Introduction

Engineering Problem/Phrase 1:
In most semi-rural areas, traffic lights all act independently without taking into account the status of other traffic lights leading to a lack of coordination and an increase in the total wait times and travel times of cars in these areas.

Engineering Goal/Phrase 2:
The aim of this project is to engineer and simulate a modular algorithm that controls traffic lights more effectively than the current method by coordinating them to reduce the average time that cars spend waiting at red lights.

Purpose

- Rural areas often do not get much attention, so they are stuck with simple independent lights.
- This project focuses on creating a better system for coordinating traffic lights which can work in rural areas.
- Two-Way coordination means that all the lights in an area will be coordinated with each other without needing to know where cars are on the road.
- Reduces cost because there is no need for much extra hardware.

Background

- Only about three percent of all traffic lights in the United States are considered “smart.” (Austin, 2019)
- Actuated Signal Control – Traffic lights which use sensors to detect cars and function accordingly.
- Arterial Corridor Coordination – Traffic lights along busy roads will often by in sync to move cars through more effectively.
- Adaptive Signal Control Technology – Large traffic control centers which use vast amounts of information to control their lights.

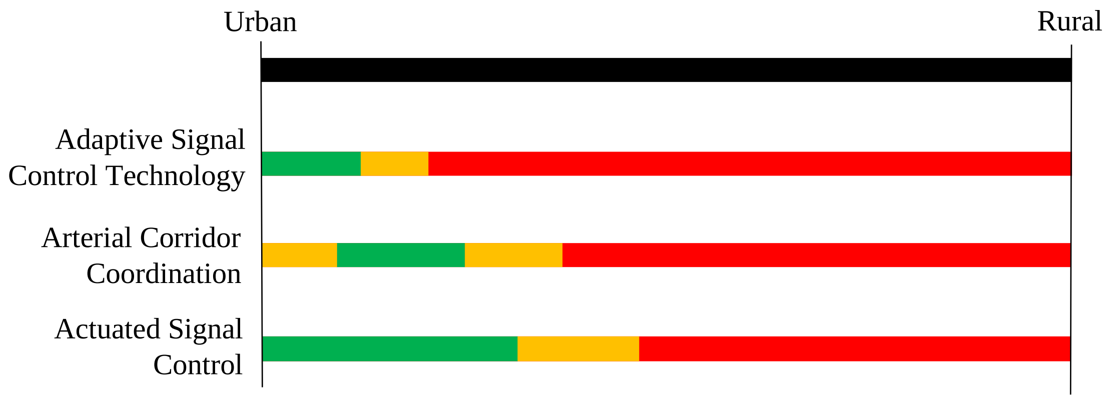


Figure 1: Example traffic light found within the model

Competitor Analysis

	Prototype Design Concepts	Two-Way Coordination	Adaptive Signal Control Technology	Arterial Corridor Coordination	Independent Lights	Actuated Signal Control
Criteria	**Max**	**A**	**B**	**C**	**D**	**E**
Low Average Wait Time Between Lights	10	8	10	6	3	7
Effectively Models Traffic	7	6	7	6	6	7
Modular to Different City Sizes/Formations	7	6	7	4	7	7
Specified to Rural Areas	8	8	4	6	8	8
Variable Traffic Density	6	6	5	4	2	4
Easy to Train	1	2	1	2	3	2
Easy to Maintain	5	4	2	4	5	4
Low Cost	9	7	4	7	9	5
Totals	**55**	**47**	**40**	**39**	**43**	**44**

Figure 2: Decision matrix of criteria and design concepts

Project Breakdown

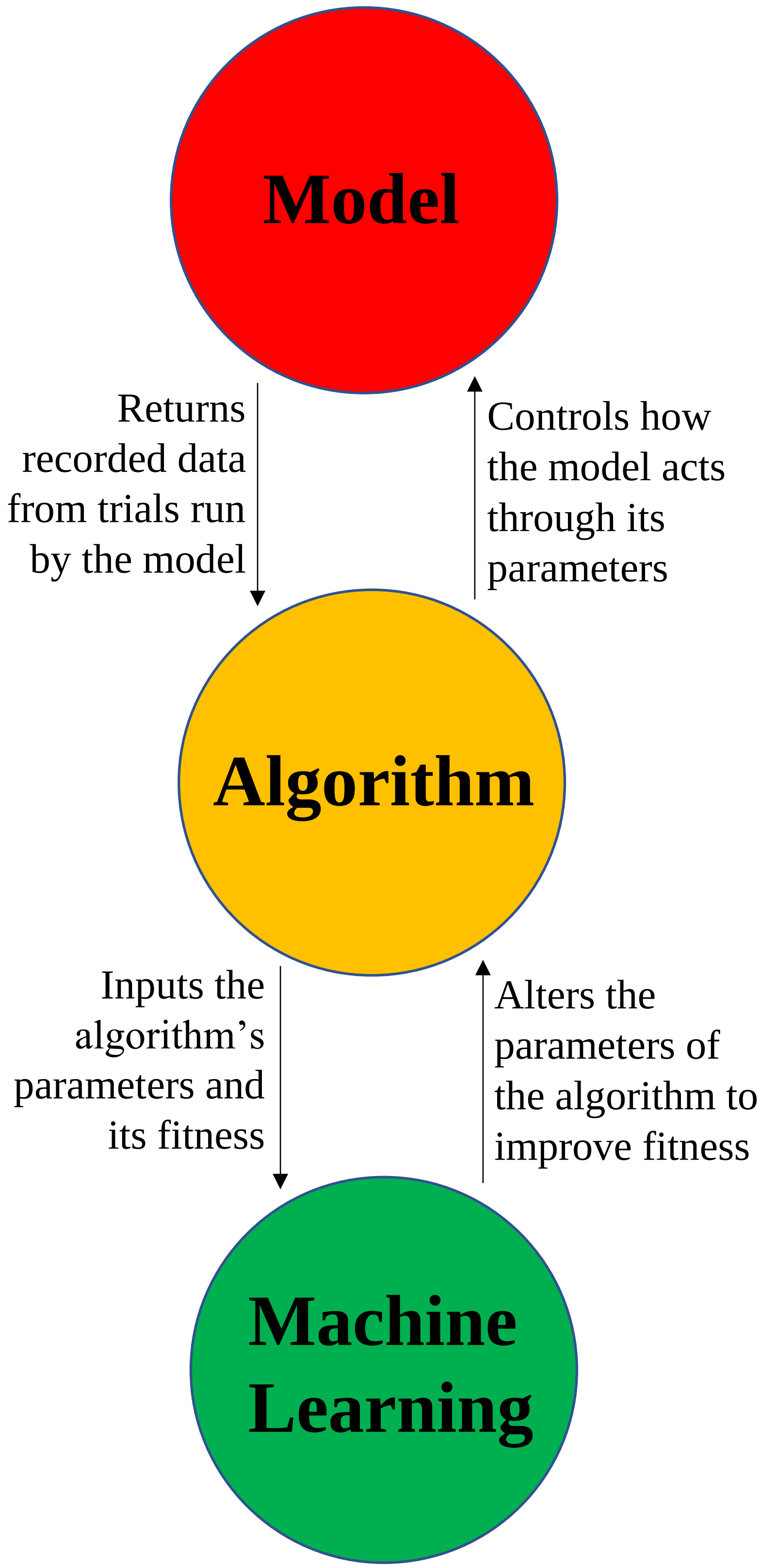


Figure 3: A diagram of how each aspect of the project works together

Timeline

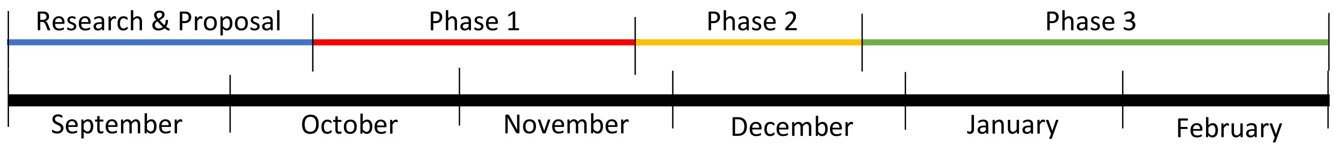


Figure 3: Project Timeline

- Research & Proposal - 1st Week of September - 2nd Week of October
- Phase 1: Modeling - 3rd Week of October - 3rd Week November
- Phase 2: Implement Algorithm - 4th Week November - 3rd Week December
- Phase 3: Machine Learning - 4th Week December - February Fair

Model

Description:

This model represents a simple city with a variable size and density.

Features:

- Capable of handling cities of different sizes and configurations.
- Can run trials of a given traffic light algorithm and can collect data on wait times.
- Can adjust size, traffic density, and many other city factors which may impact the way traffic lights operate.

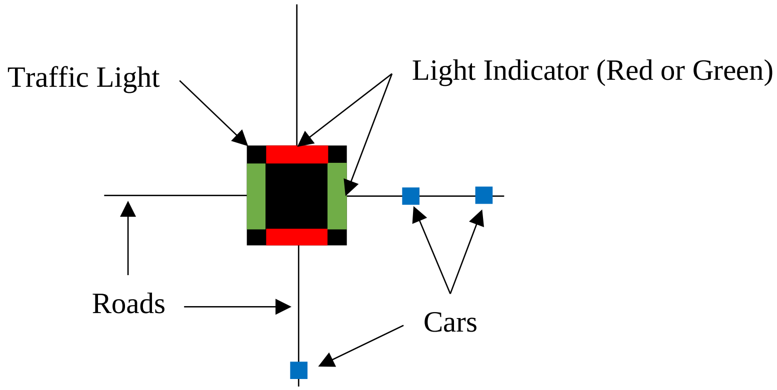


Figure 4: Example traffic light found within the model

Algorithm

Parameters:

- 8 parameters per light which determine how the light operates.

How it works:

- Lights have a baseline duration which they abide by which is modified based on the parameters and the current state of the lights surrounding them.
- In the equation, d_{new} is calculated by modifying the default duration d based on the weights of each surrounding light W_D and the current state of the lights L_1 and L_2

$$d_{new} = d - \frac{1}{4} \sum_{D \in \{N,S,E,W\}} W_D\left(\Delta d_{target} - L_1 + L_2\right) \, mod \, d$$

Figure 5: Function used for calculating the duration of the next light cycle.

Fitness Function:

This is the fitness function which is used in the model which calculates the average time cars spend waiting per red light. In the equation C represents the set of all cars in the model, t is the actual time it takes to get from point A to point B, and t_0 is the time it would take if all traffic lights were green.

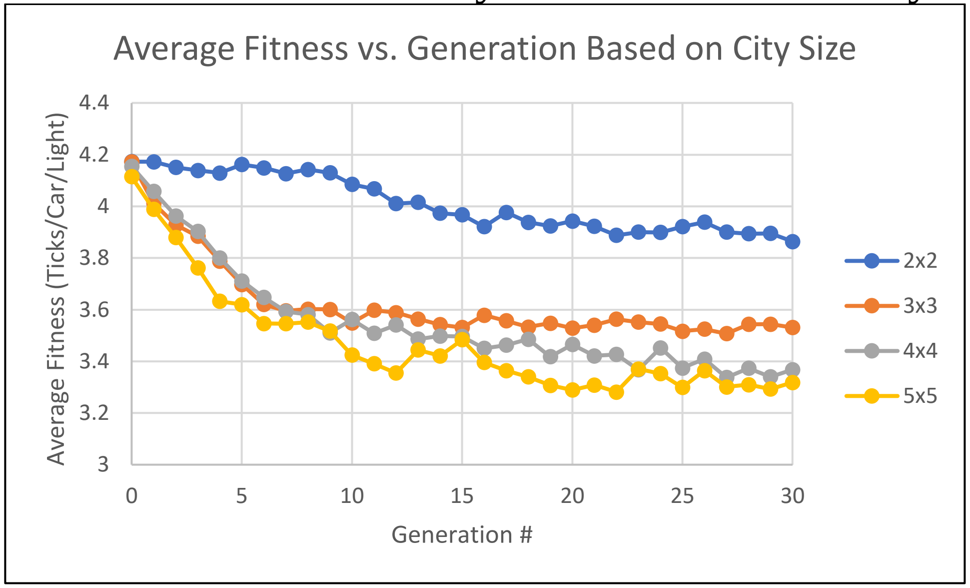
$$\frac{1}{|C|} \sum_{v_i \in C} t(i) - t_0(i)$$

Figure 6: Fitness Function of an algorithm (Dresner, 2005)

City Size

Information:

These trials examined how city size affected two-way coordination.



City Size	Percent decrease	P-Value
2x2	8.41	7.78E-34
3x3	15.93	1.08E-48
4x4	19.68	7.66E-40
5x5	21.48	1.88E-60

Figure 7: Graph analyzing how fitness changes over generations based on city size. To the side is a table showing the percent decrease in fitness from start to finish.

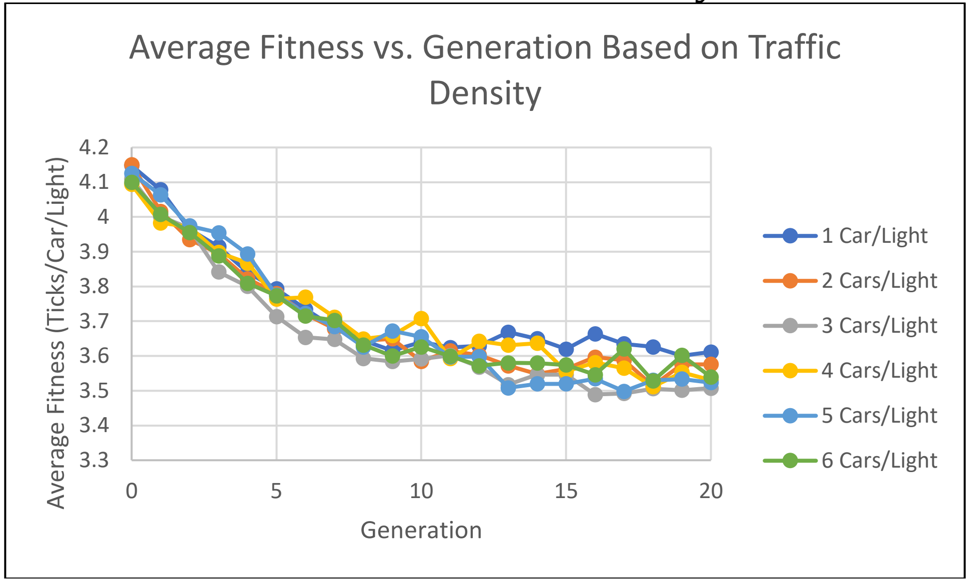
Analysis:

Based on the variation between the different city sizes, it can be concluded that city size has a significant effect on the outcome of two-way coordination (p=2.55E-46).

Traffic Density

Information:

These trials examined how traffic density affected two-way coordination.



Traffic Density (Cars/Light)	Percent Difference	P-Value
1	14.37	4.94E-27
2	16.78	3.39E-29
3	15.96	1.33E-33
4	16.82	4.53E-40
5	16.09	4.36E-34
6	15.01	2.16E-25

Figure 8: Graph analyzing how fitness changes over generations based on traffic density. To the side is a table showing the percent decrease in fitness from start to finish.

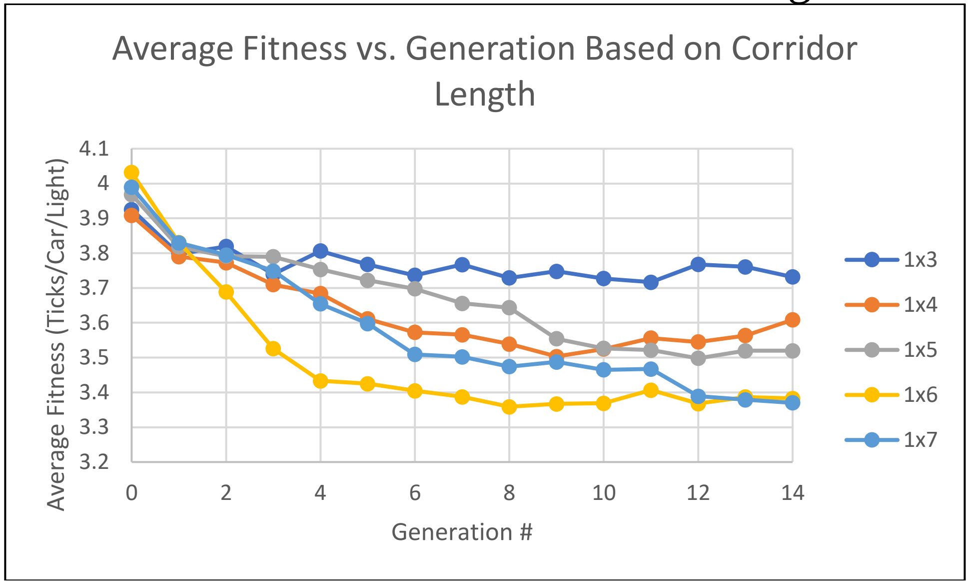
Analysis:

Based on the lack of variation between the cities of different traffic densities, it can be concluded that traffic density has a miniscule effect on the outcome of two-way coordination, however statistically significant (p=1.13E-2).

Arterial Corridor Length

Information:

These trials examined how arterial corridor length affected its coordination.



Corridor Length	Percent Decrease	P-Value
1x3	5.76	1.90E-05
1x4	10.37	1.22E-17
1x5	14.83	1.25E-26
1x6	17.94	3.90E-32
1x7	16.89	1.39E-33

Figure 9: Graph analyzing how fitness changes over generations based on corridor length. To the side is a table showing the percent decrease in fitness from start to finish.

Analysis:

Based on the variation between the different corridor lengths, it can be concluded that corridor length has a significant effect on the outcome of arterial corridor coordination (p=3.14E-12).

Conclusion

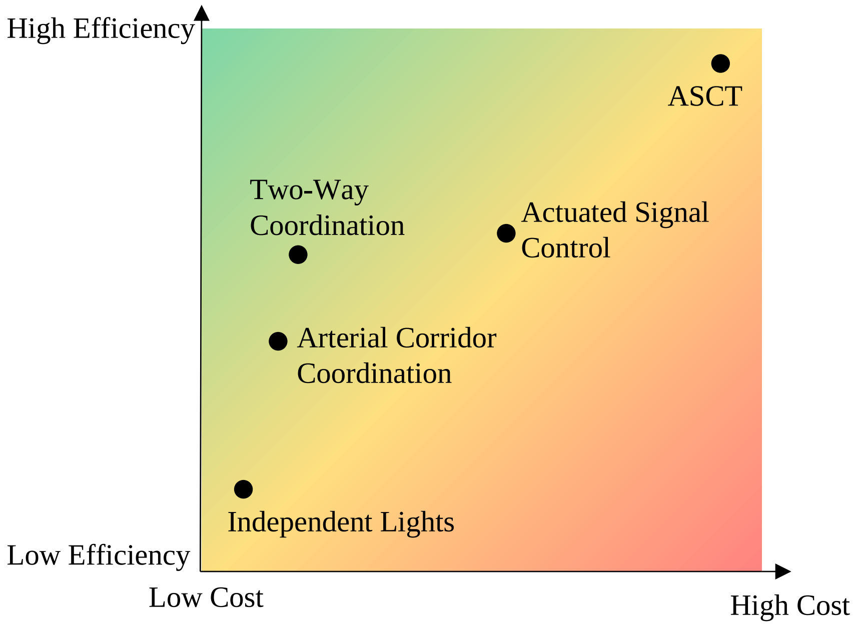


Figure 10: Chart of cost and efficiency for each traffic management style.

Future Work

- Implement actuated signal control into my model to collect data and/or integrate it into the coordinated system.
- Modify the genetic algorithm so that it can handle more complicated city formations.
- Perform a full cost analysis on how much money this would save over other traffic management methods.
- Use this model to simulate a real town’s traffic formation.

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Coordination of

Traffic Signals In

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Machine Learning