Demonstrating the Advantages of Self-Driving Cars

New Mexico

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Abstract

With the looming threat of global warming and climate change, more people are leaning towards green transportation. However, people need an alternative means of transportation that is widely available to everyone. Currently, there is research being done on a unique means of green transportation: fuel efficient self-driving car trains. Several computer models using NetLogo have been created to show the safety of these self-driving cars. The most updated model incorporated a highway setting that had two separate multi-lane highways, one with self-driving cars and the other with human driven cars. Data was collected by examining the speed limit and the distance between cars over various model parameters. It was demonstrated that self-driving cars could withstand higher speeds with a smaller distance between them than human driven cars. This data gives validity to the theorized benefits of a self-driving car train. Additionally, it offers a new, more efficient means of travel that will be available for the general public. Based on the data collected, it is safe to say self-driving cars could be the newest fuel-efficient alternative means of travel.

Problem Statement

With the looming threat of global warming and climate change, more people are leaning towards green transportation. However, people need an alternative means of transportation that is widely available to everyone. Even though train travel can be more efficient than car travel, it lacks popularity. In addition, the U.S. currently doesn't have the infrastructure to support large scale train travel. Also, the advantages to train travel can be negated by the frequency of stops, the travel to and from stations, and the number of people using the train. However, there is an alternative. Currently, there is research being done on a unique means of green transportation: fuel efficient self-driving car trains, also known as platooning. Platooning is when cars drive in a train-like fashion by driving in tight formations, increasing fuel efficiency by up to 25% more than current travel methods. Unfortunately, platooning is high unsafe for the regular driver due to "the delays in human drivers perceiving and reacting to speed changes of the vehicles ahead," according to researchers from the Centre for Integrated Energy Research. Fortunately, by 2040, 75% of automobiles will be fully automated as stated by the Institute of Electrical and Electronics Engineers, potentially making self-driving car trains feasible. This caravan of cars would incorporate some of the aerodynamic advantages of a traditional train, plus the comfort and convenience of a personal car. In order to see some of the effects of a self-driving car train, a NetLogo model was created.

Methods/Materials

First, a basic driving template was found in the NetLogo models library. Then, a model comparing self-driving cars to human drivers was created by editing this basic template. Human drivers have around a 0.15 or more second reaction time before they actually react to stimuli. This model incorporated this reaction time for the human drivers. This first model had two separate roads with one lane each. One road had only human drivers while the other had self-driving cars, distinguished by blue and red, respectively. The model begins with randomly placed cars at random speeds. The cars then speed up or slow down in accordance to the speed limit and the cars around them to form a car train. Then, a sudden "obstruction" appears in a random spot and the cars react accordingly. After creating the first model, it was determined that in order to make the model more realistic, the obstruction should have a fixed position instead of a random one. This was because in the real world, one can often see an obstruction ahead, being able to react accordingly instead of there being a surprise obstruction. After observing qualitatively, that after about 30 seconds the cars started driving the speed limit at a set distance away from each other, another model was created.

The next model assumed that the cars had been driving for a while in a single lane highway setting. This model was the same as the previous one with two exceptions. First, in this model all the cars started driving the speed limit with a fixed distance between the cars. This distance was based upon the two second rule. The two second rule states that the cars should be far enough away from each other that they should be able to stop without hitting the other car in two seconds. Later, the two seconds became a variable named "trailing-time", set before each model run. Second, this model had the cars drive towards a fixed obstruction that was present from the beginning of the model. After some research, it was determined that the self-driving cars should have some sort of wireless communication. This was another feature of the self-driving car that has been proposed to increase safety. After implementing the wireless communication, however, it was deduced that, since the cars have no reaction time, the wireless communication had no effect on the model. While it might be useful in the real world, because of the limiting constraints of this computer model the wireless communication was removed from all further models.

It was later realized that often times the "obstruction" in front of a car is another car. In order to emulate this, the fixed obstruction was eliminated and the cars just reacted to each other. It was determined that in the current model, the cars would react the same way whether the car in front was slowing down or stopped because of a crash: slamming on the brakes. This is not very realistic as people usually only slam on the brakes if the car in front suddenly stops or slows down. Because of this, a better algorithm for calculating speed was created.

Next, a third model was created to revise the methods for adjusting the cars' speeds. This new model incorporated a function to determine how fast or slow the car needs to accelerate or decelerate instead of a using a constant for acceleration and deceleration. This algorithm was a function of the time it would take for the car to reach the car in front of it. If this time was less than two seconds, the car would slam on the brakes, if the time was greater than the maximum trailing-time, the car would speed up. If the time was in between these variables, the car would use calculated value from the function.

Finally, it was suggested to see how the cars behave in a highway setting with multiple lanes. A new model was created to show the cars changing lanes. While changing lanes, a constant speed towards the y-axis was used and the car was able to change their x-axis speed according to the speed algorithm. The y-axis represents the change from one lane to another and the x-axis represents a single lane. Then, the arcsine function was used to figure out the angle the car should travel based on the two speeds.

This model also incorporated an update to the speed algorithm. The cars now reacted less strongly to a car that is changing lanes than to a car that is in its own lane. In this model, changes to the reaction time were made. It was discovered that there are three different types of reaction time ranging from 0.15 seconds to 1.25 seconds. For this reason the reaction time for the cars was changed. 85% of the regular cars would have a reaction time of 0.7 seconds and the other 15% would have a reaction time of 1.25 seconds.

While creating this model, a problem regarding the method to react to other cars was found. The original method looked in front of the car to find obstructions; however, in the new model, it is important to react to cars on the side of the car. Because of this, a new method was devised. Unfortunately, this new method calculated the distance between all the cars and found the minimum distance and reacted to that car. However, the car closest to the car would be itself. Plus, once that problem was dealt with, the car would react to something behind it by slowing down which would just create a crash. This method then had to be revised to only look for cars in front of itself. Once this was accomplished, another problem was encountered. The units used for calculations in the model were not correct and upon inspection it was not easily apparent what the error was. However, after thorough investigation the errors were found and corrected.

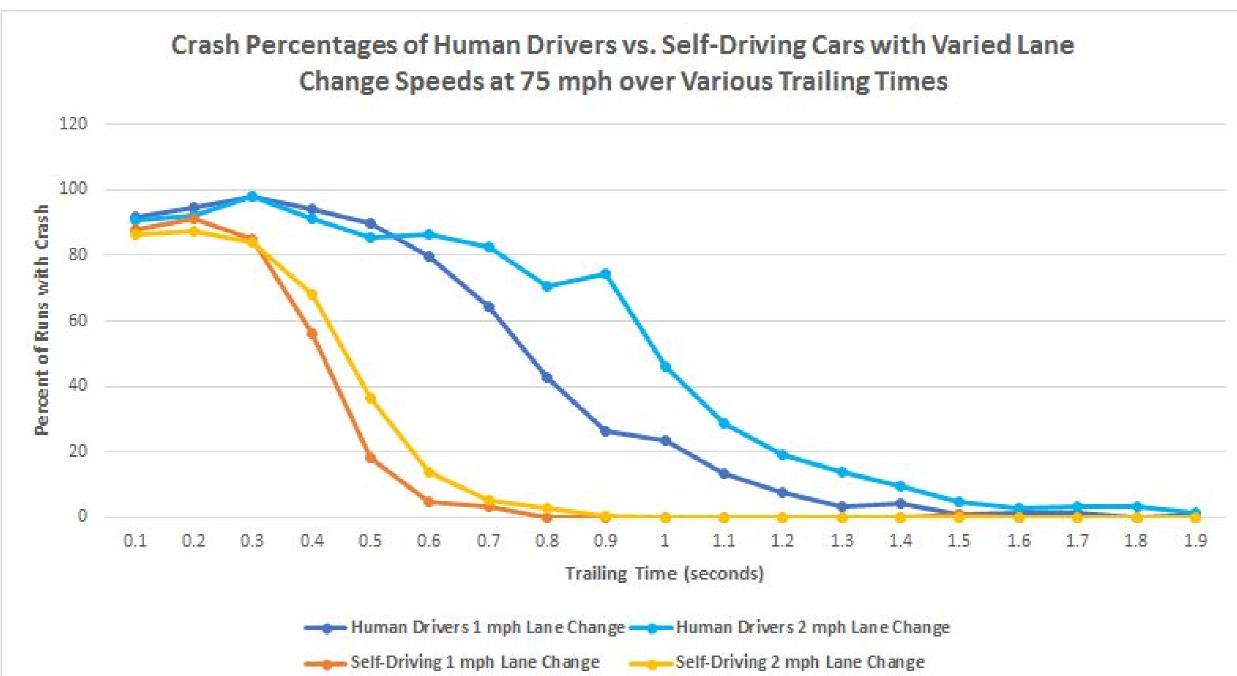
Data was then collected by running the model and recording the amount of time, in seconds, it took for each the self-driving car and the regular cars to crash. Two speed limits were tested. First 75 miles per hour was tested with a constant y-axis speed of one mile per hour. Then 75 miles per hour was tested with a constant y-axis speed of 2 miles per hour. Then the process was repeated for 90 miles per hour. For each of these trials, the trailing time was incremented by 0.1 seconds from 0.1 seconds to two seconds. 145 runs were executed for each increment. Then a graph was created to display this data.

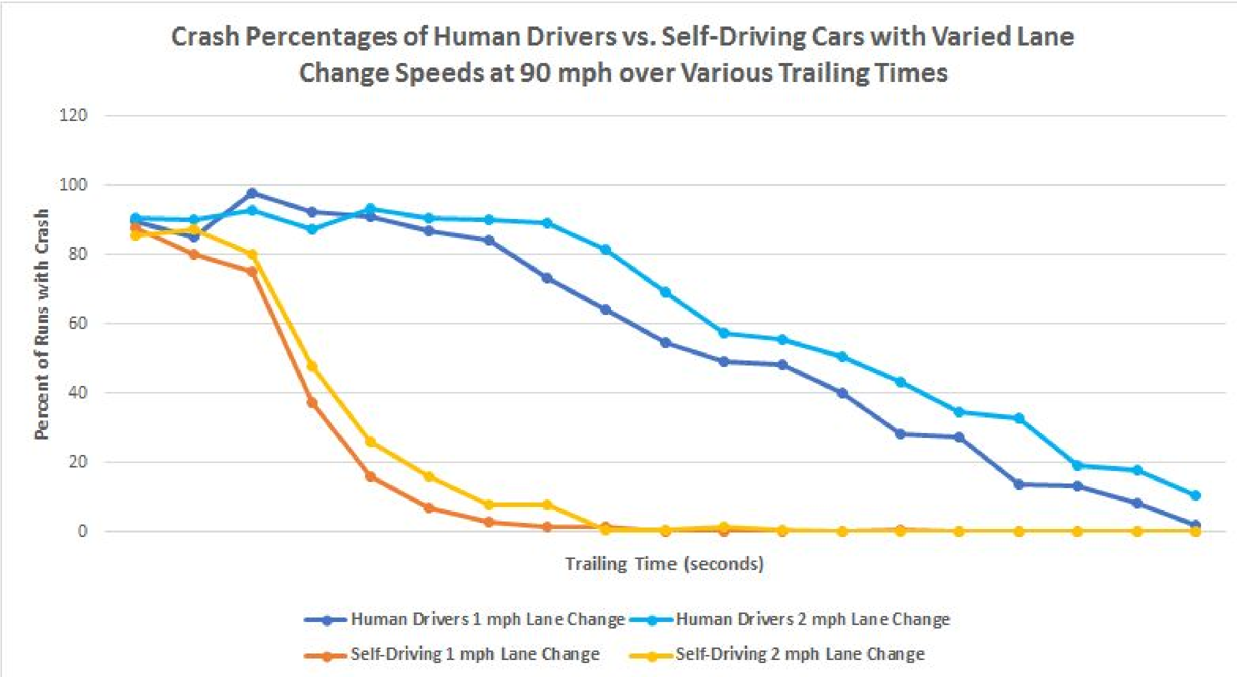
Validation of the Model

In order to convert real world units into the model, a conversion factor of miles per hour to patches per tick was used. It was determined that there would be 100 ticks in a second and that the length of a car in the model would be 14 feet, which is the average length of a car. Since each car took up 1 patch, this meant that there would be 14 feet per patch. Then, research was conducted to find the average reaction times of humans. This ranged from 0.7 seconds to 1.5 seconds according to Doctor Marc Green, an expert in human reaction time. Then, research was done to find the average acceleration and deceleration of the cars. In these models a lot of qualitative data regarding cars was applied. This includes the ways cars react to each other and behave on the road. The model was further validated and made to be more realistic by the extensive process of different model designs over time outlined in the Methods.

Results

Results for the Human drivers and self-driving cars are outlined below in the two line graphs. 145 runs were done at every iteration of trailing time leading to over 2000 pages of raw data. The data was then analyzed by custom Java code and outputted into human readable data tables which were used to produce the following line graphs:





Conclusion

The data collected in the models show that, for a given speed and lane change speed, self-driving car trains are capable of maintaining a smaller trailing time, or distance between the individual cars, than human drivers. For example in the 75 mph speed and 1 mph lane change speed simulations, nearly 80% of human driving runs crashed, when only 5% of self-driving cars did for the same given trailing time of 0.6 seconds, a significant difference. Additionally, the data collected demonstrates that self-driving car trains are able to maintain faster speed-limits, given the same lane change speed and trailing time. For instance, given 1.2 second trailing time and 1 mph lane change time, 7% of human car runs crashed at 75 mph and 48% at 90 mph, while 0% of self-driving cars crashed at 75 mph and only 0.67% at 90 mph. This data shows that the self-driving cars are not only less accident prone given the same trailing distance, but also capable of staying safer than human driver car trains even at higher speed-limits. Next, the trend in the data shows that, as the trailing time or distance between individual cars increases, the percent of accidents that occur decreases. This was expected as greater distance between the cars gives more time and space to react to sudden changes, lowering the number of accidents. Since the data aligned with this expectation, this helps prove the fundamental validity of the model. Finally, for differing lane change speeds, it is clear that higher speeds lead to a greater number of crashes. For example, at 75 mph speed and 1.3 second trailing time, 40% of the humans crashed at 1 mph lane change speed, while 51% of humans crashed at 2 mph lane change speed. This data demonstrates that faster lane changes are possible, but this needs to be taken with a grain of salt, as it potentially would lead to more accidents.

All of this data supports the argument/hypothesis that self-driving cars will be able to travel safely in a caravan like fashion where the cars are close and fast enough together to reap the fuel-efficient benefits of trains. Unfortunately, because this model lacks various realistic qualities the data should not be regarded as concrete. However, this should not prevent people from realizing the potential of self-driving cars and their unique fuel-efficient qualities. In the future, we hope to model fuel efficiency along with the speed limit of self-driving car trains.

The models created incorporate some characteristics of self-driving cars that would enable them to become the best and safest mode of transportation. These models show that the reaction time of humans limit them in terms of safety. Because self-driving cars lack a reaction time, they could be the safest mode of transportation available to people in the U.S. and around the world. Plus, because of a lack of reaction time, the self-driving car will be able to travel in a train-like fashion making it the most fuel efficient mode of transportation.

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