Master of Engineering, Energy Automation Sustainable Engineering
Arcada University of Applied Sciences, Helsinki
Åland University of Applied Sciences, Mariehamn

Pre-Assignment
Energy Automation Sustainable Engineering

Pre-assignment: This pre-assignment is a mandatory part in the application for the program in Master of Engineering in Energy Automation Sustainable Engineering offered by Arcada University of Applied Sciences in Helsinki and Åland University of Applied Sciences in Mariehamn. A score of at least 50 points on the assignment, of a maximum of 100 points, is required for being eligible for admission. The pre-assignment should be submitted no later than September 25^{th}, 2023, at 15:00 EEST, UTC+03:00. If you have questions related to accessibility, please contact Degree Program Director Matias Waller: `matias.waller@ha.ax`.

The intention of the assignment is to map the basic skills and interest needed for developing abilities to use and creatively explore modern tools for modeling and data analysis, read and analyze scientific writing within the field, and effectively communicate results.

1 Task 1: Letter of Motivation

Submit a letter of motivation of a maximum of 700 words outlining why you consider yourself a good candidate for the program. In addition to the topics you might choose to emphasize, e.g., suitable experience, visions for future roles and possibilities, possible thesis topics, etc., the letter should reflect your formal language skills. The letter of motivation can give a maximum of 40 points.

2 Task 2: Simulations

In the book *Thinking Fast and Slow*[1], the Nobel Prize laureate Daniel Kahneman differentiates between two modes of thought: “System 1” described as automatic and fast, and “System 2” as controlled and slow. To illustrate the differences with an example, assume that you are told that you pay one euro and 20 cents for a pen and an eraser and that the eraser costs one euro more than the pen. If you are asked how much you pay for the eraser and only consult “System 1”, you could give the erroneous answer that you pay one euro for the eraser. Your “System 2” would instead solve the linear equation and give the correct answer that you pay one euro and 10 cents for the eraser.
In the article, *Evolutionary game dynamics of controlled and automatic decision-making*[2], the authors study under what circumstances agents with an either-or mode of thinking can co-exist, dominate, or periodically dominate alternatingly over time. For this purpose, they, among other things, explore the system of differential equations

$$\begin{aligned}\dot{x} &= (x-1)x\left(\frac{a}{a-\beta\rho+\rho+\beta\rho x}+\frac{\rho+\beta\rho x}{a+1}-1\right)\\ \dot{\beta} &= \frac{x-\beta}{\tau_b}\end{aligned} \tag{1}$$

In the equation, $x(t)$ is the fraction of controlled agents, $1-x(t)$ the fraction of automatic agents, ρ the probability of finding a good, $\beta(t)$ the “competitive advantage automatic agents have over controlled agents in acquiring goods (where $\beta = 0$ means that both types of agents have an equal probability of acquiring goods)”, “a determines the extent of diminishing marginal returns [on consumption of goods], with lower a leading to more steeply diminishing returns”, and a lag τ_b capturing “the fact that an increase in x at time t does not always have an immediate impact on x”.
For $a = 0.8$, $\tau_b > 200$ and $0.2 < \rho < 0.3$ the fraction of controlled agents x and automatic agents $1-x$ will, according to the article, alternate periodically over time. **The assignment is** to verify this result by solving Eq. (1) for your own choice of parameters $\tau_b > 200$ and $0.2 < \rho < 0.3$. In your simulations, **what is the period** for $x(t)$? **For how long** will $x(t)$ dominate over $1-x(t)$ within one period? In your submission, **include a figure illustrating** $x(t)$ and $1-x(t)$ over time. This task can give a maximum of 30 points.

[1] Highly recommended not only for its contents but also for the enjoyable and enlightening introduction to scientific practice and reasoning.
[2] Available through `https://www.stevenstrogatz.com/` or directly at the following link

3 Task 3: Data analysis

A common digital PI-controller is given by the equations,

$$\begin{aligned} e(k) &= r(k) - y(k) \\ u(k) &= u(k-1) + K_c\left(\left(1 + \frac{T_s}{T_i}\right)e(k) - e(k-1)\right) \end{aligned} \tag{2}$$

where k is the sampling index, T_s is the sampling period, $r(k)$ is the setpoint, $y(k)$ is the (measured) process value, $e(k)$ is the control error and $u(k)$ is the controller output. The parameter K_c is called the gain and T_i is called integration time. These are typically tuned in order to achieve a desired performance of the closed-loop system.

Measurements from a heater and a heat exchanger, schematically depicted in Fig. 1, are provided in the comma-separated values file `HeatControl.txt`. The process has three control signals, denoted u_c for the pump on the cold side, u_h for the pump on the hot side, and u_p for the power to the heater. Depicted external disturbances are T_{ci} and T_{surr}, i.e., the temperature of the flow on the cold side in to the heat exchanger and the surrounding temperature. The main process values to be controlled are the flow on the cold side, $\dot{V}_c$, the temperature entering on the hot side, T_{hi}, and the temperature exiting on the cold side, T_{co}.

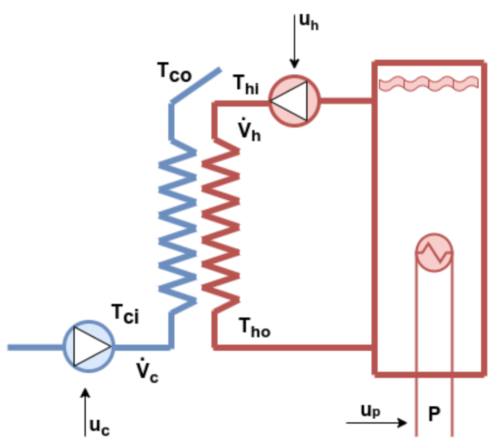

Figure 1: Schematic view of the heating process. Blue is used to illustrate the cold side of the heat exchanger and depicted are also the control signal to the pump on the cold side, u_c, the incoming temperature on the cold side, T_{ci}, the flow on the cold side $\dot{V}_c$ and the temperature exiting the cold side, T_{co}. Red is used to illustrate the hot side of the heat exchanger and heater. Depicted in red are also the control signal to the pump on the hot side, u_h, the incoming temperature on the hot side, T_{hi}, the flow on the hot side $\dot{V}_h$, the temperature exiting the hot side, T_{ho}, the control signal to the heater u_p and the power to the heater P.

In the file `HeatControl.txt`, the first three columns are u_c, u_h and u_p followed by $\dot{V}_c$, T_{co} and T_{hi}, all sampled with 1 Hz. The measurements are illustrated in Figs 2–4.

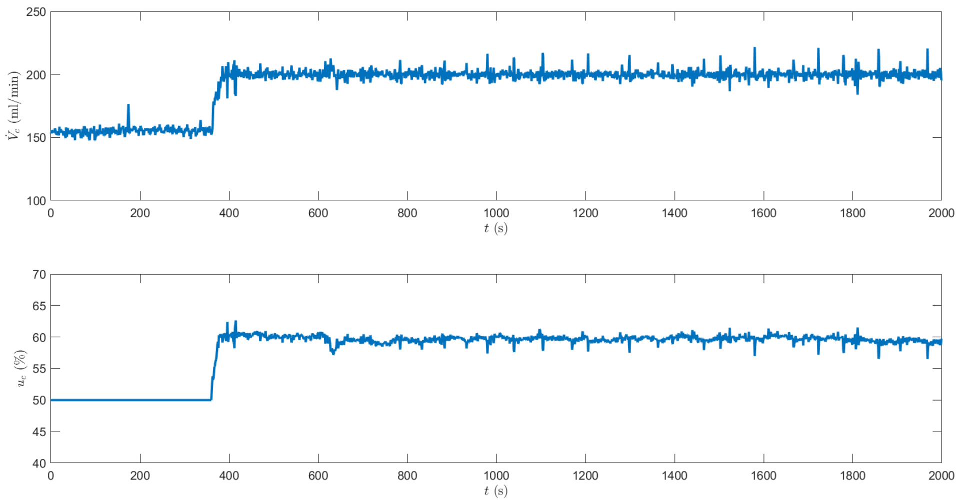

Figure 2: Upper panel illustrates the flow on the cold side, $\dot{V}_c$, for a period of 2000 seconds. Lower panel illustrates the corresponding control signal to the pump on the cold side, u_c. Automatic control is is turned on a little before 400 seconds. Data can be found in the file `HeatControl.txt`.

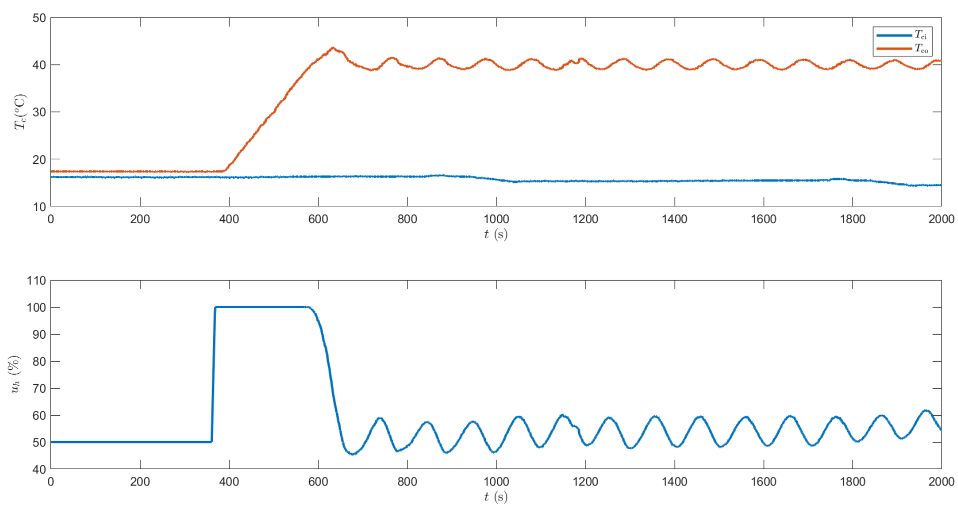

Figure 3: Upper panel illustrates the temperatures on the cold side T_{co} in red and T_{ci} in blue for the same 2000 seconds as in Fig. 2. Lower panel illustrates the corresponding control signal to the pump on the hot side, u_h. Automatic control is is turned on a little before 400 seconds. Data can be found in the file `HeatControl.txt`.

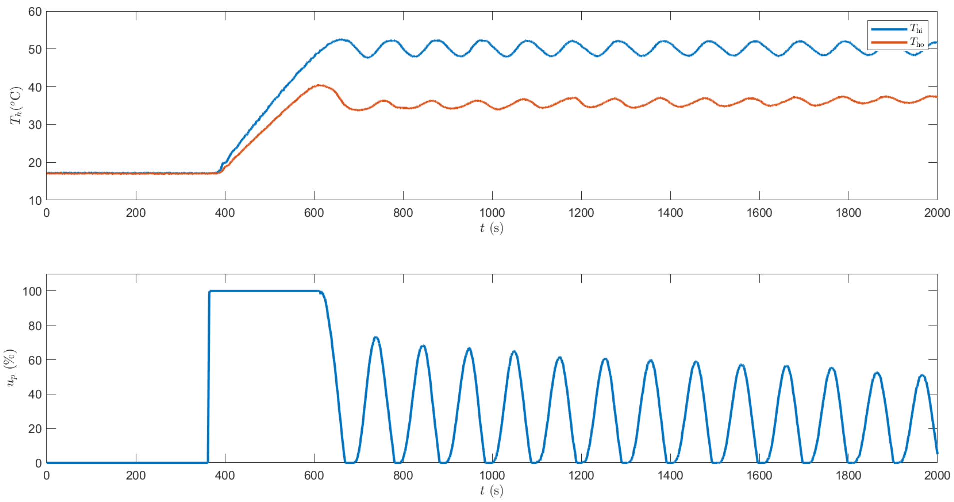

Figure 4: Upper panel illustrates the temperatures on the hot side T_{hi} in blue and T_{ho} in red for the same 2000 seconds as in Fig. 2. Lower panel illustrates the corresponding control signal to the pump on the hot side, u_h. Automatic control is is turned on a little before 400 seconds. Data can be found in the file `HeatControl.txt`.

As the figures reveal, the control is turned on a little before 400 seconds and the control action is further constrained by $0 \leq u(k) \leq 100\%$. The considered case uses three separate PI-controllers: u_c to control $\dot{V}_c$ at the setpoint 200 ml/min, u_h to control T_{co} at the setpoint 40°C and u_p to control T_{hi} at the setpoint 50°C.

The assignment is to use the measurements from the file to determine the values of K_c and T_i that are used for each of the three controllers. The sampling period is $T_s = 1$ for all controllers. This task can give a maximum of 30 points.