Cellular Automata Modelling of Motorway Traffic

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Contents

Abstract

This project uses the cellular automata model to investigate the flow patterns of traffic for a single-lane system. In the simulations, cars would move according to a set of rules, allowing cars to interact to form different traffic flows – On some occasions, they would slow down and clump together, while on other occasions they would be evenly spaced and travel at constant speeds. To understand what causes the change in traffic flow, the road density, car dawdling probability and maximum speed are varied to study their effects on the flow, respectively. It was found that, when either one of these parameters increases, the road model shows a transition from laminar traffic flow to start-and-go waves.

Introduction

The flow of cars in a traffic can be complex and unpredictable. Fortunately, Cellular automata, a system which considers space as discrete units of cells, will be able to describe such phenomenon. In this modelling system, a motorway is discretized into cells, in which each unit cell is either occupied or unoccupied by a car [7]. At each moment, indicated by a discrete timestep, a function is implemented to update each cell. The new current state of the cell depends on its previous state, and the states of the neighbouring cells in the system.

Besides Cellular automata, there are other methods to which motorway traffic can be emulated. For example, time continuous modelling can be used in place of discrete timesteps for array elements. With that said, Cellular automata is an efficient, accurate modelling framework due to its scalability. By applying simple rules, it can generate complex systems. This is because each microscopic interaction in the modelling can accumulate to form accurate description of macroscopic behaviour [4].

Due to its scalability, Cellular Automata is capable of modelling a complete system of traffic flow, and specifically, to search for parameters that results in optimal traffic flow. In such a traffic system, Cars' consumption of energy or fuel is minimised, which can be accomplished in two possible ways: Minimise the stop-and-start due to traffic, or to minimise the Journey time for the drivers which allow cars to drive at the maximum speeds [1].

This provides insights as to how driverless cars may be designed. At the present, driverless cars are limited in their modes of interaction with the world, mainly relying on devices such as sensors and cameras to recognize surroundings. However, in the future, all the driverless cars will be supported by the central system, which serves to facilitate the optimal flow of traffic. The control system would be able to find the fastest journeys for each of the vehicle, which is similar to how Cellular automata seeks to optimise the flow of traffic [1]. This is also similar to the central system used in elevators; to ensure the shortest waiting time for the passengers upon their arrivals, elevators are allocated to board the passengers to its closest locations [3].

Despite the effectiveness of central system at facilitating optimal traffic flow in autonomous driving, we have yet to reach that phase of development. Therefore, one needs to consider irresponsible behaviours in driving. This simulation will not account for accidents caused by driving above the speed limits or drink-driving, but it will account for dawdling. An common scenario, dawdling can range from drivers looking at the side windows, or slowing down when there is not a need to. These outlying scenarios explains why the Cellular automata modelling of traffic is not completely predictable, but rather gives a stochastic (probabilistic) simulation that better describes the real world. The unpredictable behaviour of drivers are similar to nature of weather forecasting and Quantum mechanics, in which every measurement comes with a probability.

Although this simulation does not represent the real traffic flow, because cars are set to move at lower speeds, and the motorway is set to be more congested than in real life, this simulation does accurately describes the scenario for slower moving cars on a densely populated motorway. Also, by observing this system of traffic flow, one sees that it gives rise to fascinating patterns.

Methods

3.1 Generation of road

Because space is discretized in this simulation, a NumPy array will be used to represent the road, which has a length L given by

$$L = Number\ of\ cells, \tag{1}$$

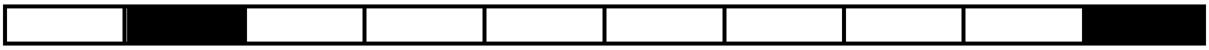
with each cell representing a space element. Subsequently, cars would occupy the road with speed v .

The speed of the car is defined as:

$$v = \frac{No.\ of\ cells\ travelled}{No.\ of\ timesteps}, \tag{2}$$

where it has the unit $c\ /\ t$.

Figure 3.1: A 10-cell discretised road, with cars populating on the 1th and 9th element of the road's array.



For convenience and simplicity, the road is generated as an array with all elements set to zero. The status of each site is denoted by an integer, in which a site of zero represents no car occupied while a value greater than 1 represents a car in that site. Specifically, the integers in the elements correspond to speeds of each car on the road. However, this setup was met with a problem: In the array, the element values corresponding to sites with no car and with stationary cars are both equal to zero. This would mean that stationary cars do not exist on the road. In order to resolve this problem, the element values corresponding to cars present were increased by 1. By doing so, the element value for a stationary car would be 1.

The element value is defined as

$$EV = v + 1\,, \tag{3}$$

where v is the speed of a car.

Figure 3.2: A road array filled with integers. An element value of 0 indicates no car present in that element, while a value of 1 or greater indicates a car present.

0	1	2	0	2	0	0	0	6	4	1

3.2 Generation of cars

In order to generate cars on a road, a closed loop system, also called a periodic system, is employed in this simulation. This is a road system whereby the cars leaving the road will re-join at the start of the road, as if forming a circular loop for the cars to go around.

To compare with a closed system, an open system was initially experimented with. In an open system, cars of various speeds are fed to a road at various times, until the density of the road k reaches the value set in the function. The road density k is defined as

$$k = \frac{No.\ of\ cars\ on\ a\ road}{Total\ \ No.\ of\ cells\ on\ the\ road}. \quad (4)$$

Here, density possesses an unit $N\ /\ c$.

In order to maintain the open system at the set density, when a number of cars leave the end of the road, the same number of cars should be fed to its beginning. However, since there is limited space at the beginning of the road, an issue can occur where the number of cars fed to a road are fewer than required to maintain the density of the road. Hence, the density of a traffic in an open system can fluctuate. In contrast, for a closed system, the number of cars on the road is constant, so that

$$Number\ of\ cars\ leaving\ the\ road = Number\ of\ cars\ joining\ the\ road\ . \quad (5)$$

This means that a closed system can maintain a constant density throughout the timesteps of the simulation. Given these features, a closed system is adapted for this simulation, since it allows for more accurate observations of a traffic system in the absence of density fluctuations.

For the closed system, all the cars are put into the road initially to reach the specified density, which is achieved by implementing a loop to count through how many cars are needed. Every car is randomly assigned to a vacant site on the road, with a random speed that can range from v_{min} to v_{max}, the minimum and maximum speed, respectively. Similar to a circular loop, but with a straight path, the road is designed to be connected throughout. To do so, the road is copied (doubled in length) to allow for interaction between the cars at the beginning of road and their copies at the end road, thereby forming a continuous system. Afterwards, the road will be restored back to its original length.

Figure 3.3: The original road, Road A, is copied to produce Road B, which is placed after Road A.

First half of Road A	Second half of Road A	First half of Road B	Second half of Road B

To restore the road to its original length, the first half of the copied road, Road B, is placed in front of the second half of the original road, Road A. Given that Road B is a copy of Road A, the cars on Road B are likewise copies of the cars on Road A, meaning that movements and the relative locations of cars will be unchanged. Hence, the car interactions that occur in Road B will also occur in Road A, except that cars in the second half of Road A can enter the first half of Road B and meet the replicated cars. Note that at the outer sections of the roads, cars may drive past the index of the road array, so these sections will not be taken for the construction of a continuous road. Hence, by using the middle section instead, a continuous road can be constructed.

Figure 3.4: A road is restored back to its original length from the double-road system, as shown in Figure (3.3).

First half of Road B	Second half of Road A

3.3 Implementation of rules

In this simulation, cars will move and interact according to a set of rules. These rules are implemented using loops and conditional statements (if / else).

Rule 1: If the velocity v of a car is less than v_{max}, and if the distance to next car is larger than $v + 1$, the car's speed increases by 1. [4]

To implement Rule 1, first consider the properties of cellular automata road. Because space is discrete in this system, the distance that a car travels across the road at each timestep is equal to its speed. In addition, if two cars are sufficiently far apart, meaning that a car will not travel to the same location (site) as its car ahead in the next timestep, it can then accelerate from v to $v + 1$. Given the discrete property of the road, the acceleration of the vehicle is $1\frac{cell}{t^2}$ and is discrete.

With the above principles, one can now incorporate Rule 1 into the code. To check for any cars in front, the element value of each cell up to $v + 1$ sites in front of the car will be summed. Suppose the sum is zero, there is no car at least $v + 1$ sites in front of the first car, and it will increase its speed by 1 in next timestep, given that its speed v in the current timestep is less than v_{max}. These principles of rule 1 results in a simplified traffic in comparison to its real world counterpart, for all cars move at discrete speeds, and if given enough space, all accelerate at the same discrete rate.

Figure 3.5: A diagram that shows the implementation of Rule 1 in the road system. A car at the 1st element of the road sees another car at the 6th element, which is greater than $v + 1 = E - 1 + 1 = E = 3$ cells apart, so it increases its speed by 1 in the next timestep.

$Timestep = 1$:

	3					5			

$Timestep = 2$:

	4					5			

Rule 2: If a car at site i sees next vehicle at site $i + j$, with speed $j < v$, it reduces its speed to $j - 1$. [4]

Similar to when a car accelerates if the distance to next car is sufficiently large, it will slow down if that distance is sufficiently small. This is the case for Rule 2; If the car on the left of the road has speed v, and its distance i to next car is less than v, then it will have travelled a greater distance in the next timestep than the distance by which two cars are separated. Therefore, the car in the left will decrease to a speed necessary to avoid collision with the car in front.

To implement Rule 2, a for loop is used to calculate the number of cells (distance) between the main car and the car in front. If that distance is less than speed of the main car, the car will decrease its speed to distance -1 in the next timestep. While Rule 2 does not perfectly describe the motion of high speeds cars, as cars moving at high speeds cannot slow down to zero speed in just one timestep, it does better describe the motion of slower moving cars in a denser traffic, whereby cars do not experience rapid decelerations.

Figure 3.6: A diagram that shows the implementation of Rule 2. A car at the 2nd element moving at speed $v = E - 1 = 4 - 1 = 3\ \frac{cells}{t}$ sees a car in front at the 3rd element. Because two cars are 1 cell apart, the car behind reduces its speed to 0 in the next timestep.

$Timestep = 1$:

		4	5		

$Timestep = 2$:

		1	5		

Rule 3: With probability p, the velocity of each vehicle (if greater than zero) is decreased by 1. [4]

The implementation of Rule 3 involves the use of a number generator that randomly assigns an integer between 0 to 100 to each non-stationary car on the road. If the number assigned to a car is less than a car dawdling probability $P(dawdle)$ (expressed in percentage), it follows that a car will decrease its speed by 1 in the next timestep.

By adding Rule 3, not all the cars will drive to facilitate the optimal flow of the traffic. Instead, they will be subjected to randomized dawdling, rendering the system from being perfectly deterministic.

Rule 4: Each car is advanced by v sites. [4]

In order to move cars across the road by v sites, the elements containing the non-stationary cars are first moved by EV sites, and the elements which used to contain the cars are deleted. This procedure ensures that cars will move by $EV - 1 = v$ sites at each timestep, which is their speeds.

It should be noted that Rule 4 is ran prior to Rule 3, due to the way in which the road system is generated. The road of a closed system is formed by two copies of the original road, and is restored back to its original length right after each car advances through the road. Suppose Rule 3 is ran first, its randomized process would lead to two different arrangements of dawdling cars for two copies of the road, meaning that the two road copies are no longer identical to one another. In that case, restoring the doubled lane system back to its original length would lead to situations whereby the number of cars on the road fluctuate, thus resulting in unexpected fluctuations to the traffic's density throughout the timesteps of the simulation. Another thing to take notice is that, when updating the positions of cars, one should loop through the whole road from its end to start, rather than looping through the other way around. The reason is that cars in front need to move first in order for the cars behind to move. Hence, it is important to follow this order of looping, otherwise an issue can arise in the road system whereby cars are replaced by other cars.

Figure 3.6: A diagram that shows the implementation of Rule 4. A car at the 1st element and speed $3 - 1 = 2\ \frac{cell}{t}$ advances 2 cells in the next timestep, while another car at the 4th element with speed 3 $\frac{cell}{t}$ advances 3 cells in the next timestep. Note that, in a closed system, a car travelling past the end of the road would be re-introduced at the start of the road.

$Timestep = 1$:

	3			4		

$Timestep = 2$:

4			3			

Results and Discussions

4.1 Effects of varying road densities on traffic flow

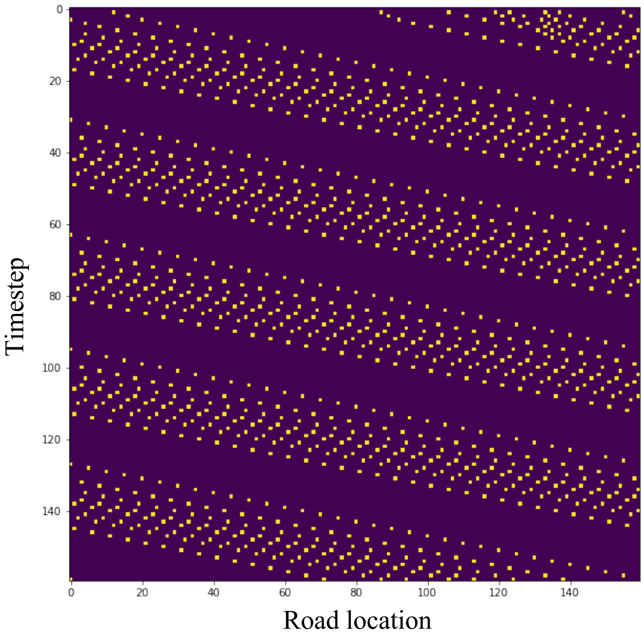


Fig 4.1: Space-time plot of traffic flow at road density of $k =$ 0.05 cars/cell. The space and time axes is oriented from left to right, and top to the bottom, respectively. Independent variables: Road length = 160 cells, v_{max}= 6 cells/t, P(dawdling) = 12%, Timestep = 160.

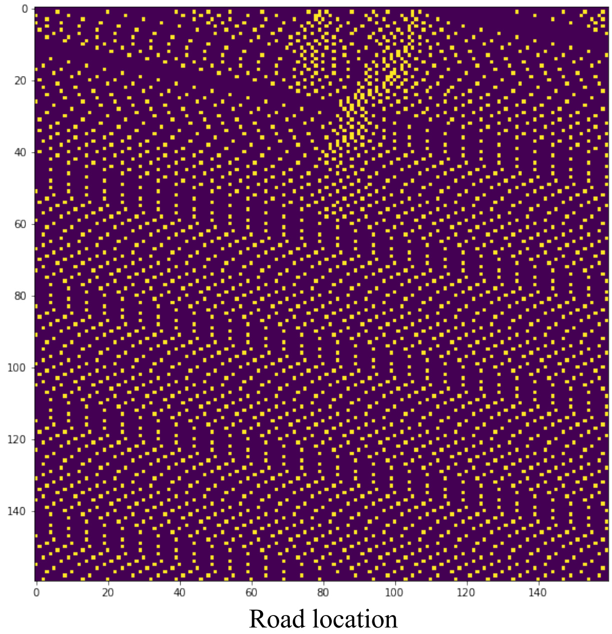


Fig 4.2: Space-time plot of traffic flow at road density of $k =$ 0.12 cars/cell. Independent variables: Road length = 160 cells, v_{max}= 6 cells/t, P(dawdling) = 12%, Timestep = 160.

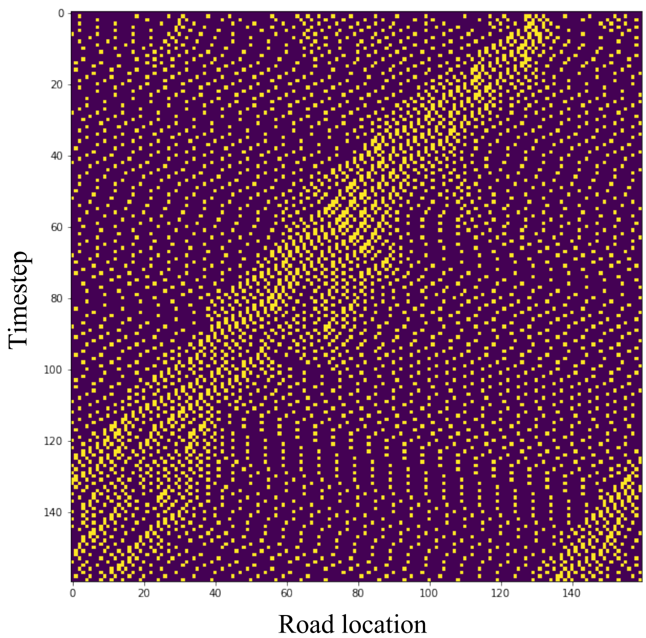


Fig 4.3: Space-time plot of traffic flow at road density of $k =$ 0.16 cars/cell. Independent variables: Road length = 160 cells, v_{max}= 6 cells/t, P(dawdling) = 12%, Timestep = 160.

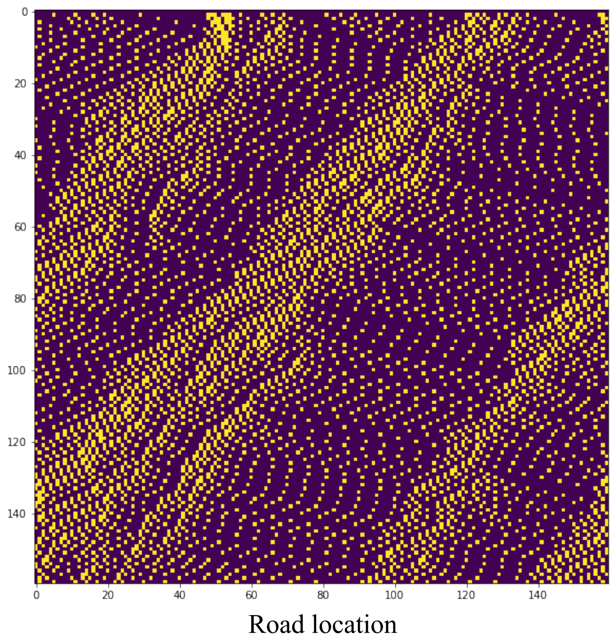


Fig 4.4: Space-time plot of traffic flow at road density of $k =$ 0.20 cars/cell. Independent variables: Road length = 160 cells, v_{max}= 6 cells/t, P(dawdling) = 12%, Timestep = 160.

In the real world, the maximum speeds of cars and the length of the road would not change, but one parameter that can vary is the densities of the road, i.e., the number of cars that occupy the length of the road. This variation can lead to different traffic flow patterns which yields meaningful implications.

The diagrams above, plotted using pyplot.imshow( ), show a bird's-eye view for the movements of cars across a single-lane road over timesteps for different traffic densities. In these diagrams, cars are represented in yellow dots, with the horizontal axis representing the position of the roads and the vertical axis representing time, respectively. Note that when the cars move across the road, they produce lines propagating along the space-time diagrams of the road, and the gradients of these lines show the speeds at which the cars travel. Based on looking at the distance between adjacent cars and the line gradient, it can be observed that when the density k of the road increases, cars are more likely to clump together, thus resulting in more jams and shockwaves.

At density $k = 0.12\ cars/cell$, as shown in Fig 4.2, one initially sees small, tiny jams formed at the upper section of the diagram. This is because the cars are given random initial speeds and sites to occupy on the roads, hence the initial jams are only random occurrences. Gradually, the jams would disappear, as seen when the line gradients of the moving cars are virtually constant down the remaining timesteps of the simulation, meaning that cars move at close to constant speeds along the road. By the CA rules, cars being able to move at constant speeds indicates that, the distance between two adjacent cars (car behind and in front) is greater than distance in which the car behind would travel in the next timestep, thus meeting the condition for Rule 1. However, even with the right condition for Rule 1, most cars in the system tend to travel at constant speeds over timesteps of the simulation, instead of accelerating over time. This is because, over time, most cars would move at their maximum speeds, so they can no longer accelerate. As such, in a low density road, the average speed of cars would converge to approximately their maximum speeds. With cars moving at nearly their maximum speeds, they form a traffic flow pattern that resembles a steady, laminar flow in fluid dynamics [2].

When the density of road increases to $k = 0.16\ cars/cell$, as shown in Fig 4.3, the jams formed at the initial timestep no longer disappear over time, but propagate throughout the timesteps of the simulation. The jams would impede the movement of cars at certain sections of the road, so the gradients of the moving cars no longer remain constant throughout most parts of the diagrams, meaning that cars do not move at constant speeds throughout duration of the simulation. Instead, the cars experience cycles of smooth movement and congestion along the road. For example, at the 0^{th} timestep beginning at the left hand side of the road, cars are more spread out from each other, thus allowing them to travel at higher speeds. However, when they move across the road over time, as represented by the diagonal lines moving down to right of the diagram, the distance between adjacent cars begins to decrease, and they eventually clump together at the right hand side of the road, forming a jam cluster. The jam cluster then spread backward along the road, forming a diagonal line that propagates from the right hand side of the road to start of the road over time. This propagating line, as mentioned at the beginning of a paragraph, is called a shockwave [7] and it returns the jammed sections of the road back to its free traffic state, which can be noted by comparing a given section at the right hand side of the road at different timesteps (vertical axis of diagram), where the jams formed initially at the section disappears over time.

Looking at the shockwave in the diagram more closely, once it reaches the start of the road at the bottom right of the diagram, it would then reflect off on other end of the road at the bottom right. This is because of the characteristic of a closed system. In this system, cars moving past the end of the road would be re-introduced at the beginning of the end. Therefore, a shockwave reaching past the start of the end would also be reflected off on other end of the road. When comparing this to real world, in a straight road, a shockwave does not propagate from one end of the road to other end, since jams formed at the beginning of the road would not directly lead to jams at the end of the road. Despite its discrepancy from a straight road, this figure does provide a realistic description of the shockwave phenomenon, which is observed in both the straight [4] and the circular road [5] when their densities are sufficiently high.

When the road density further increases to 0.2 $cars/cell$, as shown in Fig 4.4, multiple shockwaves are formed on the road and size of the shockwaves increase. This is because, with even more cars on the road, the average spacing between cars further decreases from that shown in Fig 4.3, so cars will be more likely to congregate over the course of the simulation, thus resulting in more and bigger jams shockwave.

At higher densities, as shown in Fig 4.3 and Fig 4.4, both road diagrams exhibit traffic jams that persist over the course of the simulations. The formation of traffic jams can be explained by fluid dynamics. Resembling the behaviour of a dilatant fluid, which is a fluid that tends to solidify and thickens when stress is applied [2], when the density of the road increases, the average spacings between cars decrease, so they would be more likely to congregate in a certain area of the road simultaneously. Hence, the traffic `thickens`, because cars would slow down when they are less separated from the car in front.

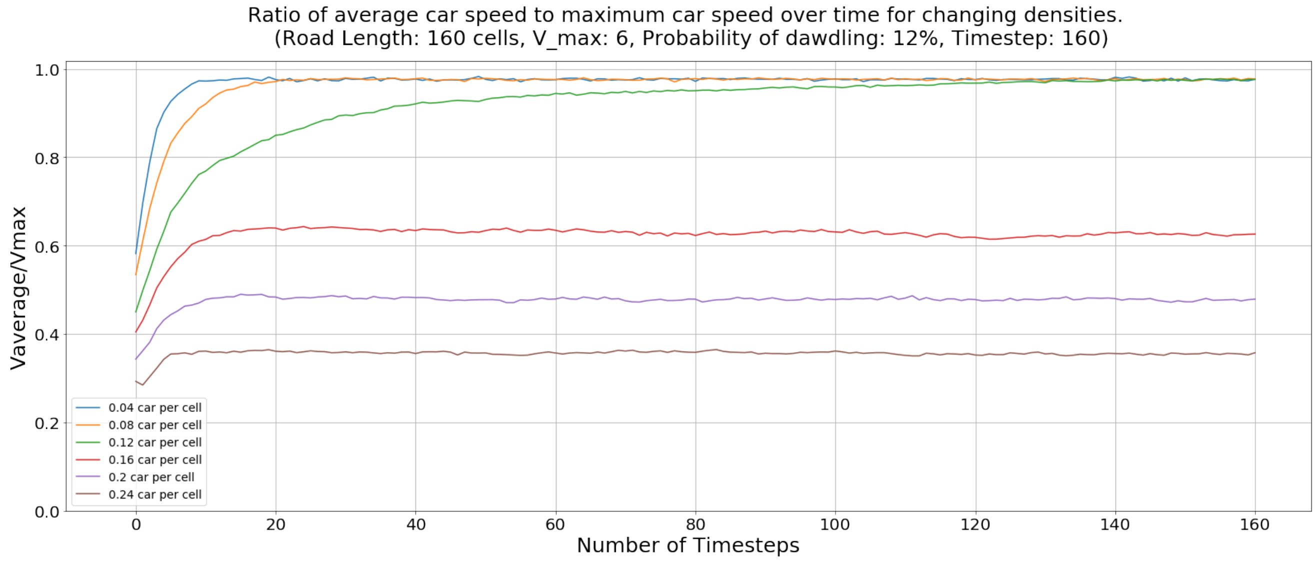


Fig 4.5: A plot that shows the effect of changing densities, from 0.04 to 0.24 $cars/cell$, on the ratio between the average speed of cars on the road to its maximum speed. The average ratio at each timestep is obtained from results of 110 simulations, and is plotted over 160 timesteps. Independent variables are labelled on the plot.

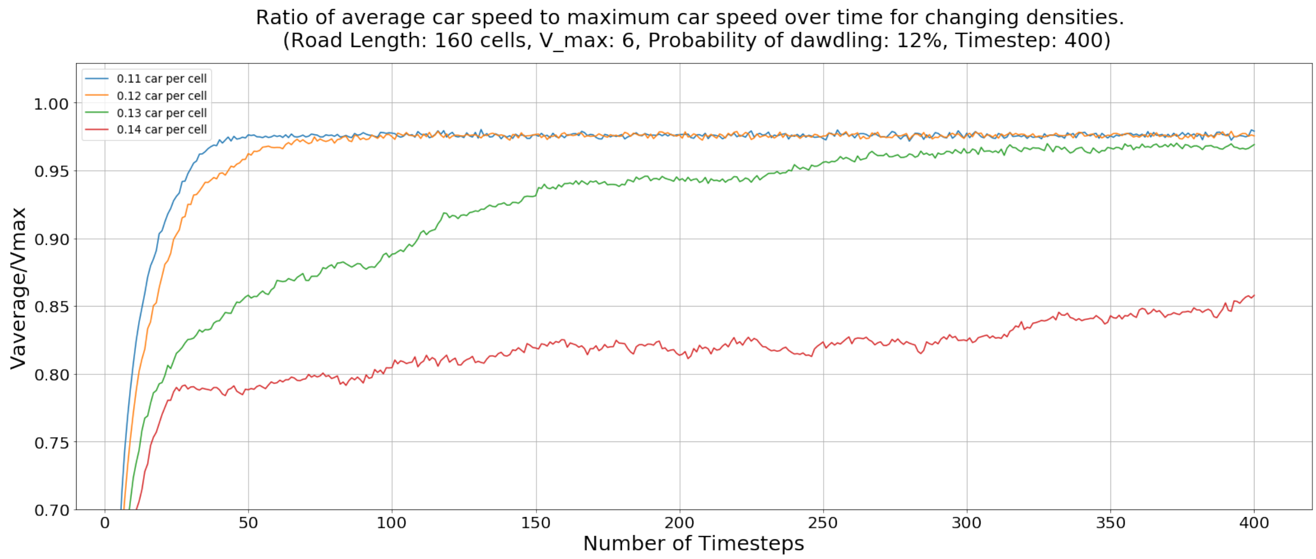


Fig 4.6: A plot that shows the effect of changing densities, from 0.11 to 0.14 $cars/cell$, on the ratio between the average speed of cars on the road to its maximum speed. The average ratio at each timestep is obtained from results of 110 simulations, and is plotted over 400 timesteps. Independent variables are labelled on the plot.

Apart from using the space-time diagrams to understand how varying densities affect traffic flow, we shall now understand the change in traffic flow through graphs. In order to do so, the ratio of the car's speed to its assigned maximum speed will be used as the metric to study the motion of cars and to identify the state of traffic flow. Since cars on the road move at different speeds, the speed of each individual car is calculated in order to find the average ratio v_{aver}/v_{max} at each timestep. This is to allow for a better representation of the entire road system.

In addition, given the random nature of car dawdling, and that cars are given random initial speeds and locations at which to occupy the road, the results of each simulation will be different. To gain a better representation of the overall results, the average v_{aver}/v_{max} is calculated for its mean value at each timestep over 110 simulations. Consequently, this mean value is plotted over a number of corresponding timesteps.

As can be observed in Fig 4.5, for a road system of $v_{max} = 6\ cells/t$, speed ratios converge to approximately 1 up to a road density $k = 0.12\ cars/cell$. This result is consistent with the observed traffic flow at density $k < 0.12\ cars/cell$, as shown in Fig. 4.1 and Fig 4.2. At such densities, both figures exhibit laminar traffic flow almost throughout entire space-time diagrams, meaning that cars drive at nearly their maximum speeds. (Note that the speed ratio does not exactly converge to 1 due to dawdling of cars, which shall be discussed later.)

On the other hand, when the density increases to $k = 0.16\ cars/cell$, the speed ratios drop off from 1, and they continue to decrease for increasing densities. This is supported by Fig 4.6, which measures the speed ratios for closer densities over a longer timestep of 400, and shows that at just above $k = 0.12\ cars/cell$, the speed ratio would begin to drop. These results are consistent with the observed traffic flow above $k = 0.12\ cars/cell$, as shown by Fig 4.3 and Fig 4.4, where permanent traffic jams are formed to impede the movement of cars, thus lowering the speed ratios.

To directly observe how the speed ratio changes with density, the ratios are taken at the 160th timestep for each density, and then plotted against the corresponding densities, as shown in Fig 4.7. The result of this figure is consistent with that found in Fig 4.5, as the converging speed ratio is observed to remain mostly constant up the density $k = 0.12\ cars/cell$, after which it will begin to drop off.

Hence, for $v_{max} = 6\ cells/t$ and P(dawdling) = 12%, the maximum density at which the maximum speed ratio can be achieved is $k = 0.12\ cars/cell$. This density is called the critical density k_c [7], and it marks a transition from laminar traffic flow to start-stop waves [4].

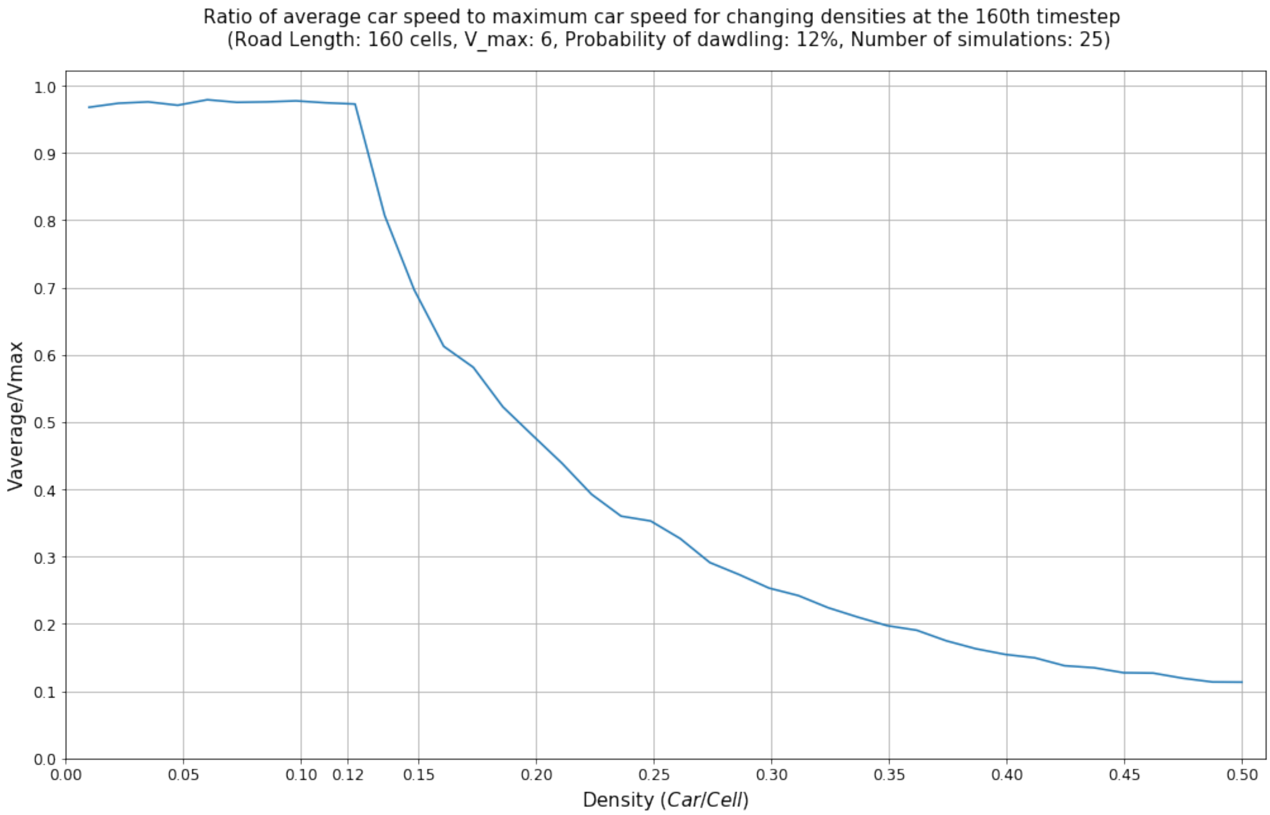


Fig 4.7: A plot that shows the effect of changing densities, on the ratio between the average speed of cars on the road to its maximum speed. The average ratio at the 160th timestep is obtained from results of 25 simulations, and is plotted against the density, ranging from 0.01 to 0.5 $cars/cell$. Independent variables are labelled on the plot.

4.2 Effects of varying dawdling probabilities on traffic flow

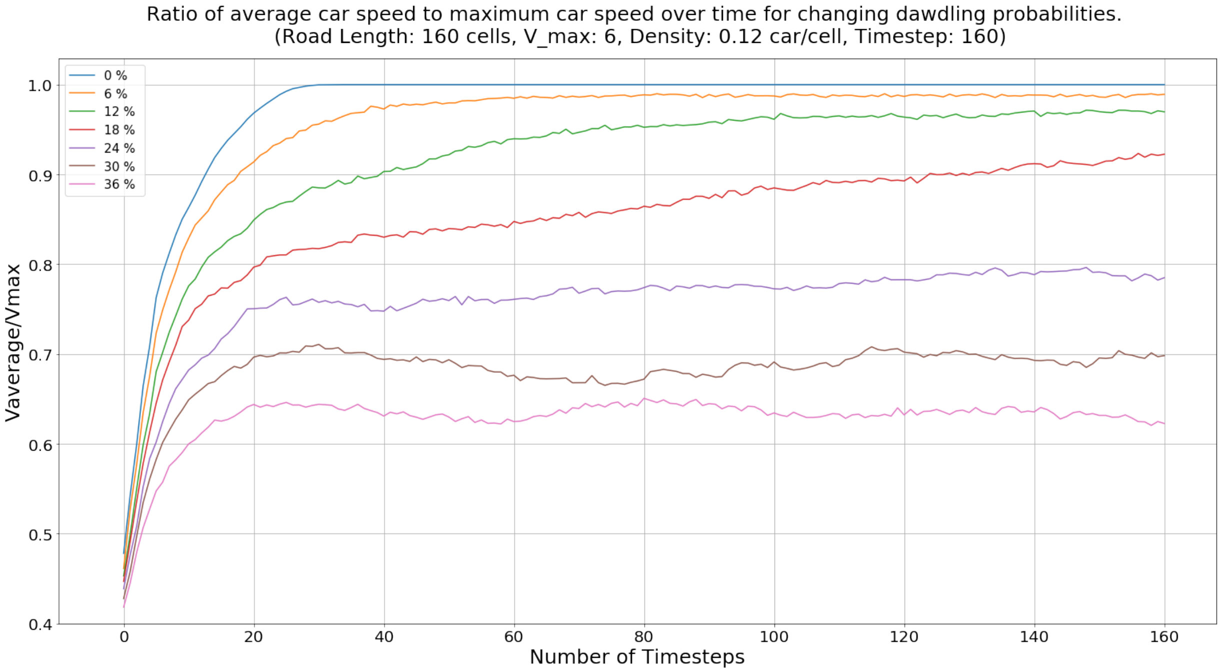
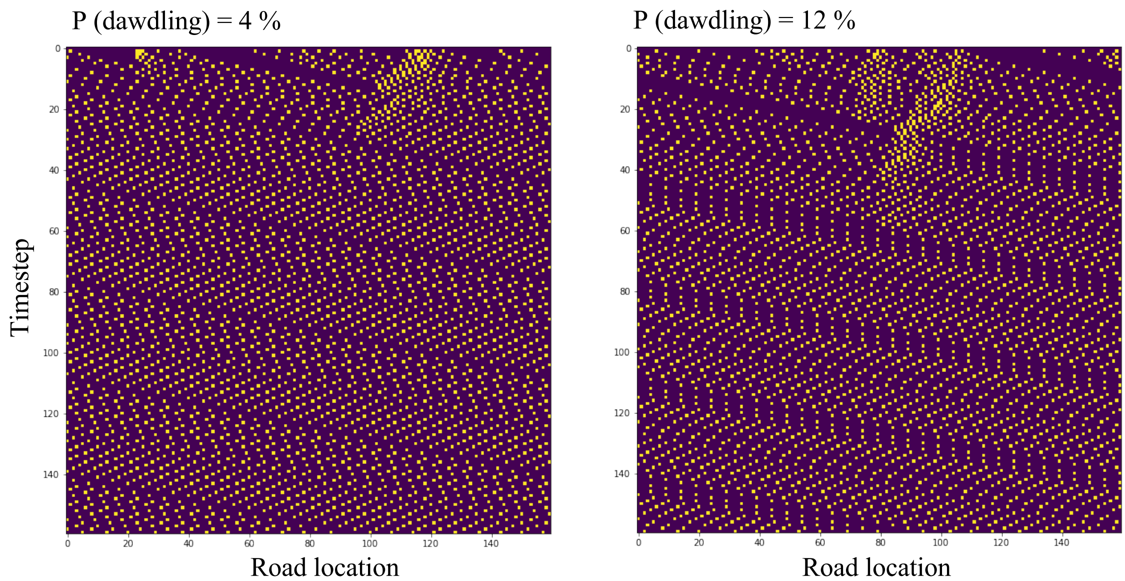


Fig 4.9: A plot that shows the effect of changing dawdling probabilities, from 0 to 36%, on the ratio between the average speed of cars on the road to its maximum speed. The average ratio at each timestep is obtained from results of 110 simulations, and is plotted against 160 timesteps. Independent variables are labelled on the plot.

When looking at how the dawdling probability affects the speed ratios over time, one sees that the ratios converge to lower values for increasing dawdling probabilities. This is reasonable, because with cars more likely to dawdle, the number of dawdling cars will generally increase, causing the motion of cars in the road to become less uniform. Hence, cars will become less evenly spaced, and they are more likely to slow down and cluster, resulting in a lower average speed ratio. In addition, the ratio difference gap between two successive dawdling probabilities is smaller for lower probabilities.

Fig 4.10 below shows the space-time diagrams for varying dawdling probabilities, and it can be observed that when the dawdling probability increases, a traffic jam lasting for longer timesteps begins to form on the road, thus further impeding and slowing down the overall car movement. This is consistent with the results shown in Fig 4.9.



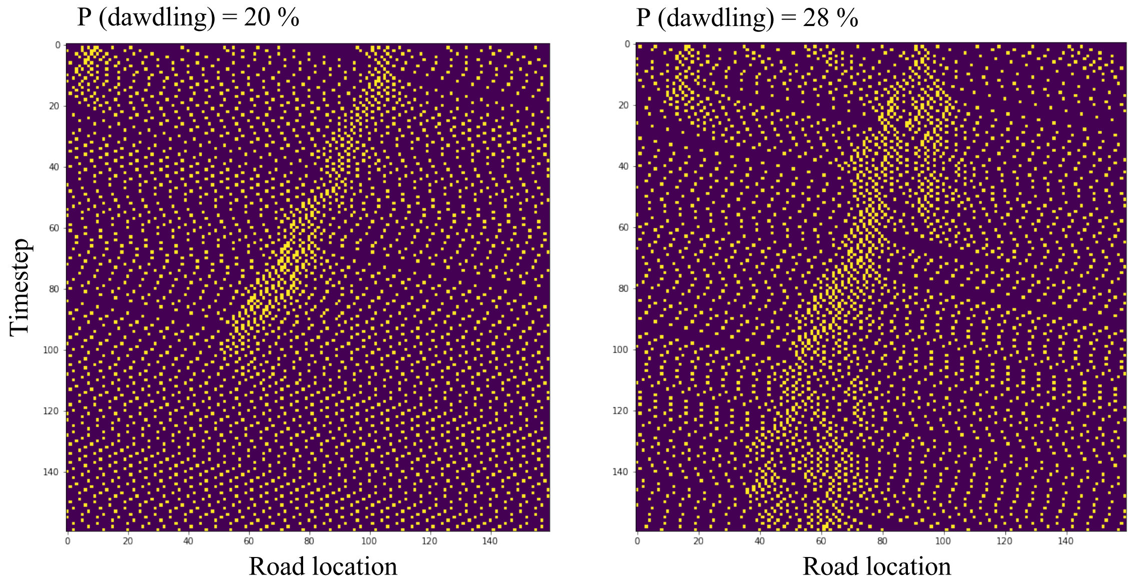


Fig 4.10: Space-time plots of the road traffic for varying dawdling probabilities, ranging from P(dawdling) = 4 % to P(dawdling) = 28 % . Independent variables: Road length = 160 cells, v_{max} = 6 cells/t, k = 0.12 cars / cell, Timestep = 160.

4.3 Effects of varying maximum speeds on traffic flow

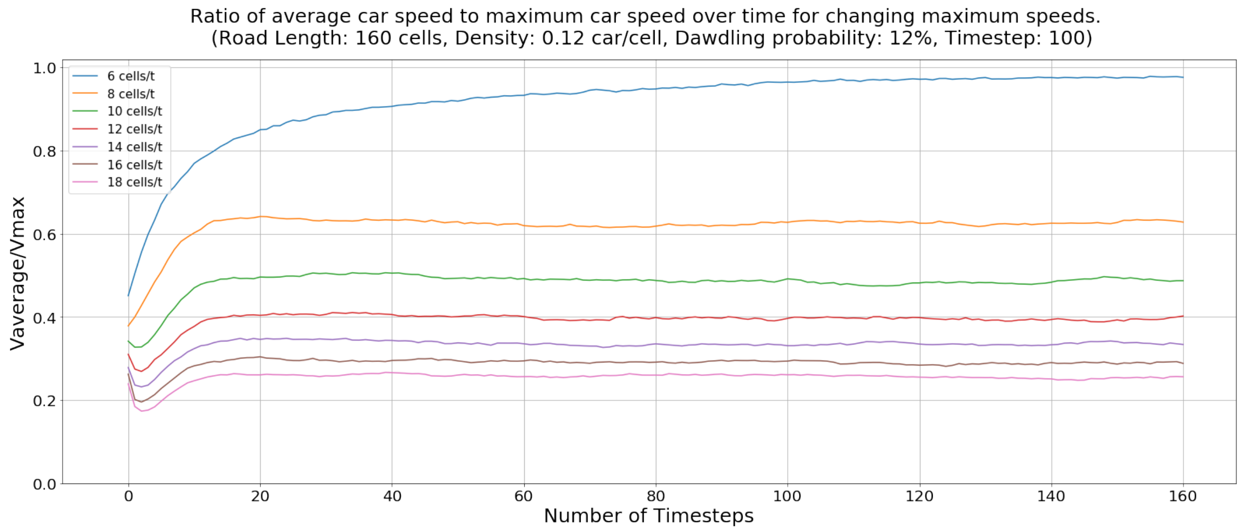


Fig 4.11: A plot that shows the effect of changing maximum speeds, ranging from 6 to 18 $cells/t$, on the ratio between the average speed of cars to maximum speed. The average ratio at each timestep is obtained from results of 110 simulations, and is plotted against 160 timesteps. Independent variables are labelled on the plot.

Fig. 4.11 shows the speed ratio for different maximum speeds, and shows that when the maximum speed of car increases, the speed ratio converges to lower value. This is because, with greater maximum speeds, the car would need more space between itself and the next car in order to accelerate to its v_{max}. However, because the road density is fixed, the average spacing between cars will not change, thus imposing a limit on the maximum speed a car may accelerate to. Since cars with greater maximum speeds are not provided with additional space needed to accelerate, this prevents them from travelling at their v_{max} and lowers their speed ratios.

Moreover, notice the speed ratios initially decrease for $v_{max} \geq 10\ cells/t$. This is because of the program's setup: when the maximum speeds of cars are set to be greater, they will generally be assigned greater speeds when introduced to a road, leading to a greater average initial speed. However, since the average spacing between cars is unchanged for any maximum speeds, this means that cars with greater initial speeds will not be provided with adequate space to maintain their motion, and thus will generally need to slow down more rapidly in the next few timesteps, as stated by rule 2. Therefore, the higher the maximum speeds, the more the speed ratios decrease from their initial values.

In order to observe how the maximum speed of car affects traffic flow, we look at the space-time diagrams for varying maximum speeds at road density $k = 0.16\ cars/cell$, and then compare those diagrams, as shown in Fig 4.12. Notice that the traffic becomes more efficient when the maximum speed decreases, as traffic jams begin to disappear on the road, and the gradients of the moving cars become increasingly constant, meaning that cars no longer start and stop and are able to move at constant speeds.

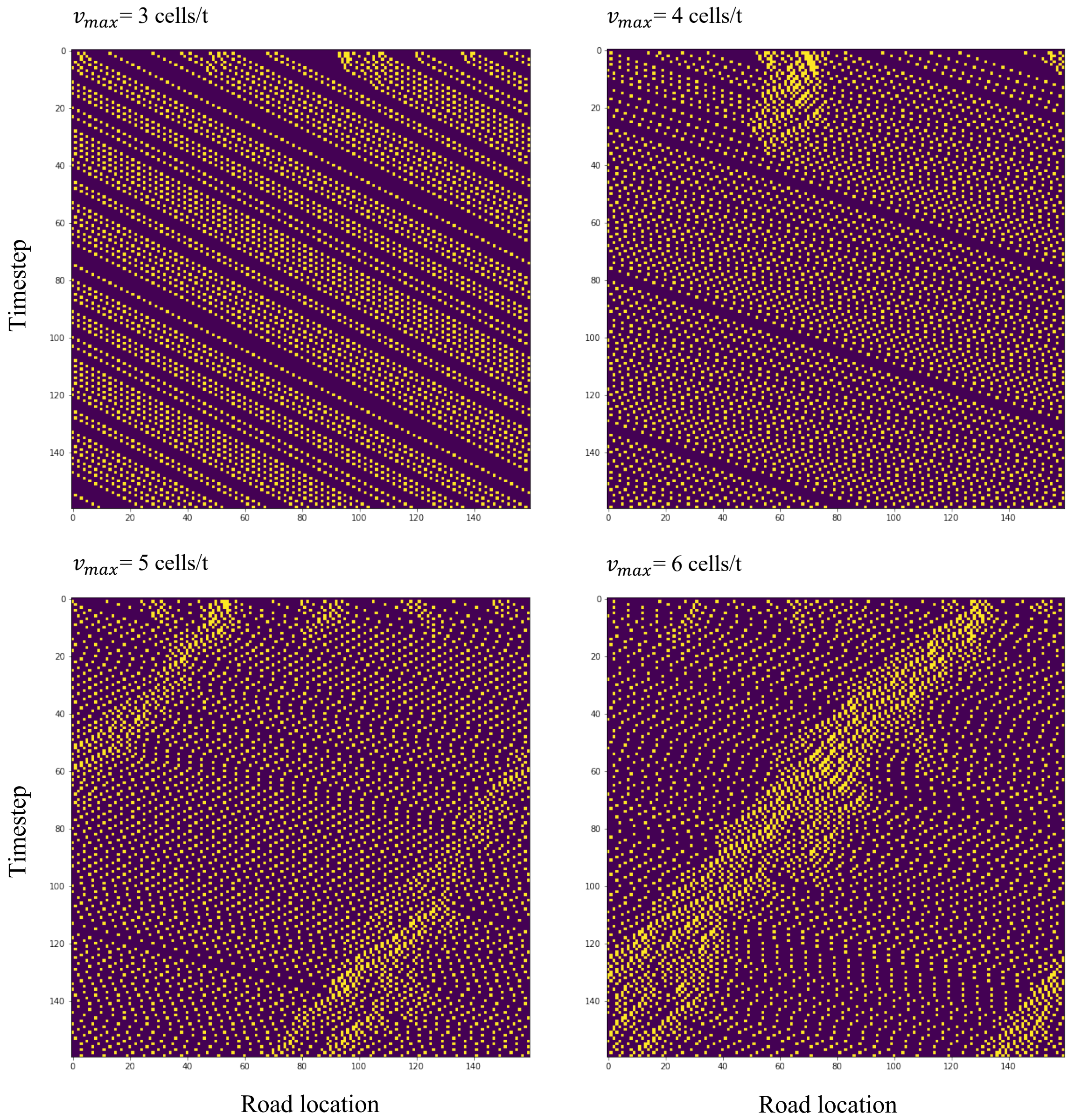


Fig 4.12: Space-time plots of the road traffic for varying car maximum speeds, ranging from v_{max}= 3 cells/t to v_{max}= 6 cells/t . Independent variables: Road length = 160 cells, k = 0.16 cars / cell, P(dawdling) = 12%, Timestep = 160.

Conclusions

The Cellular Automata traffic model has proven to be advantageous for simulating traffic flow in a single-lane system, and for identifying the key variables that affect traffic flow. By increasing either the road density, car maximum speed and dawdling probability, the model exhibits a transition from laminar traffic flow to start-stop waves, resulting in lower average speed ratios v_{aver}/v_{max}. This provides us with a couple of insights and takeaways: Instead of always looking to accelerate to its maximum speed, which could give rise to jams in the system, a driver should choose to move at the speed that seeks to maintains equal spacings between cars; by moving at the speed appropriate to its separation from the next car, and moving at equal speed to its adjacent cars. This would allow cars in the system to move smoothly across the road at constant speed. In a similar way, a driver can act to reduce dawdling to prevent cars behind from slowing down. Therefore, with responsible and rational driving behaviours, the road system would become more efficient, that is, a system whereby cars undergo less starts and stops, fuel consumption is reduced, and the average journeying time across the road is shorter.

In the future, the modelling of traffic can be extended to a two-lane system to study for the movement of cars in each respective lane and its resulting traffic flows. In addition, different types of vehicles. i.e., vehicles with different maximum speeds and lengths, can be introduced to a road system to study the lane changing behaviours of these different vehicles, allowing one to find out which lane, the left-lane or the right-lane, is preferred by each vehicle type. In order to allow for more lane-changing freedom, the model can be further extended to include road systems with more than two lanes.

To more closely mimic a motorway, features such as traffic lights, speed cameras and road intersections can also be included to produce a more realistic traffic model.

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