Our Counting Algorithm – Explained

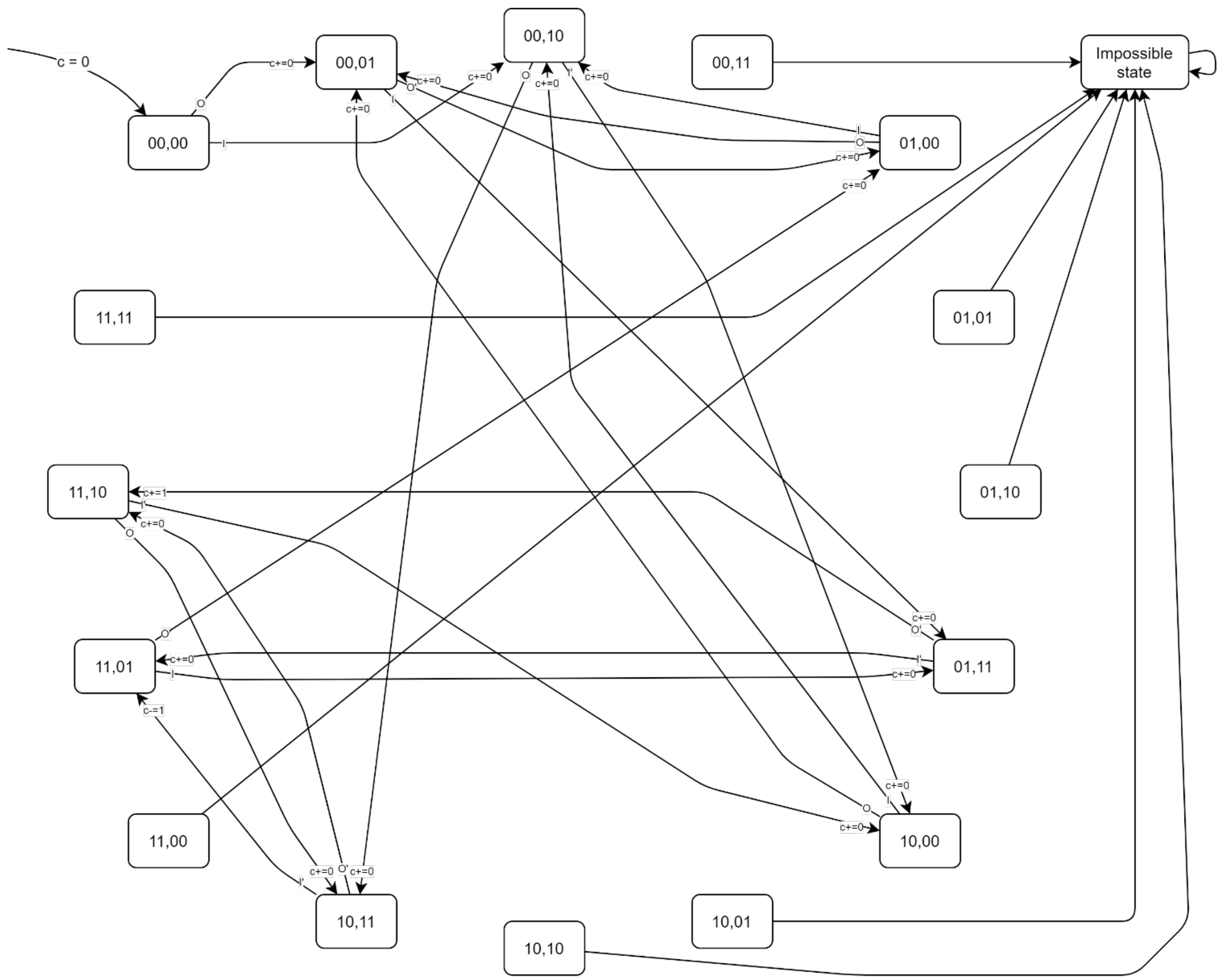

Figure 1 - State Transition Diagram

Our solution to solve the counting problem utilizes a finite state machine (FSM), capturing and tracking the pin levels of the 2 light barriers inside a state composed of 4-bits. The second half of the state represents respectively the latest pin level of the inner and the outer barrier. The first half similarly represents the previous pin levels of the light barriers. Note that a barrier pin level is 0 when there is no obstacle, and is 1 when there is an obstacle.

The notation used in Figure 1 is as follows: Letter **O** represents outside light sensor becoming obstructed, **O'** represents outside light sensor becoming unobstructed. Similarly, letter **I** is for the inside light sensor. Note that each state transition has to happen due to exactly 1 level change by a hardware interrupt. Hence, states such as "00,11", "01,10" and "01,01" are impossible to visit under normal working conditions. The only exception is "00,00" state, which is only visited once at the beginning. At the tip of each state transition arrow, there is a stateful operation indicating what happens to the **count** variable with the transition, except for the transitions from impossible states in which case nothing happens to the count.

In the following pages the corner cases given to us will be analyzed and the transitions triggered therein will be denoted with the letter notation we introduced above.

Analysis of The Corner Cases

- **Halfway enter:** Here is the sequence of transitions $\mathbf{O}, \mathbf{I}, \mathbf{I}', \mathbf{O}'$. Now let's see which state transitions and stateful operations would take place:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 11{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Halfway leave:** Here is the sequence of transitions $\mathbf{I}, \mathbf{O}, \mathbf{O}', \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 10{,}11 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 11{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Breaks outer and inner but returns G4:** Here is the sequence of transitions $\mathbf{O}, \mathbf{I}, \mathbf{O}', \mathbf{O}, \mathbf{I}', \mathbf{O}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{O'} \quad \text{c+=1}} 11{,}10 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 10{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c−=1}} 11{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Breaks inner and outer but returns G4:** Here is the sequence of transitions $\mathbf{I}, \mathbf{O}, \mathbf{I}', \mathbf{I}, \mathbf{O}', \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 10{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c−=1}} 11{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{O'} \quad \text{c+=1}} 11{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Person turned G9:** Here is the sequence of transitions $\mathbf{O}, \mathbf{O}', \mathbf{I}, \mathbf{I}', \mathbf{O}, \mathbf{O}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Unsure enter:** Here is the sequence of transitions $\mathbf{O}, \mathbf{I}, \mathbf{I}', \mathbf{O}', \mathbf{O}, \mathbf{I}, \mathbf{O}', \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 11{,}01$$
$$\xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{O'} \quad \text{c+=1}} 11{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=1}$ the **count will be as expected**.

- **Manipulation enter:** Here is the sequence of transitions $\mathbf{O}, \mathbf{O}', \mathbf{I}, \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

  Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathbf{+=0}$ the **count will be as expected**.

- **Manipulation leave:** Here is the sequence of transitions $\mathbf{I}, \mathbf{I}', \mathbf{O}, \mathbf{O}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathrel{+}= \mathbf{0}$ the **count will be as expected**.

- **Peak into and leave G11:** Here is the sequence of transitions $\mathbf{O}, \mathbf{O}', \mathbf{I}, \mathbf{O}, \mathbf{I}', \mathbf{O}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 10{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c−=1}} 11{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathrel{-}= \mathbf{1}$ the **count will be as expected**.

- **Successive enter:** Here is the sequence of transitions $\mathbf{O}, \mathbf{I}, \mathbf{O}', \mathbf{O}, \mathbf{I}', \mathbf{I},, \mathbf{O}', \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11 \xrightarrow{\boldsymbol{O'} \quad \text{c+=1}} 11{,}10 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 10{,}11 \xrightarrow{\boldsymbol{I'} \quad \text{c−=1}} 11{,}01 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 01{,}11$$
$$\xrightarrow{\boldsymbol{O'} \quad \text{c+=1}} 11{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathrel{+}= \mathbf{1}$ the **count will not be as expected** (should have increased by 2).

- **Peak into room:** Here is the sequence of transitions $\mathbf{O}, \mathbf{O}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{O} \quad \text{c+=0}} 00{,}01 \xrightarrow{\boldsymbol{O'} \quad \text{c+=0}} 01{,}00$$

Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathrel{+}= \mathbf{0}$ the **count will be as expected**.

- **Peak out of room:** Here is the sequence of transitions $\mathbf{I}, \mathbf{I}'$. Now let's do the same analysis as before:

$$00{,}00 \xrightarrow{\boldsymbol{I} \quad \text{c+=0}} 00{,}10 \xrightarrow{\boldsymbol{I'} \quad \text{c+=0}} 10{,}00$$

Since the cumulative effect of the stateful operations is $\boldsymbol{c}\mathrel{+}= \mathbf{0}$ the **count will be as expected**.

As we can see, our counting algorithm is independent of the notion of time and is able to handle 11 out of 12 corner cases suggested above.

One thing worth noting is that the initial state is always assumed to be $00{,}00$ which might not be always true, especially in case of power outages. In those cases, a possible solution could be to instantly measure the barrier pin levels L_I, L_O and initialize the FSM with $00, L_I L_O$. But this still has the disadvantage that the previous barrier pin levels are always 00. For that, we could perform 2 consecutive measurements and use these measured pin levels as the initial FSM state. But it still does not guarantee that the new measured state will be the same as the one before the power outage. Because during the power on and bootup the barrier pin levels could have changed. Therefore, there seems to be no reliable solution for recovering the FSM state from a power outage situation.

However, we can recover the **count** value after a power outage by querying the Elasticsearch database to get the latest count and initialize our local count from that.