An Overview of Computer Architecture adventure into the imaginary world of Harry Potter

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It is said that only goblins can open the vault doors in Gringotts Wizarding Bank from Harry Potter. However, a group of CS conversion master's students found an old scroll while exploring the caves of Cheddar Gorge. On the back of the scroll, they read the following sentence:

"These are instructions to open any vault in Gringotts Wizarding Bank. Do not fool yourself, these instructions can only be followed by those who understand Finite State Machines and Logic!"

On the other side there is an ancient drawing of what seems to be a state transition diagram! This is the only clue.

This is the first part of our adventure. In this workshop we will try to open Vault 713. Your help is needed to figure out the secret sequence.

1 State Transition Diagram

Figure 1 shows the state transition diagram from the old scroll. Arrows represent transitions and are labelled with the Input/Output of the system, i.e. the input is the number you enter and the output indicates whether or not the lock opens, zero for locked and one for unlock. What do you think would be the right sequence of inputs that would set the output to one? Please post your answer to the Adventure channel in teams.

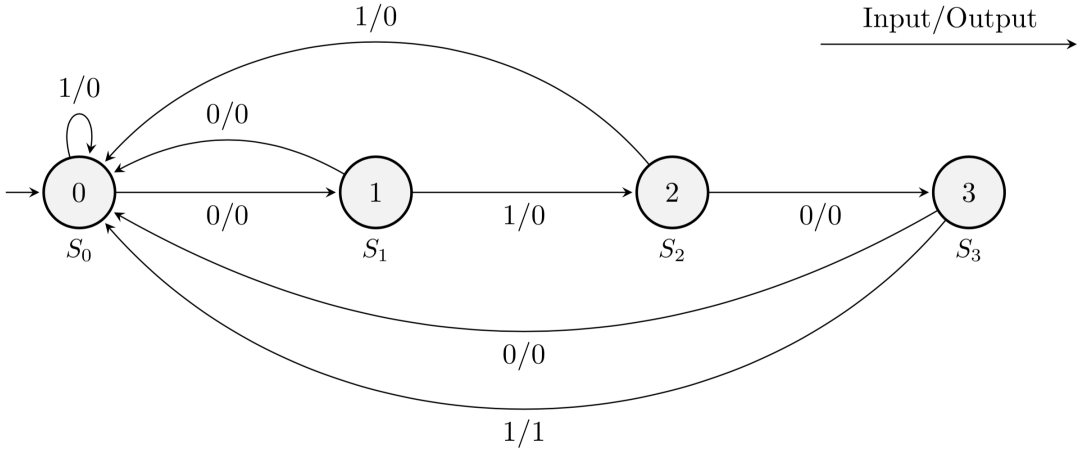

Figure 1: The state transition diagram to unlock the door of any vault in Gringotts Wizarding Bank.

Well done for figuring out the secret sequence! If you did not manage to discover the code, please contact one of the teaching assistants.

1.1 Discussion

Let us check our understanding of Finite State Machines (FSM).

1. Why does this lock FSM have four different states?
2. Why are we using two bits to represent the states of this FSM?
3. Why did we use one bit for the input and one bit for the output?
4. Why is the output different from the input and the states?
5. Why do we have a current state and a next state in the design? What is the type of this FSM, Mealy or Moore?

2 Lock circuit

Now, we can use this code to unlock the door of Vault 713. Please download the Logisim file `Lock_FSM.circ`. There are a clock signal and one input. There is also a probe to show the status of the lock. The door will be unlocked when this output becomes one. The current and next sates are displayed using four probes. The current state is represented by $S0_t$ and $S1_t$, and the next state is encoded by $S0_{t+1}$ and $S1_{t+1}$.

Your task is to control the input and the clock signals to drive the output bit (unlock signal) to one. As you are engaging with this task, discuss the following points with your group.

2.1 Discussion

1. Are these D flip-flops rising edge or falling edge trigged? How can we derive the required edge from the clock input?
2. What could happen if you used D latch instead of flip-flop? Test your answer in Logisim, replace the D flip-flops by D latches. What is the main difference between D latch and D flip-flop?
3. Can you point out some NOT, AND, OR, NOR gates in the circuit?
4. You might have noticed that the design of the current circuit is not optimal. Could you save some NAND gates?

Congratulations on engaging in this precious discussion. Do not worry if you did not manage to unlock the door. We will work on it together in the last 15 minutes before the goblins find out about us.

3 Finding the new secret code

Now we have taken the virtual treasure and increased our knowledge about Computer Architecture. We need to protect the vault content. We must change the secret sequence as the current password is compromised. We will calculate the new code using the numbers that have been engraved on the inner walls of the vault. I have a strong feeling that a CS genius from Hogwarts School of Witchcraft and Wizardry has encrypted these numbers.

1. What would you use, zeros or ones, to pad the 6 digits of the base-2 value 110101 when converted to base-16? Use 2 digits and 2's complement signed representation. Take one or zero based on your answer for the first digit of the new password, this is the Least Significant Bit (LSB).
2. What is the base-16 value AEB when converted to base-2? Use 12 digits and 2's complement signed representation. Use the fifth bit from your answer as the second digit of the new password. Start counting from the LSB as the first bit.
3. What is the base-8 value 3022 when converted to base-2? Use 12 digits and 2's complement signed representation. Use the ninth bit from your answer as the third digit of the new password. Start counting from the LSB as the first bit.
4. What is the most significant bit of the base-10 value -1161 when converted to base-2? Use 12 digits and 2's complement signed representation. Use your answer as the fourth digit of the new password, this is the Most Significant Bit (MSB).

Good job finding the new secret code! If you did not find some of the new secret digits, discuss the relevant question with your group. In case you are still concerned, then please contact one of the teaching assistants.

3.1 Discussion

Here are a few things to discuss before we wrap up for today:

1. Why do we need to pad the 6 digits of the base-2 value 110101 when converted to base-16?
2. How can we know the most significant bit of the base-10 value -1161 when converted to base-2 without doing the conversion?
3. How many binary bits do we need to represent each base-8 digit?
4. Why does the base-2 value 110101 become F5 when converted to base-16?
5. What is the value of the new secret code when expressed in base-16? Use unsigned representation.
6. What is the value of the new secret code when expressed in base-16? Use 2's complement signed representation.
7. What is the value of the new secret code when expressed in base-10? Use unsigned representation.
8. What is the value of the new secret code when expressed in base-10? Use 2's complement signed representation.

Hopefully you had a fruitful discussion and figured out the new secret code. Hold tight to this code and keep it safe. We will use it during our next adventure to design the new lock circuit.