# Decision Making under Uncertainty - Spring 2026
# Assignment

January 25, 2026

## General Rules

- The Assignment is divided into two parts: Tasks 1-2 are Part A, while Tasks 3-8 are Part B. In Part B, you can be with the same group or with a different group than the one you were with in Part A.
- Cooperation between members of different Groups is not allowed.
- The content of your report must be fully consistent with the code you submit. Implementing one thing and reporting another is considered *falsification/fabrication of results*, which constitutes very serious academic misconduct.
- All Group members are expected to contribute to all Tasks. Every member is collectively responsible for the correctness and quality of every Task.
- Any questions related to the Assignment must be directed exclusively to the course responsible. The Teaching Assistants are available only for exercise support and will not answer questions about the Assignment.
- Group Grade Determination: each Task $i$ receives a grade $g_i \in [0, 100]$ and is weighted by $w_i$ as specified. For part A, the overall Group grade $G_A$ is given by the weighted average $\sum_{i\in[1,2]} w_i g_i$. For part B, the overall Group grade $G_B$ is given by the weighted average $\sum_{i\in[3,8]} w_i g_i$ **plus** a bonus $0.1 \min_{\text{over } i\in[3,8]} g_i$ based on how well you did on your least good Task. The bonus is there to incentivize all members to tend to every Task, rather than dividing the assignment and working on separate Tasks individually.
- Individual Grade Determination: In the last Task of each Part $p$, you need to agree and jointly provide a percentage $f_{p,j} \in [0, 1]$ representing the contribution of each member $j$ to the *whole* Part's work. It has to be $\sum_j f_{p,j} \leq 1$. Each member needs to have $f_{p,j} \geq 0.1$ to pass the course. The individual grade of a member $j$ is then given by $\texttt{grade}_j = \sum_{p\in\{A,B\}} f_{p,j} \cdot N \cdot G_p$, where $G_p$ is the group grade of part $p$ as defined above, and $N$ is the number of members in the group that have $f_{p,j} \geq 0.1$.

## Problem Description

You are designing the operation of a restaurant's Heating and Ventilation system, to control the temperature and humidity. Decisions are made on an hourly basis, and the restaurant is open for 10 hours a day. The restaurant comprises two rooms. Each room $r$ of which is equipped with

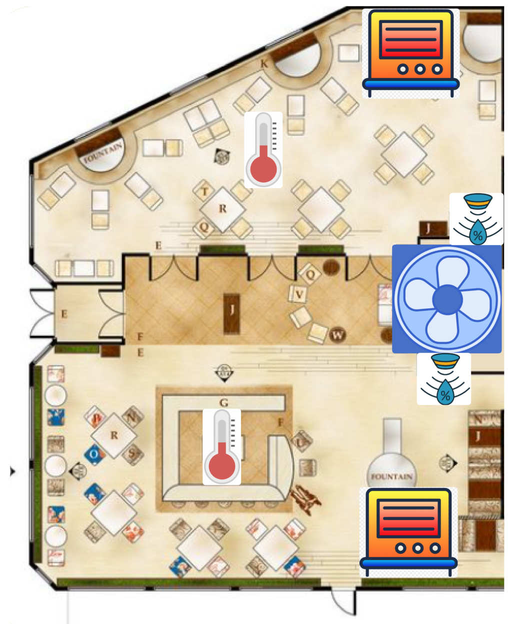
- an electric heater that can modulate its heating power continuously within given limits $[0, \overline{\mathrm{P}}_r]$;
- sensors that measure indoor temperature and indoor humidity.

The system also includes a central ventilation unit that can be switched ON or OFF, consuming a fixed amount of power $\mathrm{P}^{\texttt{vent}}$ when ON.

At each hour of operation, you get to decide the power consumption $p_{r,t}$ of each heater and whether the ventilation is ON ($v_t$). The owner wants to minimize the total electricity cost of the restaurant throughout a day of operation. The electricity price $\widetilde{\lambda}_t$ is different at each hour.

The temperature of each room at an hour $t$ is modeled as a linear function of the following:

- the room temperature at $t-1$,



- the temperature difference between the rooms, due to thermal exchange, at $t-1$ (coefficient $\zeta^{\texttt{exch}}$)
- the temperature difference between the room and the outdoors environment at $t-1$, due to heat losses through walls (coefficient $\zeta^{\texttt{loss}}$); the outdoors temperature $\mathrm{T}_t^{\texttt{out}}$ is assumed known in advance,
- the power of the room's heater at $t-1$ (coefficient $\zeta^{\texttt{conv}}$),
- the ventilation status at $t-1$ (coefficient $\zeta^{\texttt{cool}}$); if ON it decreases the room temperature,
- the room's occupancy level at $t-1$ (coefficient $\zeta^{\texttt{occ}}$) since more people increase the temperature.

Similarly, the humidity level of the whole place at a given hour $t$ is modeled as a linear function of:

- the humidity level at $t-1$ (coefficient 1),
- the room's occupancy level at $t-1$ (coefficient $\eta^{\texttt{occ}}$), since more people increase the humidity,
- the ventilation status at $t-1$ (coefficient $\eta^{\texttt{vent}}$); if ON, it decreases humidity.

Finally, the owner has informed you of the specifics of the underlying control system:

Temperature Overrule Controller:
If the temperature of a room at an hour $t$ drops below a given lower threshold $\mathrm{T}^{\texttt{low}}$, the system's overrule controller kicks in and, starting at $t$, forces that room's heater to operate at maximum power for as long as needed until the temperature surpasses a given "OK" threshold $\mathrm{T}^{\texttt{OK}}$. You cannot control the power when the overrule controller is active.
If the temperature of a room at an hour $t$ rises above a given upper threshold $\mathrm{T}^{\texttt{High}}$, the system's overrule controller kicks in and forces that room's heater to operate at zero power for hour $t$. You cannot control the power when the overrule controller is active.

Humidity Overrule Controller:
If the indoor humidity at an hour $t$ exceeds a given upper threshold $\mathrm{H}^{\texttt{high}}$, the ventilation system is forced to the ON state at $t$.

Ventilation System Inertia:
If the ventilation system is started at an hour t (i.e. it was OFF at $t-1$ and it is ON at $t$), it cannot be turned off for 3 hours (i.e. it remains ON throughout $t, t+1$ and $t+2$).

Your job is to design a policy for deciding the heating and ventilation actions at each hour. The objective is to minimize the total electricity cost (from heating and ventilation). Numerical values for all relevant parameters (power consumption bounds of heaters, power consumption of ventilation, coefficients for each term of the temperature and humidity evolution functions, temperature and humidity thresholds, outdoors temperature) are given to you in the file `SystemCharacteristics`. The electricity price and room occupancy for an hour $t$ is assumed to become known at the beginning of hour $t$. However, future electricity prices and room occupancy levels are uncertain.

Data for electricity prices and room occupancy levels:
You are given access to historical data of 100 days of operation. The files `PriceData`, `OccupancyRoom1` and `OccupancyRoom2` contain the electricity price and each room's occupancy level for each hour of each of 100 days.

# PART A

## Task 1: Optimal in Hindsight solution ($w = 0.05$)

Assume all uncertainties (occupancy level of each room and electricity price) are perfectly known beforehand for the whole day. Formulate and implement the Optimal in Hindsight solution as a mixed-integer linear program (MILP). The MILP should determine the optimal heating and ventilation actions for each hour of the day.

**Deliverables:**

1. pdf[1] describing the MILP in math mode. Follow the following template: Begin by defining the notation (nomenclature). Use calligraphic fonts for sets, italics for variables and indices, and straight or Greek letters for known quantities or coefficients. Specify clearly which are the problem's variables. Then, define the constraints and the objective function. Explain each constraint in words, in a single sentence, just before the constraint. Be concise and avoid wordy explanations.

2. Python code that implements this MILP. Use the file `SystemCharacteristics` to define numerical values for the problem's parameters. Solve the MILP for each of the 100 days of prices' and occupancy levels' data provided in the files `PriceData`, `OccupancyRoom1` and `OccupancyRoom2`. Calculate the average daily electricity cost.

3. pdf reporting the average daily electricity cost calculated. Also, plot the MILP problem's results for 2 example days of your choice, using the file `PlotsRestaurant`. Present the two figures (one for each day, containing the subfigures of the `PlotsRestaurant` template) and briefly interpret the results.

## Task 2: Define the Problem ($w = 0.05$)

Formulate the problem as a Markov Decision Process. Assume that:

- the electricity price at hour $t$ is given as a function of the electricity prices at hours $t-1$ and $t-2$;
- each room's occupancy level at hour $t$ is given as a function of its own occupancy level at hour $t-1$ and the other room's occupancy level at hour $t-1$ (i.e. there is some correlation between the two rooms' occupancies).

**Deliverable:** pdf describing the MDP in math mode: Define the state variables, the decision variables, the reward function, and the transition dynamics (if for some state variable the transition dynamics is unknown, just state so). Use calligraphic fonts for sets, italics for states, decisions and indices, and straight letters for known quantities or parameters. Be concise and precise. Avoid overly wordy explanations.

## Credit Allocation Task for Tasks 1-2

Report how each group member contributed to Tasks 1-2.

**Deliverable:** pdf where

- Each group member writes their name and one small paragraph about their own contributions to each Task. Be specific and comprehensive. The group reads, reviews, and approves each member's contributions. Take note that a false statement (for yourself or for others) is a breach of academic integrity.

[1] Include all pdf-deliverables of both Tasks in a single pdf file. Make sure to include the Group number and the names of all members in the first page.

- The group agrees and jointly provides a number $f_i$, representing each member's percentage contribution to the overall hand-in (not per Task) - see the General Rules at the top.

  Nuclear option: If you cannot reach an agreement, you can ask for a meeting with the instructor (to be scheduled after your deliverables are evaluated) where each member's contributions and overall understanding of the concepts will be assessed. Use this option only as a last resort; note that it **can** result in reduced points for all members if the assessment reveals weaknesses not discovered through your deliverables alone.

**Deadline for Part A:** *March 2nd, 2026 23.59.*