NGSIM Data Model Report

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Presentation Link:
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Abstract:

This report covers the data gathered by the United States Department of Transportation (US DOT) Federal Highway Administration (FHWA) in the early 2000's. The data stems from the Next Generation Simulation (NGSIM) program created by the US DOT, with the purpose of developing core behavioural algorithms in support of traffic simulation. The NGSIM program collected detailed vehicle trejectory data on the following roadways: Southbound US-101 in Los Angeles, Eastbound I-80 in San Francisco, Lankershim Boulevard in Universal City, and Peachtree Stree in Atlanta, GA. Each location utilized video surveilance with customized software that was able transcribe the vehicle trajectory from footage, and then log this data for future use. The data collected per area consists of vehicle trajectory data (primary), along with various supporting data of ortho-rectified photographs of the study area, Computer-Aided Design (CAD) drawings of the study area, signal timings, weather data, detector data, raw video files, and processed video files. With this informatin, this report will provide an overview of the data model with a simple analysis of the data and how it can be interpreted to manage traffic on an highway.

Keywords:

Theme:

NGSIM, Freeway data, Simulation data, Behavioural algorithm, Traffic management, Data model

Place:

Los Angeles, Hollywood, US 101, San Francisco, Interstate 80, Lankershim Boulevard, Peachtree Street.

Temporal:

2005, 2006

Data:

The primary data explored in this report is labeled as vehicle trajectory data, and consists of multiple features determined by the US DOT that was collected with video capture software. This data was then used to help build algorithms that would help research and understand driver behaviours. From the four different road locations from which the data was collected from, each data entry constisted of the following features:

Table of features present in the NGSIM Open Dataset:

Feature	Description	Value Type
Vehicle_ID	Vehicle identification number (ascending by time of entry into section). REPEATS ARE NOT ASSOCIATED	Number (Integer)
Frame_ID	Frame Identification number (ascending by start time)	Number (Integer)
Total_Frames	Total number of frames in which the vehicle appears in this data set	Number (Integer)
Global_Time	Elapsed time in milliseconds since Jan 1, 1970	Number (Integer)
Local_X	Lateral (X) coordinate of the front center of the vehicle in feet with respect to the left-most edge of the section in the direction of travel	Number (Float)
Local_Y	Longitudinal (Y) coordinate of the front center of the vehicle in feet with respect to the entry edge of the section in the direction of travel	Number (Float)
Global_X	X Coordinate of the front center of the vehicle in feet based on CA State Plane III in NAD83. Attribute Domain Val	Number (Integer)
Global_Y	Y Coordinate of the front center of the vehicle in feet based on CA State Plane III in NAD83	Number (Integer)
v_Lengths	Length of vehicle in feet	Number (Float)
v_Width	Width of vehicle in feet	Number (Float)
v_Class	Vehicle type: 1 - motorcycle, 2 - auto, 3 - truck	Number (Integer)
v_Vel	Instantaneous velocity of vehicle in feet/second	Number (Float)
v_Acc	Instantaneous acceleration of vehicle in feet/second square	Number (Float)
Lane_ID	Current lane position of vehicle. Lane 1 is farthest left lane; lane 5 is farthest right lane. Lane 6 is the auxiliary lane between Ventura Boulevard on-ramp and the Cahuenga Boulevard off-ramp. Lane 7 is the on-ramp at Ventura Boulevard, and Lane 8 is the off-ramp at Cahuenga Boulevard.	Number (Integer)
O_Zone	Origin zones of the vehicles, i.e., the place where the vehicles enter the tracking system. There are 11 origins in the study area, numbered from 101 through 111. (Refer to the data analysis report for more detailed information)	Number (Integer)
D_Zone	Destination zones of the vehicles, i.e., the place where the vehicles exit the tracking system. There are 10 destinations in the study area, numbered from 201 through 211. Origin 102 is a one-way off-ramp; hence there is no associated destination number 202. (Refer to the data analysis report for more detailed information)	Number (Integer)

Int_ID	Intersection in which the vehicle is traveling. Intersections are numbered from 1 to 4, with intersection 1 at the southernmost, and intersection 4 at the northernmost section of the study area. Value of "0" means that the vehicle was not in the immediate vicinity of an intersection and that the vehicle instead identifies with a section of Lankershim Boulevard (Section_ID, below). (Refer to the data analysis report for more detailed information)	Number (Integer)
Section_ID	Section in which the vehicle is traveling. Lankershim Blvd is divided into five sections (south of intersection 1; between intersections 1 and 2, 2 and 3, 3 and 4; and north of intersection 4). Value of "0" means that the vehicle does not identify with a section of Lankershim Boulevard and that the vehicle was in the immediate vicinity of an intersection (Int_ID above). (Refer to the data analysis report for more detailed information)	Number (Integer)
Direction	Moving direction of the vehicle. 1 - east-bound (EB), 2 - north-bound (NB), 3 - west-bound (WB), 4 - south-bound (SB)	Number (Integer)
Movement	Movement of the vehicle. 1 - through (TH), 2 - left-turn (LT), 3 - right-turn (RT)	Number (Integer)
Preceding	Vehicle ID of the lead vehicle in the same lane. A value of '0' represents no preceding vehicle - occurs at the end of the study section and off-ramp due to the fact that only complete trajectories were recorded by this data collection effort (vehicles already in the section at the start of the study period were not recorded)	Number (Integer)
Following	Vehicle ID of the vehicle following the subject vehicle in the same lane. A value of '0' represents no following vehicle - occurs at the beginning of the study section and onramp due to the fact that only complete trajectories were recorded by this data collection effort (vehicle that did not traverse the downstream boundaries of the section by the end of the study period were not recorded)	Number (Integer)
Space_Headway	Space Headway in feet. Spacing provides the distance between the frontcenter of a vehicle to the front-center of the preceding vehicle	Number (Float)
Time_Headway	Time Headway in seconds. Time Headway provides the time to travel from the front-center of a vehicle (at the speed of the vehicle) to the front-center of the preceding vehicle. A headway value of 99	Number (Float)
Location	Name of street or freeway	Object (String)

Data Collection:

The NGSIM program was was run between 2005 and 2006, collecting high quality traffic data from four different locations. The main use of data collection was through a network of synchronized digital video cameras. Custom video recognition software was built to apply onto the raw video footage in order to transcribe and log trajectory details. The result included detailed information of speed, direction, location, position, and headway information among other important factors. To support this information and provide a futhter udnerstanding of the hgihway conditions, supporting data was also compiled for researchers to utilize and undertsand the surrounding environemny. Ortho-rectified photographs of the study areas would help users to understand the landscape of the given roadway, along with computer-aided designs for specific details. Detector data helped provide highway congestion and occupancy, and signal timings were also provided for any ramp meter or traffic signal clock timings. The raw video footage can also be found by users, and are segmented into consecutive periods of time.

Figure 1: Peachtree Raw Footage vs. Processed Footage from 12:45-1:00PM Overview

Data Model:

From our data, we can create a simple data model outlining the correlation between the data points. From figure 1 below, a generalized image shows how the entirety of the NGSIM data is compromised of trajectory data from four different locations. These testings were done individually, and were then compiled into a larger list. When downloading the original dataset, each can only be uniquely identified by the location column, and from there we can organize the each entry by the vehicle using the Vehicle_ID.

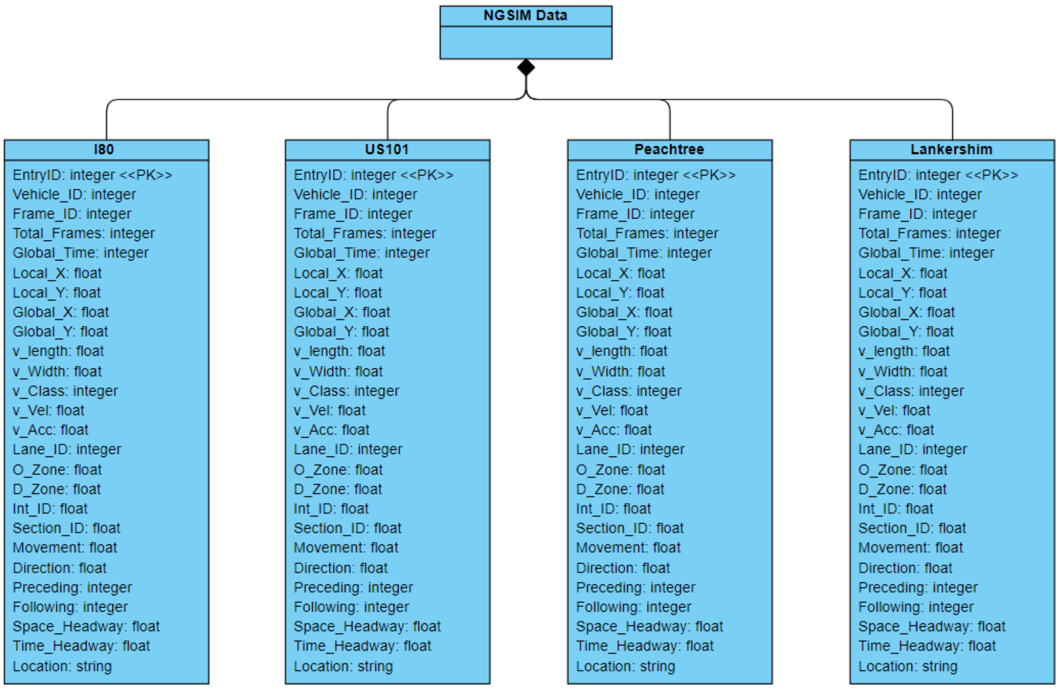

Figure 2: Overview of the NGSIM Data in a UML Diagram

Supporting data per location can also be found on the NGSIM site, where the supplmentary data includes:

1. Aerial-Ortho Photos
2. CAD Diagrams
3. Data Analysis Reports
4. Detector Data
5. GIS Files
6. Signal Timing Sheets
7. Vehicle Trajectory Data

Highway Traffic Management:

When managing highway traffic, there are many methods and systems that can be utilized to increase capacity and/or stabilise the traffic flow. There are many methods of implementing traffic management, including lane monitoring, speed control, and arterial monitoring. Along with these systems, there are many different embedded systems in use as well, including pressure sensors, video recording cameras, and visual displays. With a combination of embedded systems and information gathered through them, a successful highway traffic management environment can be created. This report will cover three different management systems that can be utilized along with the NGSIM data.

1. Ramp Metering

Ramp metering is a form of tactical highway management. The system involves the usage of lane sensors in a detector loop, that constantly monitor and sense traffic on the various lanes of the highway if the oncoming mering ramp. With each lane, the system monitors if the gaps between passing and oncoming vehicles are large enough for a vehicle to safely merge onto the moving highway. Using this information on a feedback loop, the system can control when vehicles on the merging ramp can advance or not with a traffic light. The merging ramp also uses its own three sensors. A demand sensor will let the system know a vehicle is queued to merge on the highway, along with a passage sensor to notify that a vehicle has advanced to merge. The start of the merging ramp also has an end of queue sensor, that notifies the system that the merging ramp is full and will automatically allow merging vehicles to advance on the ramp. The metering rate will vary based on the level of traffic on the highway, along with the number of cars waiting to merge onto the highway. The benefits of ramp metering can help increase the safety, travel time, throughput, and speed of the drivers. With ramp metering, a smoother traffic flow is created, which becomes a safer environment for the drivers on the road resulting in fewer collisions.

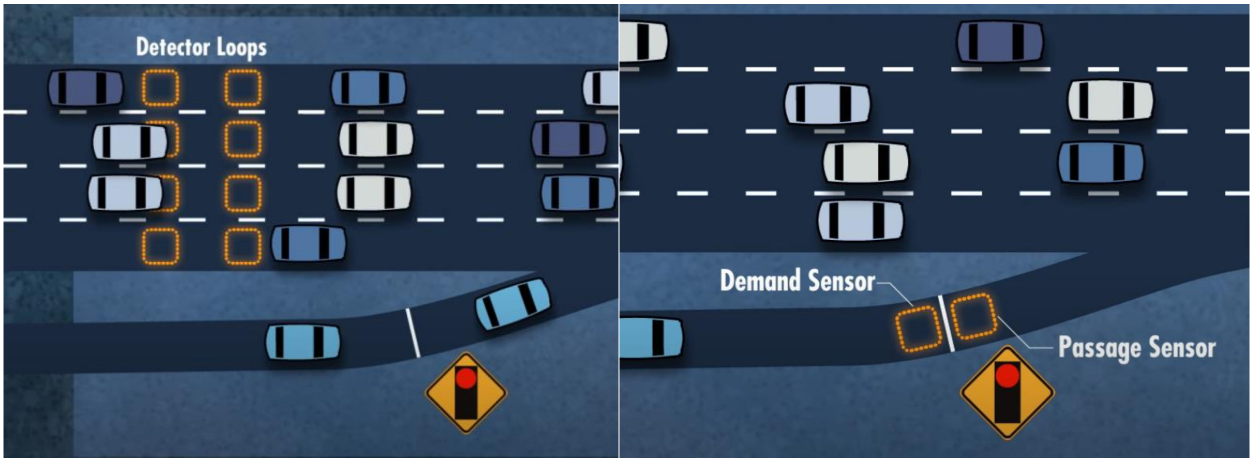

Figure 3: Image showcasing detector loop system with merging ramp

With the data collected from NGSIM, we can apply ramp metering logic with information from select columns working in tandem. We first need to identify the Lane_ID that is closest to the merging ramp. With this number, we can monitor the Space_Headway and Time_Headway columns of that lane and calculate if a vehicle waiting to merge has enough time and space to merge onto the oncoming lane. If so, the ramp meter will allow a vehicle to proceed up the ramp. With this information, a simple ramp metering system can be set up provided the NGSIM data.

Ramp Metering Data Model:

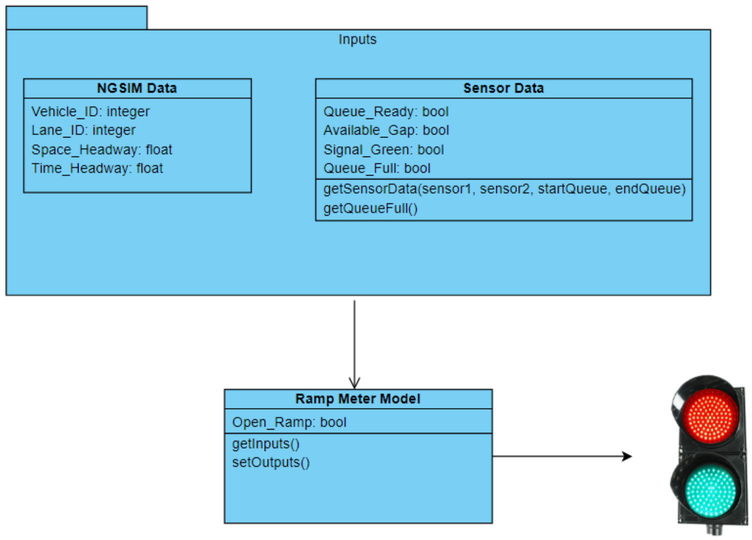

Figure 4: UML Diagram Outlining a Simple Ramp Metering System with NGSIM Data

This simple model showcases how the NGSIM data could be potentially used with sensors to create a ramp meter system. By receiving live inputs that have specific NGSIM data, we can pair it with sensor data that collects the conditions of the highway merging lane and the merging ramp. This can help create a model that will signal an oncoming car whether to proceed up the ramp. With a third sensor checking if the ramp is full, we can check the edge case if the queue is full, which forces the cars to proceed up the ramp.

With the NGSIM data, we can sort our data by time, which can allow us to interpret which cars based on their vehicle id were on the highway at a time. Using each car's space headway and time headway values at an intersection, we can create a model that will decide whether a car has enough time to merge safely onto the highway.

2. Dynamic Speed Management

Another form of highway traffic management is dynamic speed management, in which the monitoring system can change the current max speed limit for drivers based on the highway traffic conditions along with other factors. Although speed limits are regulated and legally enforced, they can also be supported by speed enforcement systems that can use video capture and various sensors to increase or decrease speed limits for all drivers at different periods of the day. On days where traffic is light, and the weather condition is dry, the speed limit can dynamically be set to a higher value on the highway electric speed signs. In heavier traffic with poor weather conditions, this limit might be reduced to a lower number to help stabilise traffic flow and increase the safety of the drivers. With a norm of having high traffic flow before and after typical office working hours, having a dynamic speed limit can help regulate the highway throughout the day.

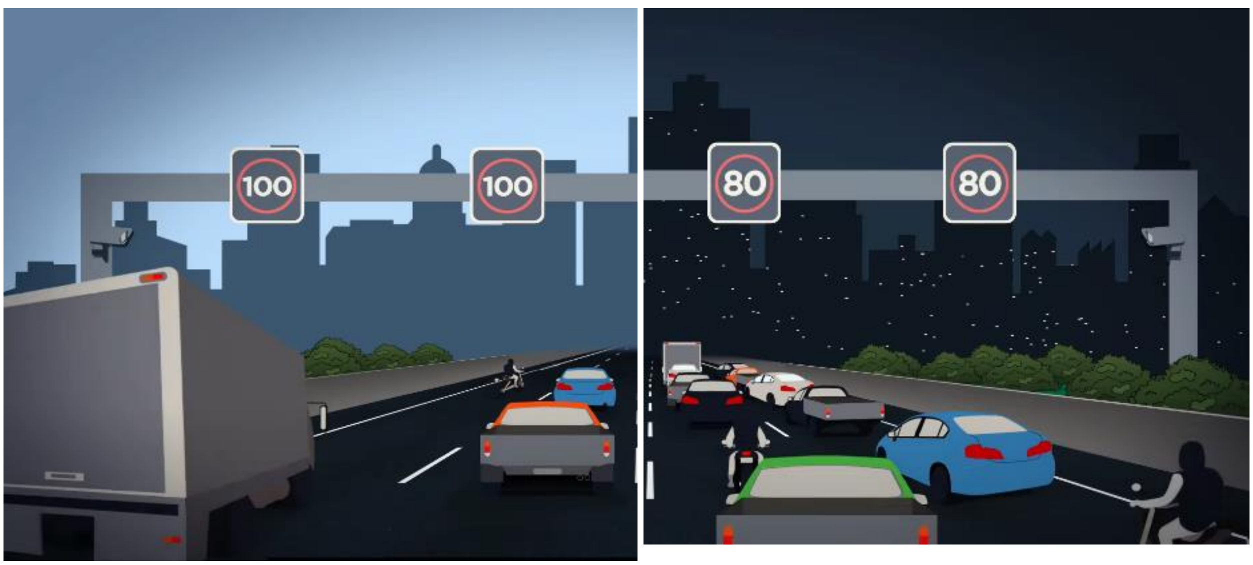

Figure 5: Variable Speed Limit Based on Traffic and Weather Conditions

With the NGSIM data, using the Global_Time, Lane_ID, Direction, O_Zone, D_Zone, we can decipher the times at which the number of vehicles on the highway are high and low. Paired with potential supplementary data of current weather conditions, a model can be created which will utilize the inputs and determine the best speed limit to be set on the highway. Although dynamic speed management has been proven to be very effective, it can only be maintained by the drivers themselves. If all drivers acknowledge the current speed limit, then traffic flow will be smooth and congestion can be delayed/prevented, however, ignoring the speed limit can cause a chain affect and result in future delays.

Dynamic Speed Management Model:

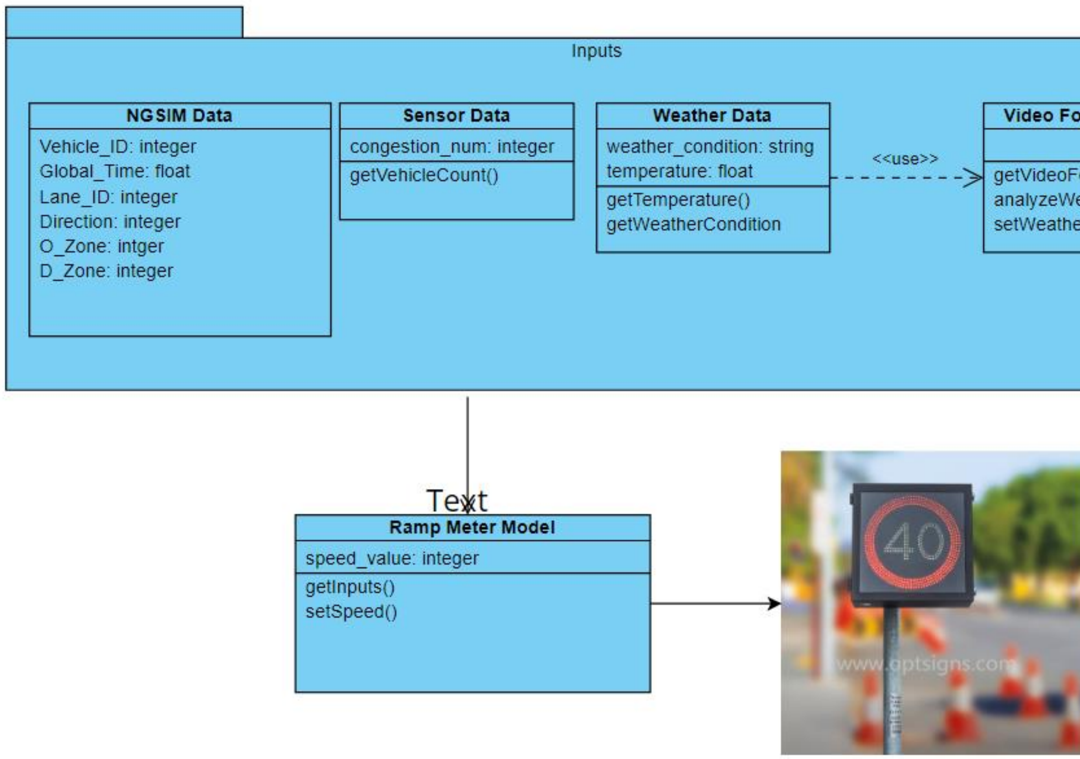

Figure 6: Simple UML Diagram Showcasing a mock Dynamic Speed System with NGSIM Data and Sensor Data

This simple model showcases how the NGSIM data could be potentially used with sensors to create a dynamic speed management model. By receiving live inputs that have specific NGSIM data, we can pair it with sensor data that collects the road congestion levels, along with outside weather conditions. The model can use this data to determine what the speed of the highway should be and dynamically set this on the LED overhead sign.

With the NGSIM data, we first can sort our entries by time. Using set intervals, we can calculate the vehicle count in set areas by getting unique value counts of vehicles in a certain direction and lane. An additional metric that can be monitored are pairs of entry and exit points on the highway, which could be causes of higher traffic. External information of weather data will also play a part in deciding what speed is suitable based on weather conditions. With this information, a model can be created to decide speeds at certain times and locations on the highway.

3. Dynamic Lane Management

An additional form of highway traffic management that can be achieved with the NGSIM data is dynamic lane control (DLM). DLM makes use of flexible traffic lanes, which can be modified with the use of an electric sign on the highway. If one direction of traffic flow is significantly greater then the opposite direction, a dynamic lane can be used to add an extra slot for heavy traffic to disperse and mitigate. This can be achieved with median lane whose direction is controlled by a sign, or by using movable median boundaries, which will identify which lanes are available to each side of traffic. Besides adding an extra lane, the dynamic lane can be used as a heavy-goods-vehicle (HGV) only lane, or a dedicated high-vehicle-occupancy (HOV) lane during peak hours containing a high number of these vehicles. With the NGSIM data, vehicle class information is available along with their direction of travel and time stamp, making a dynamic lane management system possible to implement.

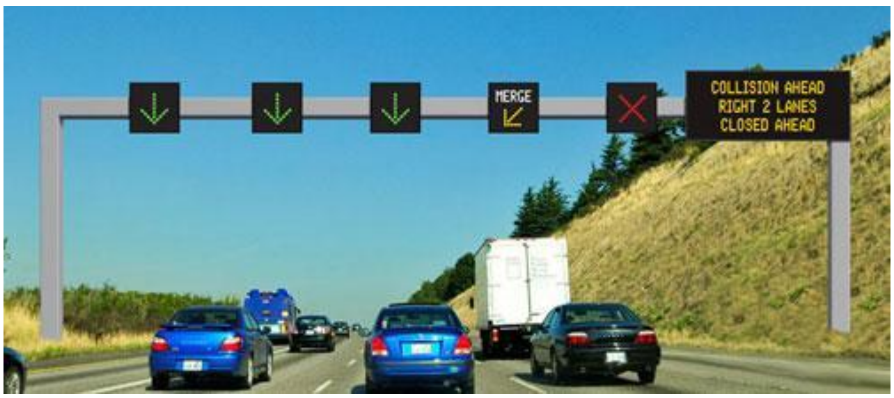

Figure 7: Implementation of Dynamic Lane Management with LED Signs

Dynamic Lane Management Model:

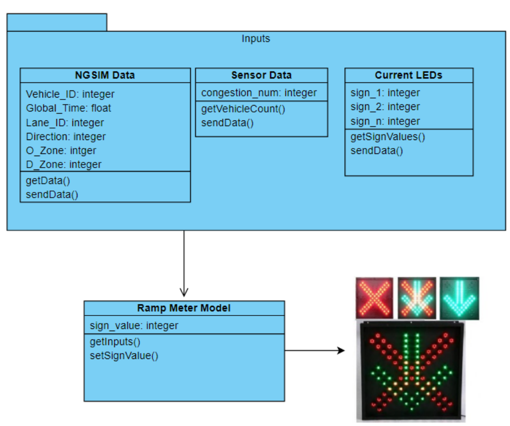

Figure 8: UML Diagram of a Simple Dynamic Lane Management Model

Similar to the dynamic speed management system, this model uses vehicle congestion levels per lane and decides if the dynamic lanes are necessary. This decision can affect the LED sign or move the median barriers to adjust the number of lanes per side of traffic. The NGSIM data is retrieved similarly as dynamic speed management, and with sensor data, instead of changing speed limit, the model will decide if a lane is necessary for traffic movement in a given direction.

Conclusion:

The NGSIM data was very thoroughly collected and can be used in various ways to help improve traffic conditions on highways. With technology advancing, there are much more accurate ways to recreate this data for current use with image recognition software paired with machine learning algorithms. Research has been done to create Long-Short-Term-Memory Neural Networks, an artificial neural network, which can use accurately predict future vehicle trajectories based on their current path. With the push for autonomous driving, this dataset can prove to be valuable when creating self-driving cars in the future. For traffic management, the NGSIM data provided valuable information that can be simplified and understood for behavioural algorithms and model creation. There are multiple ways to implement highway traffic management with the NGSIM data, with some methods being simpler but others being more effective. Overall, the NGSIM data can be used to create behavioural models with these various management systems in mind to create efficient algorithms that are able to function in unknown domains.

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