sense?
   (c) Rough estimate of time: say you can compute $J(f(x, u, w))$ in 1 ms for a particular choice of x, u and w. How long do you need to run the dynamic programming? Is it instant? Can you grab a coffee before it finishes? Can you graduate before DP finishes?
5. Simulate with the values provided in Table 1. (*Careful: you may need to run your computer for a long time.*) Report on your findings. What percentage of the peak did you manage to save compared to not having a battery at all? Provide your code in such a way that your controller can be tested against the code provided on Brightspace.

[1] The data is extracted from `https://archive.ics.uci.edu/ml/datasets/individual+household+electric+power+consumption`

[2] Đ is the very official currency of New Delft island, one Đ has roughly the same value as €1.

Table 1: Values to use when simulating

Name	Symbol	Value
Battery capacity	c^{max}	7 kWh
Charge efficiency	$\overline{\alpha}$	96%
Discharge efficiency	$\underline{\alpha}$	87%
Max charge rate	u^{min}	4 kW
Max discharge rate	u^{max}	5 kW
Price for peak electricity[2]	p_{peak}	Đ1.50/peak kW/day