

CSE 561
Modeling & Simulation Theory and Application
School of Computing and Augmented Intelligence

Fall 2023

Homework # 2

Assigned Date: September 16

Due Date: September 24

Note 1: Your submission to **Gradescope** must include the above header shown in maroon color. Do not include your name in your submission.

Note 2: Homework is to be done individually. You may discuss the homework problems with your fellow students, but you are NOT allowed to copy – either in part or in whole – anyone else’s answers. You are also encouraged to meet the TAs and the instructor.

Note 3: All submitted materials must be legible. Text-based answers must be typed. Figures/diagrams must follow the given instructions.

Note 4: Please check the Canvas Discussions for further instructions, questions, answers, and hints.

Note 5: The format Hw#-PostingID.pdf (e.g., Hw1-1234-987.pdf) should be used for naming homework assignment files.

Note 6: Generative AI is allowed. Any AI-Generated (AIG) answer or any portion of it (in the forms of text, diagrams, code, etc.) must be placed between the “**Begin AIG**” and “**End AIG**” markers. The names of tools and their versions should be included.

Answers generated by ChatGPT or other LLM tools are not necessarily correct, accurate, and precise for the following exercises. Such answers can also be unsuitable for the questions asked and insufficient. The names of tools and their versions should be included in the submitted works.

A **Stationary Stairway** (simply called stairway) is a kind of exercise equipment where a climber can enter a desired number of stairs to climb. A person can also enter a period of time to climb. The person can start and stop the stairway. The stairway incline can be increased and decreased. Assume there is a display that has a button for each of the given operations. The amount of time spent climbing and the distance traveled relative to the beginning of using the stairway can be theoretically calculated. Assume the time begins once the start button is pressed and ends when the number of stairs is climbed. The climber can also stop climbing at any time using the stop button. Assume the information about the stairway chain belt and the person’s speeds can be computed at 10-second time intervals. The lowest time resolution is 1 second. The time unit is in HH:MM:SS (hours:minutes:seconds). The speed of the person and the chain belt is the average of the last 10 seconds relative to the provided time interval.

[30 points] Exercise 1: The stairway can be modeled using the *IO Relation Observation* specification $IORO = \langle T, X, \Omega, Y, R \rangle$ specification. Restrict the specification to represent a stairway chain belt rolling at three different speeds (low, medium, and high). Assume the stairway stops after 9 minutes and 11 seconds. The speeds should be within a reasonable range of values. Hint: Determine the appropriate *kinds of trajectories* and *their relationships* for the stairway’s operation.

[40 points] Exercise 2: Extend the above model to an *IO Function Observation* specification $IOFO = \langle T, X, \Omega, Y, F \rangle$ specification. Each functionality of the stairway can be defined using $y = f(s_i, x)$ where x is the input variable, y is the output variable, and $s_{initial}$ is an initial state for the state variable s . The input, output, and state variables can be vectors.

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[30 points] Exercise 3: Sample trajectories for Exercise 2.

- (a) Provide a suitable trajectory that changes the chain belt speed at time instances t_1 and t_2 where $t_0 < t_1, t_1 < t_2$ and $t_2 < t_{max}$. Assume $t_0 = 0$ is the time instance the chain belt starts to roll and t_{max} is the time instance the chain belt stops. Identify whether the trajectory is an input belonging to X , an output belonging to Y or both. Justify your choice of the trajectory type.
- (b) Provide a suitable trajectory for the chain belt incline starting at t_h and ending at t_v with $t_h < t_j < t_m < t_p < t_v$. Provide sample values for time instances t_h, t_j, \dots . Identify whether the trajectory can be an input belonging to X , an output belonging to Y , or both. Justify your choice of the trajectory type.
- (c) Provide a suitable trajectory for the chain belt to suddenly stop after 3 minutes and 33 seconds. Identify whether the trajectory should be an input belonging to X , an output belonging to Y , or both. Justify your choice of the trajectory type.