**Proposal**

The idea of this project is to create a roadway occupied by Artificial Intelligence (AI) agents. The agents will follow certain driving rules including but not limited to speed limit, driver concentration, driver ability and driver reaction time. The aim would be to analyse the effects of manipulating those variables to find road rules that would be safer for all drivers and would lead to a decrease in crashes and mortality rates if implemented in the real world.

The concept of the project is to create a two-lane motorway road. Normal rules of the motorway will apply, so cars will be driving in the right lane and will use the left lane to overtake slower moving vehicles. Each AI agent will be unique, some would prefer to drive at a slower speed, while some at a higher, and if road rules force them to drive at an uncomfortable speed, they will be prone to making mistakes more often. The project will run through various iterations with different rules, presenting new challenges for the AI agents to solve.

The results of this project will allow for a better understanding of the effects of the traffic rules on the motorway and would present new information that would be useful in an open discussion about road rules and safety. It will aim to present answers to questions such as “Is it safer to have people driving at a comfortable to them speed or would it be better to enforce a low speed limit?” and “What is the safe speed difference to have between all vehicles on the road?” amongst others. During the course of this project, it will become obvious what the biggest issues of driving on the motorway are. The results can potentially be integrated into a strategy, aimed at reducing mortality rates on motorways by presenting information such as suggesting if the speed limit is necessary or accurate, for example, or if people would benefit from more motorway driving training, if driver ability is the most critical factor. These results would aim to be of use to anyone interested in road safety and to countries struggling with or looking to further improve it.

The project builds upon my current knowledge greatly by analysing all aspects of motorway driving and presenting clear and concise results of issues concerning it. Furthermore, it builds on my knowledge about artificial intelligence, by introducing a working environment such as NetLogo and a new programming language with it. The main aim of this project will be to build upon the current understanding of motorway driving and its’ issues and challenges and to hopefully outline some of them. By doing so, it will open up topics for further discussion and issues for consideration which are hoped to lead to safer motorway driving.

**Design**

The project aims to give an insight into different specifics of motorway driving and their potential impact on road safety.

The base idea of the project is to have a working two-lane road, which will be surrounded by grass. Lanes will be separated by a dotted white line and end of the road will be separated by a solid yellow line. AI agents will be spawned on the road and will head in the same direction. The movement of the AI will be limited, if they get close enough to the vehicle ahead, they will suddenly match their speed to avoid crashes. where AI agents can freely choose a lane to drive on. Agents will choose to swap lanes based on their patience, which would decrease when stuck behind another vehicle. Each vehicle will have a different top speed, which would create difficult situations for the AI agents to overcome. The experiment possible with this base idea will be to test if the overall, mean speed on the motorway will be impacted by manipulating the patience of the agents. The results will be useful to inform new and experienced motorists on driving practices for safe and fast travels.

The second iteration of the project involves decision-making of the AI agents. The main difference will be the enforcement of proper motorway driving rules. The agents will be cruising in the right lane. Upon catching up to another vehicle, they will swap lanes to overtake and will return to the right lane once the pass has been finished. This will have to be done by checking for other vehicles in the left lane before deciding to switch as well as checking for vehicles in the right lane before going back to it. This version of the project will create a proper motorway traffic flow and will give the opportunity to get more accurate results. This iteration will also include desired speed, which will create personality between drivers. This would in turn mean that every driver would want to drive a different speed, which may or may not be within the speed limit. The maximum speed function will be used to set the speed limit of the motorway. The experimental results of this version of the project will be more useful than the previous one as the behaviour of the AI agents will closely resemble proper motorway driving.

The final, most ambitious iteration of the project will include many finishing touches to account for many different variables which may be tested. Firstly, it will introduce crashes between vehicles, this in turn would mean that each AI agent will have to decide when to slow down and by how much when approaching another automobile. It will also include driver experience, which will influence the speed at which the driver will be safe, to account for worse car control. In turn, less experienced drivers will be more willing to drive at faster, more unsafe speeds than they can handle. Also, more experienced drivers will be better at decision-making such as when to start slowing down when approaching another vehicle. Driver mistakes will also make it to this final version. Upon chance, drivers will forget to check the left lane when starting an overtake. Less experienced drivers will have a higher chance of making a mistake. Also, in the situation where a driver’s desired speed is above the speed limit of the motorway, they will be less concentrated and more willing to make mistakes. This iteration of the project allows for many different experiments which may give great insight into potential issues of motorway driving and may be able to suggest potential solutions to those issues.

The main issue with the current project plan is that the second iteration of the project seems the hardest programming-wise. In the event of not figuring out how to complete it, the project will be left in a hollower state than it would be with a less aggressive project plan. However due to the nature of this project it is vital to have proper motorway behaviour of the AI agents before going into details of their driving. The reason behind that is the fact that results of more complex AI system without enforcing proper motorway driving may still be considered inaccurate and unrepresentable to draw a proper conclusion. With the current plan, the project may run out of time before going into the final stage of development, however due to the aforementioned reasons it will still give the best possible results compared to different plan structures.

**Implementation**

The development of the project was conducted following the plan presented in the Design section.

To start off, the development environment was set up. Desktop version 6.0.4 of NetLogo was downloaded and installed. The sample project developed by Uri Wilensky called “Traffic 2 Lanes” was used as a base. It can be found located in the root directory of the NetLogo installation, in the Social Science section for the sample models.

Arguably, the most important part of the development cycle is to properly tackle the decision-making of the AI. The first part of that is figuring out how to properly detect other vehicles. NetLogo has a built-in function for turtles (car entities) which is called “in-cone”. It creates a cone in front of the entity, which detects if there are any other car entities inside of it. It is defined by two inputs – the distance and the viewing angle. Both can be effectively used to simulate proper vision while driving. This function is used alongside another one called “min-one-of”. It can be used to find the vehicle inside the aforementioned cone that is the closest to the AI driver.

Having discussed the tools needed to detect other cars, the logic behind it is quite simple. Firstly, a cone with a far distance was placed. It was used to check the distance to the nearest car and to take the value of the current driving speed of it, which was used to calculate the speed difference between the two cars. The second cone was created to resemble the AI driver’s vision. A couple of variables were used to create a more realistic vision or point of looking for the AI agents. People tend to look at least a certain distance ahead of their vehicle, so a value of “2” was used to resemble that. Then, the speed difference to the nearest detected car ahead was used, because if a car in the far distance is driving a lot slower, it would draw the attention to the driver. Lastly, the speed difference to the car ahead was multiplied with the experience of the driver, so more experienced drivers would pay more attention to that and look further ahead than less experienced ones. This formula was created to try and create the most realistic way of looking and watching the road and other cars.

Then, the script goes onto check if a car is detected ahead in the drivers’ vision. If there is a car ahead, the script checks in which lane the AI agent is. If it is in the overtaking lane, the script just makes sure the agent is following at a safe distance, which is also related to experience – less experienced drivers will follow at a more unsafe, closer distance. However, when the agent is in the right lane – it must check if the overtaking lane is free. Unfortunately, NetLogo doesn’t have a function which can do that. To overcome this issue, the AI agent’s car is turned towards the other lane (at an angle of -60 of origin) and a cone of vision is used to check for cars in the other lane, before returning the direction of the car back to normal. There are a couple of other important things here as well. For instance, if the speed difference to the car ahead is too big, the agent slows down a bit as they change lanes. If the overtaking lane is busy, the agent slows down and starts following the car ahead. Like before, less experienced drivers follow at more unsafe distances.

Another very important part is the calculation of the mistakes chance. A formula was used to do that, which takes in consideration if the agent is driving at a higher speed than it can handle as well as the current speed difference to the desired speed. The second of which was divided by 25, since it’s more down to annoyance or concentration which wouldn’t take a big hit even if drivers are doing a different than their desired speed. To calculate whether the agent should make a mistake or not, a local variable was created. It outputs a random number between 0 and 1, if that number is higher than the mistake chance number, the agent checks for cars in the other lane. The issue with this one is that this code is run 30 times per second while following another car. This increased the chance of agents making a mistake massively, since it gave them many chances to make one. To counter that, the resulting number of the mistake chance formula was divided by 30, which led to normal amounts of mistakes present in the simulation.

The last trickier and important part of the development cycle was the collision detection. Due to the lane-changing mechanic being imperfect and because of time constraints to fix that, collision detection was made to not work while in between lanes. Therefore, it detects cars that are sitting inside the lane. Two types of crashes are recorded into variables – light ones and heavier ones. A heavy crash is reported when the speed difference between the cars was big, which would lead to a more serious crash. A regular crash is recorded when the speed difference is lower, and the crash would potentially not be a big-consequences one. To make sure each crash is detected just once, upon collision detection, the speed of the following is decreased to a significantly lower one than the car ahead, to make sure in the next frame the cars wouldn’t be counted with another collision.

Arguably, the most important parts of the implementation were discussed in this section. Full explanation of the code used in this project along with code snippets will be present in Appendix 1.

**Results**

All experiments were done with 17 cars on screen, 0.005 acceleration, 0.02 deceleration. They were run for 50 000 ticks, which is nearly 30 minutes in real-time (30 ticks per second). All tables will have 10 columns. These will represent – Speed (aimed real-life speed test in km/h), Desired Speed (value put in simulation), Mean Speed (average speed of all drivers during test), Mistakes (number of mistakes made), Crashes (amount of light crashes), Big Crashes (amount of heavy crashes), Mean Desired Speed (the average desired speed of all drivers), Min Desired Speed (the minimum desired speed from all drivers), Max Desired Speed (the maximum desired speed from all drivers), Exp. (Experience value).

The first group of experiments will be to test the effects of changing the minimum required speed of driving on the motorway.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Speed | Desired Speed | Mean Speed | Mistakes | Crashes | Big Crashes | Mean Desired speed | Min Desired Speed | Max Desired Speed | Exp. |
| 60/140 | 0.3-0.7 | 0.43-0.49 | 23 | 7 | 2 | 0.5374 | 0.3539 | 0.6986 | 1 |
| 60/140 | 0.3-0.7 | 0.39-0.44 | 21 | 6 | 1 | 0.4951 | 0.3042 | 0.6979 | 1 |
| 60/140 | 0.3-0.7 | 0.41-0.47 | 24 | 16 | 2 | 0.5289 | 0.3723 | 0.6949 | 1 |
| 80/140 | 0.4-0.7 | 0.41-0.49 | 9 | 2 | 1 | 0.5356 | 0.4102 | 0.6719 | 1 |
| 80/140 | 0.4-0.7 | 0.42-0.54 | 23 | 1 | 0 | 0.5827 | 0.4275 | 0.6872 | 1 |
| 80/140 | 0.4-0.7 | 0.42-0.46 | 11 | 4 | 0 | 0.5206 | 0.406 | 0.6921 | 1 |
| 100/140 | 0.5-0.7 | 0.55-0.59 | 8 | 18 | 1 | 0.6156 | 0.5326 | 0.6922 | 1 |
| 100/140 | 0.5-0.7 | 0.55-0.58 | 6 | 0 | 0 | 0.596 | 0.5111 | 0.6932 | 1 |
| 100/140 | 0.5-0.7 | 0.56-0.58 | 4 | 1 | 0 | 0.6065 | 0.511 | 0.693 | 1 |
| 120/140 | 0.6-0.7 | 0.62-0.64 | 4 | 6 | 0 | 0.6574 | 0.6014 | 0.6985 | 1 |
| 120/140 | 0.6-0.7 | 0.61-0.63 | 16 | 34 | 2 | 0.6544 | 0.6092 | 0.6929 | 1 |
| 120/140 | 0.6-0.7 | 0.62-0.64 | 6 | 105 | 8 | 0.6545 | 0.6135 | 0.696 | 1 |

The results show a significant effect of increasing the minimum speed limit. With 60/140 km/h having an average of 9.66 light and 1.66 heavy crashes, 80/140 km/h – 2.33 light and 0.33 heavy crashes, 100/140 km/h – 6.33 light and 0.33 heavy and 120/140 km/h – 48.33 light and 3.33 heavy crashes. The latter of these had an issue where a single mistake or crash will lead to a huge pile-up.

From the results, it seems like increasing the minimum motorway speed makes a huge difference in terms of road safety. There is a huge step between 60/140 and 80/140 km/h speed limits. With 100/140 km/h having an anomaly with one of the tests having just a single pile-up and amazing results in the other two tests. 120/140 km/h was too much for the AI to handle which will probably translate in the real world as well, with many people struggling to drive at these speeds. In terms of speed, the minimum mean speed for 80/140 km/h is about 0.42 as opposed to 0.55 for 100/140 km/h. This is about 30% increase of the minimum travel speed, whereas the speed limit was increased by 25%.

The results clearly show the negative effects of too big of a difference between minimum and maximum speed limit on the motorway. It seems like the best choice would be 80/140 km/h, as it makes sure the difference isn’t too big and still gives an option for people to drive slower.

The second experiment will take the best choice (80/140 km/h) of the results from the first test and will examine the effects of changing the speed limit of the motorway. The 80/140 km/h test results will be taken from the previous test, whereas the other ones will be made with same settings.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Speed | Desired Speed | Mean Speed | Mistakes | Crashes | Big Crashes | Mean Desired speed | Min Desired Speed | Max Desired Speed | Exp. |
| 80/140 | 0.4-0.7 | 0.41-0.49 | 9 | 2 | 1 | 0.5356 | 0.4102 | 0.6719 | 1 |
| 80/140 | 0.4-0.7 | 0.42-0.54 | 23 | 1 | 0 | 0.5827 | 0.4275 | 0.6872 | 1 |
| 80/140 | 0.4-0.7 | 0.42-0.46 | 11 | 4 | 0 | 0.5206 | 0.406 | 0.6921 | 1 |
| 80/160 | 0.4-0.8 | 0.43-0.54 | 26 | 171 | 3 | 0.5817 | 0.4017 | 0.794 | 1 |
| 80/160 | 0.4-0.8 | 0.49-0.56 | 19 | 271 | 7 | 0.618 | 0.416 | 0.7943 | 1 |
| 80/160 | 0.4-0.8 | 0.41-0.53 | 22 | 30 | 6 | 0.5888 | 0.4168 | 0.7825 | 1 |
| 80/120 | 0.4-0.6 | 0.42-0.47 | 11 | 0 | 1 | 0.5129 | 0.4091 | 0.5953 | 1 |
| 80/120 | 0.4-0.6 | 0.42-0.44 | 7 | 0 | 0 | 0.4862 | 0.4226 | 0.5908 | 1 |
| 80/120 | 0.4-0.6 | 0.42-0.47 | 15 | 0 | 0 | 0.4923 | 0.4025 | 0.5776 | 1 |
| 60/120 | 0.3-0.6 | 0.34-0.41 | 18 | 3 | 0 | 0.4384 | 0.3131 | 0.5893 | 1 |
| 60/120 | 0.3-0.6 | 0.35-0.40 | 19 | 1 | 0 | 0.4456 | 0.3033 | 0.557 | 1 |
| 60/120 | 0.3-0.6 | 0.33-0.41 | 18 | 2 | 0 | 0.4462 | 0.3012 | 0.5877 | 1 |

The results further prove the importance of having a small speed difference between all cars on the road. With 80/160 getting horrible results and struggling with similar issues with pile-ups, it is completely out of the equation. With 80/140 averaging at 2.33 light and 0.33 heavy crashes, 80/120 – at 0 light and 0.33 heavy crashes and 60/120 – 1.66 light and 0 heavy crashes.

It seems like the bigger speed difference reintroduced with 60/120 increases the likelihood of a light collision. However, the reduction of the speed limit with 80/120 as opposed to 80/140 km/h improves significantly the safety on the road. The 80/140 km/h tests give an average mean desired speed of 0.5463, whereas the 80/120 km/h average at 0.4723 which is merely a 15% difference, which shouldn’t affect average travel times significantly.

The results of the second test show a significant improvement of lowering the speed limit to 120 km/h in terms of safety. They also suggest that average travel times won’t be significantly different too.

The third experiment will try to measure the impact of driver experience to road safety. 80/120 km/h will be used for this experiment as it was deemed safest in the previous test.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Speed | Desired Speed | Mean Speed | Mistakes | Crashes | Big Crashes | Mean Desired speed | Min Desired Speed | Max Desired Speed | Exp. |
| 80/120 | 0.4-0.6 | 0.42-0.47 | 11 | 0 | 1 | 0.5129 | 0.4091 | 0.5953 | 1 |
| 80/120 | 0.4-0.6 | 0.42-0.44 | 7 | 0 | 0 | 0.4862 | 0.4226 | 0.5908 | 1 |
| 80/120 | 0.4-0.6 | 0.42-0.47 | 15 | 0 | 0 | 0.4923 | 0.4025 | 0.5776 | 1 |
| 80/120 | 0.4-0.6 | 0.40-0.45 | 12 | 0 | 0 | 0.4738 | 0.4028 | 0.5966 | 0.9753 |
| 80/120 | 0.4-0.6 | 0.41-0.46 | 8 | 1 | 0 | 0.5038 | 0.4002 | 0.5879 | 0.9722 |
| 80/120 | 0.4-0.6 | 0.43-0.47 | 12 | 1 | 0 | 0.5013 | 0.403 | 0.5904 | 0.9768 |
| 80/120 | 0.4-0.6 | 0.41-0.47 | 30 | 29 | 0 | 0.5048 | 0.4011 | 0.5855 | 0.9463 |
| 80/120 | 0.4-0.6 | 0.42-0.45 | 12 | 0 | 0 | 0.4892 | 0.401 | 0.5955 | 0.9466 |
| 80/120 | 0.4-0.6 | 0.44-0.47 | 25 | 20 | 0 | 0.511 | 0.4015 | 0.591 | 0.9459 |
| 80/120 | 0.4-0.6 | 0.43-0.5 | 34 | 55 | 1 | 0.5277 | 0.4288 | 0.594 | 0.9125 |
| 80/120 | 0.4-0.6 | 0.43-0.48 | 33 | 4 | 0 | 0.5094 | 0.4273 | 0.596 | 0.9196 |
| 80/120 | 0.4-0.6 | 0.40-0.43 | 34 | 0 | 0 | 0.4951 | 0.4139 | 0.5988 | 0.9164 |

The results for this test were going to always be predictable. It’s curious to note that, by decreasing the average experience a bit, there is a consistent increase of light crashes (two times with a single light crash). However, once the experience gets lowered, scores become quite erratic with cars sometimes creating huge pile-ups and other times lucking out of any crashes. The first test in the last segment had 55 light crashes and 1 big one, which makes 2 different pile-ups, whereas the other two tests were mostly lucky with 4 and 0 crashes.

One of the main differences between experienced and inexperienced drivers is the distance at which they follow cars. These results also show that these unsafe distances may not always result in a crash, however quite often they do. The main point to be taken from this test is that people should be taught the dangers of tailgating and safe following distances. The other point is the vision’s focus point. More experienced drivers look further ahead, which at high speeds is important. This test proves the importance of proper motorway driving training as well as driver awareness of the dangerous of bad habits.

**Discussion**

The project clearly indicates some very important aspects of safe motorway driving. It shows a clear correlation between minimum required speed on the motorway and incident rates and suggests speed difference between all drivers as an issue. It also pinpoints issues of particular bad driving habits and their potential impact on road safety, if massively applied.

The project however, leaves gaps for further investigation. As good as the indications concluded are, it struggles to provide clear evidence of the exact laws which countries should apply. The issue mainly comes from the unclear translation of driving speed in the simulation to real-world figures. The speeds were based on a random value of 0.7 – 140 km/h, which can be inaccurate. The differences between the speeds were calculated in terms of percentages (for instance 80 is 0.66 times lower than 120, and 0.4 is also 0.66 times lower than 0.6). However, the actual representation of speed is nothing more than a random guess. Another issue the project has is the lacklustre behaviour of the AI. The AI model is based on classical AI, however due to time constraints and the relatively small scope of the project, there is a lot left to be desired in terms of polish. On top of that, the AI is aimed to represent the average driver, but it is very hard to judge the abilities of one. To summarize, the project attempts to pinpoint certain aspects of motorway driving and their relative importance, however further testing must be done before concluding on the exact details.

Another point the project doesn’t address is how these changes are affected in different traffic loads. All tests were done with 17 cars, which bearing in mind the small stretch of road can be considered very heavy traffic. Further investigation is needed on the effects in light traffic, which lawmakers may consider for some motorways.

In conclusion, the project aims to identify certain issues of motorway driving and does so effectively. The importance of relatively small speed difference between all drivers and proper motorway driving training is obvious. The project opens many avenues for further research on aspects of motorway driving and brings up topics of discussion considering road safety.