Basic Setting of the BML traffic model function used for this study

- In the *bml.init* function, a matrix of 0,1,2 with a 2-dimension r-by-c lattice was generated with density p, where 1 represented the blue car and 2 represented the red car. Their initial positions were random and uniform.

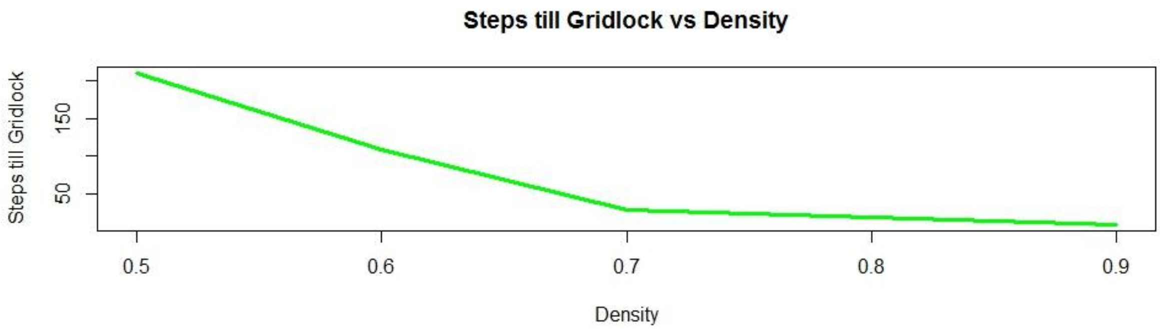
- In the *bml.step* function, in even step, all 1s move to the cell above it if there`s a 0, if it reach the boundary, it will move to the bottom of the matrix and In odd step the 2s undergoes a similar process only attempting to move to the cell to its right.

- In the *bml.sim* function, the function will keep applying the move function on the matrix, and **it will stop if the matrix remain the same after 1 movement *or* the matrix keeps changing after 1,000 movement.**

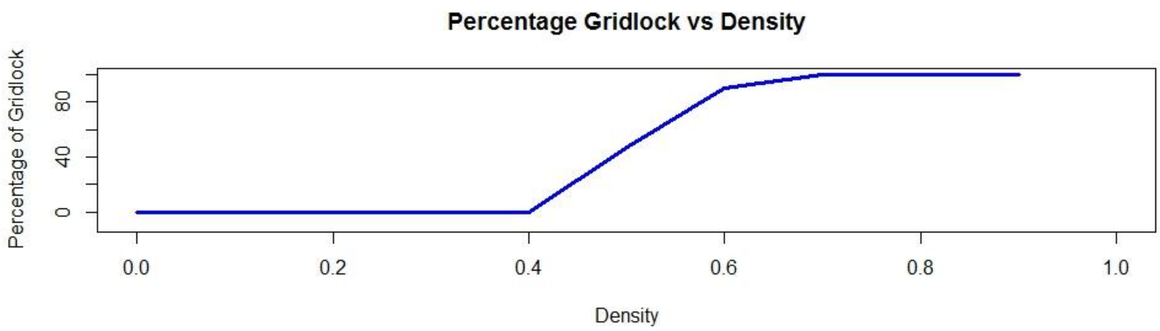
- In the *lock.count* function, it will repeat the *bml.sim* function for **100 times** and counts the steps before it hits the gridlock and **ignore** the case where there is free flow after 1000 movements.

The relation between the **density** and the percentage of gridlock and the steps taken

- In this study, the size of the matrix and row/column ratio were fixed by **100** and **1:1**, respectively and the density was taken an 0.5~0.9.



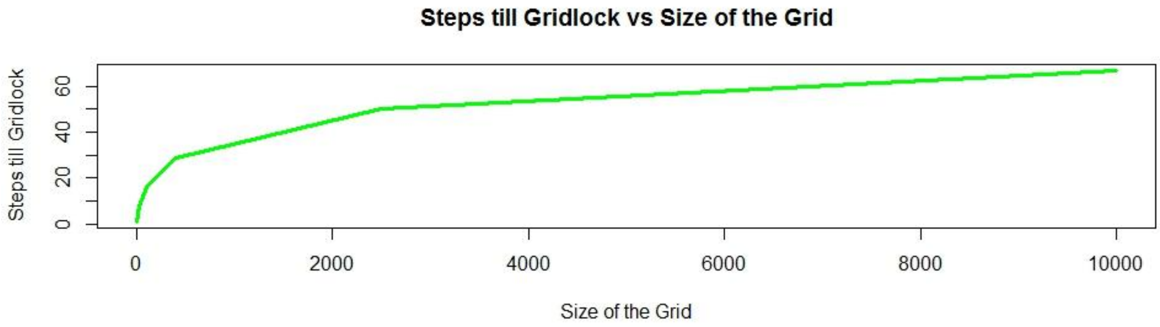
- This plot indicated that with a higher density, it took less step to hit the gridlock, which is intuitively true. The density can be think of "heaviness of the traffic". The heavier the traffic, considering every car trying to move at the same time, the harder for the cars to move.



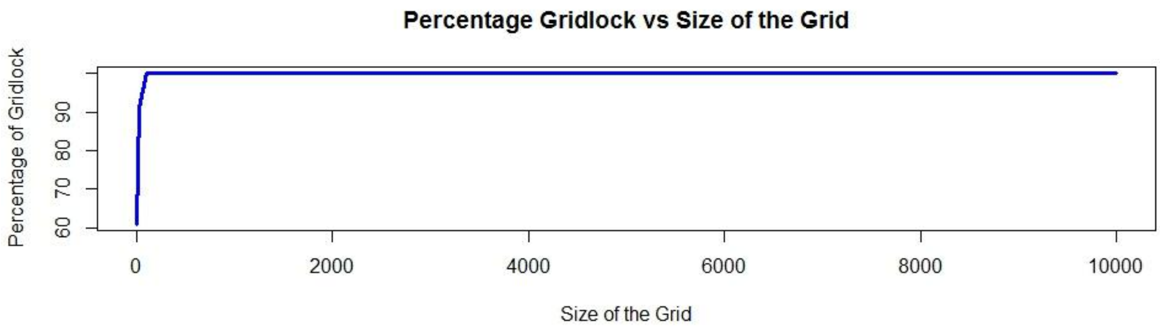
- The second plot indicates while the density is below a certain number, in this study, it is around 0.4, then the model will be completely free flow, while the density in 0.5~0.7, there will be a mixed situation of gridlock/free flow, and the percentage increase while the density becomes bigger and eventually become 100% gridlock.

The relation between the **size** and the percentage of gridlock and the steps taken

- In this study, the density and the row/column ratio were fixed at **0.8** and **1:1**, respectively and the size were taken from **2x2** to **100x100**.



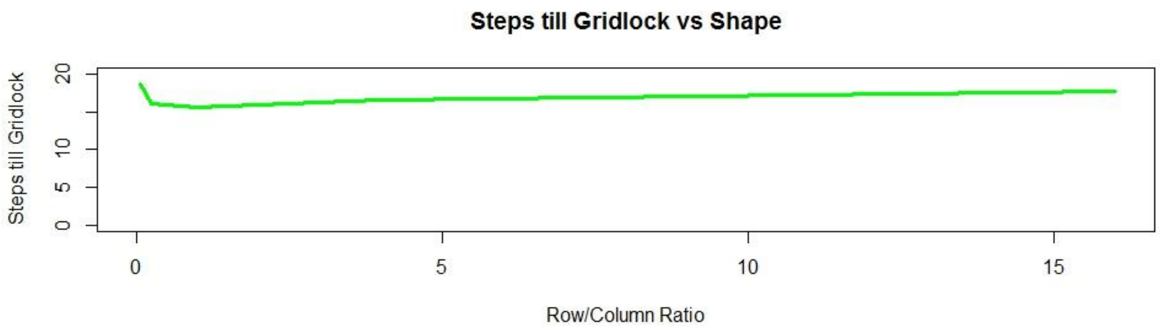
- This plot indicated that the larger the grid, more steps needs to be taken before the gridlock. Mathematically, there would be more empty space when the grid became bigger. Considering the cars only move 1 cell each time, if there`s more empty space, it is more likely the cell it was suppose to move in was empty.



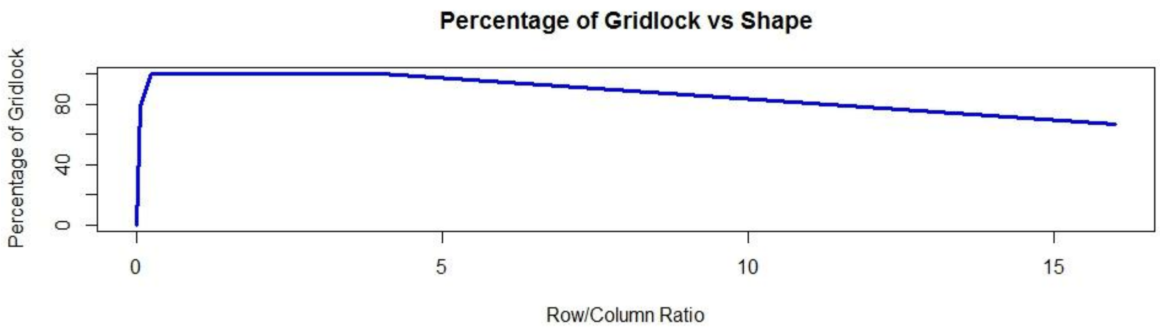
- This is somewhat interesting. There`re free flow when the grid size is small (in this case, both 2x2 and 5x5 grid has free flow) even the density is high(at 0.8).
  One possible explanation is when the grid size is small, the path of each car is relatively short. So it will be less like to cross the path of other cars hence there will be free flow.

The relation between the **shape** and the percentage of gridlock and the steps taken

- In this study, the density and the size were fixed at **0.9** and **400**, respectively and the size were taken from **2x2** to **100x100**.



- This plot showed that the shape will be affecting the steps when the ratio is extreme. But overall the model was quite stable in terms of shape.



- This plot also told an interesting fact that the grid may still be free flow when the ratio became extreme. This also could be explained by the theory from the previous issue. When the ratio becomes extreme, either the path of blue or the red cars became short, makes them harder to bump into other cars.

Conclusion

- The steps till gridlock will eventually stabilize when the density becomes bigger and eventually reach 0 when the density became 1. It is likely to increase when the grid size becomes bigger but the speed of increase will also be slower as the size got bigger. It was quite stable when the row/column was within a certain area, after that it changes quickly.

- The percentage was more interesting. Eventually, it could be considered as a probability of cars blocking each other. When the path of the car was short and the crowd was small, it would be less likely for cars to block others. But as the path of each car increase or more cars in the grid, there would be an increasing odds of them meeting each other. Hence the percentage of gridlock could be affected by density, size and shape simultaneously.