AN ALGORITH FOR MINIMIZING NUMBER OF COLLISIONS IN HIGHWAYS USING SWARM INTELLIGENCE

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DECLARATION

I hereby declare that the thesis titled "An algorithm for minimizing number of collisions in highways using swarm intelligence", submitted by me as a requirement for the fulfillment of degree of BSc in Electrical and Electronics Engineering, to the Depart of Electrical and Electronics Engineering, BRAC University, 66 Mohakhali C/A, Dhaka-1212, comprises only of my original work. Due acknowledgement has been given in the reference section to any materials used. The results of this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Road safety is a climbing inquiry everywhere throughout the globe these days. Research directed with respect to this issue utilizing different methodologies. Swarm robotics is a promising methodology portrayed by vast quantities of generally small and reasonable units. This paper will represent an algorithm that minimizes collisions on highways using the concept of swarm intelligence by considering the vehicles to be individual swarm units. As this algorithm has low calculation complexity, it shows warning sign fast, eventually avoiding a collision. That calculation meets expectations towards demonstrating a warning sign for avoiding dynamic obstacles timely, is ensured by observing the velocity and position of other swarm units. The proposed algorithm works for avoiding bi-directional dynamic obstacles.

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Chapter 1

Introduction

1.1 Objective

The objective of our thesis to propose a new algorithm that will be integrated with cars in highways and avoid collisions. The cars in highways will be equipped with nRF sensors. The nRF sensors will work following the mechanisms of swarm intelligence. Other than providing the algorithm, reducing the number of collisions in highways, and ultimately reducing the number of casualties and injuries is another prime objective. The massive amount of financial and human losses owing to accidents can be minimized.

This initiative means to help the community by giving a safe means of travelling on the highways. Furthermore, this study will provide a future pathway to the hardware implementation. Anyone willing to study further on highway accidents, collision avoidance (CA) algorithm and swarm robotics can take data from this thesis and further modify it.

1.2 Motivation

The abundance of accidents on highways of Bangladesh is one of the most alarming issues of the present time. Deaths of so many prominent people and commoners every other day touched me deeply. I wanted to work on developing the infrastructure to minimize the highway collisions. One of the major issues on the highways is cars not being able to see other cars and not perceiving the speed or the distance properly. This is why I have chosen this topic and worked on finding a viable solution.

Swarm robotics is an upcoming field in robotics. Swarm intelligence is the future of robotics and automation approaches. It is also relatively inexpensive.

1.3 Thesis Overview

In the report I have done a literature review where I discussed about the accident scenarios in Bangladesh. Furthermore, I discussed about the knowledge I gathered while researching about Swarm Robotics System, Swarm Intelligence and other related algorithms and optimizations, including ant swarms, honey bee swarms, particle swarm optimization. Application of swarm intelligence is also descriptively added in this report.

In the following chapter, I have presented my knowledge on Collision Avoidance (CA) algorithm and its methodology. Vehicle Model and Vehicle Safety Distance Model have been demonstrated in the later part of the paper. The proposed algorithm is given, alongside ideas on how to generate sample data-set for simulation purpose. In the last chapter I have given a conclusion and discussed the future scope of this thesis. References and appendices are given at the very end of this paper.

Chapter 2

Literature Review

2.1 Accidents on highways of Bangladesh

There has been a disturbing climb over highway accidents, altogether roadway accidents, in Bangladesh over a long time. As stated by an investigation led by Architecture (ARC) of BUET, street mishaps case on normal 12,000 [1] exists yearly and prompt over 35,000 [1] damages. As stated by World Bank statistics, yearly fatalities from street mishaps was found to be 85.6 [1] fatalities for every 10,000 [1] vehicles. Hence, those streets in Bangladesh have ended up deadly.

However these statistics, numerically stunning they might be, fizzle with reflect the social catastrophe identified with each term lost to way too many mishaps. One memory that I can recall more than once is the demise of 44[2] school children one July, where the truck couch they were voyaging in slipped and fell under a pond. 44[2] juniors dreams and trusts lost because of rash driving.

Fig 2.1.1: 44 school kids died back in 2010 in a road accident

[1] S.M. Sohel Mahmud, Transport System in Bangladesh: Issues and Options for Sustainable Development, 2015
[2] http://www.bbc.co.uk/news/world-south-asia-14106051

Just a month afterward this tragedy, Bangladesh lost two splendid citizens, movie producer Tareq Masud and writer Mishuk Munier, in a road mishap owing to the driver's fault [3]. We, the individuals were shocked, goaded; what's more a number headed challenges of the lanes requesting prompt activity should achieve justice for the individuals murdered. Likewise, from the lines cited to start with starting with everyday newspaper, one could view that those casualty rate figures express no progress.

A secondary development for urbanization and mechanization could make identifier as a standout amongst those variables prompting those higher amounts of street mishaps[4]. Late investigations case that those twelve-month urban Growth Rate on Bangladesh remained in 4%[4] over 2010, in as much as the introduce development.

Year	Number of Accidents	Death	Injury
2009	**3381**	**2958**	**2686**
2010	**2827**	**2646**	**1803**
2011	**2667**	**2546**	**1641**
2012	**2636**	**2538**	**2134**
2013	**2029**	**1957**	**1396**
2014	**2027**	**2067**	**1535**
2015	**2394**	**2376**	**1958**
2016(Up to July)	**1489**	**1422**	**1289**

Table 2.1.1: Number of Accidents, Deaths and Injuries according to BRTA (Bangladesh Road Transport Authority)

[3] Zahangir Shah, Tareque, Mishuk among 5 killed, The Daily Star, 2011
[4] Bangladesh Road Transport Authority, Statistics of accident and casualities, 2016

Consequently, the way frameworks need aid encountering more amazing congestion, physical crumbling safety issues. As stated by a WB report, main 40%[5] of the fundamental streets (National Highways and the Zila Roads) need aid on useful state.

According to the World Health Organization, around 1.25 million [5] people worldwide die each year as a result of traffic crashes. These accidents are caused, mostly because of bad infrastructure of highways, driver reaction time, traffic situation on the road, bad condition of roads, weather change, not having proper guidance about driving and mostly, overtaking.

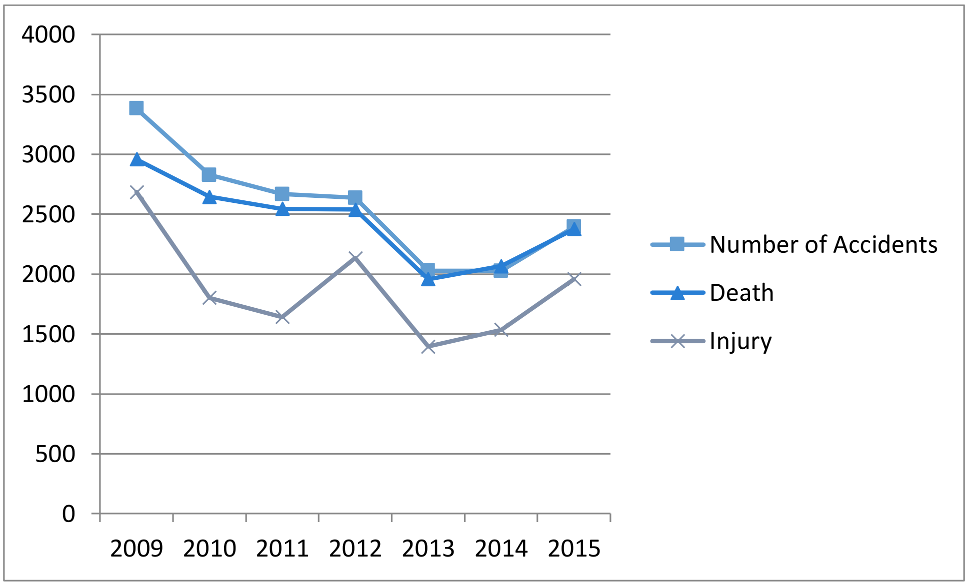

Fig 2.1.2: Yearly scenario of death and injuries on highways.

2.2 Swarm Intelligence

In various areas like computer science applications, robotics etc. there always arise a need to design an intelligent system capable of

[5] World Health Organization, Road Traffic Accidents, World Bank Blogs, 2015

performing complex tasks with the help of multiple self-organizing autonomous nodes which are distributed in nature and have no central control [1]. Many researchers were inspired by collective behavior of groups of animals like school of fishes, flocks of birds and social insects like ants, bees etc. while designing such systems.

Various algorithms were designed for distributed problem solving devices based on the intelligent behavior of swarms. This way of problem solving which was inspired by the intelligent collective behavior [3] of swarms was defined as swarm intelligence. In nature swarms (ants, bees, termites etc.) consists of simple creatures as individuals which have limited intellectual capabilities still the swarm as a whole presents an intelligent and efficient solution for complex problems such as shortest path finding [3], predator evasion. If we take the example of ants and bees they both search for their food but using somewhat different strategies. Ants are capable of finding the shortest path for their food and they do it by communicating through their environment using a chemical substance called pheromones as they can’t communicate directly. This indirect communication through the environment is known as stigmergy [4].

Honey bee swarms are capable of finding good quality food sources. They do it by sending their scout bees [1] to search for food sources and then after searching good quality food source scout bees perform a kind of dance which encodes some information by which conveys the direction and quality of the food source. The location for which enough number of scouts vote is chosen. Thus based on such intelligent behavior of swarms various algorithms have been designed.

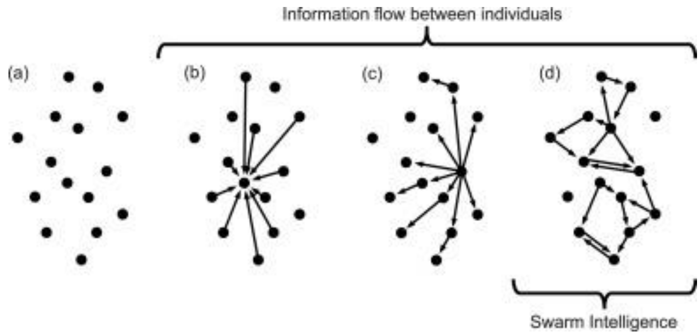

Fig 2.2.1: Bridge between individual swarm units [2]

2.2.1 Ant Swarms

An ant colony consists of a complex social structure in which each ant type has its own functions to do in the rest if its life. Ants in the colony include a hierarchical organization [5]:

* Queen ant is responsible for laying eggs for future colony members.
* Soldier ants take care of the whole colony defending the nest from other insects, including ants belonging to other colonies.
* Explorer ants look for food leaving pheromone traces in their path.
* Worker ants follow pheromone path left by explorers' ants.

There exist many ant-based algorithms, nevertheless the most important one is Ant Colony Optimization (ACO) algorithm. ACO is inspired by the experiment described in Fig 2.2.2. An ant colony has access to a food source through a bridge which has two paths [6], one longer than the other. After certain period of time, most of the ants will end up going through the shortest path. Furthermore, the probability of choosing this shortest [6] path increases in proportion to the difference between the shorter and longer path distances. Ants have the ability to modify the environment they explore by leaving tracks [5] of pheromone on the soil. In a decision point (path bifurcation) the probability of selecting one particular path [5] is based in the quantity of pheromone they sense on each path. Ants choose the shortest path by following paths marked by other paths that have got to the food source and back to the nest in the least [5] amount of time. Followings ants sense more pheromone in the path increasing the probability for the next ant choosing the same shortest path.

Fig 2.2.2: Bridge between nest and food source [6]

In the ACO algorithm the main task is for each ant to find the shortest path [5] between a source node s and a destination node d as highlighted in blue and shown in Fig 2.2.3. In these problems route length is computed by minimizing the number of hops the ant has to take.

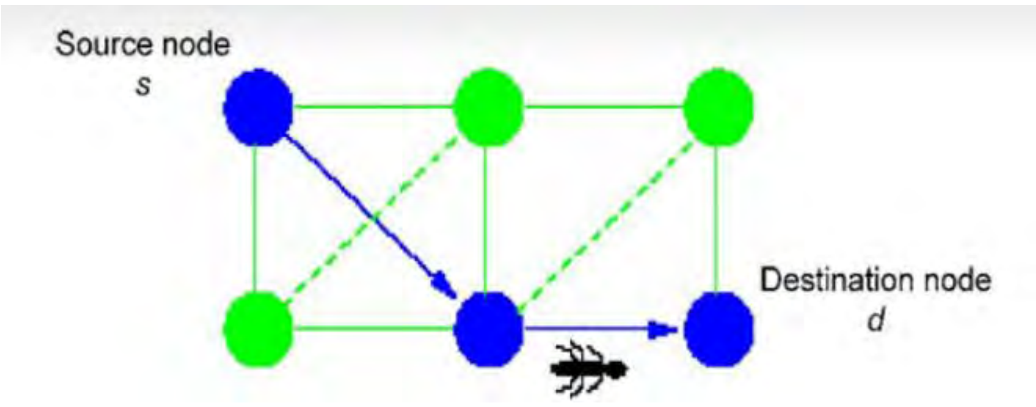

Fig 2.2.3: Optimal route of length two from source node s to destination node d. [6]

2.2.2 Honey Bee Swarms

Another interesting swarm in nature which has been used as an inspiration for an efficient and intelligent distributed system is honey bee swarm [7]. Honey bee swarms are capable of dividing various tasks among bees in the swarm dynamically in an intelligent manner. Bees perform their various day to day tasks like foraging, storing, retrieving and distributing honey and pollen, communication, predator evasion and adapting themselves to the changes in the environment in a collective manner but without any central control [7]. Various algorithms have been by using intelligent behavior of bees to model distributed systems with autonomous nodes. Foraging [7] in bee swarms is different than that in ant swarms. An algorithm serving the same purpose as that of Ant Routing Algorithm i.e. finding best path between source and destination in an ad hoc network is designed using food foraging in bee swarms.

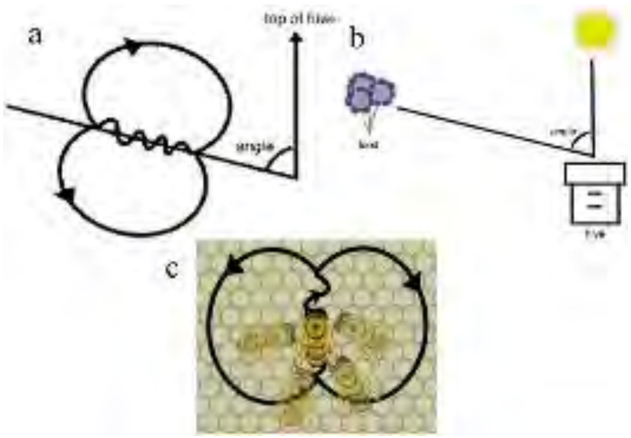

Fig 2.2.4: (a) Orientation of waggle dance with respect to the sun; (b) Orientation of waggle dance with respect to the food source, hive and sun; (c) The Waggle Dance and followers [7]

2.2.3 Particle Swarm Optimization

It is a Meta heuristic for stochastic optimization of continuous functions which is based on the foraging behavior of flocks of birds [8]. This technique is inspired by the way the swarms of birds search for their food. In this technique it is imagined that a flock of birds is searching for their food in a particular area and in that defined area there is a single piece of food. Now to reach to the exact location [8] where the food is laying, the flock of birds will flew in a way that each bird will follow the bird in the flock which is nearest to the food. The algorithm works by assuming that each virtual bird knows its personal best position X_{pbest} and globally best personal value X_{gbest}.The velocity and position of birds are modified in each iteration using following equation [8]:

$$V' = V + C_1R_1(P_{best} - X) + C_2R_2(G_{best} - X) \quad (1)$$

$$X' = X + V' \quad (2)$$

In above equations V and V' are current and new velocities respectively and X and X' are current and new positions respectively while C_1 and C_2 are the acceleration coefficients and R1 and R2 are distributed random variables. Inspired by the behavior of birds, takes particles at random positions as that of birds and every particle is a solution in the search space [8] for the problem.

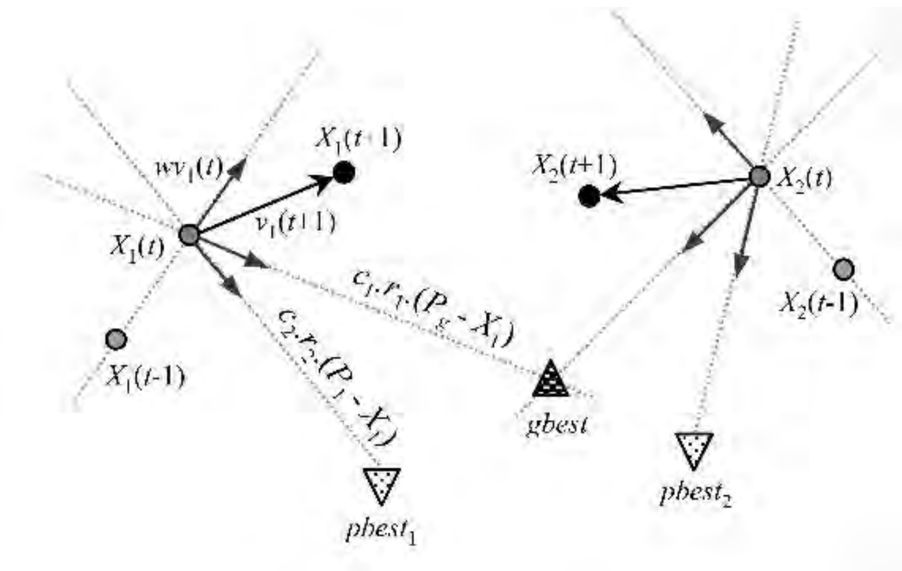

Fig 2.2.5: Function used to define particle position [8]

2.3 Application of Swarm Intelligence:

Thus various algorithms have been discussed so far based on the intelligence of different swarms i.e. ants, bees, termites and birds. But instead of limiting the scope of swarm intelligence to a specific swarm a general framework for problem solving technique based on swarm intelligence can be designed. This common framework includes all the characteristics of swarms. It is considered as a multiagent system in which agents communicate through the environment for solving the given problem. This general framework follows the following principles [9]:

Principle 1: This principle says that swarm artificial intelligence uses a multiagent [9] system in which the problem is divided into various subtasks and different agents perform the subtask given to it. All the agents are autonomous in nature i.e. there is no central control on any agent. It is the task of the designer to divide the problem into various sub problems in a logical manner.

Principle 2: This principle says that an agent in swarm artificial intelligence has to be fast in processing, simple in working and should be of limited perspective. However an agent can receive any kind of sensory information [10] but to be simple in working it should consider only that information which is needed to perform the task given to it. Thus only small amount of information will be processed by it as an agent is responsible for the subtask given to it not for the whole problem. Also the processing will be faster as small amount of information is processed by it.

Principle 3: If we consider the first two principles alone then it looks like Swarm AI takes into account the locally important data only and neglects the globally important data. But the third principle does away with this concern by providing a way to the system to act globally. The third crucial characteristic of Swarm AI is that its agents are capable of communicating with each other indirectly and in a simple manner [10].

More concisely we can say that this communication can take place in two ways. First way of communicating information is by altering the environment in a manner such that the other agents can take crucial decisions by noticing the change in the environment and this way of communication is known as stigmergy [10]. In the second method an agent communicate the information to the other agents by changing its own state such as its location or velocity so that other agents can act differently depending upon the information conveyed to them.

Chapter 3

Collision Avoidance Algorithm

3.1 Collision avoidance:

The paper creates a wellbeing impact separation model through numerous car principle knowledge (collision avoidance methodology on highways, vehicle model, vehicle safety distance model etc). In addition, the target vehicle's position and speed at the present moment are considered to improve the safety collision model. Thus, the model successfully decreases those numbers from claiming false caution. Here, every vehicle is considered as individual swarm units.

3.2 Collision avoidance technique on highways:

Ideally, each car needs an nRF [14] sensor in both front and back of the car which communicates with all the cars inside a 250 meter range [15], sending information from speedometer alongside position from GPS. Those nRF sensors go about as both information transmitters and receivers [14]. The algorithm functions based on the data received from the nRF sensors. We used dataset generated by a system designed on MATLAB that includes all possible real life traffic scenarios. The data acquisition process is described on the later part of this paper. Acknowledging situations in light of impact conditions, this methodology is developed to minimize collision on highways.

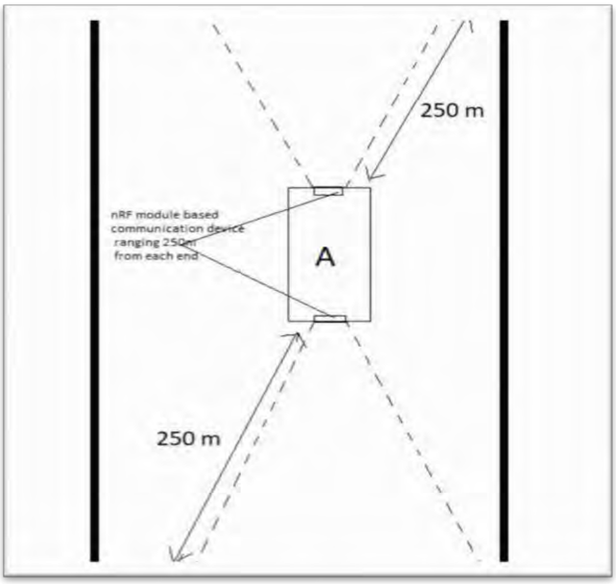

Fig 3.2.1: nRF based car model considered as individual swarm units

Car A represents all individual swarm units that have nRF module based communication device that sends and receives data from each car in a range of 250m [15] from both end individually.

$0<S_A<|S_{max}|$; $S_{max} = [-S, S]$; $S< 435.31$ km/h[6]

Where, S_A denotes speed of my car, A. S_{max} is the maximum speed of my car in kilometer per hour.

When vehicles on the highway, starting position $Z(x_0, y_0)$ of the vehicle in t_0 obtained by GPS.

3.2.1 Sample data set construction:

Development of a few sample data-sets was the first step of the methodology. As per the first assumption, we need two parameters from

[6] Speed and Acceleration Characteristics of Different Types of Vehicles on Multi-Lane Highways Arpan Mehar1 Satish Chandra2, and Senathipathi Velmurugan3

each car to make the algorithm lightweight and less complicated, so that it can show the warning sings fast and minimize the risk of collision.

As the most elevated speed of a car have been acknowledged under 435 km/h[6], the maximum speed any car is considered to be that. Velocity, as we know cannot be negative, so the minimum speed is considered to be zero. The sample dataset was generated using MATLAB2017a software with a separate generator function, where coordinate position of the cars were considered to be realistic as all the negative values for coordinate points have also been included in the generator. Which in other words, is the position extracted from GPS from the hardware device of the vehicle.

At the moment of the vehicle front wheel steering angle obtained by the sensor inside the vehicle ,so as to vehicle speed S vehicle acceleration a ,If we know the length and width of the vehicle h,w, and the distance from vehicle front axle to vehicle rear axle, L.

3.2.2 Vehicle model

The vehicle is modeled as a unicycle-type [12] vehicle,

$$\dot{x}(t) = u\cos(\psi(t)), \qquad x(0) = x_0, \tag{3}$$

$$\dot{y}(t) = u\sin(\psi(t)), \qquad y(0) = y_0, \tag{4}$$

$$\dot{\psi}(t) = r(t), \qquad \psi(0) = \psi_0, \tag{5}$$

Where, x (t) and y (t) are the vehicle's Cartesian coordinates, u is the forward speed, and $\dot{\psi}$ (t) and r (t) are the heading and heading rate.

Similarly, the vehicle model is designed for the algorithm proposed in this paper. Here, obstacles are considered to be of any type and size to be considered as another swarm unit using the above mentioned equations

According to the vehicle coordinate position Z (x_i, y_i), the angles of vehicle body ψ, the length and width of Vehicle h,w at it, we can calculate the coordinate position of vehicle B with respect to vehicle A using equation 3.

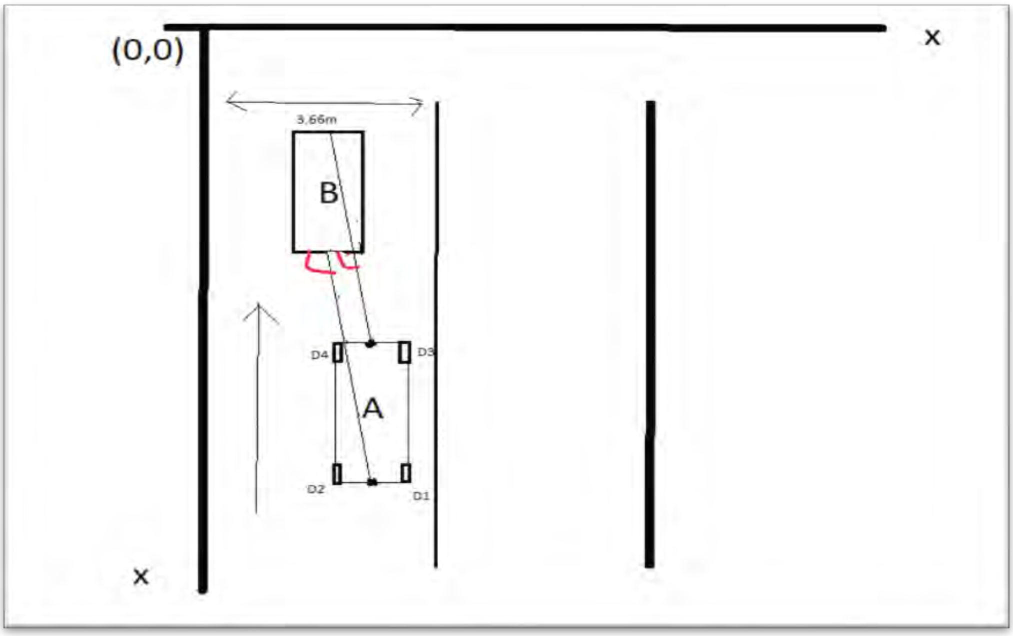

Fig 3.2.2: Car B position with respect to Car A

3.3 Vehicle safety distance model:

A vehicle safety distance model was developed for making overtaking decisions for this algorithm. Overtaking decisions, however depends on a few parameters like the time taken by the said car to overtake the car in front. Human reaction time during driving is another important parameter as it varies from person to person. Width of a single lane, the length of an average car is also considered for developing this model.

Overtaking Time of car, T = 4s [7]

Width of a lane = 3.66m [8]

Human Reaction Time during driving, T_r = 0.25s

Algorithm Threshold Time, T_h = 0.05s [22]

Car Length, h = 4.5m [9]

Assumption 2:

Safety Distance, S = 1m

Future position of my car, $Z*$

For safety cases, $S_1 = Z_A - Z_D \geq S$

For, Risky scenarios, Risky = $\{C < (T_r + T_h) \times S_A \leq S$

Here, C represents collision between the swarm unit in my car and any other swarm unit thus any other vehicle. S_A denotes the speed of car A, the swarm unit to be observed.

If at any position, the incoming car from the opposite direction hits my car, in the case of safety, all of the following will have to happen, the car will be considered to be safe to overtake any incoming or upcoming car.

[7] The interpretation of reaction time in information processing research Robert G. Pachella Michigan University 3 seconds rule; Thumb rule of driving safety

[8] Evaluation of average effective vehicle length in queue: New England Section ITE Technical Committee

[9] Eng. GolamMostofa, Assistant Engineer, Local Government Engineering Department, Dhaka District Office

When,

$$Z^*{}_A S_A - Z^*{}_B S_C > S$$

$$Z^*{}_B S_B - Z^*{}_A S_B > S$$

$$Z^*{}_c S_c - Z^*{}_c S_c \geq S$$

Where, $Z^*{}_A = Z_A S_A + S_A T_{OT}$ (6)

$Z^*{}_B = Z_B S_B + S_B T_{OT}$ (7)

$Z^*{}_C = Z_C S_C + S_C T_{OT}$ (8)

Now, for the time required to develop the overtaking decision, a separate model for time is mentioned here. This time is denoted by t and derived as follows, where S_u denotes the speed generalized swarm unit to be observed for overtaking decision making procedure, S_v triggers at the speed of the swarm unit in front of S_u.

Time, t = (Z^*S_u – Z^*S_v + S) / (S_A – S_B), if $S_A \neq S_B$

Otherwise, time = 0;

$$Z^*{}_A S_A = Z_A S_A + S_A t_A$$

$$Z^*{}_C S_C = Z_C S_C - S_C t_C$$

$$Z^*{}_E S_E = Z_E S_E + S_E t_E$$

In the cases of risky scenarios, where the collision depends on the drivers reaction time. Studies show, that the reaction time [22] of the driver depends on a few factors like the expertise of the driver, his/her experience, if the person is sleepy or not etc.

$$R=\begin{cases} (Z^*{}_C S_C - Z^*{}_A S_A) * (S + T_r + T_h) * (S_A + S_C + S) \\ (Z^*{}_A S_A - Z^*{}_D S_D) < (\mathrm{S} + (-(0.2 * T_h) + T_r) * (S_D - S_A)) + \mathrm{S} \end{cases}$$

R denotes to the cases where it is risky to overtake the car in front and might result into collision.

Where,

$$Z^*{}_A = ZS_A + S_A T_{OT}$$

$$Z^*{}_C = ZS_C + S_C T_{OT}$$

$$Z^*{}_D = ZS_D + S_D T_{OT}$$

Here, all the parameters denote to attributes which are mentioned previously.

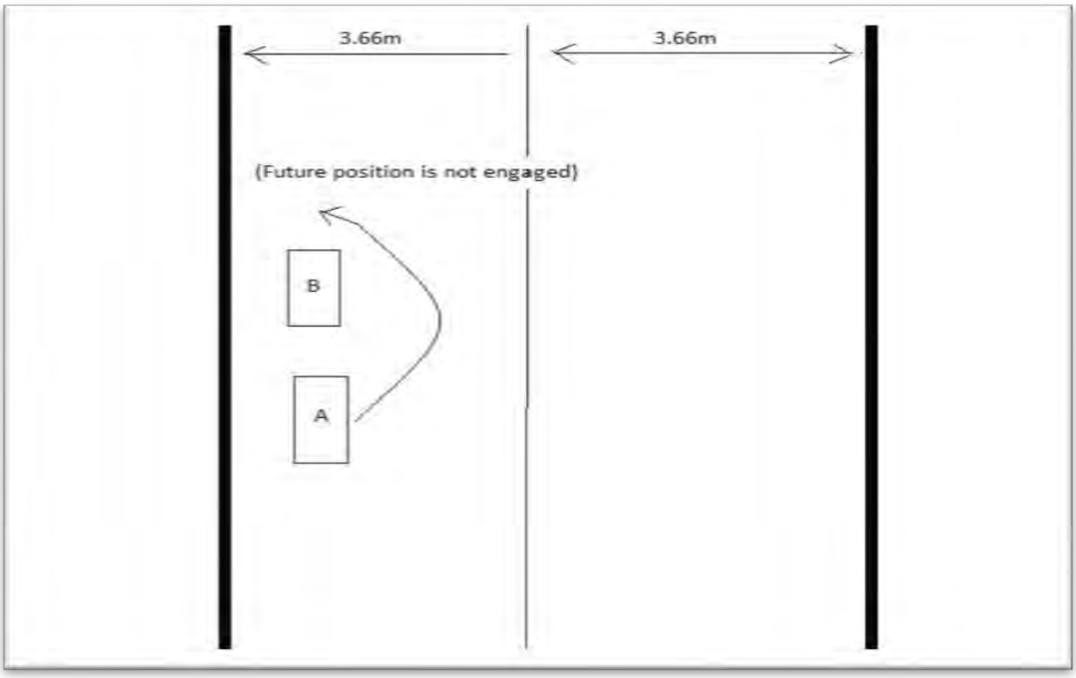

Fig 3.3.1: Future position is not engaged by any other car

In Fig 3.3.1, Speed of my car A, is greater than speed of the car that is infront of my car, B denoted as $S_A > S_B$. Here, future position of my car $Z^*{}_A$ is not engaged by any other car.

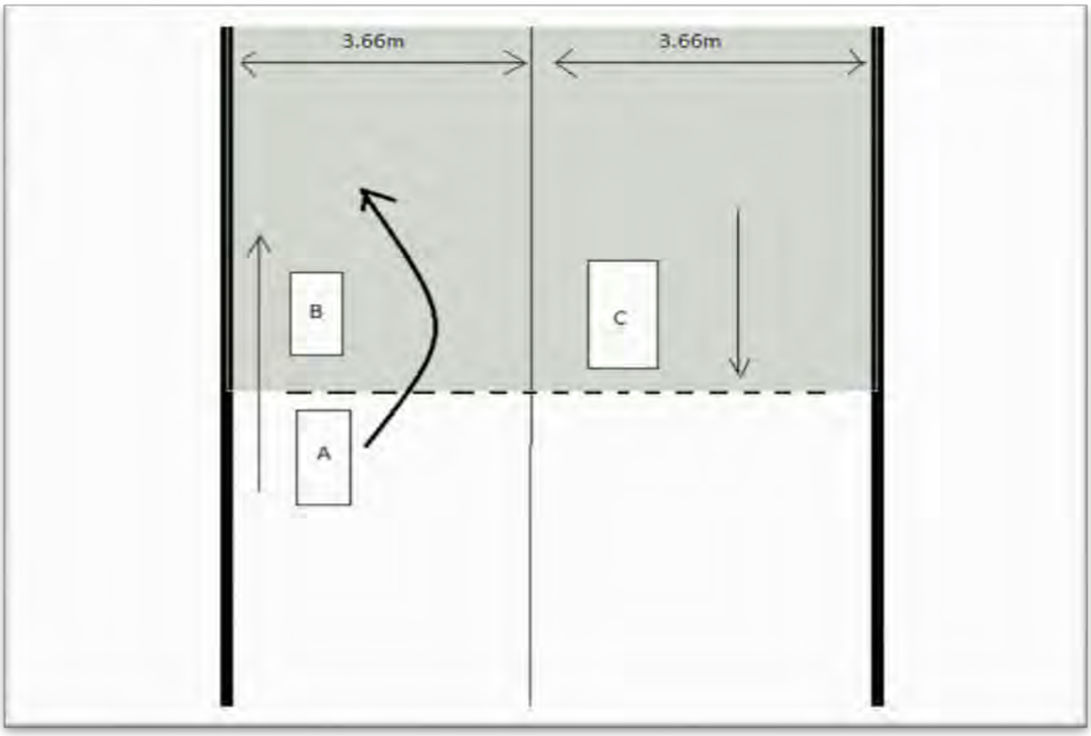

Fig 3.3.2: Car C is coming from opposite direction.

Considering a second case in Fig 3.3.2, a car C is coming from the opposite direction and Car A and Car B have a same speed as described in Fig 3.3.1. Here, the speed of car C is a matter of concern as the overtaking decision for car A as $S_A > S_{B;}$ C.

However, all the other cars that are in the white zone coming from the opposite direction are not considered, as that is not possible in terms of colliding with car A.

Collision cases do not depend on $S_{C.}$

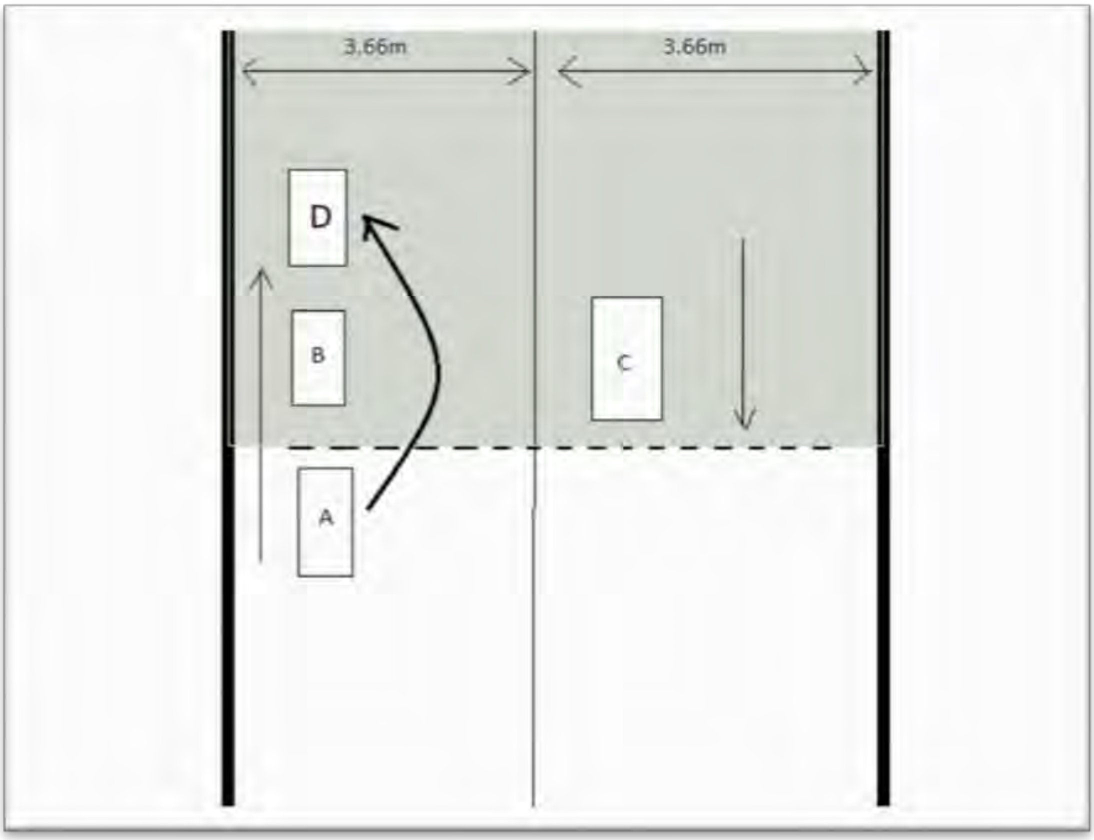

Fig 3.3.3: Future position is engaged by any other car with higher speed

Now for Figure 3.3.3, the future position of my car, Z* is engaged by another card D, where, Speed of my car A is greater than the speed of car B. car C runs with a greater speed than car A. Car D, however, may or may not run at a speed greater than car A.

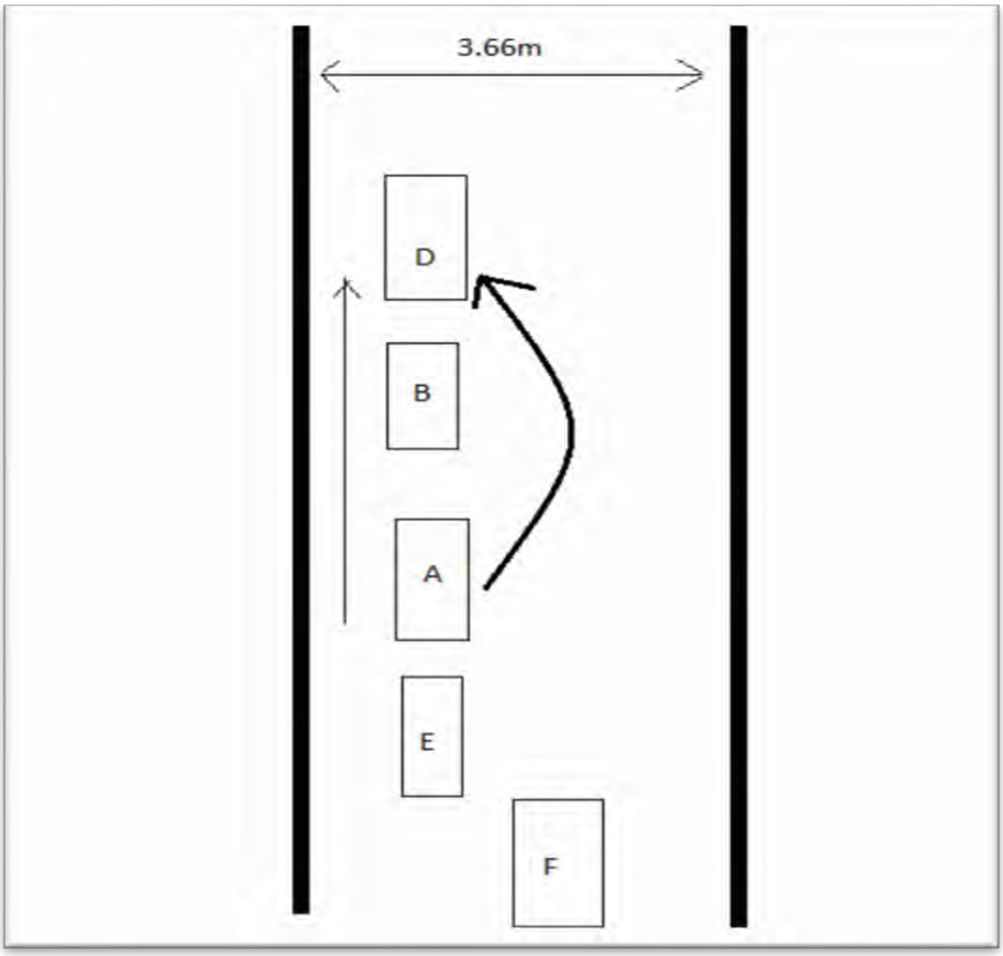

Fig 3.3.4: Optimization for cars on single lane

For a single lane, a car F Another car F (S_F>S_E) is coming from behind might cause a collision for car A. So, this condition is included in the algorithm for avoiding such situations where, cars A is running at a speed higher than that of car B. S_E>S_A> S_B. Z^*_A is engaged by car D.

Car E is coming from behind of car A, where, another car F is coming from behind of car E. Now, as mentioned in Fig 3.3.4 the speed and position of car F will be transmitted to car E and car E will be transmitting it to car A. Thus, car A will make its overtaking decision according to the algorithm.

For any kind of calibration during the scenarios mentioned above,

For, car A, B, C, D, E, F

$$Z^{*}{}_{u} = Z_{v} - Z_{A} \tag{9}$$

Next calibration for car A, B, D, E, F

$$Z^{*}{}_{u} = Z_{v} + S_{u}t \tag{10}$$

For car C,

$$Z^{*}{}_{u} = Z_{u} - S_{u}t \tag{11}$$

$$\text{Over taking decision} = \begin{cases} 1;\ \text{Distancebetweenallcars} = \text{S1} \\ 1;\ \text{Distanceoffirsttwo} > \text{S1} \\ O; Reactiontimes < .25 \end{cases}$$

To justify all the theoretical facts stated above, a simulation using MATLAB2017a software was conducted. Numerous sample data set were generated and used for the simulation purpose as inputs. The results of the simulation is discussed in details with necessary figures in the later part of this report.

3.4 Experimental Results

The experiment conducted as a simulation in MATLAB2017a software, took two parameters, velocity and position of each swarm unit generated by the generator model developed separately as described in 3.2.1. The output is shown in the form of number of cars which were saved from collision before and after using the algorithm proposed in this paper for different sample data set. In each graph, black denotes swarm units that avoided collision successfully, on the other hand, white shows the units that had collision with other units.

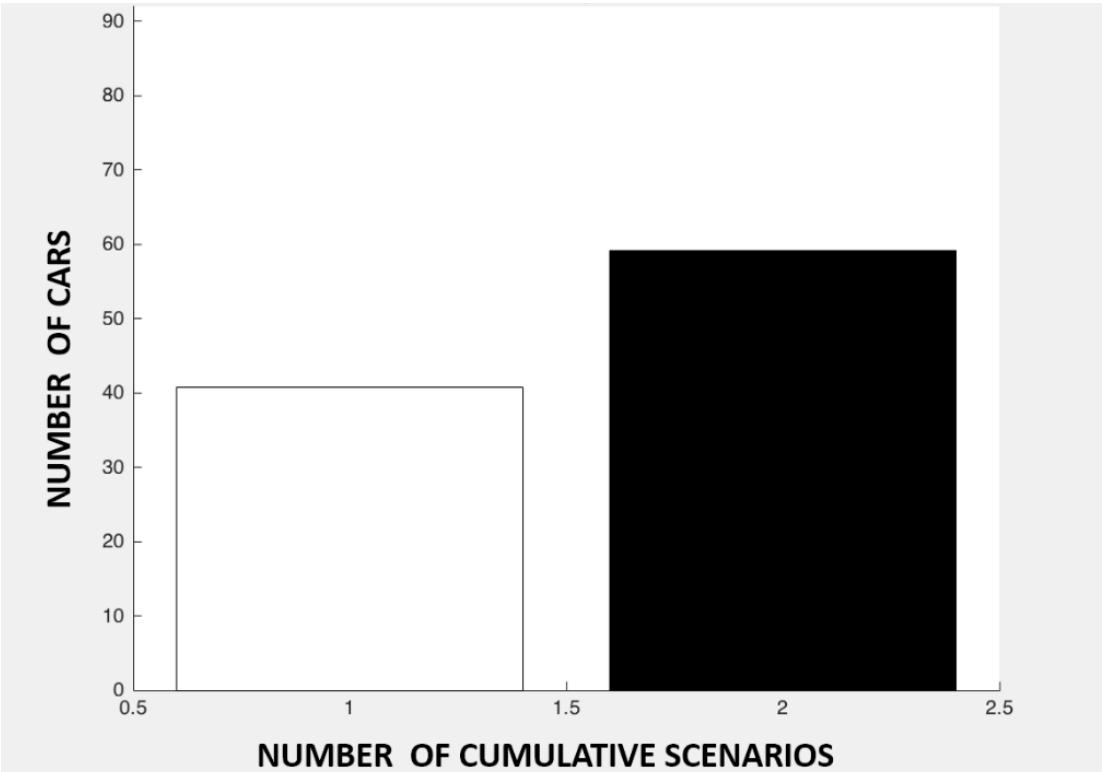

Fig 3.4.1 Output from sample data of 100 cars before applying the proposed system

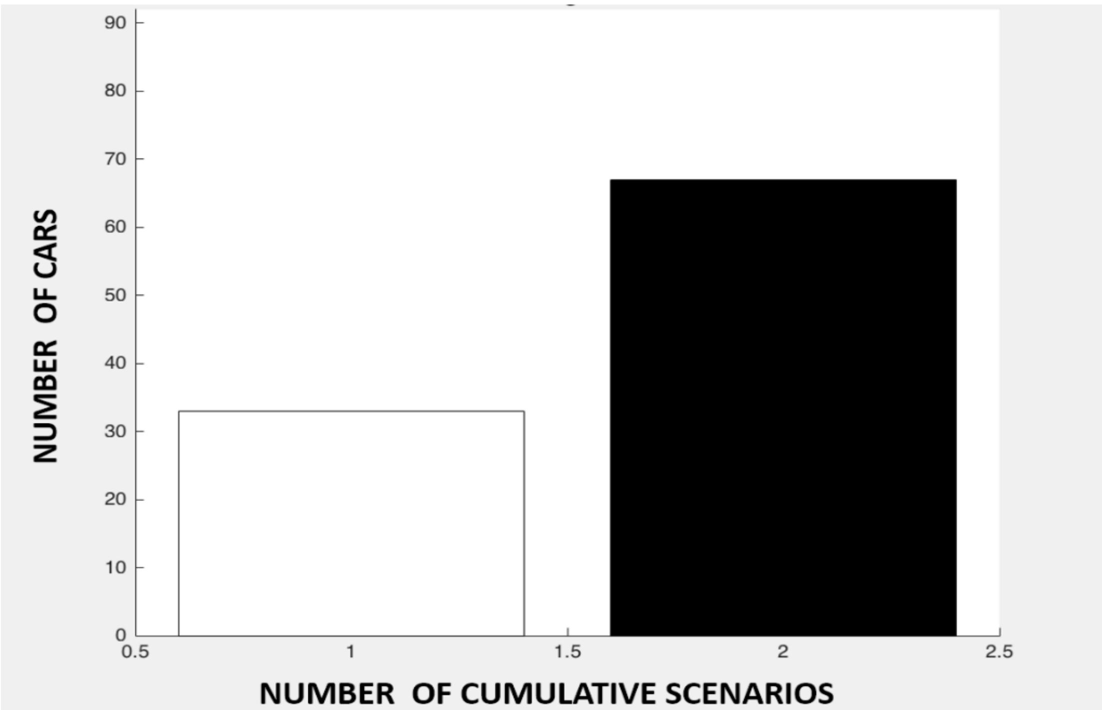

Fig 3.4.2 Output from sample data of 100 cars after applying the proposed system

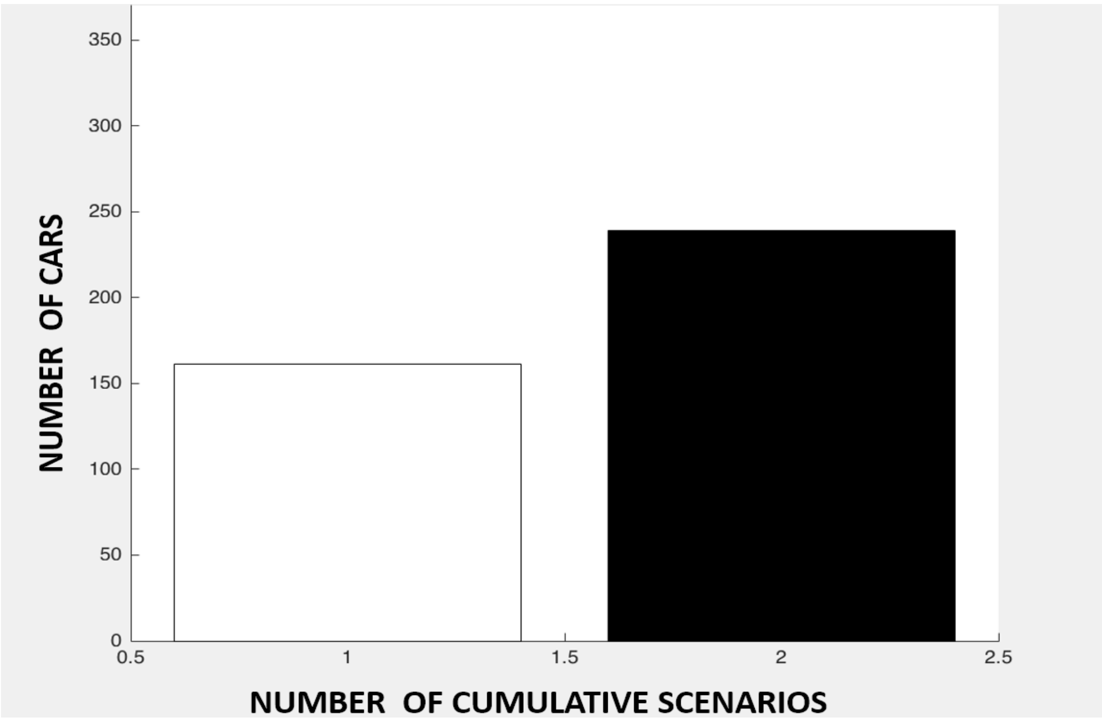

Fig 3.4.3 Output from sample data of 400 cars before applying the proposed system

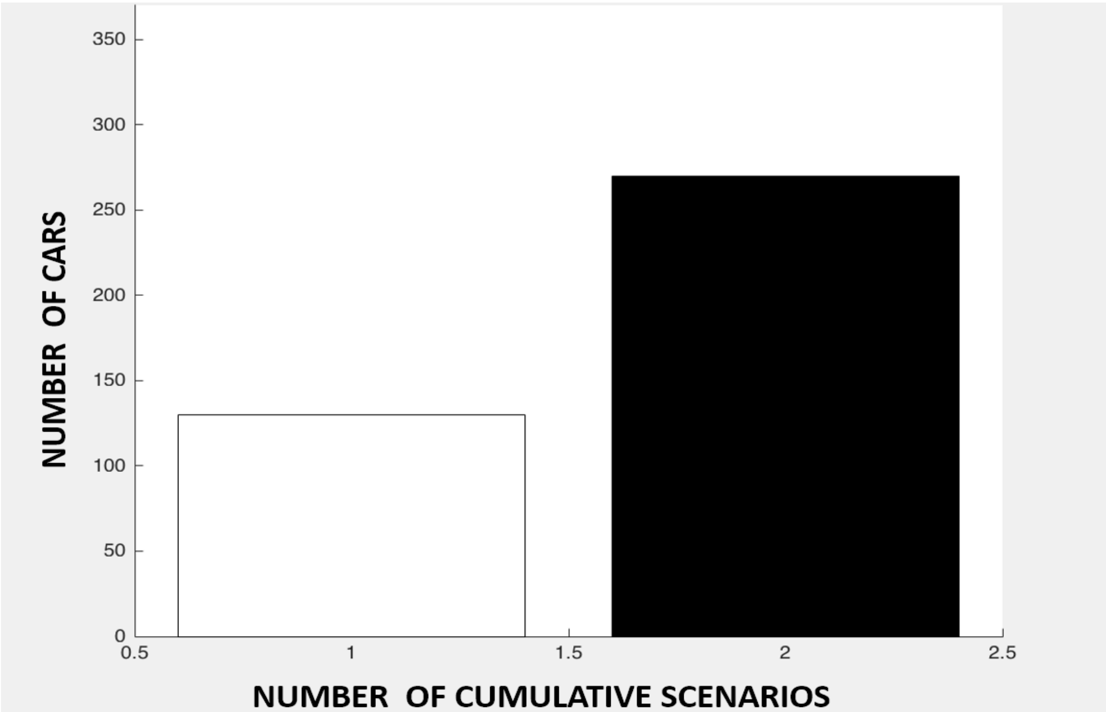

Fig 3.4.4 Output from sample data of 400 cars after applying the proposed system

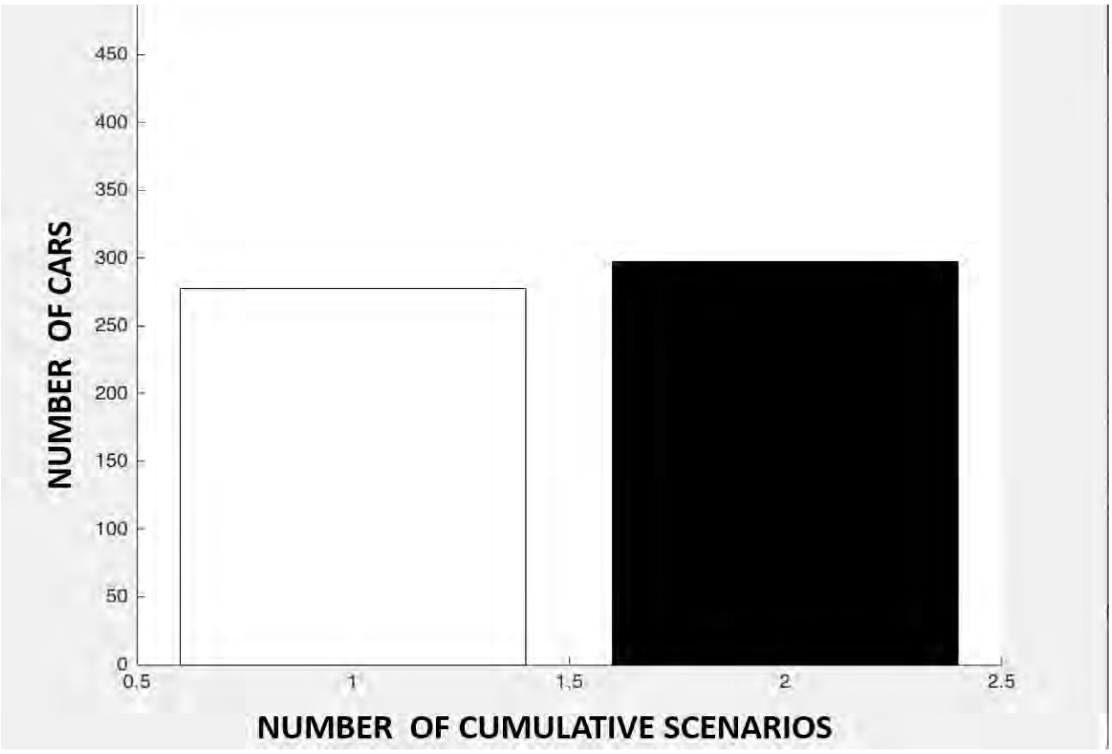

Fig 3.4.5 Output from sample data of 575 cars before applying the proposed system

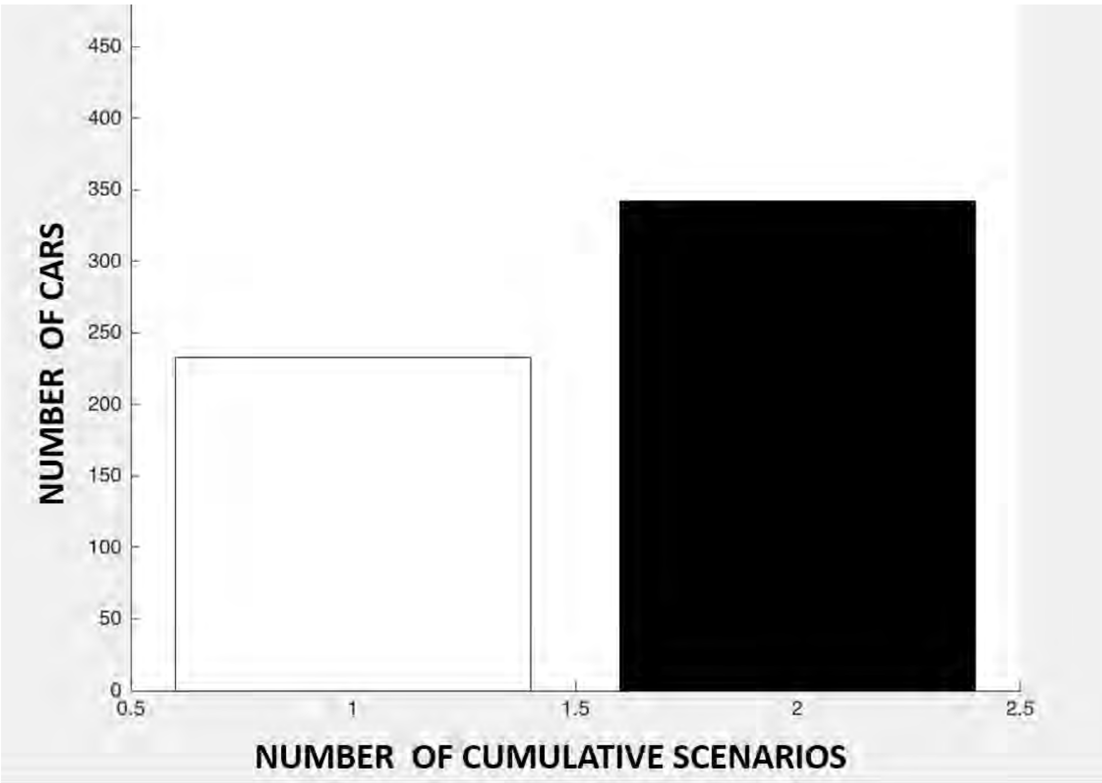

Fig 3.4.6 Output from sample data of 575 cars after applying the proposed system

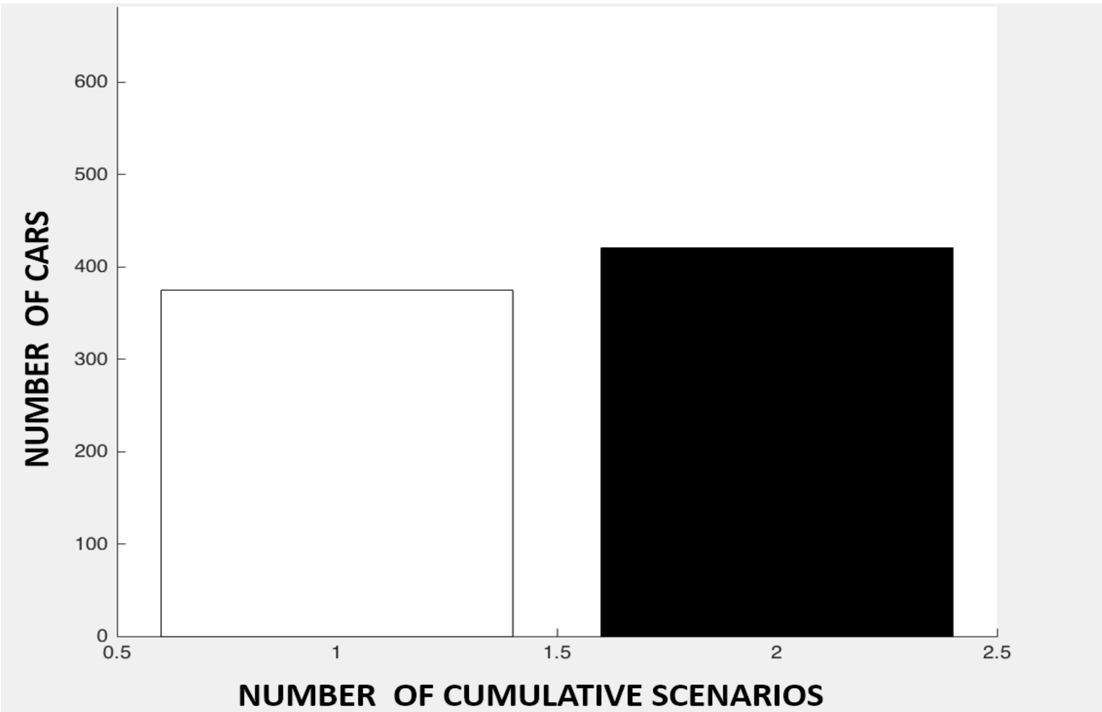

Fig 3.4.7 Output from sample data of 796 cars before applying the proposed system

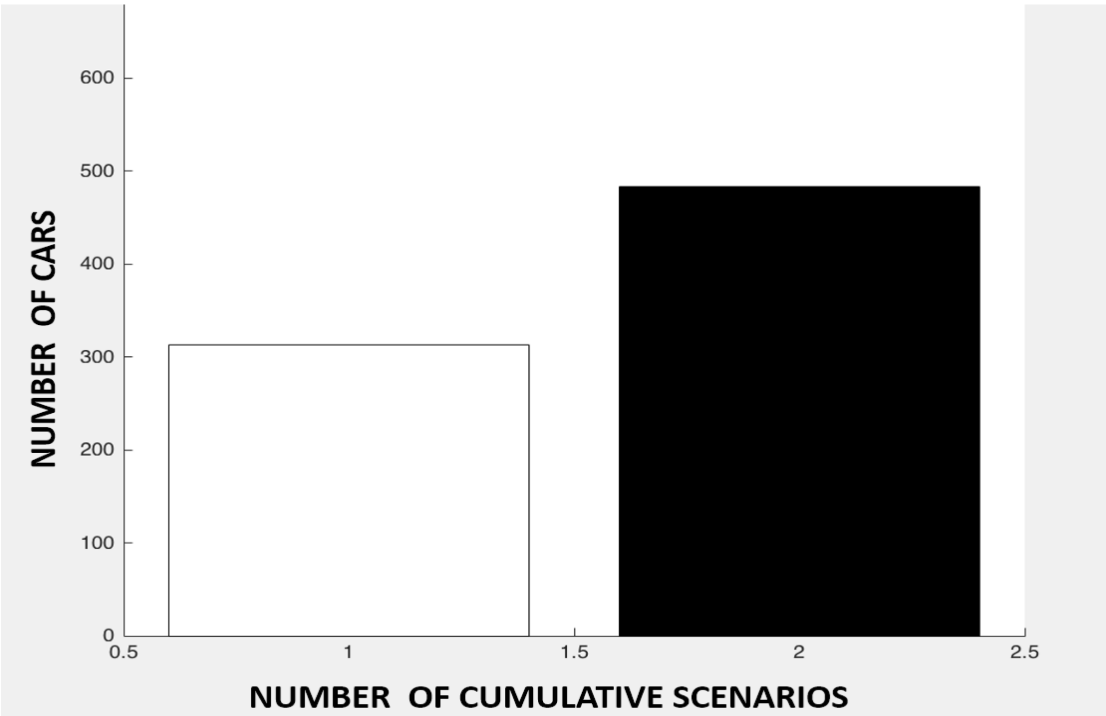

Fig 3.4.8 Output from sample data of 796 cars after applying the proposed system

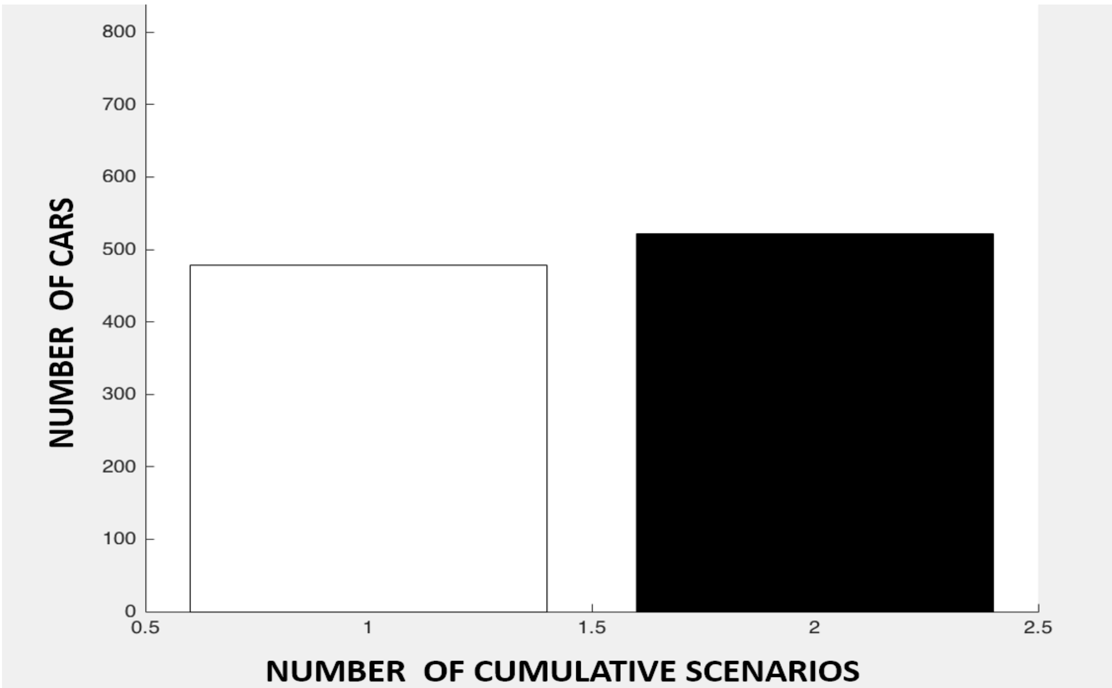

Fig 3.4.9 Output from sample data of 1000 cars before applying the proposed system

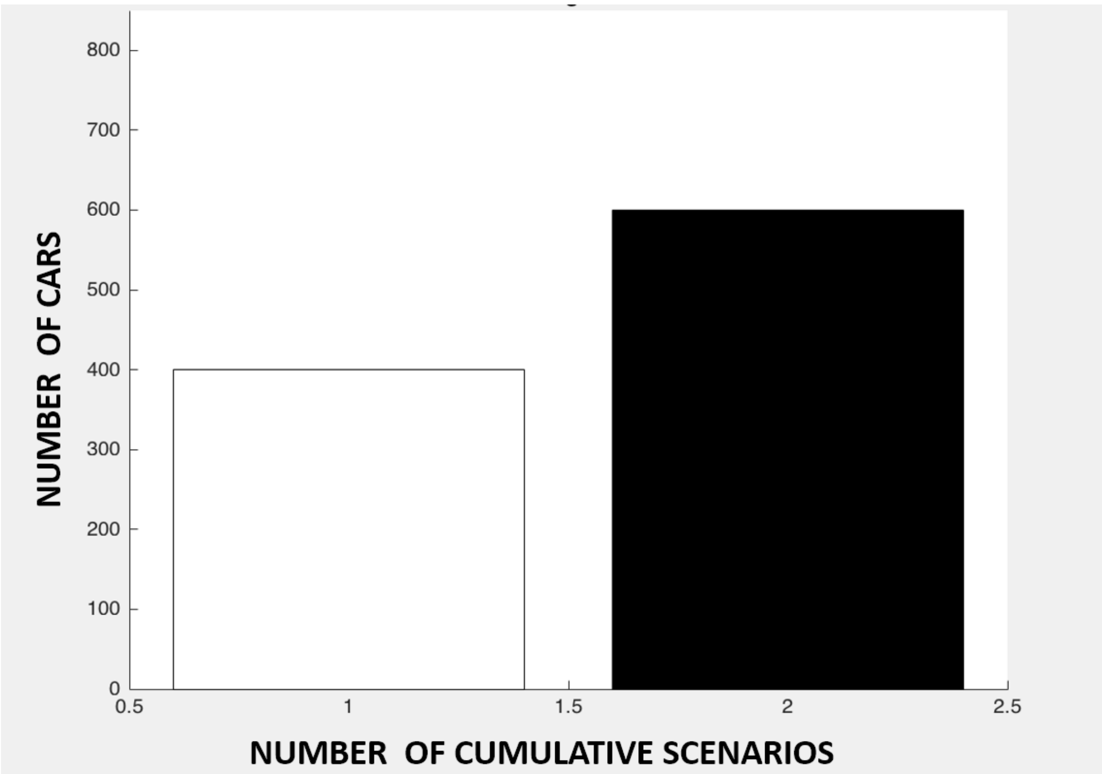

Fig 3.4.10 Output from sample data of 1000 cars after applying the proposed system

From the results extracted by the simulation in MATLAB for all the different sample data sets, it is justified that under any circumstances, the proposed algorithm successfully minimizes number of collisions if compared with the ones where the algorithm was not in action, irrespective of the number of cars. However, collisions that took place, are subject to the ignorance of the driver towards the warning sign showed by the algorithm or for mechanical fault of the vehicle.

Chapter 4

Conclusion and Future Scopes

Accidents and collisions on highways are an alarming issue for a densely populated country like ours. My research will help solving the problem in this domain that I believe.
Due to some limitations like time constraints and lack of a proper computer lab I could not further study on the subject matter. In spite of all these constrains, I finished my work, so that it might result into being helpful for future researchers in related field. In the field of research related to swarm intelligence, this paper will be helpful in understating the whole point of swarm robotics and developing other swarm robotics systems (SRS). I believe this project has the potential to solve the problem of highway collisions by a huge amount and bring down the number of casualties.

In the near future I wish to work on the further development so that in case of a collision, the identification number of each swarm units to be collided, can directly be stored in a cloud and the data can be used for future references. This data will help future research and law enforcement agencies to justify any accident.

The hardware system that is proposed in 3.2, is a justified model. The implementation of this hardware device based on nRF, that could not be done because of time constrain, is one of my future work plans.

Anyone can take information from this paper and implement the hardware using nRF, module and the algorithm for research purpose. Source code might be provided on request. Code for interfacing arduino mega with nRF sensor might also be provided on request for hardware implementation of the nRF based device.

APPENDIX

Collective Behavior: emergent from the interaction between the robots and the interaction of robots with the environment

Decentralized Behavior: the distribution of power, in small yet effect units rather than in one central system

Foraging: dynamically changing group behavior in a system.

Multiagent: a computerized system composed of multiple interacting intelligent agents within an environment.

Bi-directional: is a vehicle that can be driven in either direction, forwards or backwards.

Generator Function: A function that generates output according to the specifications given as input by the user

CA: Collision avoidance, a well-known research field specified for solving collision problems for industrial automation and related sector.

Ant Routing Algorithm: Algorithm for collision avoidance created by taking inspiration from the behavior of ants

Ad hoc Network: decentralized type of wireless network

Meta Heuristic: higher-level procedure or heuristic designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem

Path bi-function: a quantity that is well defined so as to describe the path of a process through the equilibrium state space of a thermodynamic system.

Stochasting Optimization: the minimization (or maximization) of a function in the presence of randomness in the optimization process

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