Traffic Light Controller

Requirements Definition Document (RDD)

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1 Introduction

Traffic control is a cornerstone of effective city planning. It is essential to ensure a safe and effective transportation network for pedestrians and vehicles alike. To create a robust traffic control system, there are specific requirements which must be met. A complete system must be reliable, scalable, flexible, safe, and secure.

To achieve these goals, we will construct a traffic control system using module controllers. Through the use of module controllers, each controller component can be tested individually before incorporating them into a live environment. This is done to ensure the functionality of each element, while building compartmentalization into the core of our designs.

A key challenge is to ensure that each controller component is synchronized and responsive, as any failure could compromise a significant sub-system. In order to avoid this, and to optimize traffic flow throughout of public roads and walkways, we will utilize a central TransitFlow controller.The TransitFlow controller is capable of analyzing events from across the city and responding appropriately by communicating with a Traffic Light Controller, Pedestrian Light Controller, and Bus Light Controller. By utilizing such a control structure the system can easily prioritize the movement of emergency vehicles, thus minimizing response times and improving safety.

However, a centralized remote system controller introduces new vulnerabilities that must be considered. Anticipating diverse scenarios including: power failure, scheduled maintenance, traffic accidents, and cybersecurity threats is critical. Our design will include robust safeguards to ensure the security of our traffic controller while maintaining its adaptability and functionality.

2 Objectives

To ensure a complete and robust traffic control system these key objectives will be at the forefront of the design process.

- Reliable
  - Prevention is the optimal way to reduce errors and costs. A reliable system is constructed free of errors and logic flaws so that traffic signals within the system malfunction at a minimal rate.
- Flexible & Modular
  - Modular sub-systems are modifiable so that different traffic conditions can be efficiently met, such as power outages, maintenance work, damage, updates to software, etc. TransitFlow will control traffic light signal states for dealing with many diverse conditions in its design and external factors.
- Scalable
  - Scalability will primarily benefit from compartmentalization which ensures TransitFlow will be efficient for larger, repetitive cases.
- Testable
  - Isolating, identifying, and fixing modular sub-systems built on controller components ensures fast and easy repairs. The implementation of failure checks throughout the software will allow easy large scale maintenance of TransitFlow.
- Secure
  - The safety of public traffic is maintained by the security of the system. Security features will be ran by isolated instances of sub-systems that are encrypted to prevent malicious activities impacting public safety and disrupting traffic flow.
- Guarantee Safety of Vehicles, Pedestrians, and Bicyclists

  - Efficient and clear communication of displayed traffic light signals foster environments that increase the public's safety on and near roads and walkways. Signals maximize the understanding of traffic light managed conditions to prevent injuries of pedestrians, drivers, and bus passengers.

- Prioritize Emergency Vehicles
  - Safely allowing the passing of priority vehicles so that medical services are not impeded. Priority, emergency vehicles will be able to effectively travel within emergency situations outside of expected or unexpected traffic congestion.

- Optimize Traffic Flow
  - Optimizing the flow of foot and vehicle traffic will reduce congestion and travel times. The public expects to reach their destination within a reasonable time when using state or federally funded roadways with any mode of transportation.

- Minimize Environmental Impact
  - TransitFlow will create a positive environmental impact by giving the public access to a variant array of safe and efficient methods of transportation as to not have a critical reliance on personal vehicles to travel.

3 System Organization

The System Organization of TransitFlow is represented with a Black Box model diagram. The Black Box model is designed to allow simple comprehension of the broad basics of the overall system. This allows easy interpretation of all inputs leading into and all outputs leading out of the TransitFlow software.

All input components are abstracted as programmed objects with interfaces the system is consistently receiving information data packets from. The TransitFlow controller analyzes, parses, and transforms data packets through functions and their calculations so they may be used by the output components. The control system will then transfer the revised data to the specified output component which frames a seamless traffic ecosystem.

3.1 Traffic Controller Black Box Model

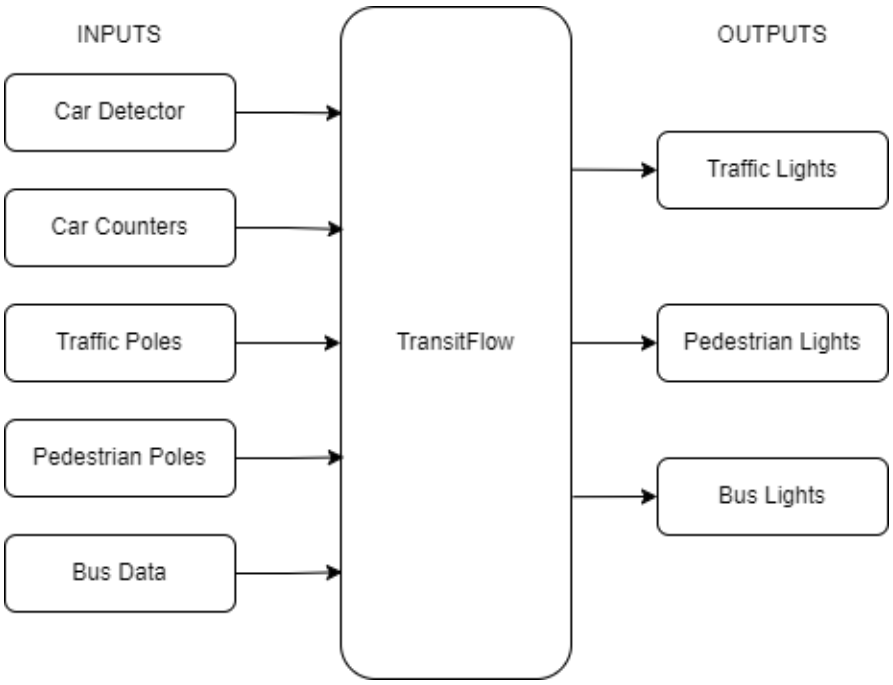

Figure 1: The Traffic Controller Diagram is a Black Box model diagram that shows all the inputs and outputs of the traffic system.

3.2 TransitFlow

The following subsections explain each of the input and output components ofTransitFlow, including how they will function once their instances are active.

3.3 Inputs

Inputs will be various hardware devices that will communicate with the TransitFlow controller about the presences of vehicles and pedestrians, allowing for efficient and safer changing states of lights.

3.3.1 Car Detector

A Car Detector such as a sensor or pressure plate will be used to signal to the Traffic Light Controller then to the TransitFlow controller, whether a car is present in any lane within the system. Having this detector will allow for more efficient traffic flow and reduce backups. The Car Detector also allows for safer left turns reducing possible accidents by adjusting the light time based on the amount of traffic. During the night, the system will change to a secondary timer where traffic lights will only change if there is a car present and waiting.

3.3.2 Car Counters

As cars pass through the intersection a car counter will be incremented to keep track of the permitted number at that point in the cycle.

3.3.3 Traffic Poles

These collections of the different classifications of traffic lights will contain the needed computer system which will communicate with the central TransitFlow controller. The computer unit will relay the current status of the traffic light signal to the main control unit, which will return the next type of signal to be displayed.

3.3.4 Pedestrian Poles

Pedestrian traffic poles have a push button that triggers an interaction flag to indicate to the TransitFlow controller that a pedestrian would like to cross the intersection. The TransitFlow controller schedules the corresponding pedestrian, traffic, or bus light to change signal states in response.

3.3.5 Bus Data

When a bus is approaching a bus traffic light, a detection system will inform the TransitFlow controller to schedule the bus light to turn green. The Traffic Light Controller will then turn the bus light green in synchronization with the lights in the general traffic lane turning red. Such a system will allow the the bus to continue its course uninterrupted, which will reduce ecological impacts and improve efficiency of the public transportation system.

3.4 Outputs

The output components are monitored by the TransitFlow controller and consist of both traffic lights and pedestrian signals. This monitoring of inputs will allow the TransitFlow controller to determine and transmit the appropriate instructions to the respective sub-system as outputs.

3.4.1 Traffic Lights

These signals instruct personal vehicles on when it is safe to turn a specific direction and or proceed straight.

- Green solid lights instruct the vehicles in the appropriate lane that it is safe to proceed when deemed appropriate by the driver.
- Yellow solid lights, including arrows, instruct the vehicles in the appropriate lane that the red light is about to signal, thus the driver should begin to slow or yield.
- Red solid lights, including arrows, will indicate that it is not safe for vehicles in the lane to proceed.
- Green left and right arrows will tell users in the left turn lanes, or leftmost lane if not available, that it is safe for the vehicles in those lanes to make a left turn. The absence of this light will indicate that turning left is by driver discretion.

3.4.2 Pedestrian Lights

Pedestrians, bicyclists and other users who are not operating motor vehicles at designated crossing areas will be instructed when it is safe to cross the intended street with the following signals on a box located on each traffic pole at the eye-level of the user.

- A Red Hand will indicate that it is not safe to cross the intended street. The pedestrian light shall remain in this state until the input switch attached to that pedestrian light has been pressed. Upon activation of the input switch, the Traffic Light Controller communicates with the TransitFlow controller to schedule the pedestrian light to switch states at the successive interval to display the solid green light.
- The image of a walking person will indicate to pedestrians that it is now safe to cross the designated crossing lane. Shortly afterwards, the Red Hand will appear with a decreasing timer displaying the remaining duration of safe crossing for pedestrians. When the countdown timer deactivates, it is no longer safe for pedestrians to cross and the input switch for the associated pedestrian light will need to be activated again.

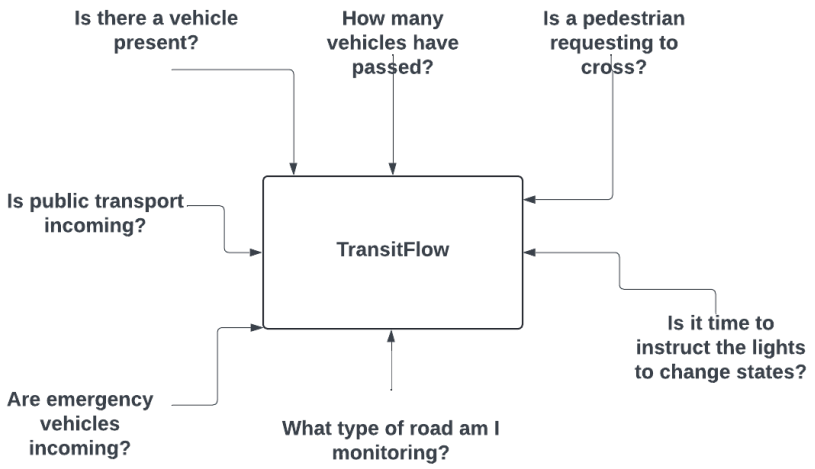

Figure 2: Real-time monitoring on TransitFlow

3.4.3 Bus Lights

When buses reach an intersection in which regular traffic or pedestrians must cross their lanes, bus traffic lights will be used to guide each bus. These signals will be the same as stated in the Traffic Lights section. The only difference being that no turn signals will be included as these roads are only used for buses. Regular traffic and pedestrians may only cross through the lanes North or South but not East or West direction.

4 Capabilities

The capabilities section details the features which are prioritized by TransitFlow. They represent the main goals of the software package and are paramount to its function and operation.

4.1 Output Signal Control

The TransitFlow Controller will be responsible for taking input signals from the Traffic Light Controller sensors, on their respective poles, then respond back to change the traffic light signals accordingly. Traffic and bus light signals are automated and will be changed by the TransitFlow Controller when appropriate conditions are met (see Signal Timing).

Pedestrian output signals will be instructed to change state by the TransitFlow controller when the perpendicular set of traffic lights at an intersection display the red signal on the condition that the TransitFlow Controller had previously received an input signal from the switch corresponding to the respective pedestrian light.

4.2 Signal Timing

Each traffic light will be connected to the Traffic Light Controller with an identifier indicating to the controller whether the light is a main road intersection traffic light or a bus traffic light. The Transit-Flow Controller will then adjust signal timings according to the appropriate data for the identifier.

- Main intersection traffic light signals will change between states in coordination with the speed limit at the traffic light's street segment. During rush hour periods, the TransitFlow controller will decrease the duration of red lights at intersections in an attempt to prevent extended backups from an increased influx of vehicles. Such a strategy will encourage implemented safety protocols at main intersections and promote the objective to optimize the flow of traffic.

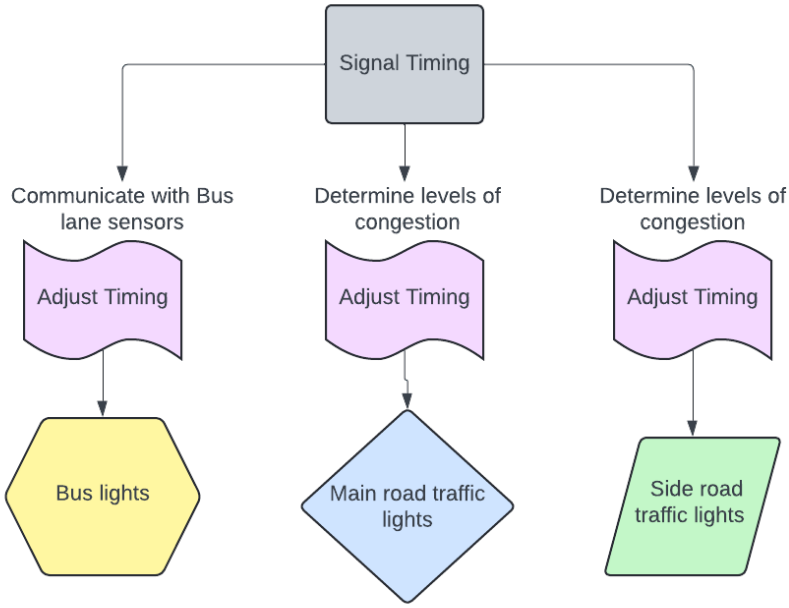

Figure 3: Signal Timing

- Bus traffic lights exist within separate public transportation lanes with separate signals for buses. Public transportation lanes will have sensors at intersections to detect whether a public transport vehicle is within range. If so, the Traffic Light Controller will add a state for allowing the public transport vehicle to continue or make a turn, without interfering with traffic from pedestrians or personal vehicles.

4.3 Intersection Scheduling

At each intersection, the TransitFlow Controller will be responsible for monitoring the states of all traffic light signals, pedestrian light signals, and bus light signals within the intersection. The goal is to prevent the TransitFlow Controller from scheduling perpendicular lanes to enter the same proceed states at any given time. Parallel lanes within an intersection will be scheduled by the TransitFlow Controller to always enter the same state, ensuring safety for all users a each intersection.

4.4 Pedestrian Input

The pedestrian proceed light signal will be activated by a pedestrian pressing a button in the associated direction they would like to cross. The activation informs the Traffic Light Controller to display the proceed signal at the next safe state (see 3.4.2). The manual activation of a pedestrian crossing button allows the Traffic Light Controller to ensure pedestrians have the appropriate amount of time to cross an intersection and optimizes the wait time for vehicles at intersections when no pedestrians are present.

4.5 Public Transportation Lanes

There will be a public transportation system as a second means of travel available to the public. This system will have its own designated road so that the public will have faster transportation in case of traffic congestion. However, there will be sections in which the public transport will cross paths with main road traffic. The TransitFlow controller will be able to manage these two different types of transportation so their interaction will be safe for personal vehicle drivers, bus passangers and pedestrians.

4.6 Emergency Vehicle Prioritization

As an emergency vehicle approaches an intersection, a proximity detector attached to that emergency vehicle will inform the Traffic Light Controllers, in-range, that an emergency vehicle is approaching, activating a flashing light signal on each traffic light pole in the intersection that an emergency vehicle is approaching, allowing vehicles near the intersection the opportunity to yield.

5 Design Constraints

TransitFlow must fall within the technological and budgetary constraints of the contracting public entity such that it can be easily applicable and implementable within many diverse traffic conditions. The traffic control system must promote maximum safety and traffic flow for the public.

5.1 Budget Constraints

Limited financial resources will set a limit to the complexity of our system. We must account for a limited budget in both the following.

- A limited construction budget.
- A limited maintenance budget.

5.2 Existing Infrastructure

Existing communication, plumbing, and electrical infrastructure must be accounted for during the installation of our systems.

- Existing public infrastructure may not be able to be moved or adjusted.
- Private infrastructure, including buildings and private land must be considered. Requisite space must be available for compliant roads.

5.3 Environmental Impact

Existing environmental features must be considered to avoid unnecessary erosion or interference with water flow and other geographical features.

- Proper consideration must be given to existing arroyos, bridges, culverts, and other water control features.
- Certain features may be drilled through, however this is not always an option given the geological makeup of the area or the budget.
- Animal crossing signs may be necessary to indicate locations where migratory or grazing animals are common, especially in more rural zones.

5.4 Software/Controller

All software for the traffic control system must be written in Java. Designing TransitFlow to function through the JVM leads to shortcomings in time and power efficiency which could otherwise be achieved with system-level languages.

- Java requires more sophisticated physical hardware due to being a higher level programming language which may not be supported on many low cost controller systems.
- TransitFlow must be swift enough to respond to traffic conditions quickly. As such, the software must be written efficiently to minimize the runtime.

5.5 Security

The prevention against cybersecurity threats will be essential for the safety of the public in road travel.

- Cybersecurity measures will be implemented making it difficult to attack the TransitFlow.
- Access control within and from contributors to the software will prevent issues.
- Encryption will be used to prevent unauthorized access.

5.6 Data Management

The traffic control system should be able to handle large volumes of data from sensors of external signals to make effective decisions.

- Versatile and fast memory for retrieval and storing of data to ensure proper data handling.
- Scalable storage allows for increased data loads.
- Fast data processing for efficient decision making.

5.7 Compliant

The software is compliant with jurisdictional law dictating the needs of the contracting entity. Will follow the regulations regarding the design of traffic control signals outlined under Chapter 4D. Traffic Control Signal Features of the Manual on Uniform Traffic Control Devices (MUTCD) .

- State law compliant
- County compliant
- City and or village compliant

5.8 Maintenance & Upgrades

The system should facilitate the ease of maintenance and updates to prevent disruptions or down-times in traffic flow.

- Modular design will make compartmentalized changes simple.
- Comprehensive documentation will support maintenance and update activities.

5.9 Operational Constraints

- Power supply of the system will be reliant on the power available from the contracting entity.
- The pedestrian crossing button must be accessible for the public to use and interact with.
- Regular maintenance is expected and should accessible to government workers.
- Will be designed within the constraints of the contracted budget.

5.10 Mentality

This will not truly reflect how traffic will flow as we are using best case scenarios and assume traffic laws will be followed.

- We can't predict what real life drivers will do in certain scenarios
- Last second decision making
- Moods and quality of drivers translating to the simulation

6 Conclusion

TransitFlow will adhere to strict and comprehensive design decisions by being reliable, scalable, flexible, and safe, to facilitate pedestrian, public, and personal vehicular use of public roads and walkways. This software package utilizes modular sub-components (i.e. Traffic Light Controller) to handle expansive and repetitive traffic signal needs. The public will benefit from moderate travel times, even during congestion, greater environmental conditions, safer travel, and responsive emergency and public transportation systems.

7 Definition of Terms

- **Black Box Model:** A Black Box Model is a system which can be viewed in terms of its inputs and outputs, without any knowledge of its internal workings.
- **TransitFlow controller:** The central system controller for traffic.
- **Traffic Light Controller:** The individual sub system that controls a single traffic light.
- **Block Modules:** A method of testing which allows for individual testing of components before they are incorporated into the live environment.