CSE/EEE 120 Capstone Design Project Spring 2021

Project Summary

The goal of this project is to design the automation required for an autonomous wheelchair to be able to navigate down a path without any intervention by the passenger. The project is now in the prototype stage, where a simplified version of the wheelchair will be built. You are in charge of keeping track of the lateral position of the wheelchair, that is, the position of the wheelchair to the left or right of the centerline of the path it is on.

Note that other teams are responsible for designing other aspects of the wheelchair project. These other aspects include generating motion forward and backward, monitoring sensors to avoid obstacles, and so on. Your project is just to monitor the position to the left or right of the centerline of the path.

You will receive two inputs: **left** and **right**. These inputs dictate what the computer controlling the wheelchair has directed it to do. The input definitions are shown in the following table:

left	right	Meaning
0	0	The wheelchair has maintained its left-right position
0	1	The wheelchair has moved one position to the right
1	0	The wheelchair has moved one position to the left
1	1	You need to define this functionality

When both left=1 and right=1, you need to pick a function that makes sense. There are two restrictions on how you define this case:

1. left=1, right=1 may not be a don't care. That is, it must result in some defined action.
2. left=1, right=1 must have a distinct action from the others. That is, the four combinations of left and right must all differ.

For safety, the wheelchair is never permitted to move more than 3 positions to the right or left of the centerline. Therefore, if the wheelchair is currently 3 positions to the right, then left=0, right=1 has no effect. Likewise, if the wheelchair is currently 3 positions to the left, left=1, right=0 has no effect. Note that since it is a critical safety feature to remain within 3 positions of the centerline, these input combinations should not be treated as don't cares in case a bug elsewhere in the system results in an illegal move.

It is up to you to decide what to do if the wheelchair has reached 3 positions to the right or left. That is, is it stuck there until reset or is permitted to move back toward the center?

For the purposes of the prototype, the simulation is restricted to 16 clocks. During each clock, the left and right inputs will be provided to you. At the end of 16 clocks, the simulation ends and you should analyze the results to verify correct behavior.

Note that the left/right motion of the wheelchair is independent of forward/backward movement. That is, the wheelchair can move sideways even if it doesn't move forward or backward. For your design, how far the wheelchair moves forward or backward is not relevant.

The circuit has two outputs as defined in the following table.

output	Meaning
far_left	Wheelchair is 3 locations left of center
far_right	Wheelchair is 3 locations right of center

To re-cap, you have two digital signals as inputs and two digital signals as outputs.

Your first task is to interview several customers (at least 3) to gain insight into what type of features and functionality are preferred by potential clients. These customers can be professors, TAs, UGTAs, or other classmates. You have to weigh their opinions to help you finish certain features regarding this design. These people may have conflicting opinions. It is up to you to document these findings and judge which suggestions to accept. You will need to analyze how your design adds value from multiple perspectives (technological, societal, environmental, financial, etc), so be sure to ask questions other than just about the automation, but about the environment and type of customer that will be using it. Make sure you record the names of the people you speak to about your design in your template.

Once you go through this customer discovery, create **two** finite state machine designs applying what you learned from your interviews and using different assumptions. This means documenting the assumptions made for each design and going through the design process (State Definition Table, State Transition Diagram, State Transition Table, Combinational Logic Design). Note that the two designs you create must be functionally different. That is, you can't create the same design once as a Mealy machine and once as a Moore machine. That is, the assumptions you make for left=right=1 and what happens when 3 locations from the centerline must be different for the two designs. In addition, at least one of the designs must be based on Karnaugh maps and logic gates. You will also need to figure out if you want to incorporate any asynchronous inputs (Preset, Clear).

Once you have completed two different designs, you will need to choose one design to implement and simulate in Digital. To do this, you will need to select at least 5 different criteria to use for comparison of each design and aid in your decision-making process. These criteria can originate from your customer interviews or from your own engineering intuition. Examples of criterion can be "ease of design, response time for passenger, size of circuit, extra features." Each criterion must be given a weight (totaling 100%) of how important it is to include in the final design. Each design will then need to be rated against how well it meets each of the suggested criteria. Based on these ratings, select the best design that meets the customer's needs, and implement it in Digital, then simulate it through 16 different clock cycles showing each possible state transition. (Depending on your design, this may take multiple simulations.)

Items which go into your template include all of your design documents. These include state definition tables, state transition diagrams, Karnaugh maps, behavioral equations, etc. When you implement the design in Digital, be sure to include a screenshot of your completed design.

You will also create a video in which you showcase your design. Topics to be covered in the video should include, but are not limited to,

1. The design assumptions you made
2. A brief description of your two designs and why the one you built was best
3. Showing your Digital design schematic and its features
4. Simulating the design in Digital showing some different scenarios

Deliverables

- You need to propose two different sets of assumptions for what to do if right=left=1 and what to do if 3 positions left or right of center.
- You need to design two finite state synchronous machines that you can demonstrate to your stakeholders. This would usually be the company liaison, but in this class the stakeholders are your (UG)TAs, classmates, and instructors.
- The designs must be different in their functionality. This can be addressed by differences in how you define left=right=1 and what to do if the wheelchair is 3 positions left or right of center.
- You should comment on why your controller adds value from multiple perspectives (technological, societal, financial, environmental, etc.). One or two sentences is sufficient.
- The number of states is not defined, you can use as few or as many as you need to provide the desired functionality.
- If something is not clearly documented in the summary, you need to make assumptions. The assumptions need to be documented.
- Please remember that you can design the state machines and add functionality to the design as you see fit. However, you need to collect feedback from at least one stakeholder. The optimum would be three stakeholder/customer "interviews". Again, stakeholders are your UGTAs, the lab TAs, and the instructors.
- You should describe in a sentence or two how you changed your design based on the feedback you received.
- You can use D flip flops, T flip flops or J-K flip flops in your design. The type does not matter. Mixing different types of flip flops with different trigger edge sensitivity is possible but not recommended.
- You need to properly document your designs. If you do a "classic" paper-based design, you need to include diagrams and state tables as well as K-Maps and logic. If you decide to go with a different implementation (ROM, HDL), you need to comment your code. You must have a schematic design in Digital which matches your simulation.
- You need to pick the best design and explain why it is the best. It is very helpful to have judgement metrics in mind, for example, number of states, features, ease of building, number of logic elements, your understanding of the design, or others that you can come up with. You need to define the weight of each of these metrics. That is, ease of building is worth 10 points, number of logic elements 20 points, number of states 40 points, etc.

Award points to each design. For example, if one design is easier to build than the other, it might get 6 of the 10 points in the category while the other design gets the remaining 4. The design which has the highest point total is the best! Again, it is up to you to define the categories (minimum of 5) and the number of points each category is worth. You must justify the points awarded with one sentence per category. (Do NOT write an essay!)

- You will need to simulate one design in Digital. Simulate multiple scenarios: getting through all 16 clocks without getting 3 positions from the centerline, hitting the right extreme, hitting the left extreme, etc.
- **A short video, the contents of which were described above.**
- **Upload your completed template (which must include a link to your video) and a zip file of your capstone folder.**

Grading Policy

The grade will be allocated as follows:

- 5% for the value proposition.
- 5% for the stakeholder interviews.
- 5% for documenting the changes performed to your original idea.
- 20% for documentation in the report of how the first circuit performs the application.
- 20% for documentation in the report of how the second circuit performs the application.
- 5% for establishing reasonable criteria for picking one design as the “best” design. (The one design you build in the hardware lab does not need to be the “best” design.)
- 5% for picking a preferred, “best” design.
- 15% for Digital implementation
- 15% for the video demonstration.
- 5% for following design template guidelines (organization, legibility)

2% (Extra Credit) Completed Self-Assessment Worksheet