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SIMULATION OF TRUCK PLATOON SYSTEM USING ANYLOGIC SOFTWARE

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Abstract

This paper presents the simulation of the truck platoon system using the Anylogic simulation software. A Platoon is a collection of trucks/vehicles moving together with same average distance in between vehicles. Trucks especially in road freight transportation are subjected to aerodynamic drag, which increases fuel consumption. A reduction in the space between vehicles can reduce the drag force, especially for the tailing vehicles. Reducing the space between vehicles will reduce their reaction time, especially for human drivers, hence automated vehicles or semi-automated vehicles are employed with little or no need for drivers. A connection established between the vehicles can increase the vehicle's response time and therefore the inter-vehicle distance can be decreased and as the distance between the vehicles is reduced, aerodynamic drag will be decreased. An agent-based-model of a platoon of five trucks on an Automated Highway System was simulated using the Anylogic simulation software. The behavior of the platoon was observed in various intersections and stop lines. Also, the observed was a truck exiting the platoon and how the rest of the platoon was able to communicate and cover the space left by the exiting truck to maintain the set inter-vehicle distance.

Keywords: Lead truck, Tailing trucks, platoon, inter-vehicle distance, AnyLogic software

Introduction

Platooning is the process of connecting two or more vehicles in a convoy with the use of connection technologies and automated driving assistance systems. (ACEA, 2017). These vehicles are expected to move with an equal desired distance between them and at an equal desired speed. The truck platoon system employs the use of autonomous trucks and in most cases, communication is established between the trucks. Truck automation can decrease the response time of trucks to about one-fifth the response time for human drivers (Liu et al., 2021, Iliyasu et al., 2022). The communication established between trucks in a platoon allows the trucks to communicate and identify when the immediate truck before them is braking or stopping completely. The use of autonomous systems in platoons also smoothens the acceleration and deceleration maneuvers of the vehicles in the platoon hence, energy is saved and reduces emissions of criteria pollutants such as CO_2.(Tsugawa et al., 2016). A platoon consists of the lead vehicle (the first vehicle in the platoon) and the tailing vehicles (the subsequent vehicles or the following vehicles in the platoon). Vehicles traveling on a highway are subjected to aerodynamic drag. This drag force overworks the engine and increases fuel consumption. In platooning however, given that the distance between vehicles is reduced to the minimum safe distance, the drag force is reduced for the vehicles in the platoon. The tailing vehicles experience less aerodynamic drag than the lead vehicle in the platoon. An Automated Highway System or an Intelligent Transport System is a system that has the potential of connecting road users and road signs using wireless, electronic and automated technologies to improve transportation safety, efficiency and convenience (Shaheen and Finson, 2013). Communication enabled vehicles and infrastructure can form a cooperative system where the users exchange information and cooperate to improve characteristics such as safety, fuel consumption, traffic efficiency and comfort. (Bergenhem et al., 2012).

Review of Similar Works

Control techniques are very vital in ensuring effective output from the plant or systems (Abdulwahab et al., 2022). As such several control techniques employed to solve the platooning problem are reviewed:

Ogitsu and Omae (2015) studied the design and testing of vehicles following control for systems with small electric vehicles that can communicate with each other. The study investigates platooning systems for personal vehicles in depopulated villages to improve mobility of the entire village. This aims to reduce population decline in rural areas and also to reduce the shortage of parking space. A vehicle control system consisting of two personal vehicles on a flat road was designed integrated with both CACC and ACC. The system makes use of cooperative adaptive cruise control if communication is established and Adaptive Cruise Control if communication is lost. These vehicles use Wi-Fi for communication. The following vehicle uses a velocity sensor to track the velocity of the lead vehicle and a laser range finder to track the inter-vehicular distance between them at a frequency of 50ms. The steering of both vehicles is controlled by their respective drivers. The experiment was started with the lead vehicle accelerated to a speed of 20km/hr and programmed to decelerate to a speed of 10km/hr in 3 seconds. The algorithm provided a good vehicle following performance and efficiency. The experiment considered the formation of a platoon consisting of only two vehicles which are less efficient and more studies have to be done for a bigger platoon size. The experiment also did not consider external unexpected disturbances that can affect the performance of the platoon.

Humphreys et al. (2016) evaluate a prototype of a system that increases fuel efficiency for driver-assisted vehicles in the platoon. The platoon system is equipped with V2V (vehicle-to-vehicle communication, GPS, radar and incorporates active safety measures. Owners of fleets always look for methods to reduce costs in order to increase profit and productivity. Fuel consumption cost is one of the major expenditures in such organization and reducing fuel consumption will increase the profit by far. A single truck was first modelled at the speed of 65mph. the aerodynamic drag of the truck was calculated from the simulation. Then to evaluate the reduction in aerodynamic drag, a pair of driver-assisted-truck is simulated with inter-vehicular distances of 30ft, 40ft, 50ft, 75ft and 150ft. It was found that as the distance between the trucks is reduced, the aerodynamic drag is reduced. It was concluded that as the aerodynamic drag is reduced, the fuel consumption decreases. The decrease in fuel consumption for the lead truck is not as appreciable as that of the following truck. The article focuses on a pair of trucks (two vehicle platoon) and did not consider the advantage of the platoon in economic usage of the automated highway system.

Morozova (2016) this article optimized the setting for a platoon identification and accommodation algorithm that reduces vehicle emissions. The method was created and implemented in the AnyLogic framework, and it was tested against previous research results. This study also covers the results of efforts to use high-resolution data from Morgantown's WV-705 corridor. A model was created on AnyLogic software with a road network consisting of four intersections. The arrival time of the platoon was recorded and used to calculate the offset of the downstream intersection. The VT-Micro microscopic emission model is used in the simulation to compute vehicle emissions. The link between platoon variables and least- and maximum-emission situations was investigated through optimization tests. It was found from the calculations that emissions decreased by 15.5%. It was also observed that Identifying platoons and dealing with them in a systematic manner improves all traffic since overall delay for all automobiles is decreased by up to 22.4 percent.

Ki et al. (2019) The purpose of this research is to look at routing algorithms for automated highway systems (AHS). The central unit in AHS is in charge of routing choices for all cars on the highway and traffic distribution. Drivers need not to drive or pick a route upon entering the AHS and indicating their destination. The AHS may determine the best routes for the vehicle, and autonomous cars communicate with the AHS to function. The implementation of AHS is intended to considerably better the functioning of highway traffic. The routing algorithms' goal is to minimize the mean travel time of vehicles through the automated highway network. The research employs the use of AnyLogic 7.3, an agent-based simulation program, to model the routing actions of an AHS. Using the road traffic library and programming in Java, the elements of the AHS was built. A road network consisting of several lanes and nodes connecting the lanes was created. It was assumed that the simulation follows the First in First out (FIFO) rule in the junctions and nodes. Vehicles are simulated to come on the highway through set tollgates. It was assumed the tollgates does not have traffic signals or stop intersections. It was found that vehicles with the same destination tend to choose the same shortest route and hence the route gets congested and arrival time increases. If the route gets congested, the AHS selects the next best route for the next incoming vehicle. The research considered only independently driven vehicles and assumed no traffic signals on the road network.

Hexmoor and Alshiddi (2021) this article looked at truck platooning in particular, which is used to convey freight, and how it might help with freight transportation by increasing road capacity and lowering fuel use. Experiments demonstrate that compared to independent driving, the following trucks in the platoon traveling at a 10m distance can save up to 20% on fuel. The goal of this paper is to determine the optimal position to start platooning the vehicles given a road map and a collection of trucks distributed on their journeys from a shared source to a common destination. To be more specific, the platooning point is where the trucks agree to meet in order to form a platoon for the balance of their journey to their destination. These meeting points are usually gas stations or rest areas. Anylogic version 8.5 was used for the simulation, first considering a platoon of three trucks and then a platoon of six trucks. The trucks were simulated to start from different locations at different times but all with the same destination point. Different meeting point was simulated for the platoon to find out the best route that will suit all the trucks. The trucks are assumed to be for the same company, hence each knows where the other trucks are exactly at every given time. It was observed from the simulation that the trucks when simulated independently arrive earlier than when within a platoon. It was also observed that for a platoon of bigger size, a longer waiting time is required and more fuel is saved. The paper did not consider the distance between the starting point of the trucks. Hence if trucks are initially hours away from each other, the cost of waiting time will not be worth it.

Materials and Methodology

A model of a platoon with five trucks was developed and simulated using Anylogic version 8.7 professional. The platoon was simulated to move through the road network at a speed of 50km/hr.

The trucks in the platoon are connected to each other so they can communicate with changes in speed with each other.

Development of a highway with five trucks.

i. A highway was created on the main graphical editor with a parking lot to represent the waiting area of the trucks.
ii. A truck agent was added and a flowchart to simulate the truck agent entering into the model.
iii. A state chart was added to the truck agent to simulate different states of the truck agent and define the initial movement of the trucks.

Establishing connections and setting the platoon in transit.

i. A function created sets the position of each truck indicating whether it's the lead or a following truck.
ii. A new flowchart was developed to simulate the movement of the platoon to its final destination.
iii. Connection was established between the trucks and they were set into the new flowchart with the aid of an event.

iv. An event was created to maintain the desired inter-vehicle distance in the platoon.

Simulation of intersections, stop signs and a truck leaving the platoon.

i. Developed traffic lights at intersections to simulate the traffic flow of cars and people at the various stop lines.

ii. A garage was simulated for the faulty truck to drive into.

Discussion of Results

The trucks were injected into the simulation at a node that is assumed to be the starting point of the trucks' route. The trucks meet at the waiting area which is represented by a parking lot on the road network. The figure 1 below shows the trucks in the waiting area;

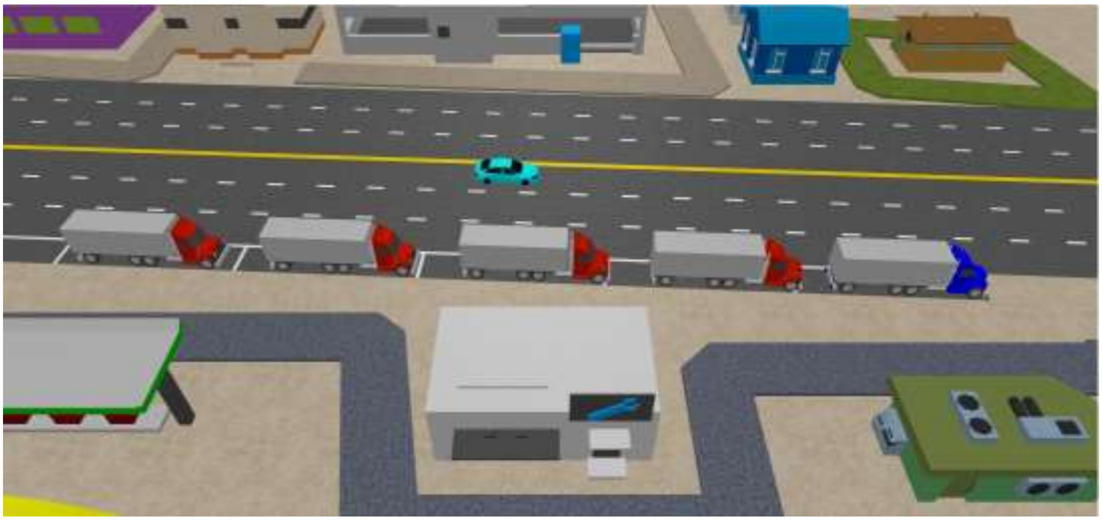

Figure 1: Trucks in the waiting area.

The waiting area is where the trucks establish connections with each other. A successful established connection triggers the trucks to move through the highway. The tailing trucks constantly check their distance to their immediate head and either speed up or slow down to maintain an equal close distance. The platoon moves as a unit with equal distance between them. Upon reaching a red stop sign, the platoon comes to a stop maintaining the same inter-vehicle distance. Figure 2 below shows the platoon at an intersection;

Figure 2: Platoon at an Intersection.

A truck exiting the platoon communicates with its immediate head truck and its immediate tail truck and disconnects from the platoon. The tail truck and head truck of the exiting platoon then connects with each other and cover the tail truck(s) speed up to cover the space left by the exiting truck to maintain the platoon inter-vehicle distance. Figure 3 below shows a truck exiting the platoon;

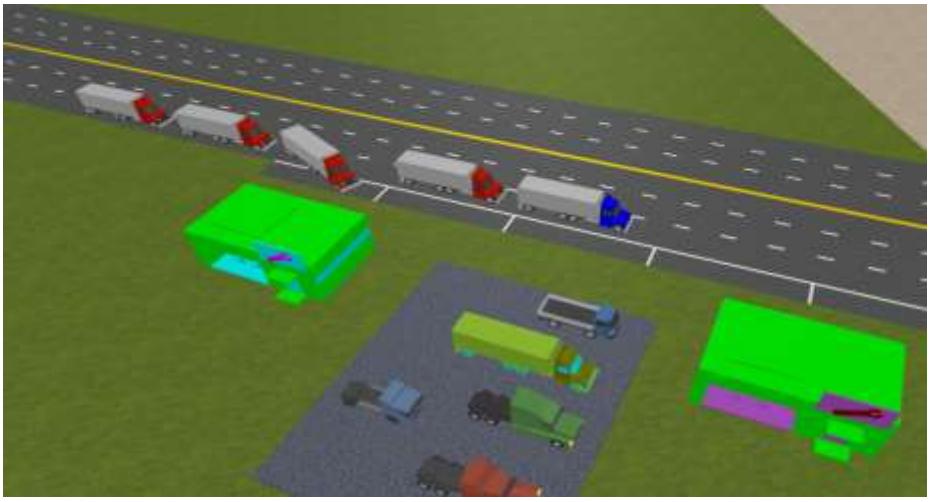

Figure 3: Truck exiting platoon.

Conclusion and Recommendations

This paper employs the use of the AnyLogic software to develop a simulation of a platoon system consisting of five trucks. A road network was made with various stop lines to show the movement of the platoon system. The process modelling library was used to simulate the movement of the platoon. The platoon was seen to move with the same speed and maintain the same distance between them. The platoon system responds to road signals such as traffic lights. It was seen that the platoon system also uses the road more efficiently. It was also seen how the platoon reacted to a truck exiting it by covering the space immediately after the truck pulls over. In addition, a reduction in the air drag force reduces the average fuel consumption of the trucks, showing the cost efficiency of the platoon system.

A platoon with dynamic size can be considered to be more efficient as it decreases/eliminates the waiting time of trucks. Also simulating the effects of aerodynamic drag on the trucks will show how much the platoon is of economic advantage, especially to truck fleet owners.

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