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An Efficient Collision Avoidance Scheme for Autonomous Vehicles using Genetic Algorithm

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ABSTRACT

Fast growing trend of autonomous vehicles has put researchers to find a better algorithm that can optimistically take decisions in real traffic environment in order to make sure a safe and collision free transportation system. This research study revolves around the same subject. To ensure that the decision taken by the autonomous vehicle to avoid the collision is the optimal one, Genetic Algorithm (GA) has been proposed. The proposed algorithm utilizes speed, break, inner tire angle and time to avoidance as four genes of chromosomal structure being used by GA to generate initial population. Field analysis has been done to analyze the driver's reaction in order to avoid collision in real environment, so that our proposed algorithm gives decisions accordingly. Results have shown that the suggested idea comes out to be an efficient way to direct the self-directed vehicles on road to cope safely with different dangerous scenarios on road.

KEYWORDS: Autonomous Vehicles, Collision Avoidance, Chromosome, Genetic Algorithm

1. INTRODUCTION

Road accidents are such tragedy of human life which cannot be ignored. According to [1], each year more than 1.2 million people lose their lives in road accidents. In [2], it has been mentioned that every year more than 7000 road casualties occur only in Pakistan. According to [3], the main cause of these road accidents is human driver. The main faults of human drivers are texting during driving , drinking before start driving, drowsiness and in-vehicle distraction like chatting with other passengers and eating etc. [4-6]. In this scientific era different efforts have been made by different researchers to decrease these human drivers' distractions. The researchers have introduced the concept of driver assistance systems [7], which generates audio/video alarms to the human drivers about collision leading situations and take control from the driver, if he/she does not perform in-time action to avoid the collision. However this research is still not very mature. Another solution has been provided by researchers by replacing human driven cars by self-driving vehicles.

The autonomous vehicle or self-driving vehicle can be viewed as a passenger car, which has ability to take his passengers to their destination without human intervention [8]. The concept of autonomous car is not new one. The first successful effort to build a functional autonomous car was made in 1977 by Tsukuba Mechanical Engineering Laboratory Japan [7].The latest development in this regard is Google car [9].According to a report [10] first autonomous vehicle will be available for the commercial use in 1920. By 1940 autonomous vehicles will rule on the roads of advanced countries [11].

The dream of autonomous cars is moving toward reality very rapidly due to its promise of very less road accidents and safe travelling [12][13]. In this regard collision avoidance decision making and avoidance mechanism of autonomous cars is getting very important. More efficient mechanism leads more robust collision avoidance decision and hence safer road travel will be achieved.

The main aim of this research work is making collision avoidance decision function of autonomous vehicle more optimized and efficient. For this purpose a well-known Genetic Algorithm (GA) has been adopted to calculate optimized values for decision parameters (Speed, Brake, Angle, and Time to Avoidance (TTA)) that will help to avoid collision in autonomous vehicles. The suggested algorithm is tested by simulating the real life traffic scenarios in which vehicles are moving at random speed. The algorithm first computes the front, rear, left and right distances between vehicles, then according to these values algorithm suggests the ideal decision to avoid collision. Results suggested the efficiency of the proposed algorithm.

The remaining paper has been organized as follows: In section 2 we have given the literature review covering the idea of autonomous vehicles being implemented by our peers in past few years. Section 3 gives the exact problem

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statement whose solution has been proposed in this study. In Section 4 proposed algorithm has been discussed. Section 5 covers the simulation and results and finally section 6 has been provided with the conclusion.

2. LITERATURE REVIEW

Genetic algorithm has been used to save the ship from the congested areas in [14]. The gene vector and noise model is used to save the ship. In this system ARPA (Automatic Radar Plotting Aids) is used to gather information of obstacles around the ship. In this experiment we draw results that our ship efficiently moves from the 18 ships without colliding with other ships. The data is collected by ARPA is used to create the stochastic predictor.

In this [15],a collision free motion planning problem of autonomous robots has been solved using genetic algorithm. For this purpose authors have proposed a position-based force control approach. To compute the fitness of solutions, an energy based fitness function has been advised and the best switching sequence of partly stable controllers is obtained by genetic algorithm.

In [16], mission planning issues for training a group of UAVs to carry out a number of tasks such as classification, attack and verification, against multiple targets has been discussed. The authors have presented a graph representation, which is used for task assignment and sequencing. For the optimal path formation to achieve the goal Dobbins vehicles use genetic algorithm [16].

Other than genetic algorithm different techniques have been proposed for avoiding collision avoidance between semi and fully autonomous vehicles. One of them is Vehicle-2-Vehicle (V2V) communication system [17]. V2V communication system can convey the cars and drivers a 360-degree situational awareness to address further crack situations, like when a driver needs to select if it's safe to pass on a two-lane road (potential head-on collision) or make a left turn across the path of oncoming traffic. It can also inform a driver when a vehicle approaching at an intersection appears to be on a collision path [17]. However in V2V communication system the decision of collision avoidance is left to the drivers. Whereas it has been proved by [18] that human drivers are not very efficient in making collision decisions efficiently.

Another scheme for collision avoidance between autonomous vehicles is VITA II (VISION TECHNOLOGY APPLICATION). In this, cameras installed in the car obtain information about the environment. The hardware consists of two clusters of parallel processors. The application cluster hosts the computer vision, arrangement, decision and control modules to implement driving tasks such as lane keeping with desired speed, slow down the vehicle in narrow curves following the limitations given by traffic signs, following the cars in front with adaptive distance control, computer vision based traffic sign recognition, object detection and recognition around the car and autonomous fast collision avoidance plans including overtaking. The vehicle cluster offers a simple structure to control the cars through computation [19].

In [20] the role of Wide Area Differential Global positioning system (WADGPS) has been evaluated to build the highly responsive digital computer control algorithm for autonomous vehicle. It has been claimed that WADGPS is very accurate. Every vehicle transmits its speed direction and current position using WADGPS to the other neighboring vehicles to avoid collisions on U-turn, intersections and lane changing scenarios. The proposed responsive digital computer control algorithm is then successfully tested by a six degree of freedom simulation.

3. Proposed system:

The main purpose of our research is to enable us to avoid collisions between autonomous vehicles. For this purpose, we are going to use genetic algorithm. According to the distance of each direction (left, right, front and rear), our algorithm gives the ideal decision and decision parameters or initiated gene. Then it calculates fitness of every genes and according to that and gives the optimal solution to avoid collision.

3.1. Genetic Algorithm Approach

The GA approach works as follows. First it checks the hurdle or vehicle in the range that has been set. In case of any hurdle, a pool of available solutions to cope with the given hurdle is produced. Finally the optimized solution is selected. The genetic algorithms use the concept of biological characteristics such as chromosomes and genes. Functions like crossover and mutation are applied on these chromosomes to get the next population of the solutions. There is a possibility that the new pool of solutions be better than those in the original population or they may be even worse than the original set of solutions.

3.2. The Chromosome structure and initial population

Before we start with the definition of the chromosome structure, we must have the information and understanding of the genes of the chromosome that will constitute its structure. The genes in this particular research would be the individual parameters that will be considered for the decision-making process. The whole structure of the chromosome and the order of each of the genes can be explained with the help of the following table.

Table 1. Structure of chromosome

Order	Gene	Range
1	Speed	60-120
2	Angle	60-120
3	Break	0-1
4	Time to avoidance(TTA)	20-90%

We can start with the generation of an initial population of 100 chromosomes. This population size can be increased if the results are not satisfactory in the provided solution set. These first population chromosomes are not only selected randomly but also have random values for each of the gene specified in these chromosomes. Some of these solutions may be the good ones while the other ones may be the worst solutions. In order to increase the possibility of good solutions in the next generation, we apply the fitness function to this initial population and perform operations like selection, crossover and mutation.

3.3 Next generation of chromosomes and fitness function:

When numbers of solutions are available, genetic algorithm chooses the best offspring or chromosome among them. The selection in genetic algorithm is based on fitness function. There are several methods available for the selections. Two of them are mentioned here "NO- dominated ranking" is used for selection but in this work we have used "Roulette Wheel selection" method. NO- dominated ranking is also known as "Fitness proportionate selection" method and is normally used for recombination of the best results in succeeding group. The associated probability of each chromosome can be find by using the following equation.

$$p(i) = f(i) / \sum_{j=1}^{N} f(i) \qquad (1)$$

The equation1 can be interpreted as. The p(i) in equation refers to the probability associated to each chromosome in the population, f(i) is depicting the fitness of chromosome lying at index i and N is representing the total chromosome in population.

According to "Roulette Wheel method" the higher probabilities chromosomes should survive for the next generation and lower probability chromosomes should be restricted to transfer in next generation. The next step in Genetic Algorithm is crossover and mutation after selecting the higher fitness chromosomes.

3.3.1 Speed: In the chromosome structure, the fitness of first gene has been calculated by the following equation.

$$Difference\ (D) = Requested\ \text{speed} - \text{speed}\ in\ chromosome \qquad (2)$$

Equation (2) will tells us the difference between requested speed and speed in chromosome which is in the form of absolute decimal number. When we calculate this difference, we have to specify a variable 'p' between the specified limits on speed (i.e. 60-120). Within the limit, it can be any number. The fitness of speed by focusing on variable 'p', when difference 'D' is smaller than 'p' then following equation is used.

$$Fitness\ (S) = x * (D/P) \qquad (3)$$

Where "x" shows the specified weight of speed. Our research contains the value of "x" as 25 because each parameter in chromosome gets equal weight of 25%. When 'D > P', then we will follow equation (4).

$$Fitness\ (S) = x \qquad (4)$$

3.3.2 Inner tire angle: Fitness calculation of angle gene is similar first gene, again we calculate the difference between the given angle in the chromosome and the angle given by the user which is under consideration. The difference will be measured by the following equation.

$$Difference\ (D) = Angle\ in\ QoS - Angle\ in\ the\ chromosome \qquad (5)$$

Here in angle gene, the considered variable is 'Q' and should be within the specified limits of parameter angle (60-120). If the calculated difference is less than specified "Q", then the following equation will be used to calculate the fitness of the angle gene.

$$Fitness\ (A) = x * (|D|/Q) \qquad (6)$$

Otherwise

$$Fitness\ (A) = x \qquad (7)$$

The "x" represents the weight of angle parameter. In equation (6) the Angle gene has also weight equal to 25.

3.3.3 Break: The fitness function of break is 0 and 1.

$$\text{Difference (D)} = |\text{break in QoS} - \text{break in chromosome}| \qquad (8)$$

Whenever the calculated difference is not equal to zero (0), the break genes are 100% unequal. In such situations, fitness will be set to 25, which means that it is far away from the optimized solution. But in the reverse case break has accurately matched the QoS break and thus fitness will also be zero (0).

3.3.4 Time to Avoidances: The Time to Avoidance (TTA) is the final gene of chromosome's structure. The difference between the (TTA) in the chromosomes and the (TTA) requested by the user or application using the equation (9) is

Difference (D) =| (TTA) in QOS – (TTA) in chromosome under consideration (9)
Considered variable is ‘R’ .The value of ‘R’ for the TTA can be any number in between the defined limits of (20-90). If the calculated difference is less than specified value of ‘R’ then Fitness is given as

$$Fitness\ (TTA) = x * (|D| / R) \quad (10)$$

Otherwise

$$Fitness\ (TTA) = x \quad (11)$$

Where the ‘x’ variable in equation 10 is representing the contributed weight of TTA gene in the overall weight of chromosome, which is 25 in our work.

3.4. Proposed Algorithm:

1. Generate real life scenario (random generate the value of distances and decision parameter)

```
2 .If (front > rear)
        {
          Speed = speed + 20;
          break1 = 0;
            }
Else
        {
If (rear > 20)
          {

            break1 = 1;
            Speed = speed - 20;
            }
Else
          {
            Speed = speed - 10;
            break1 = 0;
              } }
If (left >right)
        {
          Angle=angle+20;
Tta=tta+10;
          }

Else

            {

            Angle = angle - 20;
Tta = tta - 10;

                        }
```

3. Initialize 100 population of chromosomes.
4. Calculate the fitness of each genes or decision parameter.
5. Calculate total fitness of chromosome
6. Selection probability.
7. Crossover operator.
8. Mutation.
9. optimized decision.

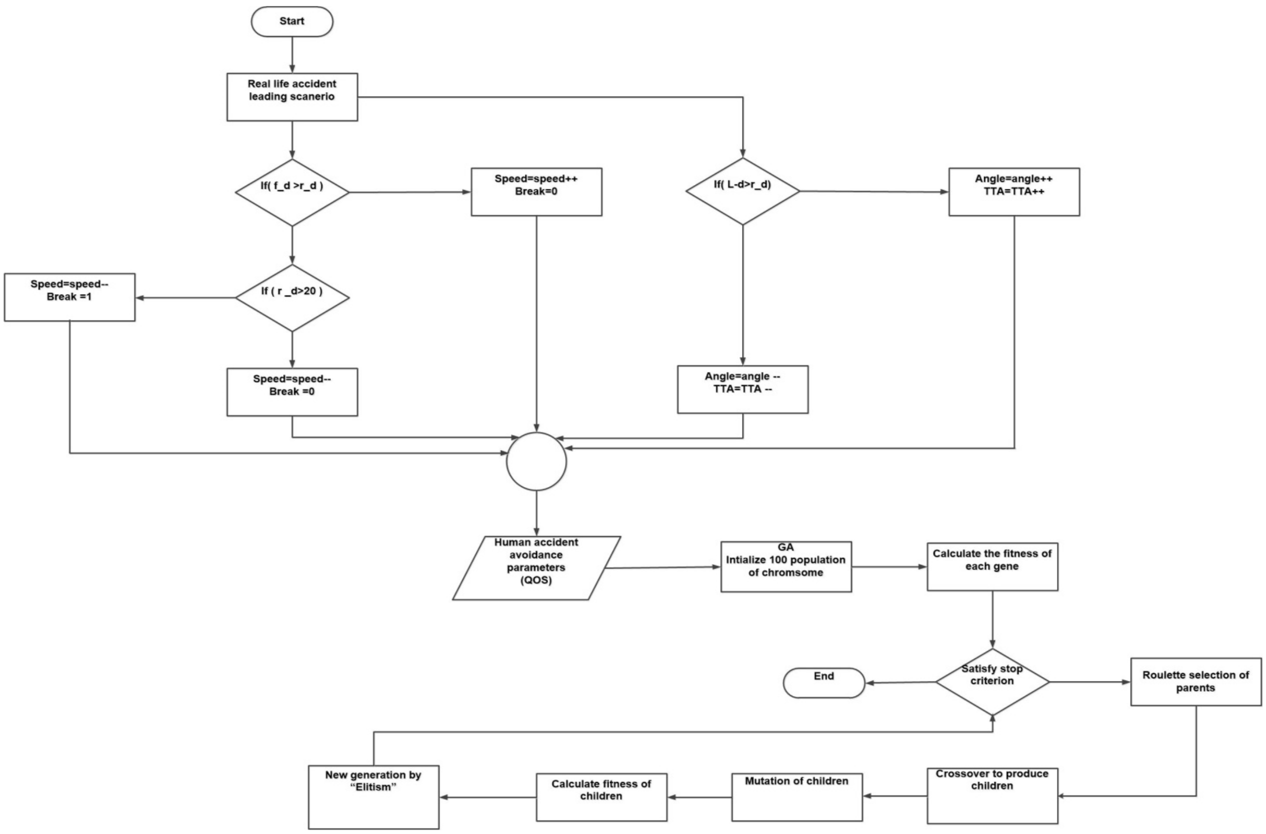

Fig 1. Flow chart of proposed GA based collision avoidance scheme

The above flowchart describes the flow of our software. Very first real life accident leading scenario can be generated and then check the distance of each direction (left, right, front and rear) and on the basis these distances human accident avoidance parameter initialize and then initialize the 100 population of chromosome of these parameter, and then calculate the fitness of each genes if the satisfy stop criterion then end. Otherwise using roulette wheel selection method to choose bigger fitness genes and perform crossover operation to produce children and then mutation of the children and then calculate the fitness of children and then check again if the satisfy stop criterion then end.

4. SIMULATION & RESULTS

For simulation purpose, C sharp language using .NET platform has been implemented as shown in Fig2.

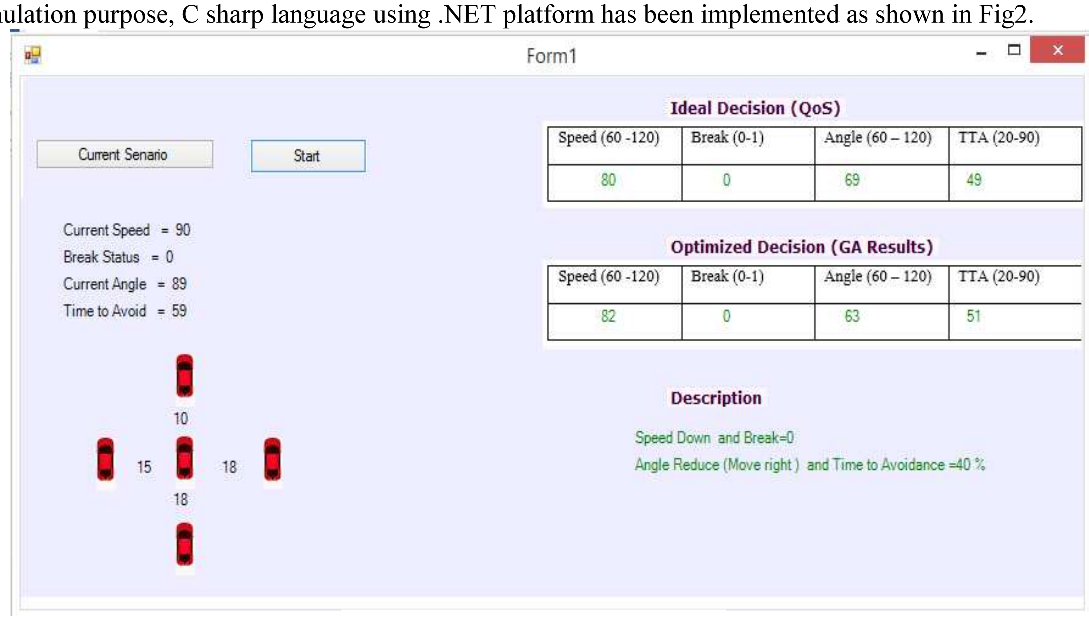

Fig.2 Main simulator screen

In above figure for generating the real life scenario, we have generated random speed, angle of autonomous car, brake, time to avoidance and also random randomly generate the distances between target and bullet car from left, right, rear and back side as shown in Table 2. According to current scenario, algorithm generated an ideal decision (QoS).

Table 2 Random values for initial population

Left distance	Right distance	Front distance	Rear distance	Current speed	Break status	Current angle	(TTA)
15	18	10	18	90	0	89º	59%

On this ideal decision (QoS), genetic algorithm is executed and returned the optimal decision in the given situation to avoid the collision.

Table 3. Ideal decision generated by GA

Speed(60-120)	Break(0-1)	Angle(60-120)	TTA(20-90)
80	0	69	49

Table 4. Optimized decision generated by GA

Speed(60-120)	Break(0-1)	Angle(60-120)	TTA(20-90)
82	0	63	51

5.1. Results

The following section describes the testing procedure used to validate the design as well as the results of said testing. In order to validate the efficiency of said scheme, simulator has been provided with several ideal decisions which are then optimized by GA.To validate the simulation extensive testing has been performed. Before start testing total ten test cases were designed and each test case was tested ten times repeatedly. Hence total 100 tests have been performed. Table 5 is showing the ten test cases, whereas their corresponding results along the stander deviation are given in table 6.

Table 5 Ideal test case 1 and corresponding optimized collision avoidance decisions

Test case no	Parameter 1 (Speed)	Parameter 2 (Break)	Parameter 3 ($\propto_{if}$)	Parameter 4 (TTA)
1	100	0	100	84
2	70	1	104	52
3	107	0	75	30
4	113	0	110	74
5	116	0	111	66
6	73	1	113	53
7	102	0	75	59
8	117	0	114	75
9	63	1	62	33
10	109	0	60	69

From table 5 it can be noted that the performance of proposed collision avoidance system has been tested over different high speeds of autonomous vehicles. The upper limit of speed is 117; whereas the lower speed is 63. As over speeding is one of the main causes of road accidents hence it motivates us to design test cases which have high value for the speed parameter. The values for TTA are taken randomly for all test cases, and this random phenomenon depicts different real life collision leading situations. The final results of all testing scenarios are given in the table 6.

Table 6 Overall results of 100 test cases along with standard deviation

Sr. No.	Speed	Break	$\propto_{if}$	TTA
1	99.333 $\pm$ 2.598076	0 $\pm$0	101 $\pm$3.24037	83.55556 $\pm$3.811532
2	71.55556 $\pm$ 5.93951	1 $\pm$ 0	105.2222$\pm$3.767552	52.3333$\pm$ 3.640055
3	107.4444$\pm$ 4.275252	0 $\pm$ 0	75.66667$\pm$ 3.640055	28.44444$\pm$ 5.570258
4	112$\pm$ 4.153312	0$\pm$ 0	109.1111$\pm$ 5.90433	72.22222 $\pm$ 3.492054
5	113.7778$\pm$ 3.99305	0$\pm$ 0	110.1111$\pm$ 5.510092	66.66667$\pm$ 4.387482
6	73$\pm$ 2.738613	1$\pm$ 0	113.4444$\pm$ 3.503966	54.22222$\pm$ 3.929942
7	101.6667$\pm$ 3.535534	0$\pm$ 0	73.33333$\pm$ 4.444097	60.66667$\pm$ 5.958188
8	114$\pm$ 2.828427	0$\pm$ 0	115.4444$\pm$ 2.74368	75.88889$\pm$ 7.184087
9	67.77778$\pm$ 4.521553	1$\pm$ 0	65.22222$\pm$ 6.119187	33$\pm$ 5.97913
10	108 $\pm$ 4.949747468	0 $\pm$ 0	62 $\pm$1.732050808	68.67$\pm$ 4.031128874

It can be seen that the proposed GA based collision decision scheme generates optimized decision with 2.598 deviation, inner front angle with 3.24 deviation and TTA with 3.81 deviation. On the analysis of overall results it can be seen that the maximum deviation for speed is 5.93 and minimum is 2.59 , the maximum deviation for$\propto_{if}$ is 6.11 and minimum is 1.73 and maximum deviation for TTA is 7.18 and minimum is 3.64. Hence the test results given in table 5 validate the functionality of proposed algorithm in making collision avoidance decisions at high speeds.

6. Conclusion:

In this research study we have implemented a genetic algorithm that gave us an optimized solution and helped the autonomous vehicles to avoid collision with other vehicles. First of all values are generated according to the scenario and forwarded it to the QoS. Afterwards these values are fed in to the genetic algorithm which provided more optimized and best solution to avoid collision.

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