

Adaptive Traffic Light Controller Project

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1 Introduction

This project involves designing an **adaptive traffic light controller** for a four-way intersection. The system adapts dynamically to real-time traffic conditions to ensure collision-free operation and prioritize heavily congested lanes.

The traffic light controller is modeled as a **Finite State Machine (FSM)** with 12 states corresponding to each lane's traffic light conditions.

2 Problem Statement

The goal is to develop a **traffic control system** with:

1. **Dynamic Timing:** Extend green light duration for congested lanes based on sensor inputs.
2. **Collision Avoidance:** Only one lane can have a green or yellow light at any time.
3. **Skipping Idle Lanes:** If no cars are detected in a lane, the FSM skips to the next lane in the sequence.
4. **Efficient Lane Priority:** Ensure a fair balance between lane priorities while dynamically adjusting for congestion.

3 System Requirements

1. **Lanes:** Four main lanes: NS1, NS2, EW1, EW2.
2. **Sensors:**
 - S1_NS1, S5_NS1 for North-South Lane 1.
 - S1_NS2, S5_NS2 for North-South Lane 2.
 - S1_EW1, S5_EW1 for East-West Lane 1.
 - S1_EW2, S5_EW2 for East-West Lane 2.
3. **Traffic Lights:** States: **RED, GREEN, YELLOW.**
4. **Timers:**
 - Default green timer: 20 seconds.
 - Yellow timer: 5 seconds.
 - Extended green timer: 30 seconds if congestion ($S5 = 1$) is detected.

4 FSM Overview

4.1 States

The FSM has **12 states**:

1. NS1_RED, NS1_GREEN, NS1_YELLOW
2. NS2_RED, NS2_GREEN, NS2_YELLOW
3. EW1_RED, EW1_GREEN, EW1_YELLOW
4. EW2_RED, EW2_GREEN, EW2_YELLOW

4.2 Transitions

Transitions are triggered by:

1. **Sensor Inputs:** Cars detected ($S1 = 1$) or congestion ($S5 = 1$).
2. **Timer Expiry:** States transition when their timers expire.
3. **Idle Lane Skipping:** If a lane is in RED and no cars are detected ($S1 = 0$), the FSM skips to the next lane in sequence.

5 FSM Table

Current State	Condition (Inputs)	Next State	Output	Timer Extension Condition
NS1_RED	$S1_NS1 = 1$	NS1_GREEN	NS1: Green; All others: Red	No
NS1_RED	$S1_NS1 = 0$	NS2_RED	NS1: Red; All others: Red	No
NS1_GREEN	Timer expires && $S5_NS1 = 1$	NS1_GREEN	Extend Green for NS1	Yes (if $S5_NS1 = 1$)
NS1_GREEN	Timer expires && $S5_NS1 = 0$	NS1_YELLOW	NS1: Yellow; All others: Red	No
NS1_YELLOW	Timer running	NS1_YELLOW	NS1: Yellow; All others: Red	No
NS1_YELLOW	Timer expires	NS2_RED	NS1: Red; All others: Red	No
NS2_RED	$S1_NS2 = 1$	NS2_GREEN	NS2: Green; All others: Red	No
NS2_RED	$S1_NS2 = 0$	EW1_RED	NS2: Red; All others: Red	No
NS2_GREEN	Timer expires && $S5_NS2 = 1$	NS2_GREEN	Extend Green for NS2	Yes (if $S5_NS2 = 1$)
NS2_GREEN	Timer expires && $S5_NS2 = 0$	NS2_YELLOW	NS2: Yellow; All others: Red	No
NS2_YELLOW	Timer running	NS2_YELLOW	NS2: Yellow; All others: Red	No
NS2_YELLOW	Timer expires	EW1_RED	NS2: Red; All others: Red	No
EW1_RED	$S1_EW1 = 1$	EW1_GREEN	EW1: Green; All others: Red	No

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Table 1 – Continued from previous page

Current State	Condition (Inputs)	Next State	Output	Timer Extension Condition
EW1_RED	$S1_EW1 = 0$	EW2_RED	EW1: Red; All others: Red	No
EW1_GREEN	Timer expires && $S5_EW1 = 1$	EW1_GREEN	Extend Green for EW1	Yes (if $S5_EW1 = 1$)
EW1_GREEN	Timer expires && $S5_EW1 = 0$	EW1_YELLOW	EW1: Yellow; All others: Red	No
EW1_YELLOW	Timer running	EW1_YELLOW	EW1: Yellow; All others: Red	No
EW1_YELLOW	Timer expires	EW2_RED	EW1: Red; All others: Red	No
EW2_RED	$S1_EW2 = 1$	EW2_GREEN	EW2: Green; All others: Red	No
EW2_RED	$S1_EW2 = 0$	NS1_RED	EW2: Red; All others: Red	No
EW2_GREEN	Timer expires && $S5_EW2 = 1$	EW2_GREEN	Extend Green for EW2	Yes (if $S5_EW2 = 1$)
EW2_GREEN	Timer expires && $S5_EW2 = 0$	EW2_YELLOW	EW2: Yellow; All others: Red	No
EW2_YELLOW	Timer running	EW2_YELLOW	EW2: Yellow; All others: Red	No
EW2_YELLOW	Timer expires	NS1_RED	EW2: Red; All others: Red	No

6 State and Transition Explanations

6.1 NS1 (North-South Lane 1)

1. NS1_RED:

- If $S1_NS1 = 1$, transition to NS1_GREEN.
- If $S1_NS1 = 0$, skip to NS2_RED.

2. NS1_GREEN:

- If Timer expires && $S5_NS1 = 1$, extend the green light duration.
- If Timer expires && $S5_NS1 = 0$, transition to NS1_YELLOW.

3. NS1_YELLOW:

- If the timer is still running, remain in NS1_YELLOW.
- When the timer expires, transition to NS2_RED.

6.2 NS2 (North-South Lane 2)

4. NS2_RED:

- If $S1_NS2 = 1$, transition to NS2_GREEN.

- If $S1_NS2 = 0$, skip to $EW1_RED$.

5. $NS2_GREEN$:

- If Timer expires && $S5_NS2 = 1$, extend the green light duration.
- If Timer expires && $S5_NS2 = 0$, transition to $NS2_YELLOW$.

6. $NS2_YELLOW$:

- If the timer is still running, remain in $NS2_YELLOW$.
- When the timer expires, transition to $EW1_RED$.

6.3 $EW1$ (East-West Lane 1)

7. $EW1_RED$:

- If $S1_EW1 = 1$, transition to $EW1_GREEN$.
- If $S1_EW1 = 0$, skip to $EW2_RED$.

8. $EW1_GREEN$:

- If Timer expires && $S5_EW1 = 1$, extend the green light duration.
- If Timer expires && $S5_EW1 = 0$, transition to $EW1_YELLOW$.

9. $EW1_YELLOW$:

- If the timer is still running, remain in $EW1_YELLOW$.
- When the timer expires, transition to $EW2_RED$.

6.4 $EW2$ (East-West Lane 2)

10. $EW2_RED$:

- If $S1_EW2 = 1$, transition to $EW2_GREEN$.
- If $S1_EW2 = 0$, skip to $NS1_RED$.

11. $EW2_GREEN$:

- If Timer expires && $S5_EW2 = 1$, extend the green light duration.
- If Timer expires && $S5_EW2 = 0$, transition to $EW2_YELLOW$.

12. $EW2_YELLOW$:

- If the timer is still running, remain in $EW2_YELLOW$.
- When the timer expires, transition to $NS1_RED$.