Vehicle Crash Avoidance Modelling and Simulation Using Artificial Neural Network Approach

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

____

(Mr. Syaifuddin Mohamad)

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TRONOH, PERAK

June 2005

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMMAD RADZI BIN ZAHIR

ABSTRACT

The objectives of this project are to study kinematics of vehicles in crash avoidance maneuvers, to model and simulate vehicles in crash avoidance scenarios in Matlab Simulink environment, and also to develop crash avoidance algorithm utilizing artificial neural network approach. The problem that leads to the development of this project is that accidents happened mostly caused by human error, in which traffic delays and congestion can eventually take place. The project involves a preliminary study on the simulation of changing lane and also merging into highway traffic. This project consists of two main components, which represents the method. The first component is whereby studying of vehicle kinematics in crash avoidance maneuvers is done. The second component is the process of modeling and simulation of crash avoidance scenarios in Matlab Simulink environment. Based on the project that is to be done, the accidents caused by lane changing and merging can be avoided through the design of intelligent vehicle and intelligent highway. As a conclusion, the results of this paper could be used to investigate on how to improve the safety of lane changing maneuvers and to provide warnings or take evasive actions to avoid collision when combined with appropriate hardware on board vehicles.

ACKNOWLEDGEMENTS

My utmost gratefulness goes to the Almighty God for me to complete this project well, in time and in focus. I would like to express my relief for that I have completed my Final Year Project with so much effort given into the project. I would like to take this opportunity to share and express my gratitude to those who have helped and encouraged me all the way throughout my project accomplishment.

My most sincere thank you is specially goes to my beloved Supervisor, Mr. Syaifuddin Mohamad, who has been extremely supportive and very helpful towards making my project a success. Without his help this project would never had gone this far.

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Notations

a = acceleration

v = vehicle speed

u = vehicle initial speed

t = time

HP = Horse power

g = gravitational constant

W = Weight of vehicle

M = Mass of Vehicle

Ax = longitudinal acceleration

Fx = Tractive force of the ground

Da = aerodynamic drag force

Abbreviation

IVHS Intelligent Vehicle Highway System

PI Proportional Integral Controller

PID Proportional Integral and Derivative Controller

CHAPTER 1
INTRODUCTION

1.1 Background of Study

In the 1930's, the introduction of affordable mass-produced cars provoked a rapidly increasing population of drivers demanding paved city and rural roads. This fact quickly expanded the scope and intensity of the traffic problems. The increase of automobiles and trucks during several decades after the car boom has resulted in the construction of more and more highways.

The modeling of a vehicle has been studied for a long time in order to design a high performance vehicle controller. All the vehicle models have been constructed numerically in the form of dynamic equations. A neural network can give a solution to this end. I need to model an intelligent vehicle using a neural network in order to design a lateral controller for autonomous steering.

Neural network approach is widely used now to design and simulate in the Intelligent Highway System projects. This is the explanation of the design and simulation of vehicle that can be done using this software. This is the example of using this software to design and simulate about vehicle. The neural network vehicle model is basically intended to the off-line construction of the lateral controller for autonomous steering. Figure 1.1 depicts the lateral control scheme with state-feedback. S(n) denotes the state of the vehicle's dynamics.

S(n) = [Ys(n), Ys'(n), Yt(n), Yt'(n)]

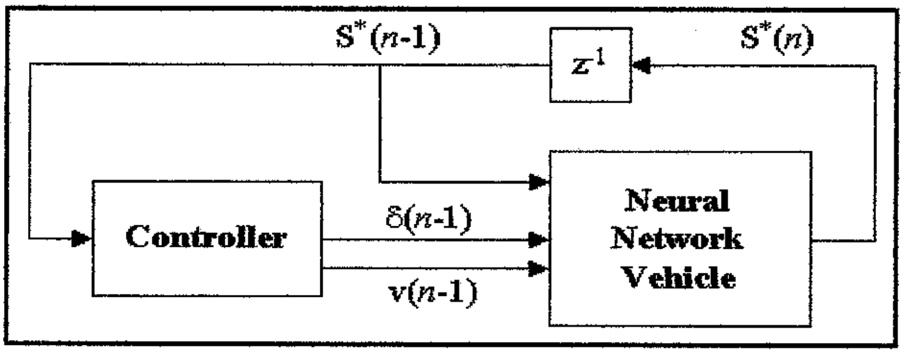


Figure 1.1: State-feedback lateral control scheme

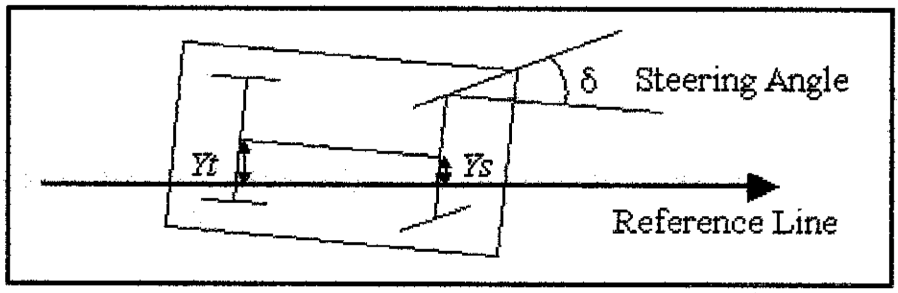


Figure 1.2: The definition of the vehicle states Ys, Yt

In Figure 1.2, the reference line is the one for the vehicle to follow. In case of magnet-based lateral control, it is an array of magnetic markers along the road. Or in case of wire-based control, it becomes a wire through which the electric current flows. We used an electric wire for our Demo. Ys(n) in the state vector is the lateral distance from a reference line to the mid-point of the front wheel shaft, Yt(n) is to the mid-point of the rear shaft. Ys'(n), Yt' (n) are the rates of change of Ys(n), Yt(n). As shown in Figure 1, the neural network predicts the next state of the vehicle from the steering angle *d*, the velocity *v*, and the current state that is used as a recurrent input to the network. The lateral controller generates a sequence of the steering angle *d* and the velocity command *v*. Thus, the neural network vehicle in Figure 1.1 has the structure of a real-time recurrent network shown Figure 1.3.

The external input layer consists of 6 neurons: 4 neurons representing the elements of a state vector at time n-1 and 2 neurons representing the steering angle *d* and the velocity *v* at time n-1. The external output layer consists of 4 neurons which are the elements of the state vector at time *n*. The hidden layer consists of 4 neurons. The 8 neurons in the hidden and output layers are recurrent, and all the outputs of the network are fed back to the input layer. The equations governing the real-time recurrent learning algorithm for the network are shown in Equations (2), (3), and (4):

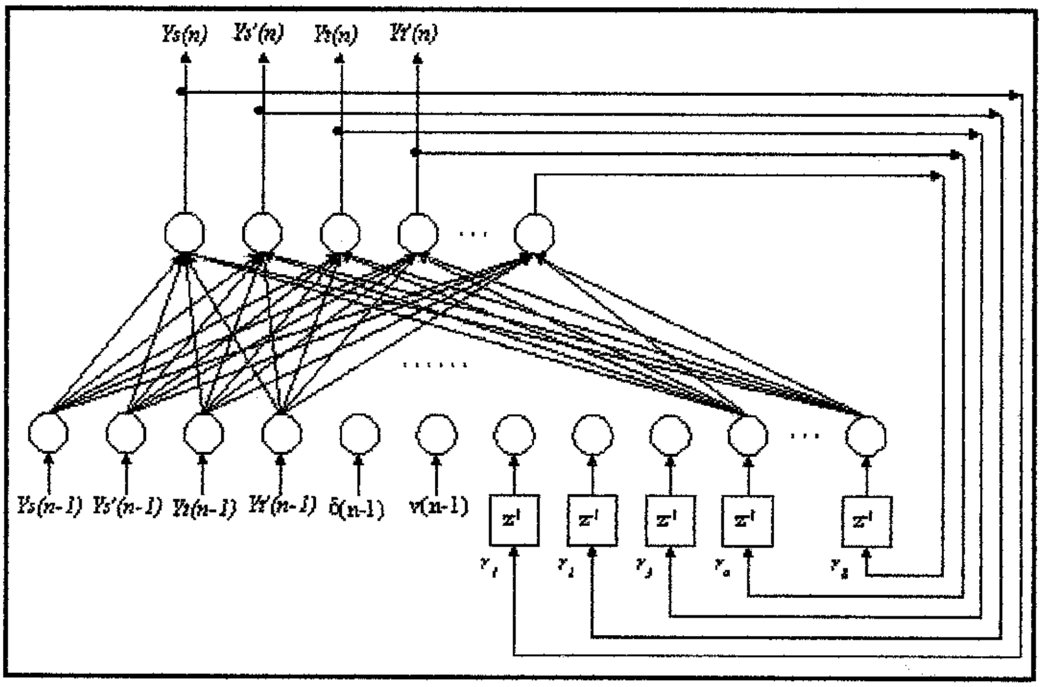


Figure 1.3: Real-time recurrent network structure for the neural network vehicle.

$$\pi^{j}_{kl}(n+1) = \varphi'(v_j(n))\left[\sum_{j\in\beta} w_{ji}(n)\pi^{j}_{kl}(n) + \delta_{kj}u_l(n)\right]$$

$$\pi^{j}_{kl}(0) = 0 \qquad (2)$$

$$\Delta w_{kl}(n) = \eta \sum_{j\in\xi} e_j(n)\pi^{j}_{kl}(n) \qquad (3)$$

$$w_{kl}(n+1) = w_{kl}(n) + \Delta w_{kl}(n) \qquad (4)$$

where w_{ji} is the weight, index ***i*** is for the input layer, and index ***j*** is for the output layer. $\varphi(v_j(n))$ is the output of ***jth*** output neuron. δ_{kj} is Kronecker delta equal to 1 when ***j = k*** and zero otherwise. $u_i(n)$ is the concatenation of the external inputs and the recurrent neuron outputs. β denotes the set of recurrent neurons in the input layer. ξ denotes the set of neurons that provide externally reachable outputs. $\pi^j_{kl}(n)$ is just a triply indexed variable for calculating $\Delta w_{kl}(n)$, the weight change while $e_j(n)$ is the output error.

1.2 Problem Statement

1.2.1 Problem Identification

Majority of the accidents happened on the highways are caused by human error. One of the riskiest maneuvers that a driver has to perform in a conventional highway system is to merge into the traffic and/or to perform a lane changing maneuver. Lane changing/merging collisions are responsible for one-tenth of all crash-caused traffic delays often resulting in congestion. Traffic delays and congestion, in general, increase travel time and have a negative economic impact. In addition, all vehicles caught in traffic jams consume more fuel, which certainly give economic impact on individuals. Everybody, without exception, has experienced the frustration of being captured in a traffic jam. The traffic congestion is, to a great extent, responsible for the increased accident rates and their consequences, which include human life losses time, increased air pollution and expensive repairs.

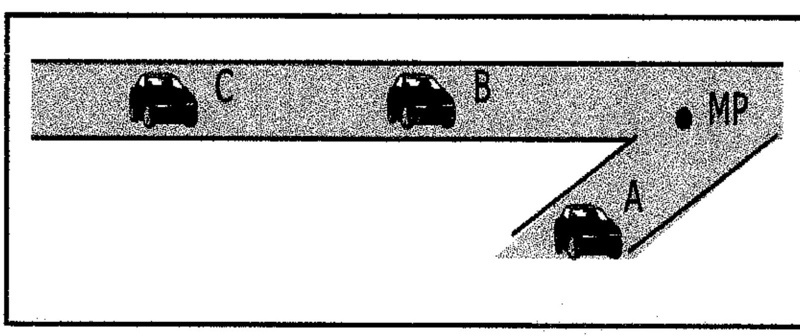


Figure 1.4: Highway Merging Scenario

If situation of the above occur vehicle A must do the following action in order to avoid collision:

1) To move fast into the lane
2) To brake and wait until vehicle B and C pass by
3) If velocity vehicle B and C are zero, the vehicle A can move into the lane.

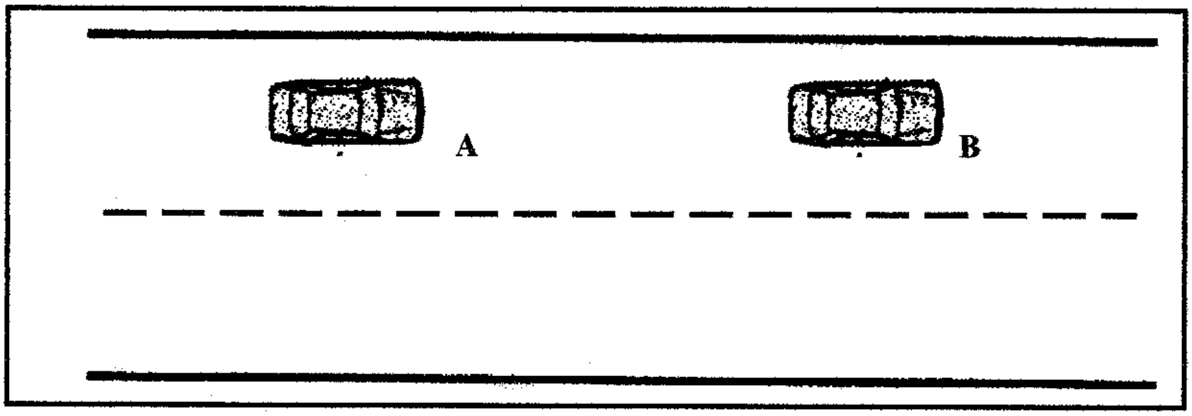


Figure 1.5: Changing lane scenario at highway

Lane changes are governed by a set of rules, taking into account both deterministic and stochastic psycho-physical aspects. In the model a lane change takes place when the leader vehicle is slower than the following vehicle.

A generic vehicle *A* can move to the **lane-changing mode** in two cases:

1. While in the free driving mode, the driver perceives a slower vehicle ahead and changes lane without braking;

2. While in the conscious braking mode, the driver stops braking and changes lane at a speed $v_A < v_B$.

1.2.2 Significant of the Project

The development of an advanced crash avoidance system could help reduce the number of vehicle collisions in major highways. This project, together with appropriate sensors and equipment on the board of vehicles, could be used to assess the safety of lane changing maneuvers and provide warnings or take evasive actions to avoid collision.

This system focuses on a more safe way of driving, without neglecting the efficiency of a car.

1.2.3 Neural Network Approach

Neural Network Predict is an integrated, state-of-the-art tool for rapidly creating and deploying prediction and classification applications. Predict combines neural network technology with genetic algorithms, statistics, and fuzzy logic to automatically find optimal or near-optimal solutions for a wide range of problems. Predict incorporates years of modeling and analysis experience gained from working with customers faced with a wide variety of analysis and interpretation problems. Neural network approach was used in this project because of some reasons, which are:

1) *Easy To Use* -In the Microsoft Windows environment, Predict runs as an Add-in with Microsoft Excel. This means both a familiar interface as well as access to a wide variety of ancillary capabilities that you can employ to put Predict outputs into formats suitable for presentation to or use by a wide variety of audiences. The basic process of building a model with Predict is completely automated. With the Build Wizard activated, a step-by-step guide is provided by short series of dialog boxes. Creating and training a model is easy. Neural network results are written back into the spreadsheet, where a quick graph makes the results suitable for presentation to a wide variety of audiences.

2) *Powerful* - Predict automatically performs all the actions necessary to build a prediction or classification model. A genetic algorithm rapidly builds and evaluates mini-networks to identify not only which domain inputs are significant, but also the type of transform function that ultimately produces the best network. Then the final neural network is constructed, trained and, and tested. In many situations the resulting network can be deployed immediately. Predict incorporates 6 basic transform types and two additional miscellaneous transforms.

The basic transform types are:

- Continuous
- Logical
- Enumerated Integer
- Enumerated String
- Fuzzy; and
- Quintile

3) *Comprehensive*- Three levels of interface accommodate the diverse needs of new users, application engineers, and neural network engineers. The Build Wizard guides model building with a sequence of high level dialogs which do not require any detailed understanding of the model components. Advanced and Expert modes provide increasing levels of access to all the details of the internal algorithms.

1.2.4 Innovation

Intelligent Vehicle Highway Systems (IVHS) is a subject which encompasses a range of smart car and smart highway technologies. These technologies improve the safety, efficiency, and environmental friendliness of our highway system. Advanced traffic management systems are designed so as to make traffic flow more efficient in cities. Many ATMS programs are now in place. Some examples include streets with timed traffic lights and smart lights which signal you to stop when the opposing traffic appears. There are more advanced regional traffic-control centers that watch for slowdowns using the following things: vehicle-flow sensors, closed-circuit cameras, hovering helicopter, and police reports. All this information is used to control freeway on-ramp traffic signals and to communicate alternate routes around congested areas via electronic message boards and by radio station traffic reports. In the near future, in-car navigation systems will be made to receive information from traffic-control centers directly and to plot courses around congested areas. It is anticipated that some IVHS systems will involve communications between vehicles and the roadside. This will probably be implemented using short radio communication links of a few hundred meters in length or less. Collision avoidance radars will work over similar short distances.

1.3 Objective and Scope of Study

The main objectives of the project are:

1) *To study kinematics of vehicles in crash avoidance maneuvers.*

   In completing the project, I need to learn and study on the kinematics of vehicles, focusing on how collisions can be avoided.

2) *To model and simulate vehicles in crash avoidance scenarios in Matlab Simulink environment.*

   A model will be produced from this project for a more understandable approach of viewing. Simulation of vehicles will also be undergone in crash avoidance scenarios in the Matlab Simulink environment. Firstly I need to design only particle that move on the highway using equation of motion that is in the physics. Then I will continue with modeling the actual vehicle using vehicle dynamics equation.

3) *To develop crash avoidance algorithm utilizing artificial neural network approach.*

   A process of finding out the algorithms for this project in terms of crash avoidance will be carried out, which utilizes artificial neural network approach.

The scope of the study is as below:

1) The study is limited to average size of passenger car vehicles that are mostly used nowadays.
2) The highway that will be referred is as in our country. The dimension of the highway also will be measured to get an ideal measurement for national highway.
3) I assumed that for all the simulations in this project for all vehicles, involved in the lane changing/merging maneuver, were initially at steady state, or in other words, their velocities were constant prior to the maneuver.
4) Vehicle crash avoidance analysis is a complex procedure because the factors affecting accident occurrence are numerous and not independent. This project will be limited for lane changing and merging analysis only.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Literature Review

Research was undergone, and from the national highway traffic safety website, I have discovered that the accidents caused by lane changing or merging include various types of vehicle collisions, vehicle collisions, such as rear-end collisions, single vehicle road departure accidents, side-wipe, and angle collisions. In the year 1991 alone, the collisions caused by lane changing or merging contributes to about 4.0% of all police-reported collisions. Those collisions accounted for about 0.5% of all fatalities. This lane changing type of crash actually is responsible for one-tenth of all crash-caused traffic delays, in which often resulting in congestion. Although this type of crash problem is relatively small and the level of fatalities is not that high, but relating to the problems caused, this crash should be avoided. This problem of traffic delays and congestion generally can increase the travel time and give the economy a negative impact.

Generally, traffic delays and congestion increases travel time and have a negative impact on the economy. In practice, the possibility of merging collisions can be reduced by adjusting relative velocities and increasing the longitudinal inter-vehicles' spacing. Since roadway capacity is proportional to vehicle speed and inversely proportional to longitudinal inter-vehicle spacing, a large reduction in speed or a large increase in spacing leads to a low capacity highway system.

According to statistical data from U.S., the average travel speeds at rush hour in the larger U.S. cities drop to about 36 miles per hour. Annually, this leads to some 5 billion collective hours of delay and estimated productivity losses of $50 billion nationwide.

This in addition, can cause all vehicles to be caught in traffic jams, causing those vehicles to consume more fuel. The traffic congestion is responsible for the increased accident rates and their consequences, in which individuals waste more time, and air pollution increases besides expensive repairs.

2.2 Theory

2.2.1 Aerodynamic Forces

Automotive aerodynamics is the study of the aerodynamics of road vehicles. The main concerns of automotive aerodynamics are reducing drag, reducing wind noise, and preventing undesired lift forces at high speeds. For some classes of racing vehicles, it may also be important to produce desirable downwards aerodynamic forces, to improve cornering.

Automotive aerodynamics differs from aircraft aerodynamics in several ways. First, the characteristic shape of a road vehicle is bluff, compared to an aircraft. Second, the vehicle operates very close to the ground, rather than in free air. Third, the characteristic speeds tend to be lower. Fourth, the ground vehicle has fewer degrees of freedom than the aircraft, and its motion is less affected by aerodynamic forces.

Automotive aerodynamics is studied using both computer modeling and wind tunnel testing. For the most accurate results from a wind tunnel test, the tunnel is sometimes equipped with a rolling road. This is a movable floor for the working section, which moves at the same speed as the air flow. This prevents a boundary layer forming on the floor of the working section and affecting the results. Aerodynamics is a branch of fluid dynamics concerned with the study of gas flows. The solution of an aerodynamic problem normally involves calculating for various properties of the flow, such as velocity, pressure, density, and temperature, as a function of space and time.
For a typical passenger car cruising at a speed higher than approximately 80 km/h, the power required to overcome the aerodynamic resistance is greater than that required to

overcome the rolling resistance of the tires and the resistance in the transmission. Thus it is very importance to study about aerodynamic force in this project. The aerodynamic resistance is generated by two sources: one is the air flow over the exterior of the vehicle body, and the other is the flow through the engine radiator system and the interior of the vehicle for purposes of cooling, heating, and ventilating. Of the two, the former is the dominant one, which accounts for more than 90% of the total aerodynamic resistance of a passenger car. The external air flow generates normal pressure and shear stress on the vehicle body. According to the aerodynamic nature, the external aerodynamic resistance comprises two components, commonly known as the pressure drag and skin friction. The pressure drag arises from the component of the normal pressure on the vehicle body acting against the motion of the vehicle, while the skin friction is due to the shear stress in the boundary layer adjacent to the external surface of the vehicle body. Of the two components, the pressure drag is by far the larger, and constitutes more than 90% of the total external aerodynamic resistance of a passenger car with normal surface finish.

In practice, the aerodynamic resistance is usually expressed in the following form:

$$\text{Drag} = \frac{\rho}{2} Cd\, Af\, V^2$$

Where ρ is the mass density of the air, Cd is the coefficient of aerodynamic resistance, A_f is a characteristic area of the vehicle, usually taken as the frontal area, which is the projected area of the vehicle in the direction of travel, and V, is the speed of the vehicle relative to the wind.

In this project the value of all the parameters is according to the average value for the normal car and conditions.

Cd = 0.3

ρ = 1.225 kg/m^3

A = 1.8m^3

2.2.2 Rolling Resistance Forces

The rolling resistance of tires on hard surfaces is primarily caused by the hysteresis in tire materials due to the deflection of the carcass while rolling. Friction between the tire and the road caused by sliding, the resistance due to air circulating inside the tire, and the fan effect of the rotating tire on the surrounding air also contribute to the rolling resistance of the tire, but they are of secondary importance. Available experimental results give a breakdown of tire losses in the speed range 128-152 km/h (80-95 mph) as 90-95% due to internal hysteresis losses in the tire, 2-10% due to friction between the tire and the ground, and 1.5-3.5% due to air resistance.

When a tire is rolling, the carcass is deflected in the area of ground contact. As a result of tire distortion, the normal pressure in the leading half of the contact patch is higher than that in the trailing half. The center of normal pressure is shifted in the direction of rolling. This shift produces a moment about the axis of rotation of the tire, which is the rolling resistance moment. In a free-rolling tire, the applied wheel torque is zero; therefore, a horizontal force at the tire-ground contact patch must exist to maintain equilibrium. This resultant horizontal force is generally known as the rolling resistance. The ratio of the rolling resistance to the normal load on the tire is defined as the coefficient of rolling resistance.

Surface conditions also affect the rolling resistance. On hard, smooth surfaces, the rolling resistance is considerably lower than that on a rough road. On wet surfaces, a higher rolling resistance than on dry surfaces is usually observed.

Tire Type	Tire Construction	Dry		Wet	
		μ_p	μ_s	μ_p	μ_s
Goodyear Super Hi Miler (Rib)	Bias-ply	0.850	0.596	0.673	0.458
General GTX (Rib)	Bias-ply	0.826	0.517	0.745	0.530
Goodyear Unisteel R-1 (Rib)	Radial-ply	0.802	0.506	0.700	0.445
Goodyear Unisteel L-1 (Lug)	Radial-ply	0.768	0.555	0.566	0.427
Michelin XZA (Rib)	Radial-ply	0.768	0.524	0.573	0.443
Goodyear Custom Cross Rib	Bias-ply	0.716	0.546	0.600	0.455
Michelin XZZ (Rib)	Radial-ply	0.715	0.508	0.614	0.459
Average		0.756	0.540	0.641	0.467

Table 2.1: Values of Coefficient of Road Adhesion for Truck Tires on Dry and Wet Concrete Pavement at 64 km/h (40 mph)

2.2.3 Braking System

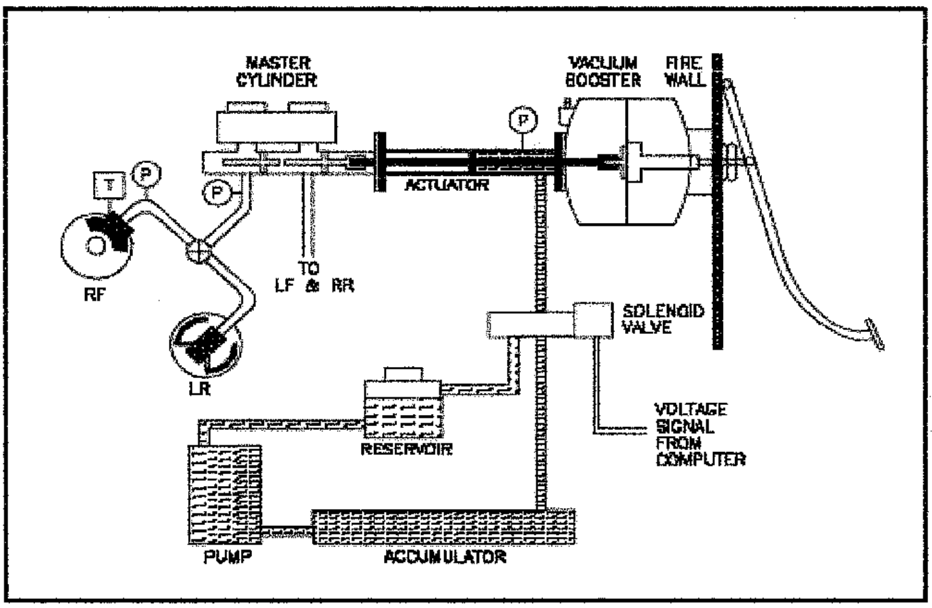


Figure 2.1: Brake System Diagram

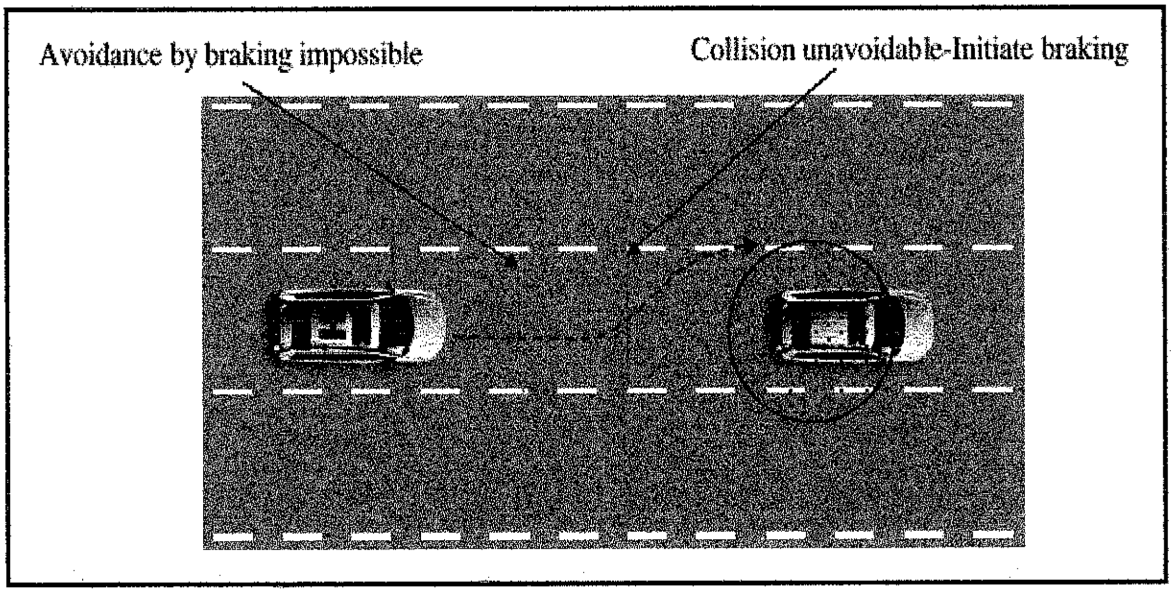


Figure 2.2: Braking Distance

Braking model is very important in order to do analysis about vehicle crash avoidance. There is critical distance for car to stop. The analysis had been made by manufacturer to ensure safety while braking. The table below show the critical distance for car to stop. The parameters that had been used are according to standard car nowadays. This included a brake pedal force limit of 500 N. Also, the brake lining temperature prior to each stop was required to be between 65 and 100 C. The stops were in a straight line and began at 100 km/h. The measured nominal peak friction coefficient of the wet and dry asphalt during testing was 0.66 and 0.86 respectively.

In the research that had been made, human errors contribute to above 90 % of all traffic accidents. In stead of that, Rear-end collision constitute about 30 % of all traffic accidents. So the analysis of breaking system for vehicle can avoid the vehicle.

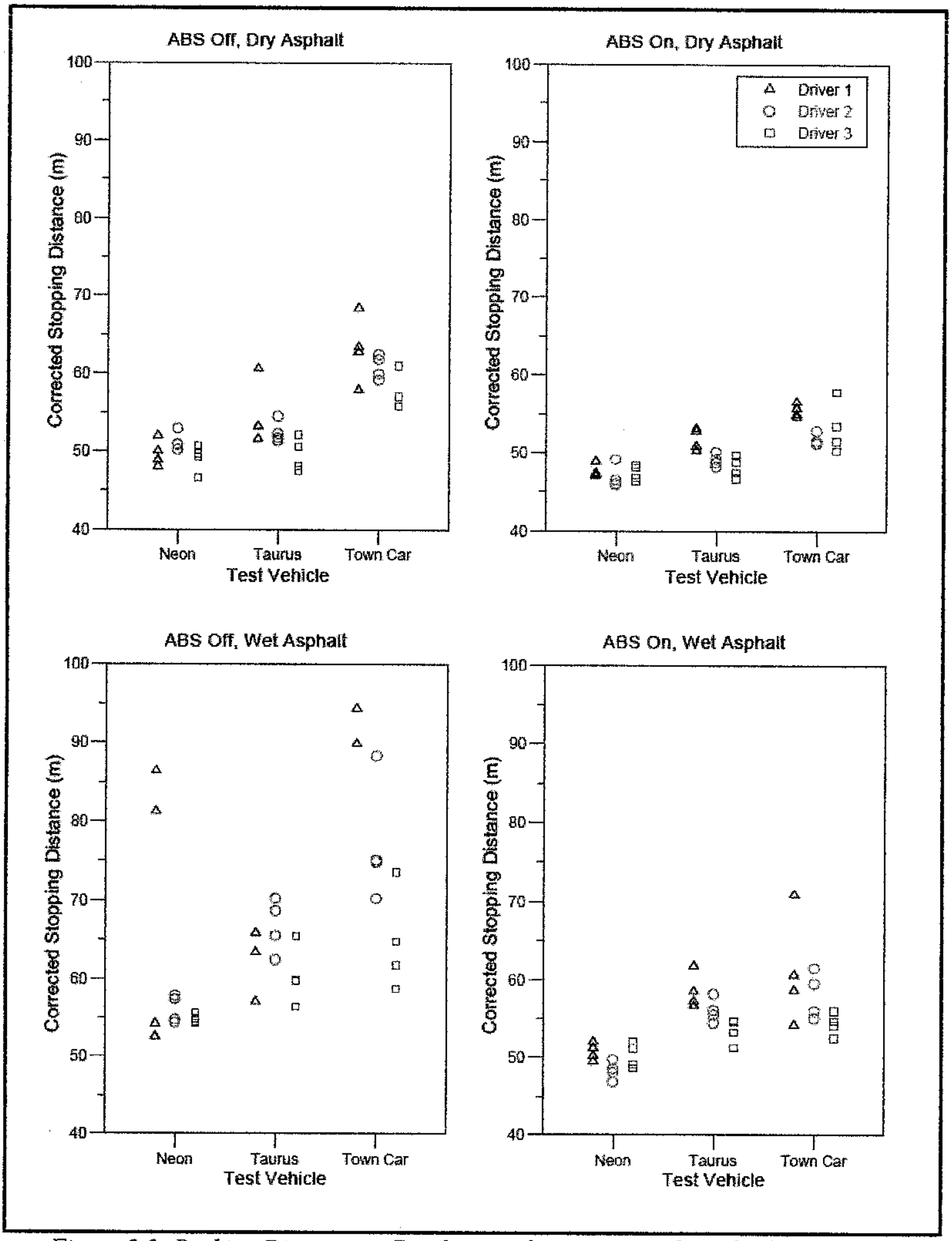


Figure 2.3: Braking Distance in Graph according to types of car, brake and road.

2.2.4 Steering System (bicycle model)

Steering is the term applied to the collection of components, linkages, etc. which allow for a car or other vehicle to follow a course determined by its driver, except in the case of rail transport in which rail tracks combined together with railroad switches provide the steering function.

The most conventional steering arrangement is to turn the front wheels using a hand–operated steering wheel which is positioned in front of the driver. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear–wheel steering. Tracked vehicles such as tanks usually employ differential steering—that is, the tracks are made to move at different speeds or even in opposite directions to bring about a change of course.

Most modern cars use rack and pinion steering mechanisms. Older designs often use the recirculation ball mechanism, which is still found on trucks and utility vehicles. In a rack and pinion design, the steering wheel turns the pinion via the steering column which may use universal joints. The rack moves from side to side and applies torque to the kingpins of the steered wheels via tie rods and a short lever called the steering arm. Ackermann steering geometry is commonly used to allow each wheel to trace the correct path while traveling in a curve.

Modeling of vehicle also much related to the steady state handling with related of the usage of steering. In this analysis the inertia properties of the vehicle are not involved to make the equation not too much complicated. When a vehicle is negotiating a turn at moderate or higher speeds, the effect of the centrifugal force (an inertia force arising from the normal component of acceleration towards the center of the turn) acting at the center of gravity can no longer be neglected. To balance the centrifugal force, the tires must develop appropriate cornering forces. A side force acting on a tire produces a side slip angle. Thus, when a vehicle is negotiating a turn at moderate or higher speeds, the four tires will develop appropriate slip angles.

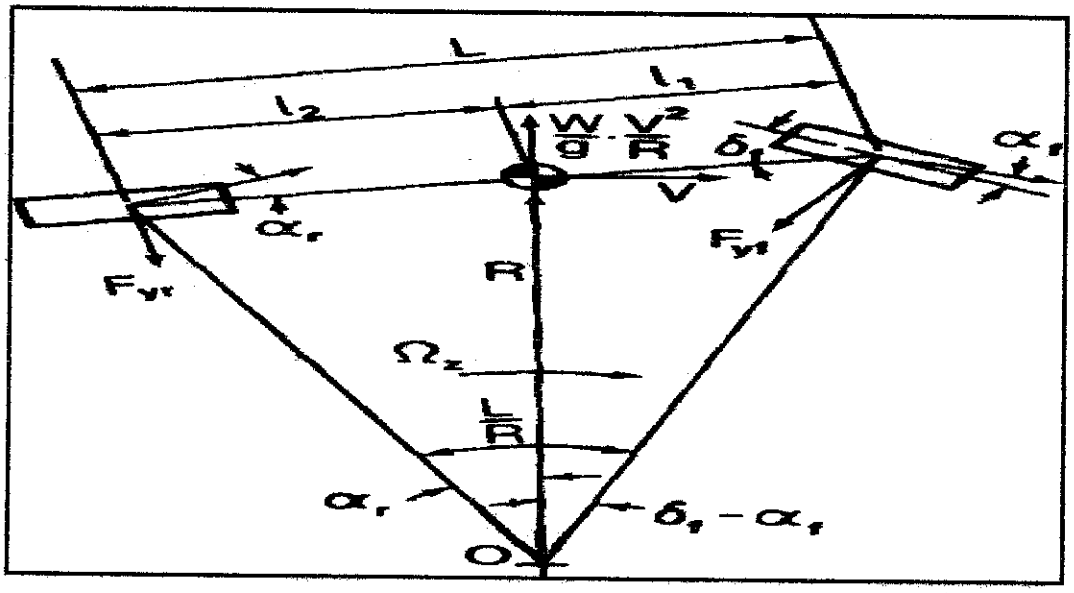


Figure 2.4: Bicycle model and parameter

To simplify the analysis, the pair of tires on an axle is represented by a single tire with double the cornering stiffness, as shown in Fig. above. The handling characteristics of the vehicle depend, to a great extent, on the relationship between the slip angles of the front and rear tires, α_{f} and α_{r}. The steady-state response to steering input of a vehicle at moderate and higher speeds is more complex than that at low speeds. From the geometry shown in above, the relationship among the steer angle of the front tire α_{f}, the turning radius R, the wheel base L, and the slip angles of the front and rear tires α_{f} and α_{r}, is

$$\delta_{f} - \alpha_{f} + \alpha_{r} = L/R$$

$$\delta_{f} = L/R + \delta_{f} - \alpha_{f}$$

From simplifying the equation in the figure above, the final equation for turning radius of the steering is

$$R = \frac{L}{\partial f - {}^{Ku\,\partial y}\!/_{g}}$$

CHAPTER 3
METHODOLOGY

3.1 Methodology

1) *Vehicle modeling*

   Firstly particle that moves on the highway using equation of motion that is in the physic need to design. Then continue with modeling the actual vehicle using vehicle dynamics equation. The dimension of the vehicle is taken from mostly-used car in highway.

2) *Matlab and Neural Network training*

   Learnt and understand how to use and apply this software especially in Simulink and animation in order to simulate vehicle crash avoidance.

3) *Vehicle and highway modeling and animation*

   The third step for this project is to model both vehicle and modeling, which includes animation.

4) *Simulation of vehicle lane changing and merging*

   Simulation for the vehicle lane changing and merging is then done to find out the appropriate algorithm for a safer ride.

5) *Neural Network control and implementation*

   Finally, the neural network control and implementation of the system is done.

3.2 Tools and Equipment Used

The tools and equipments used for this project are:

1) Matlab Simulink and Neural Network Toolbox.

3.3 The Timeline for Final Year Project Vehicle Crash Avoidance Analysis and Simulation Using Neural Network Approach

3.3.1 The Timeline for Semester 1

For my first semester of my project, Table 3.1 below shows the tasks done in respective tentative timeframe. Refer to the Gantt chart below for more detail.

Month	Specific Task	Note
July	➢ Find out the objectives of the project. This is to make sure the objectives for this project will be achieved at the end of semester ➢ List of references and literature review- to clear about the topic by read additional material ➢ Plan for the whole semester- to make sure the project is done in neat and step by step.	
August	➢ Learnt and understand how to use and apply this software especially in Simulink and animation in order to simulate vehicle crash avoidance. ➢ Find out the value for parameter that will consider in this project such as dimension for the road and ideal car. ➢ Find analysis for vehicle- powertrain. Consider about tractive effort and gear ratio. The parameter that been use	

	is average value for a normal car. ➢ Find power required for vehicle using calculation. ➢ Submission of Preliminary Report	
September	➢ Analysis on steering model. Find out the value for parameter that involve in equation for braking and steering. Use bicycle analysis to find steer angle. Inertia has been neglected to simply the analysis. ➢ Analysis on braking system. Find out the parameters value that involve in the equation for braking. Find out the distance for braking using calculation and from experiment that has been done by group of people. ➢ Prepare draft for progress report	
October	➢ Modeling steering and braking in Matlab Simulink. ➢ Analysis on braking and steering model. Compared the result with actual steering at car by doing experiment and from internet. ➢ Submit progress report to supervisor.	
November	➢ Find out the neural network input that will be used in next semester. Neural network input are got from braking model in Matlab and calculation. ➢ Submit the Interim Report to Supervisor ➢ Oral presentation	

Table 3.1: Timeline for Final Year Project Semester 1

3.3.2 The Timeline for Semester 2

For my second semester of my project, Table 3.1 below shows the tasks done in respective tentative timeframe. Refer to second semester Gant chart for more detailed.

Month	Specific Task	Note
December	➢ Learnt and understand how to use and apply Matlab especially in Simulink and animation in order to simulate vehicle crash avoidance. ➢ Study how to use Simulink to do modeling, simulation and implementation ➢ Study all the commonly use block in the Simulink	
January	➢ Review and modifying steering braking and powertrain simulation. ➢ Need to add force for friction between tire and road in the powertrain Simulink ➢ Change the value for the aerodynamics force in the powertrain Simulink ➢ Find the steer angle at the steering Simulink for vehicle to take over.	
February	➢ Find the input for neural network analysis from the Simulink. ➢ Compared the result from the Simulink with calculation for input that need in neural network. ➢ learnt neural network approach ➢ Submit progress report I	

March	➢ Combining steering, braking and powertrain Simulink ➢ Continue to study neural network ➢ Apply neural network in the project ➢ Submit progress report II	
April	➢ Analysis the result from neural network ➢ Modifying the Simulink to make it user friendly and look nice ➢ Submit the Dissertation Report DRAFT (repair any correction)	
May	➢ Oral presentation ➢ Submit the Dissertation Final Report to Supervisor	

Table 3.2: Timeline for Final Year Project Semester 2

3.3.3 Gantt Chart for Semester 1

Gantt Chart for the First Semester of 2 Semester Final Year Project

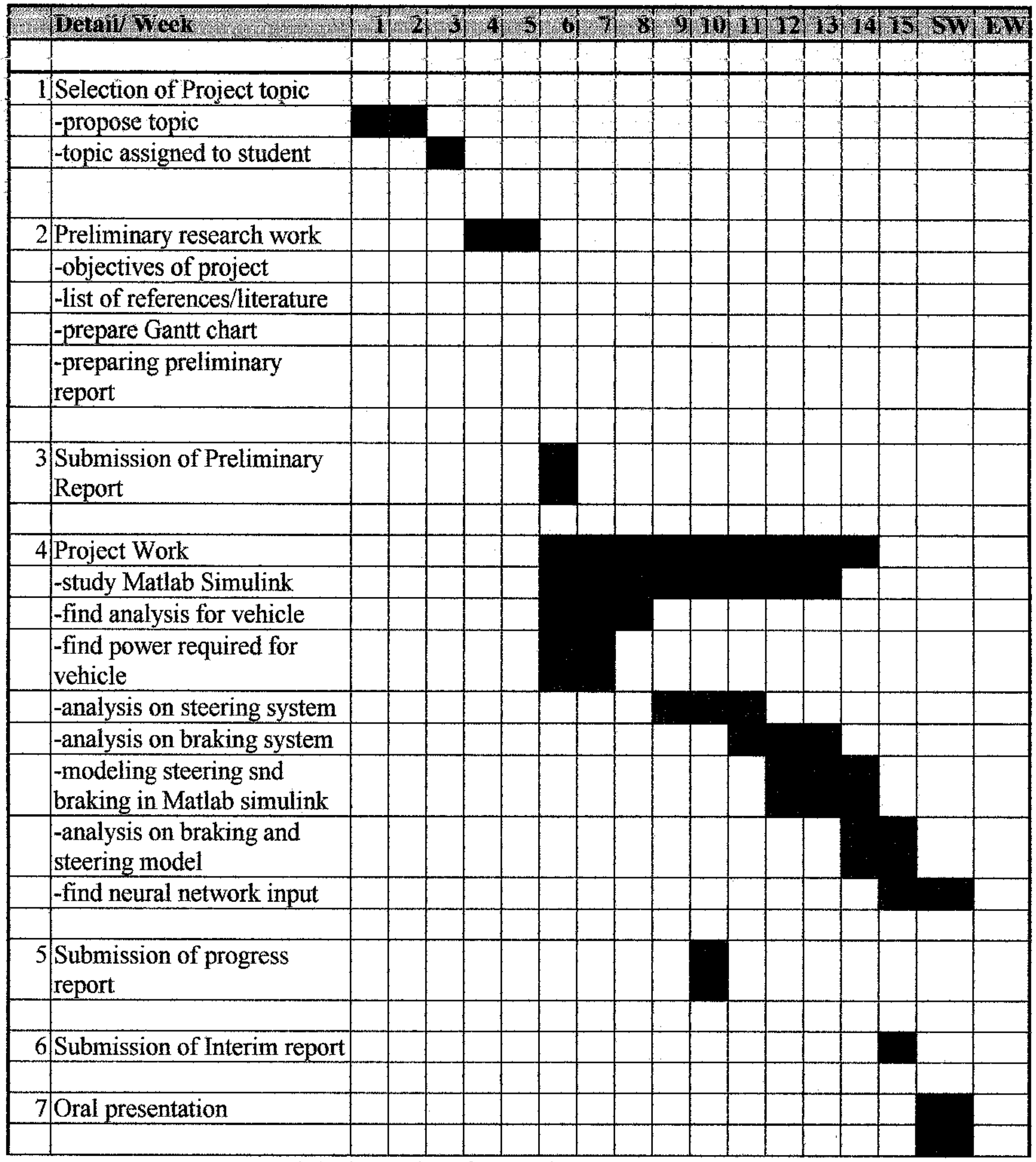


Figure 3.1: Gantt chart for Final Year Project Semester 1

3.3.4 Gantt Chart for Semester 2

Gantt Chart for the Second Semester of 2 Semester Final Year Project

	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	SW	EW
1	Project Work Continue	■	■	■	■													
	- Learnt and understand how to use and apply Matlab (Simulink)																	
	- Review and modifying steering, brake and powertrain Simulink.																	
	-find data (input) for neural network																	
2	Submission of Progress Report 1					■												
3	Project Work Continue					■	■	■	■	■								
	- combine steering and braking simulink																	
	- Learnt and understand neural network																	
	- apply neural network in the project																	
4	Submission of Progress Report 2									■								
5	Project Work Continue									■	■	■	■	■	■			
	- neural network control and implementation																	
	- analysis data from neural network																	
6	Submission of Dissertation Final Draft															■		
7	Oral Presentation																■	
8	Submission of Project Dissertation																	■

Figure 3.2: Gantt chart for Final Year Project Semester 2

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Vehicle Power Requirement

There are two limiting factors to the performance of a road vehicle: one is the maximum tractive effort that the tire-ground contact can support, and the other is the tractive effort that the engine torque with a given transmission can provide. The smaller of these two will determine the performance potential of the vehicle. In low gears with the engine throttle fully open, the tractive effort may be limited by the nature of tire road adhesion. In higher gears, the tractive effort is usually determined by the engine and transmission characteristics. To predict the overall performance of a road vehicle, the engine and transmission characteristics must be taken into consideration.

$$P_{req} = P_{aero} + P_{roll} + P_{grade} + P_{acce}$$

$$P_{req} = \frac{1}{2}\rho C d A v^3 + mg\,Crr\,v$$

$$P_{req} = 0.5\ (1.225\ kg/m^3)\ (0.3)\ (1.8m^2)\ v^3 + (1000kg)\ (9.81)\ (0.009)\ v$$

$$P_{req} = 0.33075\ v^3 + 88.38\ v$$

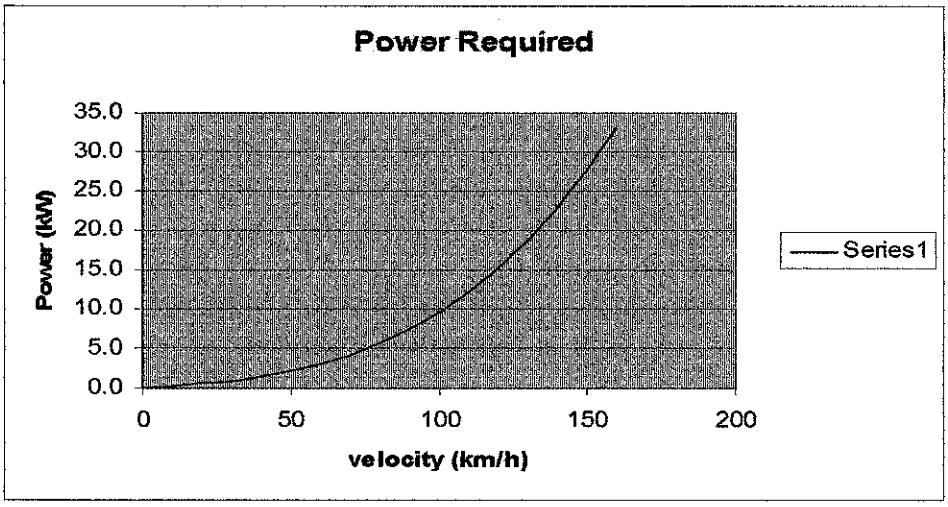


Figure 4.1: Power required in the car

		Unit (W)		
km/h	m/s	P aero	P roll	P total (kW)
0	0	0	0	0.0
10	2. 78	7.08	245.25	0.3
20	5. 56	56.71	490.50	0.5
30	8. 33	191.40	735.75	0.9
40	11. 11	453.70	981.00	1.4
50	13. 89	886.14	1226.25	2.1
60	16. 67	1531.25	1471.50	3.0
70	19. 44	2431.56	1716.75	4.1
80	22. 22	3629.63	1962.00	5.6
90	25.00	5167.96	2207.25	7.4
100	27. 78	7089.12	2452.50	9.5
110	30. 56	9435.61	2697.75	12.1
120	33. 33	12250.00	2943.00	15.2
130	36. 11	15574.80	3188.25	18.8
140	38. 89	19452.55	3433.50	22.9
150	41. 67	23925.78	3678.75	27.6
160	44. 44	29037.04	3924.00	33.0

Table 4.1: Power required in the car

4.2 Steering Systems

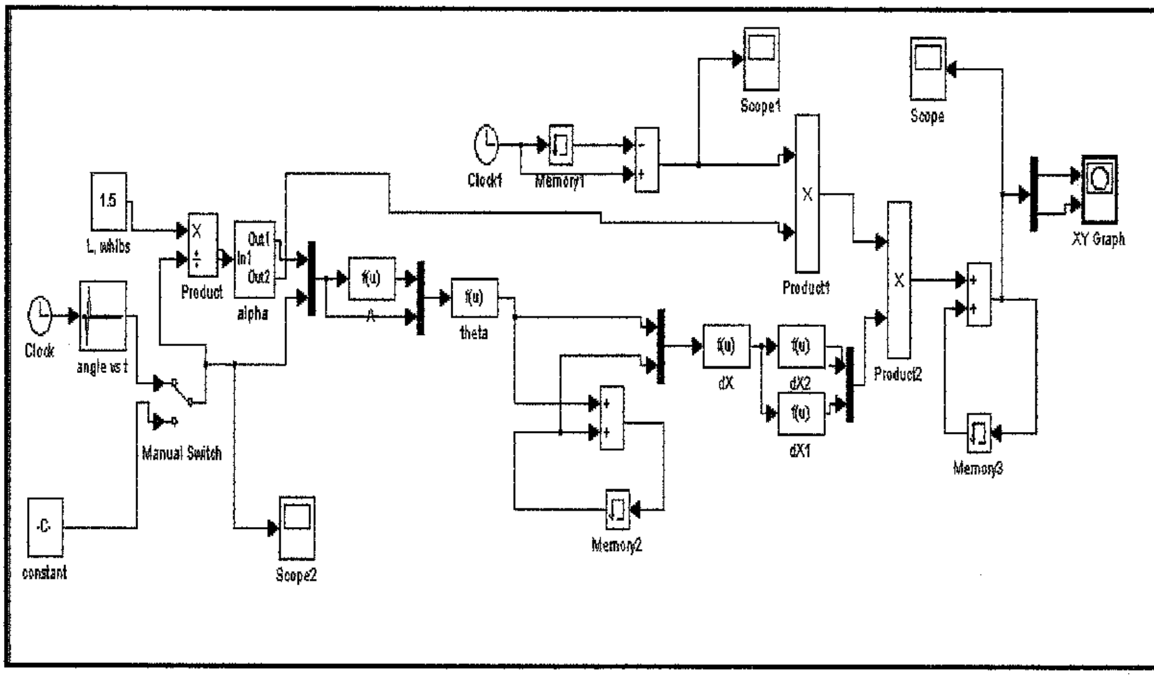


Figure 4.2: Simulink model for steering system

Figure 4.2 above shows the Simulink model for steering system. This Simulink is derived from several equation to show the position of the car when we put in the values for steer angle and time.

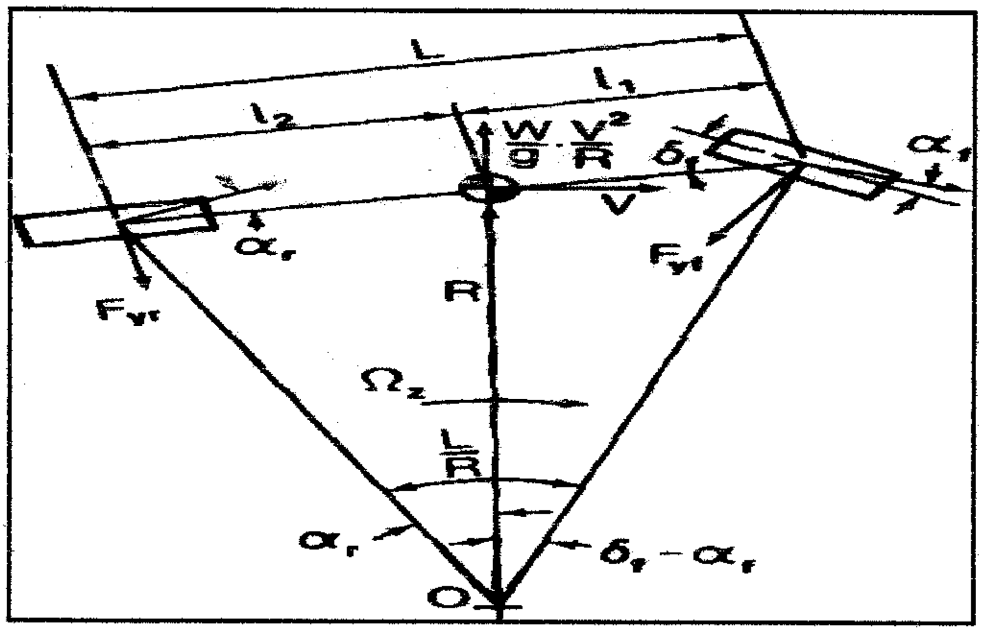


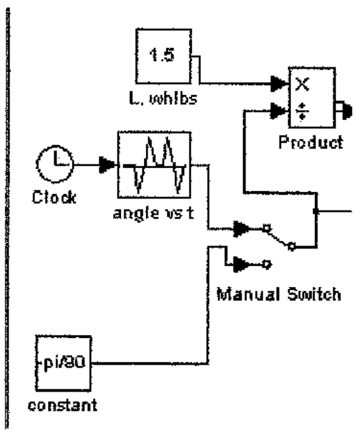
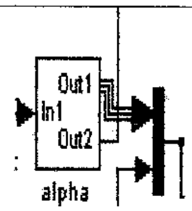
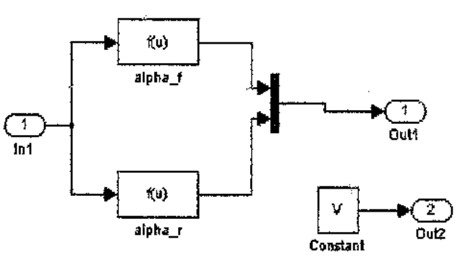
Figure 4.3: Bicycle model and parameter

From the geometry shown in Figure 4.3, the relationship among the steer angle of the front tire δ_f, the turning radius R, the wheel base *L*, and the slip angles of the front and rear tires α_f and α_r, is

$$\delta_f - \alpha_f + \alpha_r = L/R$$

$$\delta_f = L/R + \delta_f - \alpha_f$$

From simplifying the equation in the figure above, the final equation for turning radius of the steering is, $R = \frac{L}{\partial f - \frac{Ku\,\partial y}{g}}$

Simulink diagram	descriptions	equations
	From left hand side the clock block is put in to make the output simulation in time. The value of time can be shown when we tick it to display time. Angle vs time block is for us to put the input values for the steer angle of the front tyre, δ_f. The manual switch is put in after that to make us easier to use the two input values and it will toggles when we double click on it.1.5 is the value for wheelbase.	$R=\frac{L}{\partial f-\frac{Ku\partial y}{g}}$ δ_f = steer angle of the front tire R = the turning radius, L= the wheel base α_f = the slip angles of the front tires α_r= the slip angles of the rear tires
 	The output 1 is the slip angles of the front and rear tires, α_f and α_r, while output 2 is the velocity of the vehicle.	$\alpha_f = (W_f / C)(V^2/g R)$ $\alpha_r = (W_r / C)(V^2/g R)$

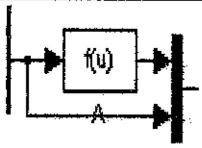
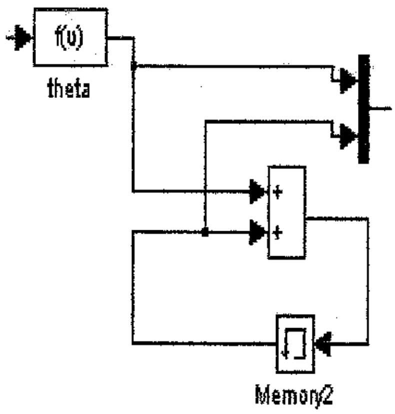
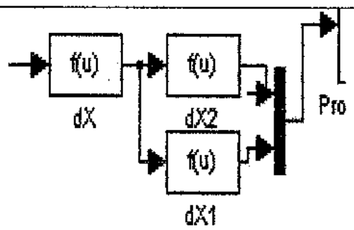
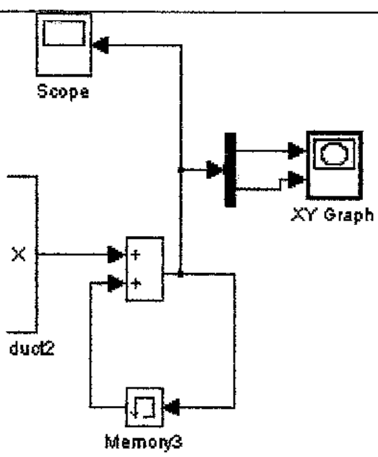
	The block diagram is used to calculate A, that is the side angle of θ, the position angle of vehicle.	$A = 180^\circ - [(90^\circ - \alpha_r) + \alpha_r + (\delta_f - \alpha_f)]$
	The block diagram is used to calculate θ, the position angle of vehicle. The block memory2 is used to continous adding value for θ, likes at the equation at beside.	$\theta = 180^\circ - [(90^\circ - \alpha_r) + \alpha_r + (\delta_f - \alpha_f)] - A$ $\theta = \theta_i + \theta_{i+1 \ldots\ldots}$
	The block diagram is used to calculate the position of vehicle in x and y direction. The values are got when we differentiate the value.	$\Delta X = V \sin [90^\circ - (\phi_o + \theta_1)]\ \Delta t$ $\Delta Y = V \cos [90^\circ - (\phi_o + \theta_1)]\ \Delta t$
	The block diagram is used to find the position of vehicle. The block memory is used to make the position values continuously be added like at the equation beside. The XY graph is used as output to show the position of vehicle to us.	$dx = dx_i + dx_{i+1}$ $dy = dy_i + dy_{i+1}$

Table 4.2: Description of simulink model for steering

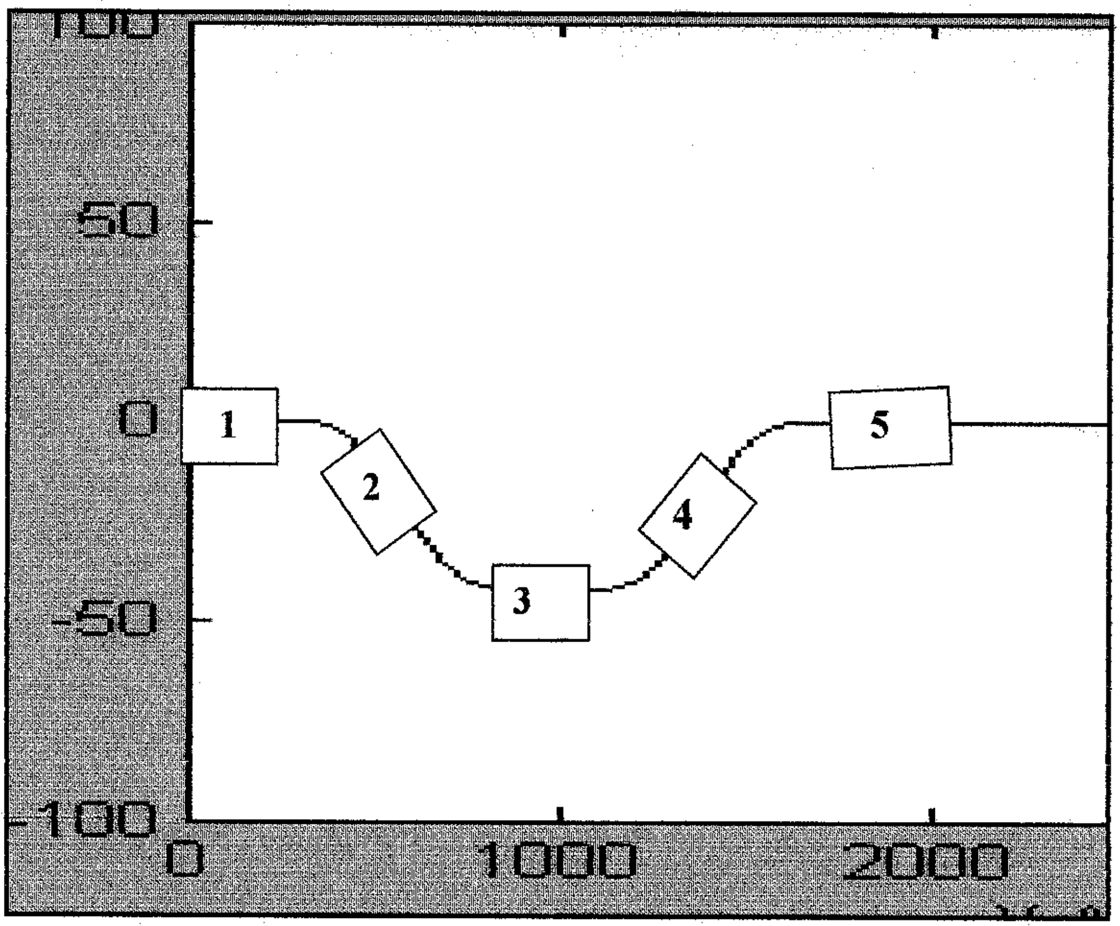


Figure 4.4: Position of vehicle to overtake the front vehicle

POSITON OF VEHICLE	STEER ANGLE (degree)	TIME (second)
1	0	0
1	0	10
1	0	20
1	0	30
2	-1	40
2	-1	40.02
2	0	60
2	1	70
2	1	70.02
3	0	90
3	0	110
3	1	120

3	1	120.02
4	0	140
4	-1	150
4	-1	150.02
5	0	170

Table 4.3: Time, steer angle and position of vehicle while overtake front vehicle.

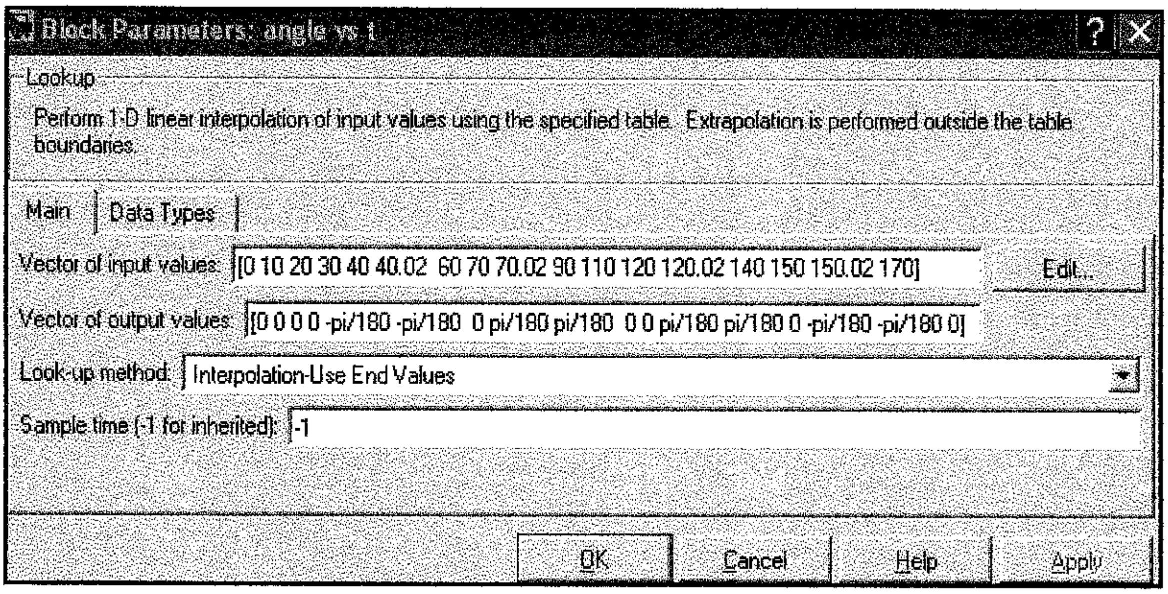


Figure 4.5: Time (top) and steer angle in Matlab

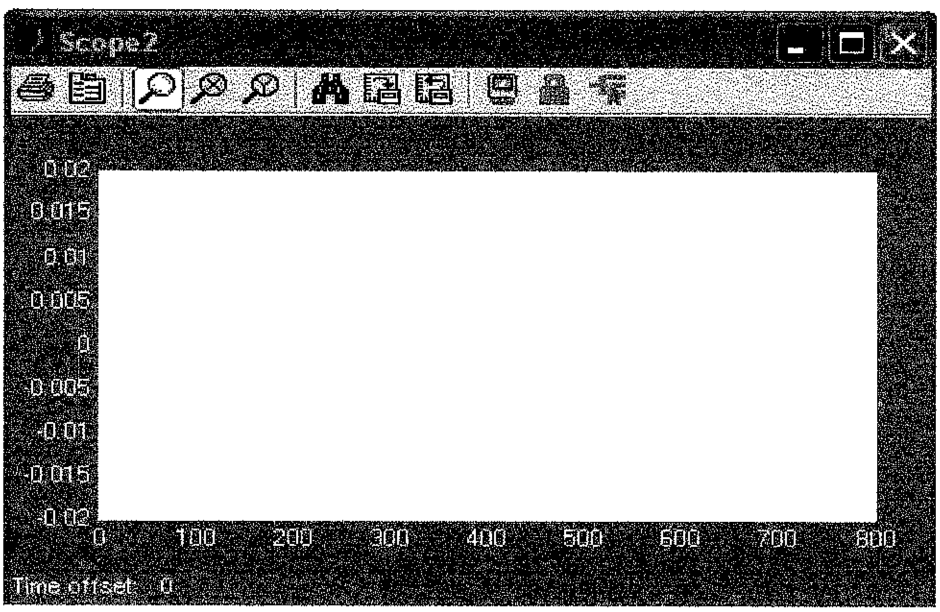


Figure 4.6: Angle of steering

4.3 Powertrain and Braking Modeling

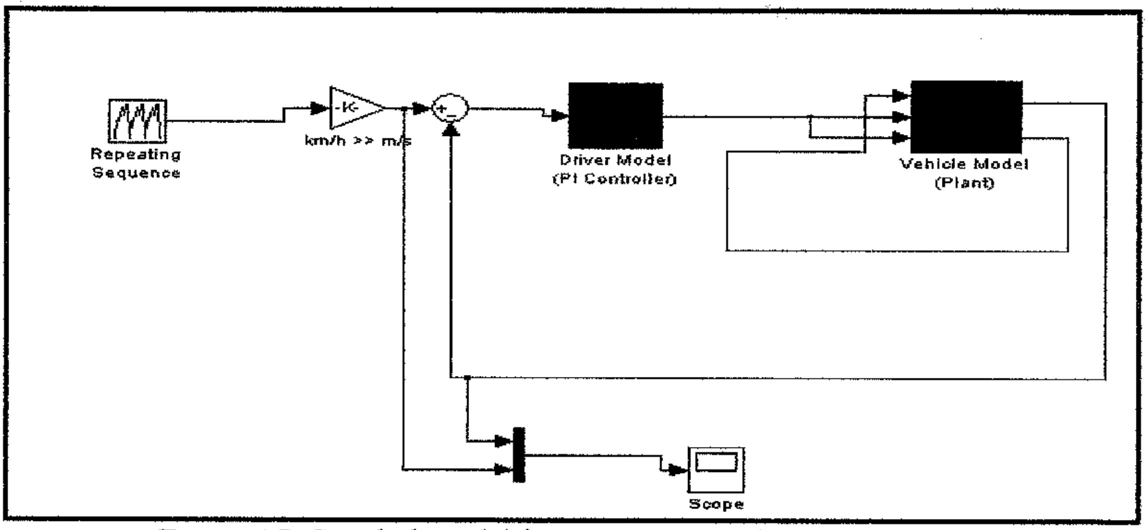


Figure 4.7: Simulink model for powertrain and braking modeling

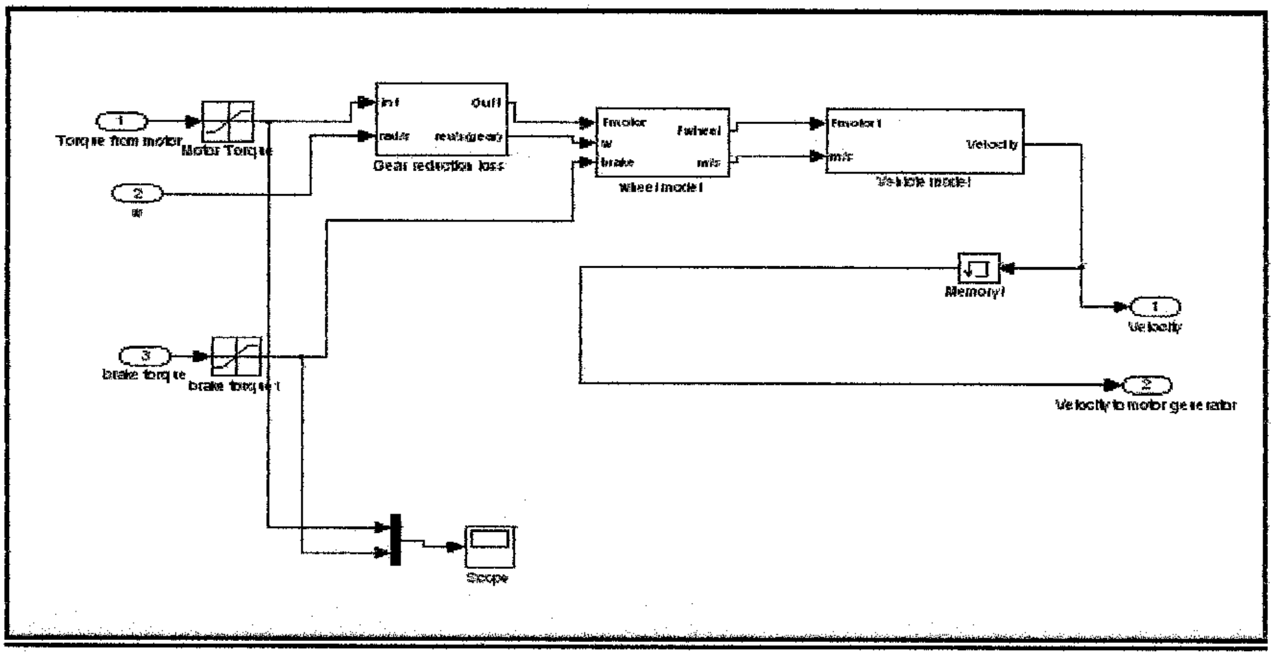


Figure 4.8: Simulink model for powertrain and braking modeling

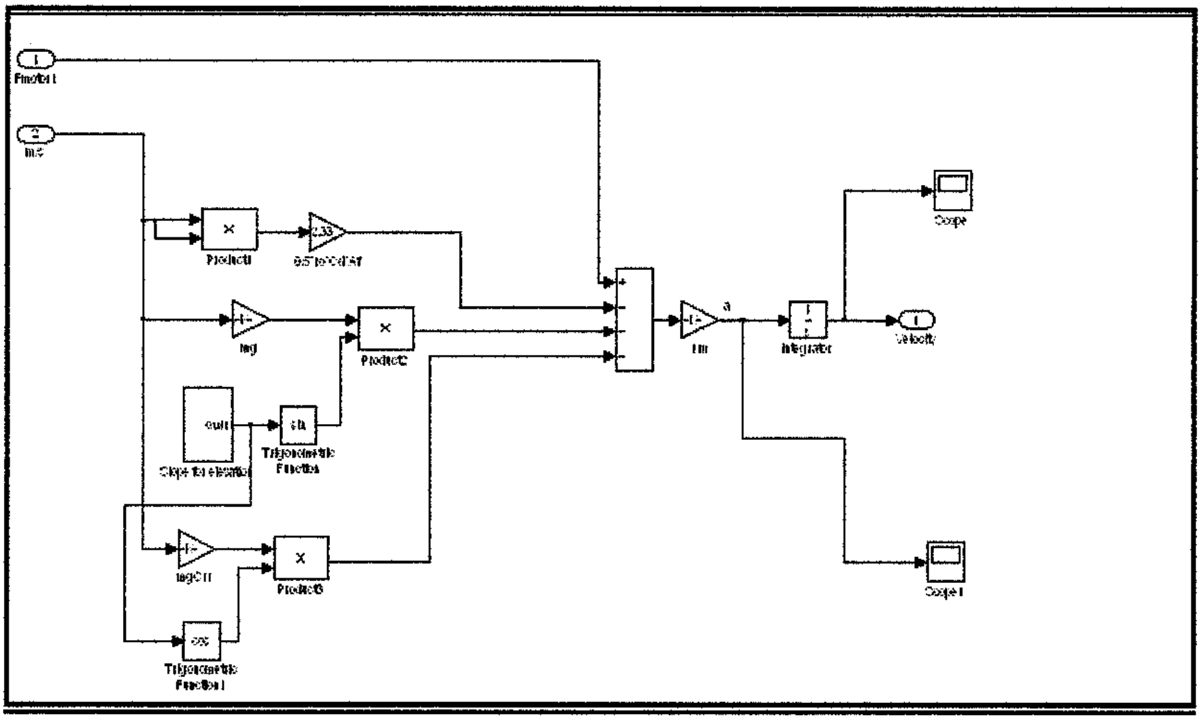


Figure 4.9: Simulink model for powertrain and braking modeling

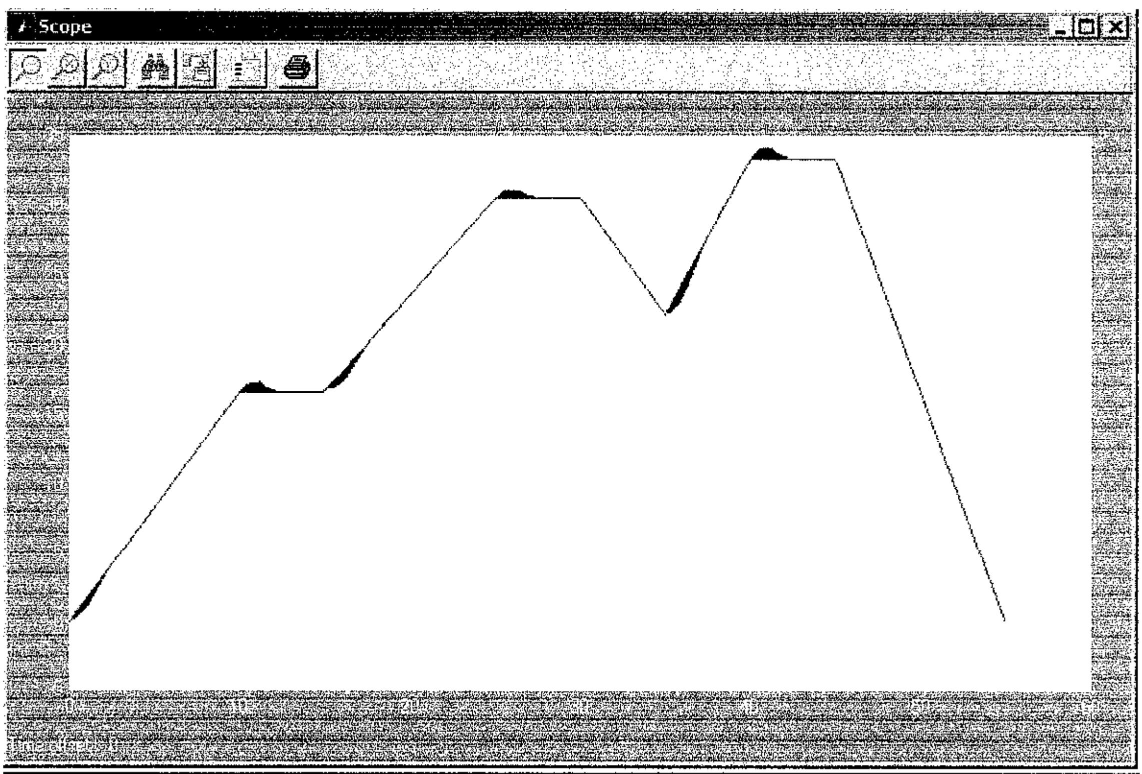


Figure 4.10: Velocity actual (yellow) and velocity required (pink)

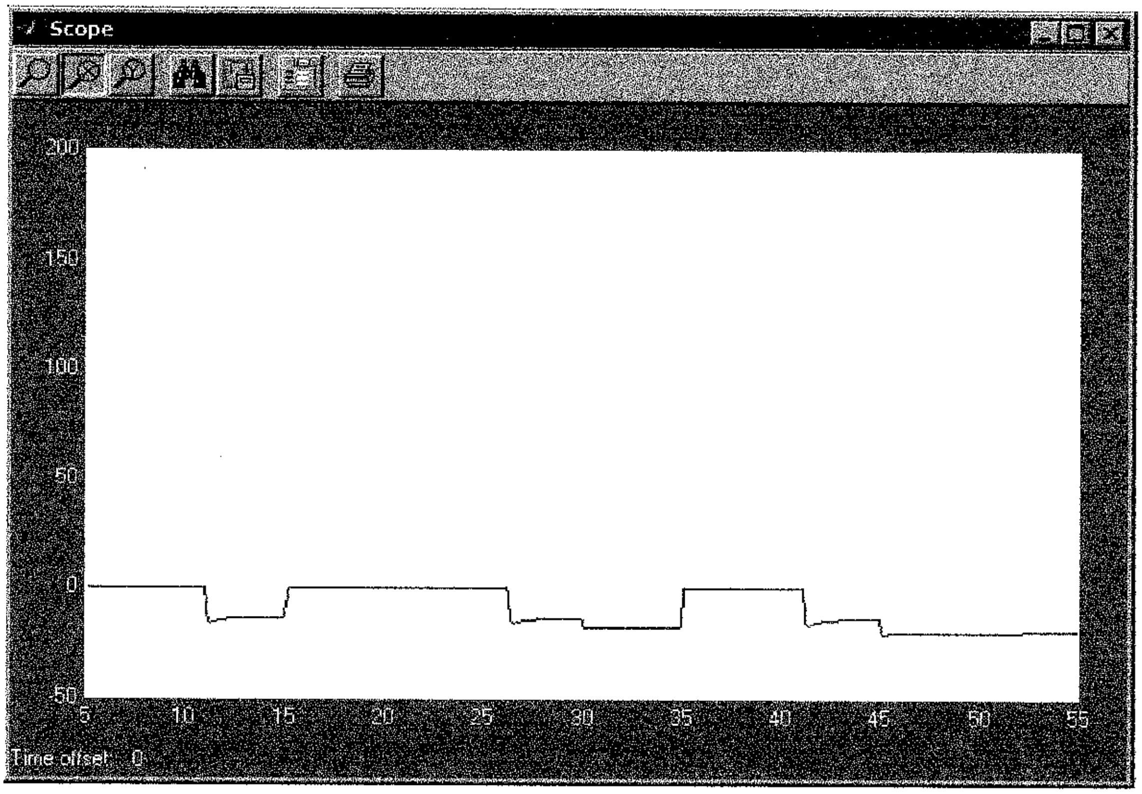


Figure 4.11: Torque (yellow) and braking force (pink)

4.4 Two Cars Simulation- Braking Distance Study

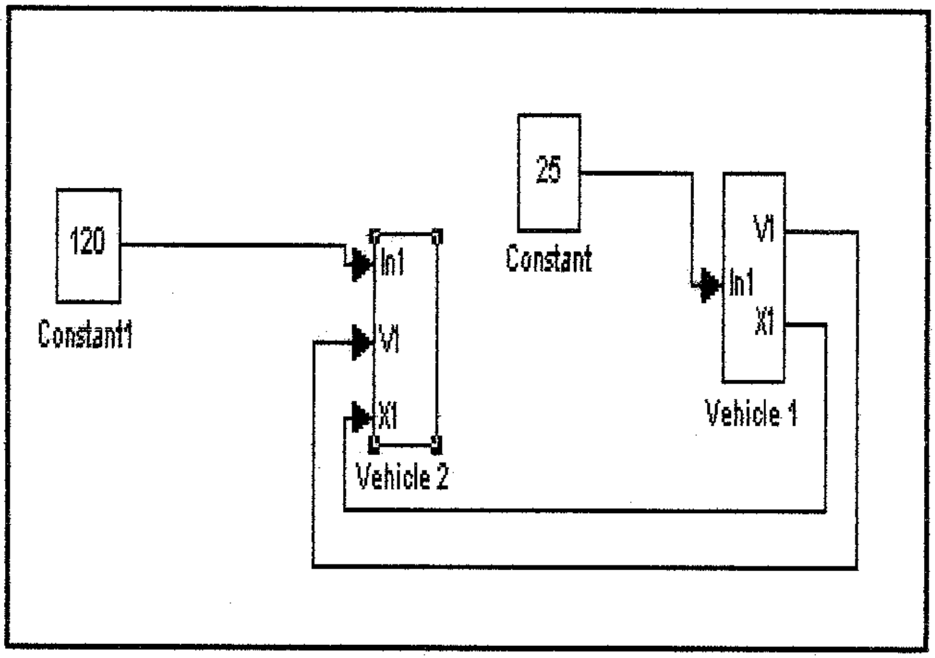


Figure 4.12: Two Cars Simulation- Braking Distance Study

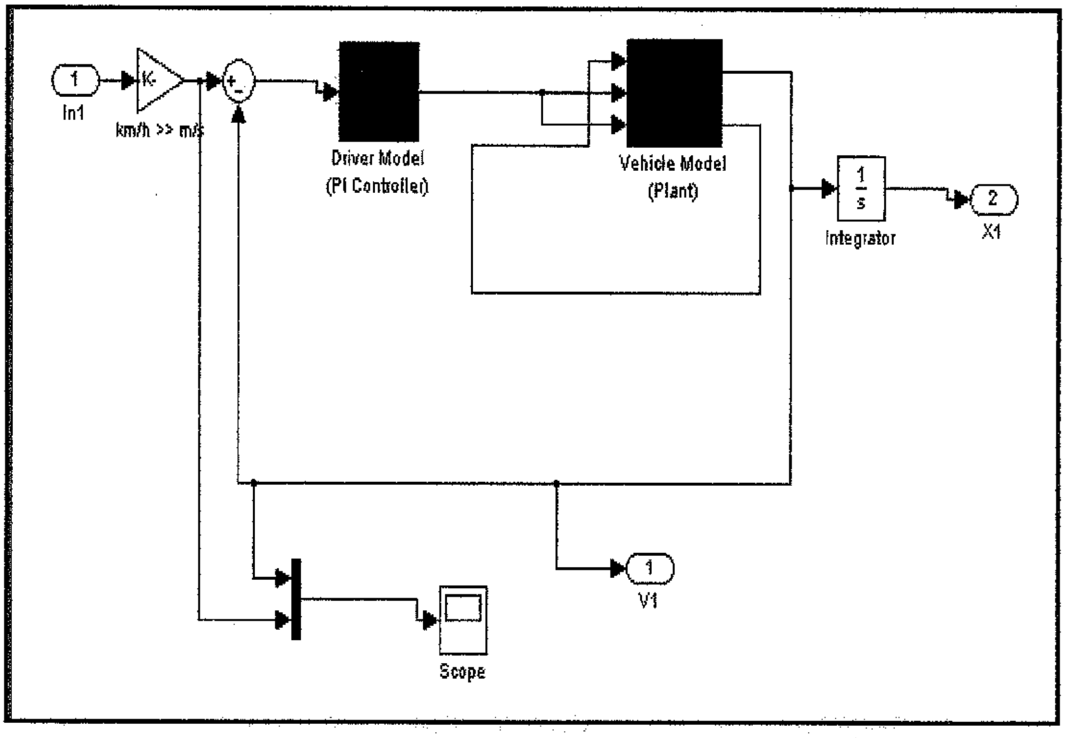


Figure 4.13: Vehicle 1 study

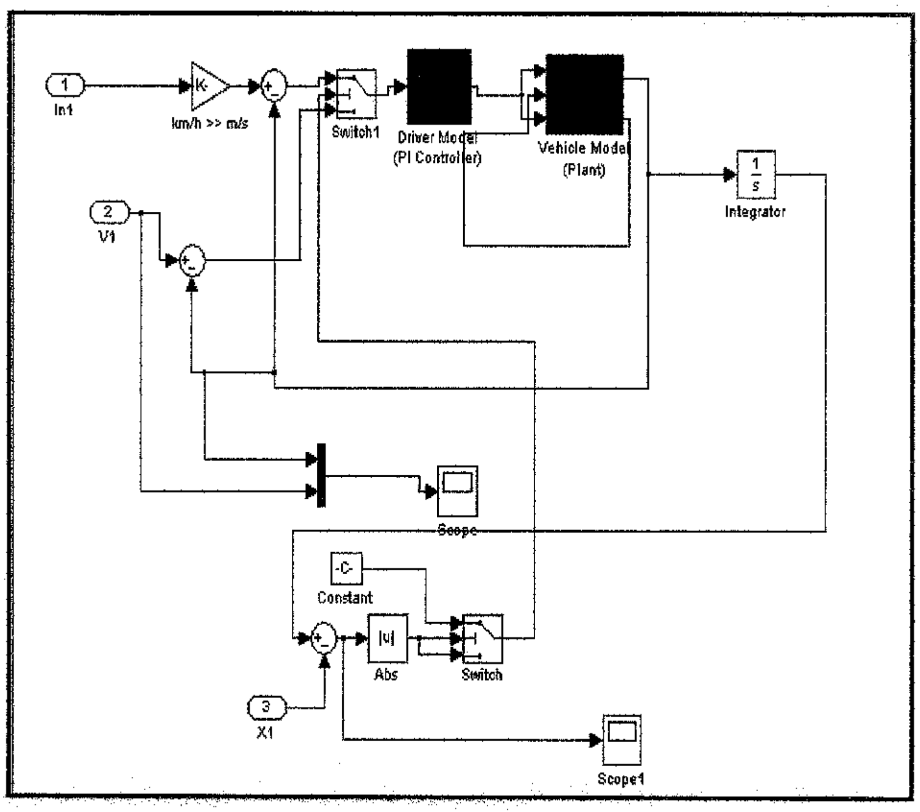


Figure 4.14: Vehicle 2study

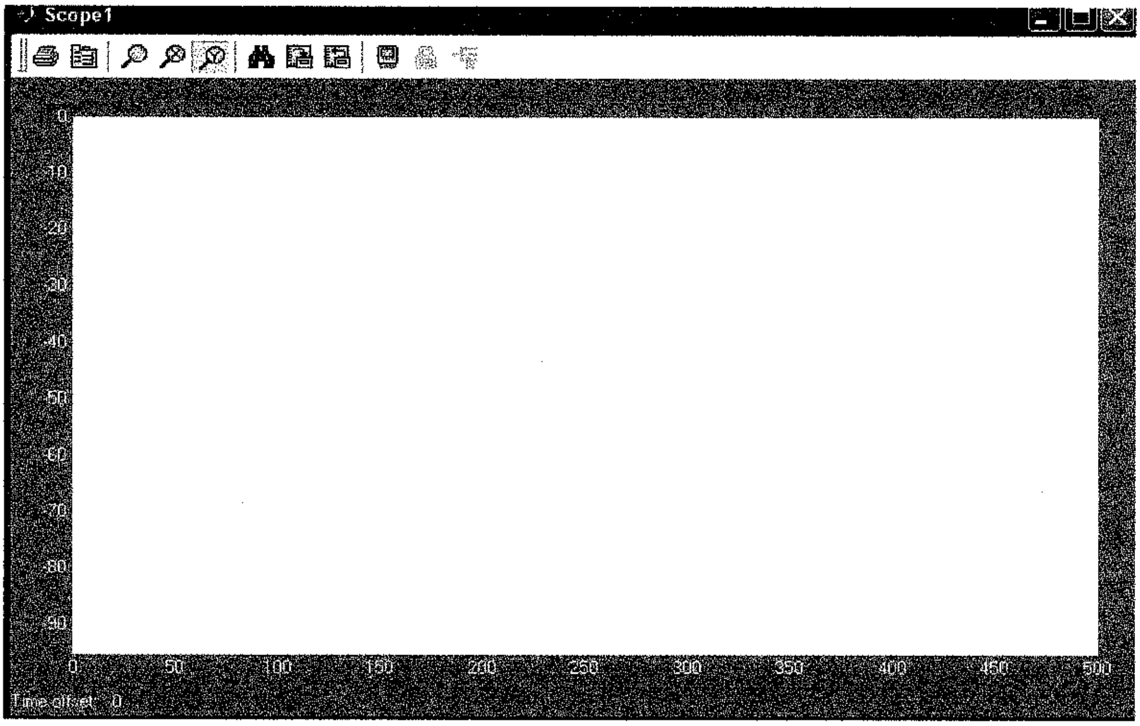


Figure 4.15: Distance of braking vehicle using simulation

The graph in Figure 4.15 shows the distance of braking for vehicle. In this condition the behind car came from high velocity from long distance. At this time the car do not senses in front car. When the car senses the front vehicle which is slower, the vehicle will brake and tries to follow the front vehicle with same velocity. This method only applied when the behind vehicle have enough distance to brake.

Vehicle 1		Vehicle 2		Braking Distance Required (m)	Time (s)
km/h	m/s	km/h	m/s		
60	16. 67	50	13. 89	5.81	0.38
70	19. 44	50	13. 89	12.68	0.76
80	22. 22	50	13. 89	20.61	1.14
90	25.00	50	13. 89	29.59	1.52
100	27. 78	50	13. 89	39.63	1.90
110	30. 56	50	13. 89	50.73	2.28
120	33. 33	50	13. 89	62.89	2.66
130	36. 11	50	13. 89	76.10	3.04
140	38. 89	50	13. 89	90.37	3.42
150	41. 67	50	13. 89	105.69	3.80
160	44. 44	50	13. 89	122.08	4.18

Table 4.4: Distance of braking vehicle using calculation

The table above shows the distance of braking for vehicle using calculation. The result will used to compare with simulation result above. The equation that has been used is linear equation of motion.

In kinematics, four equation of motion apply to bodies moving linearly (one dimension) with uniform acceleration.

The vehicles are considered at two instant in time, one 'initial' point and one 'current'. Often problems in kinematics deal with more than two instants and several applications of the equations are required. The equations are;

$$V = u + at$$

$$S = 0.5\,(u + v)\,t$$

$$S = ut + 0.5\,a\,t^2$$

$$V^2 = u^2 + 2\,a\,s$$

Where, s = distance traveled from initial state

v = current speed

t = the time between the initial and current states

a = constant acceleration

4.5 Neural Network

Neural network approach was used as a training application to predict optimum or near-optimum solution for a wide range of problems. In this project, the training is used to predict whether the car have collision or not. The setup input values was used such as shown in Table 4.4 to train this application. When the project is running, this application will provide information to the system whether the vehicle behind, which has a higher velocity, can brake in time or hit the front vehicle.

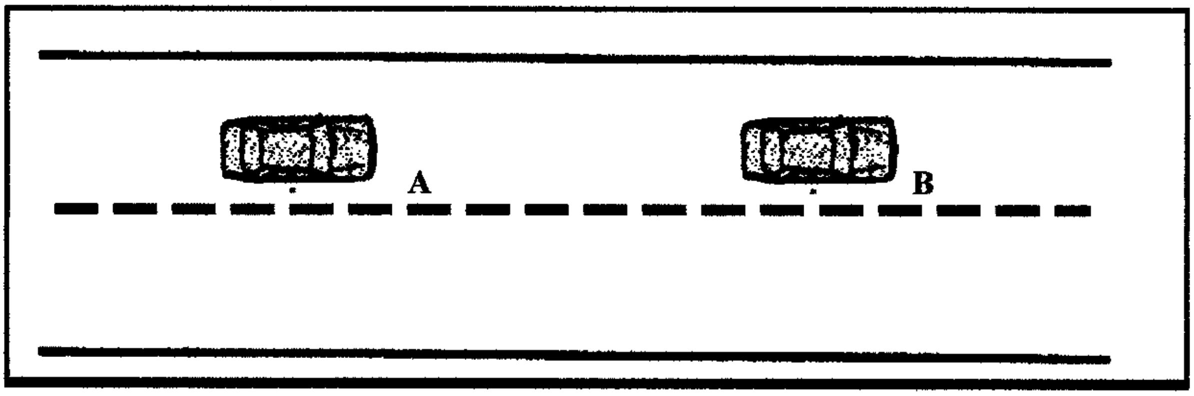


Figure 4.16: Position of Vehicle A and Vehicle B

V_A \ V_B	0	10	20	30	40	50	60	70	80	90	100
200	X	X	X	X	X	X	X	X	X	√	√
190	X	X	X	X	X	X	X	X	√	√	√
180	X	X	X	X	X	X	√	√	√	√	√
170	X	X	X	X	√	√	√	√	√	√	√
160	X	X	√	√	√	√	√	√	√	√	√
150	√	√	√	√	√	√	√	√	√	√	√
140	√	√	√	√	√	√	√	√	√	√	√
130	√	√	√	√	√	√	√	√	√	√	√
120	√	√	√	√	√	√	√	√	√	√	√

(All Velocity in km/h)

V_B = Velocity Vehicle B (front car)

V_A = Velocity Vehicle A (car behind)

X = hit the front vehicle

√ = brake in time

Table 4.5: Set-up input values for Neural Network

4.6 Combining steering and brake modeling with Neural Network Approach

4.6.1 Neural Networks

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. We can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements

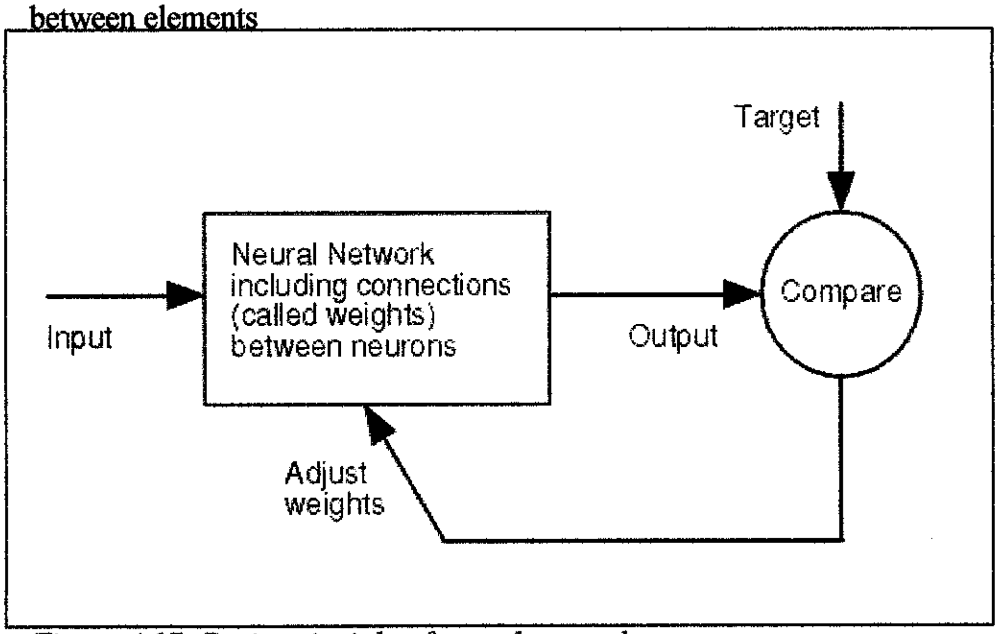


Figure 4.17: Basic principle of neural network

Batch training of a network proceeds by making weight and bias changes based on an entire set (batch) of input vectors. Incremental training changes the weights and biases of a network as needed after presentation of each individual input vector. Incremental training is sometimes referred to as "on line" or "adaptive" training.

Neural networks have been trained to perform complex functions in various fields of application including pattern recognition, identification, classification, speech, vision and control systems.

Today neural networks can be trained to solve problems that are difficult for conventional computers or human beings. Throughout the toolbox emphasis is placed on neural network paradigms that build up to or are themselves used in engineering, financial and other practical applications.

Today neural networks can be trained to solve problems that are difficult for conventional computers or human beings. Throughout the toolbox emphasis is placed on neural network paradigms that build up to or are themselves used in engineering, financial and other practical applications.

The supervised training methods are commonly used, but other networks can be obtained from unsupervised training techniques or from direct design methods. Unsupervised networks can be used, for instance, to identify groups of data. Certain kinds of linear networks and Hopfield networks are designed directly. In summary, there are a variety of kinds of design and learning techniques that enrich the choices that a user can make.

The field of neural networks has a history of some five decades but has found solid application only in the past fifteen years, and the field is still developing rapidly. Thus, it is distinctly different from the fields of control systems or optimization where the terminology, basic mathematics, and design procedures have been firmly established and applied for many years.

Neural networks have been applied very successfully in the identification and control of dynamic systems. The universal approximation capabilities of the multilayer perceptron make it a popular choice for modeling nonlinear systems and for implementing general-purpose nonlinear controllers [HaDe99]. Three popular neural network architectures for prediction and control that have been implemented in the Neural Network Toolbox:

1. Model Predictive Control
2. NARMA-L2 (or Feedback Linearization)
3. Control Model Reference Control

There are typically two steps involved when using neural networks for control:

1. System Identification
2. Control Design

In the system identification stage, you develop a neural network model of the plant that you want to control. In the control design stage, you use the neural network plant model to design (or train) the controller. In each of the three control architectures described in this chapter, the system identification stage is identical. The control design stage, however, is different for each architecture.

1. For the model predictive control, the plant model is used to predict future behavior of the plant, and an optimization algorithm is used to select the control input that optimizes future performance.
2. For the NARMA-L2 control, the controller is simply a rearrangement of the plant model.
3. For the model reference control, the controller is a neural network that is trained to control a plant so that it follows a reference model. The neural network plant model is used to assist in the controller training.

I have choose to use NARMA-L2 control because of it is quite simple and will provide accurate result. It is because the controller the controller is simply a rearrangement of the plant model.

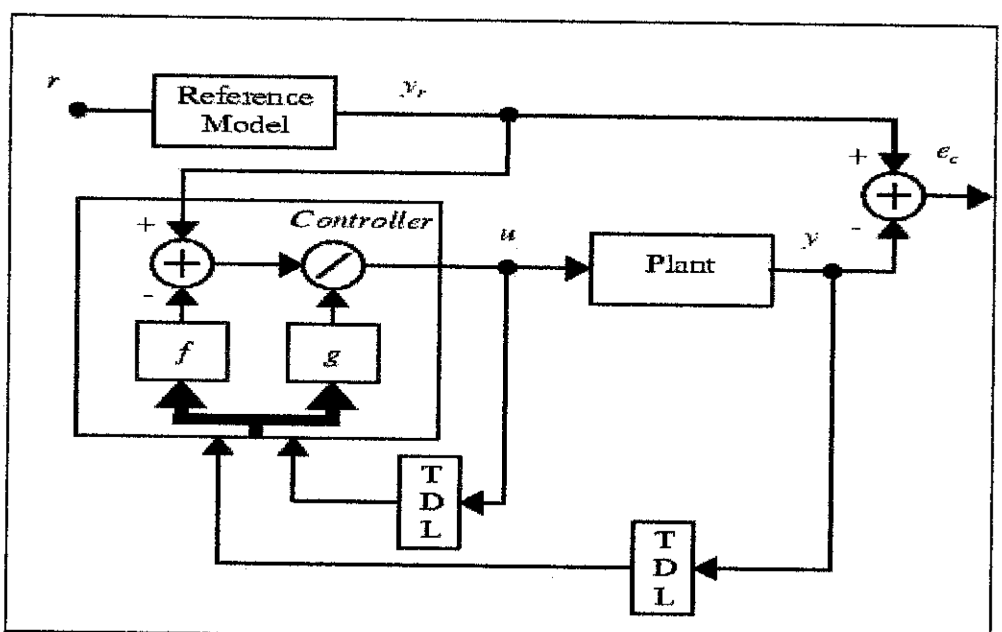


Figure 4.18: Basic principle of NARMA-L2 control

4.6.2 Modeling 1 vehicle in neural network

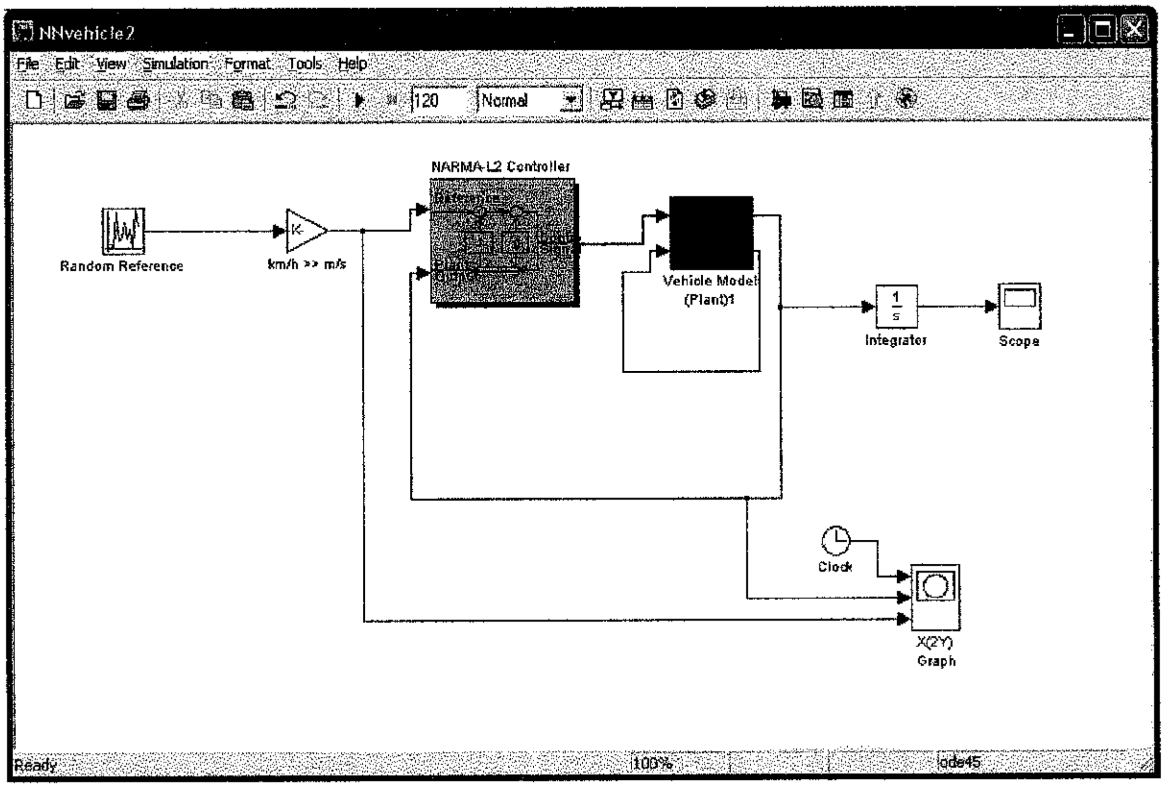


Figure 4.19: One vehicle modeling in neural network

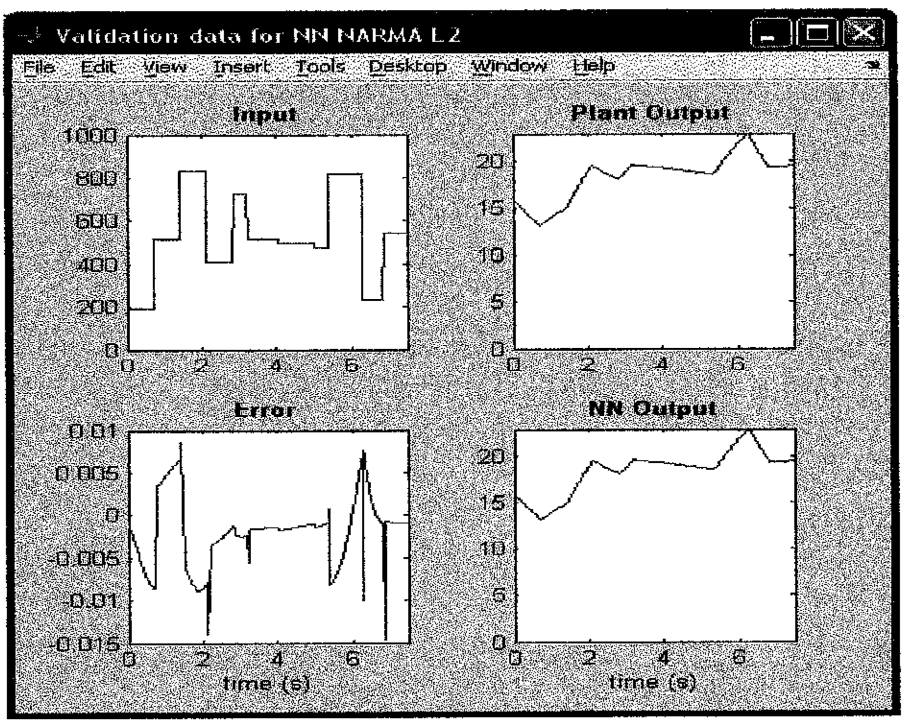


Figure 4.20: Training data for one vehicle modeling in neural network

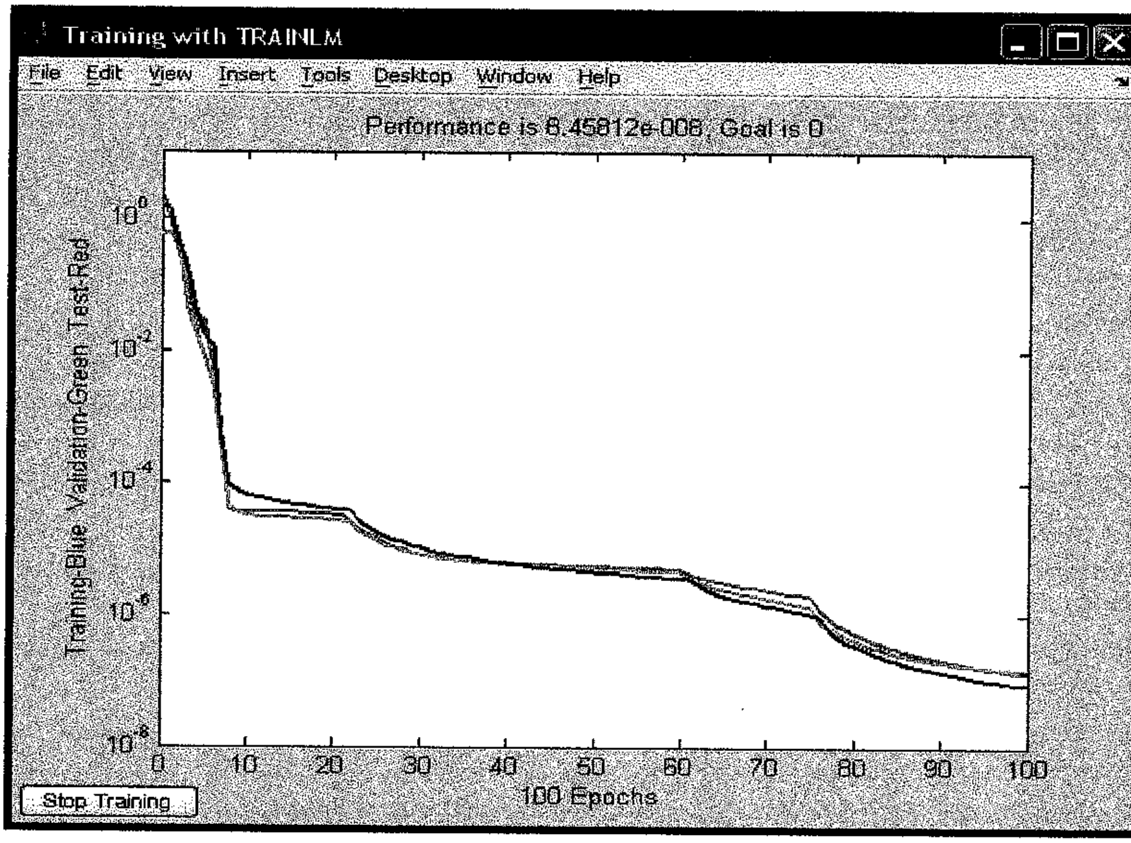


Figure 4.21: Training weight for one vehicle modeling in neural network

4.6.3: Two vehicle models.

4.6.3.1: First design

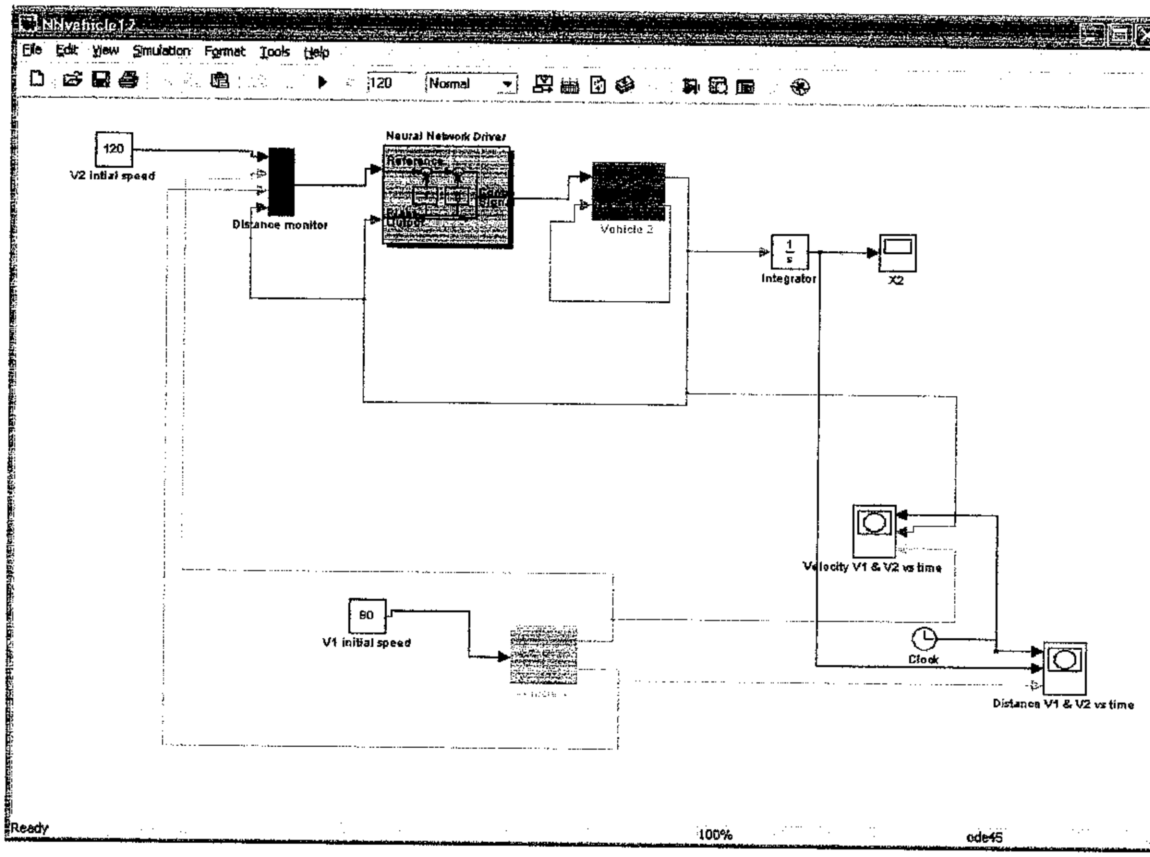


Figure 4.22: Two vehicle models, vehicle 2 is controlled by a neural network controller, vehicle 1 is a slower moving vehicle

Refer to the Simulink digram above velocity vehicle 1 initial is 120 km/h and the velocity for vehicle 2 initial is 80 km/h.

The initial position for vehicle 1 is at 0 m and the initial position for vehicle 2 is at 250 m (250 m distance).

The distance sensor is 50 meters. This means vehicle 2 will see vehicle 1 when at the distance between vehicle 1 and vehicle 2 is 50 meters. The result that will get after running the Simulink diagram is at the two figures above.

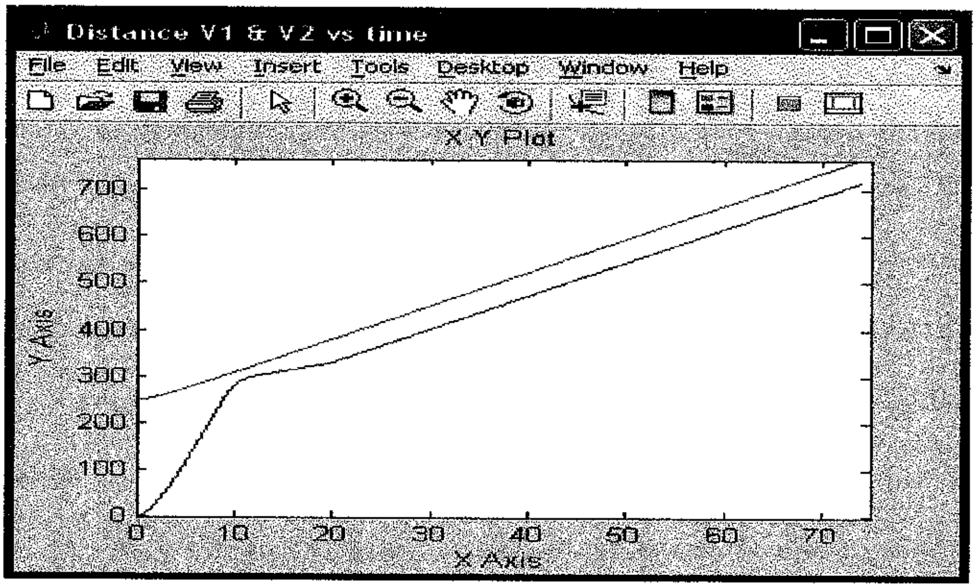


Figure 4.23: Position of vehicle 2(blue color) and vehicle 1(green color)

The figure above shows that vehicle 2 has slows down after sensing vehicle 1 and then maintain 50 meter distance.

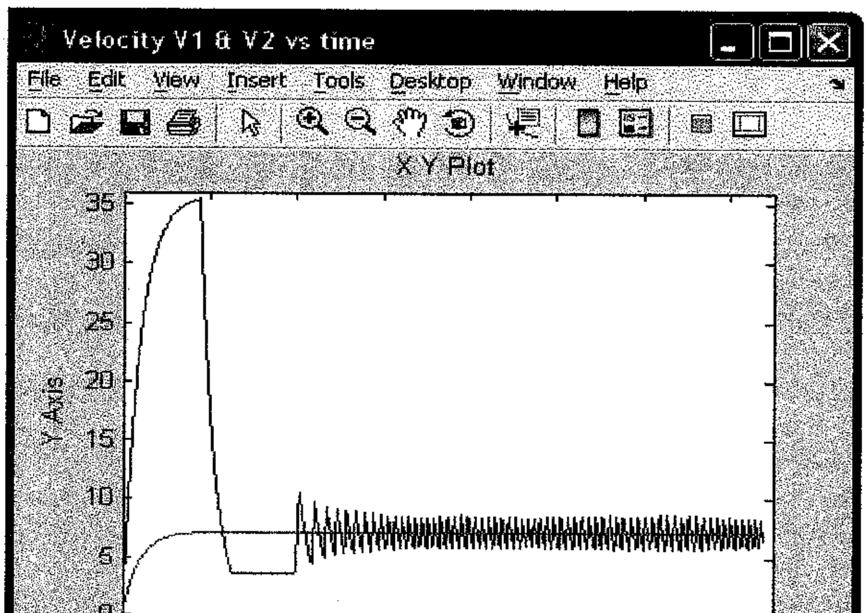


Figure 4.24: Velocity of vehicle 2(blue color) and vehicle 1(green color)

The figure above shows the velocity of the two vehicles. The vehicle 2 will slow down after sensing vehicle 1. Problem with control since it tries to maintain 50 meters distance.

There are also some problem occur in this model which is braking torque is not properly train. Therefore the training is decided to break up into two neural network controllers which is engine and brake.

4.6.3.1: Second design

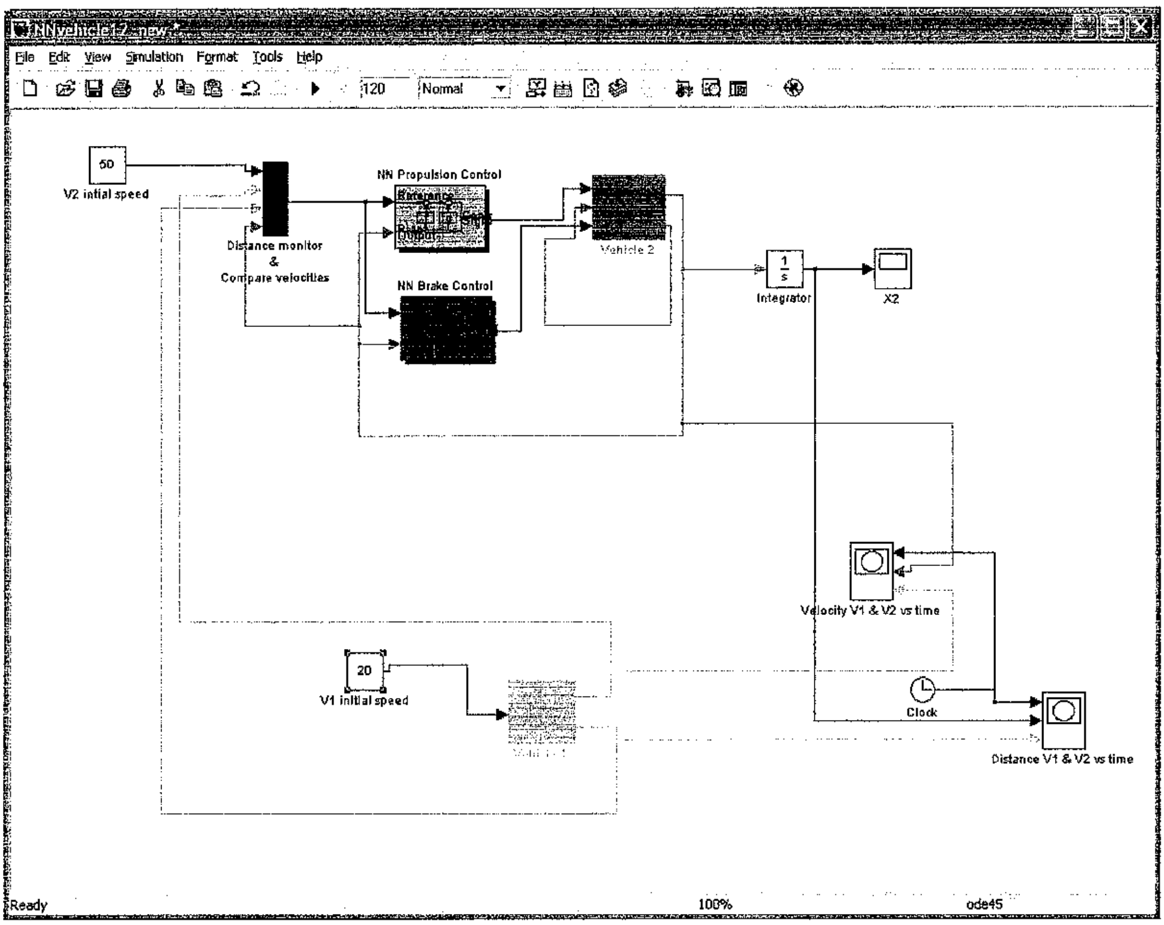


Figure 4.25: Two vehicle models, vehicle 2 is controlled by a neural network controller, vehicle 1 is a slower moving vehicle

Refer to the Simulink digram above velocity vehicle 1 initial is 120 km/h and the velocity for vehicle 2 initial is 80 km/h

The initial position for vehicle 1 is at 0 m and the initial position for vehicle 2 is at 250 m (250 m distance).

The distance sensor is 50 meters. This means vehicle 2 will see vehicle 1 when at the distance between vehicle 1 and vehicle 2 is 50 meters.

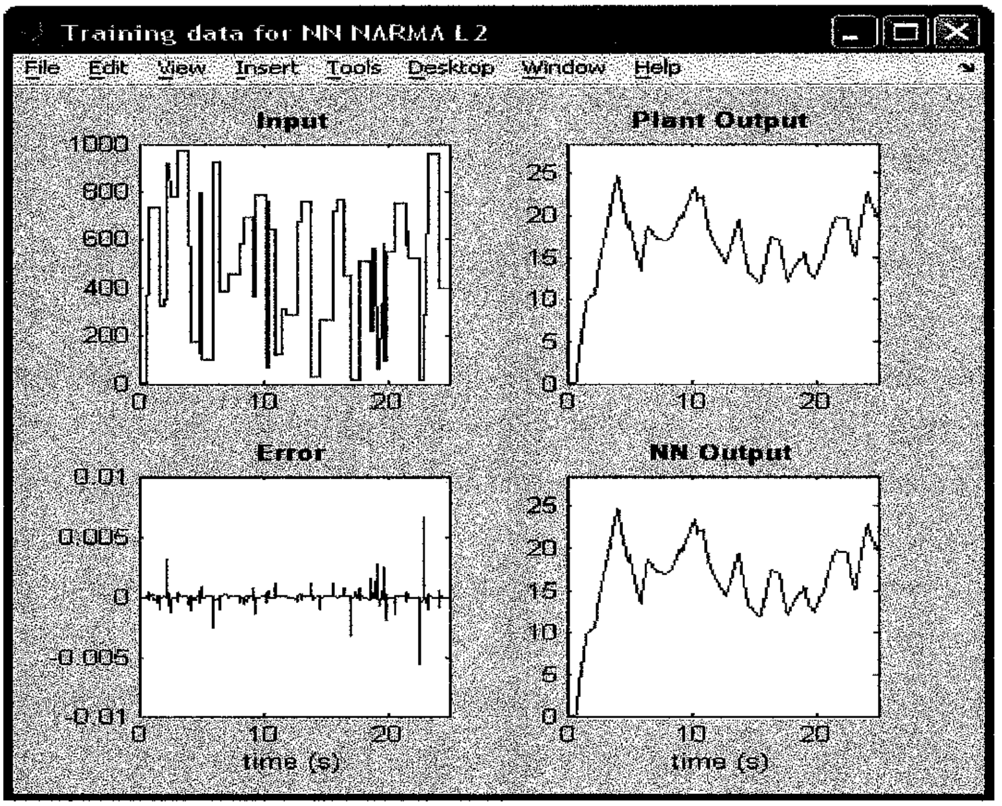


Figure 4.26: Training data for propulsion in neural network

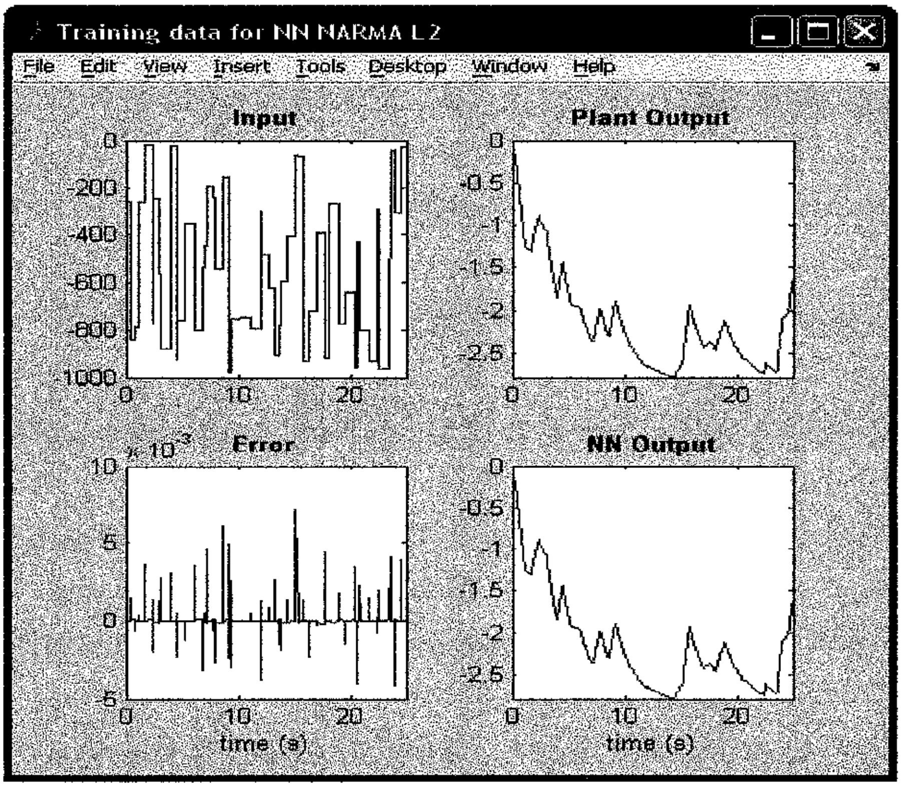


Figure 4.27: Training data for brake system in neural network.

Refer to the Simulink digram above velocity vehicle 1 initial is 120 km/h and the velocity for vehicle 2 initial is 80 km/h. The initial position for vehicle 1 is at 0 m and the initial position for vehicle 2 is at 250 m (250 m distance). The distance sensor is 25 meters. This means vehicle 2 will see vehicle 1 when at the distance between vehicle 1 and vehicle 2 is 50 meters. The result that will get after running the Simulink diagram is at the two figures above.

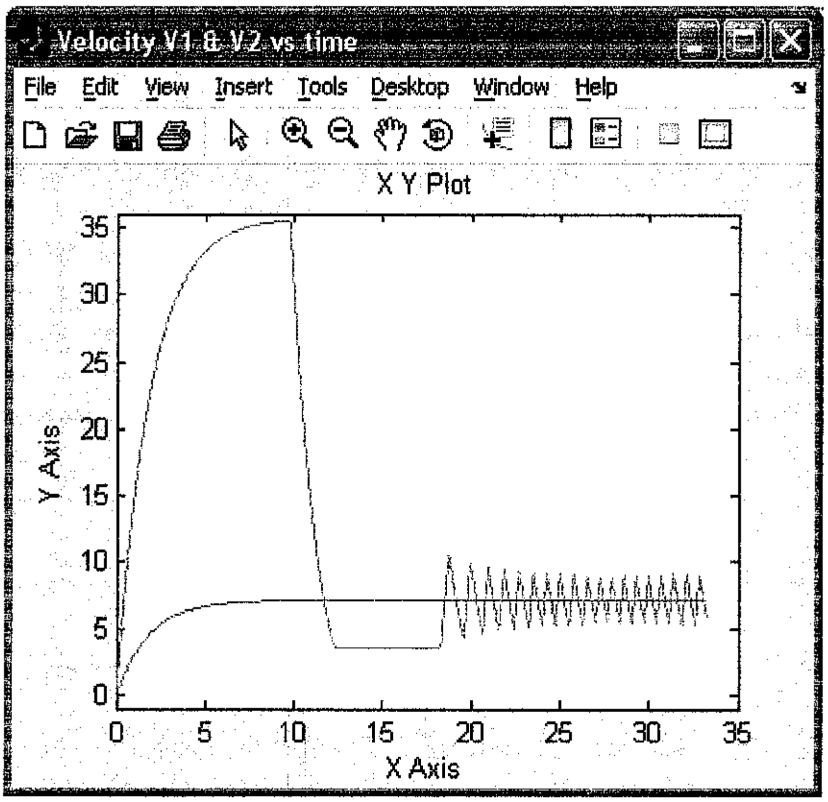


Figure 4.28: Velocity of vehicle 2(blue color) and vehicle 1(green color)

The figure above shows the velocity of the two vehicles. The vehicle 2 will slow down after sensing vehicle 1. Problem with control since it tries to maintain 50 meters distance.

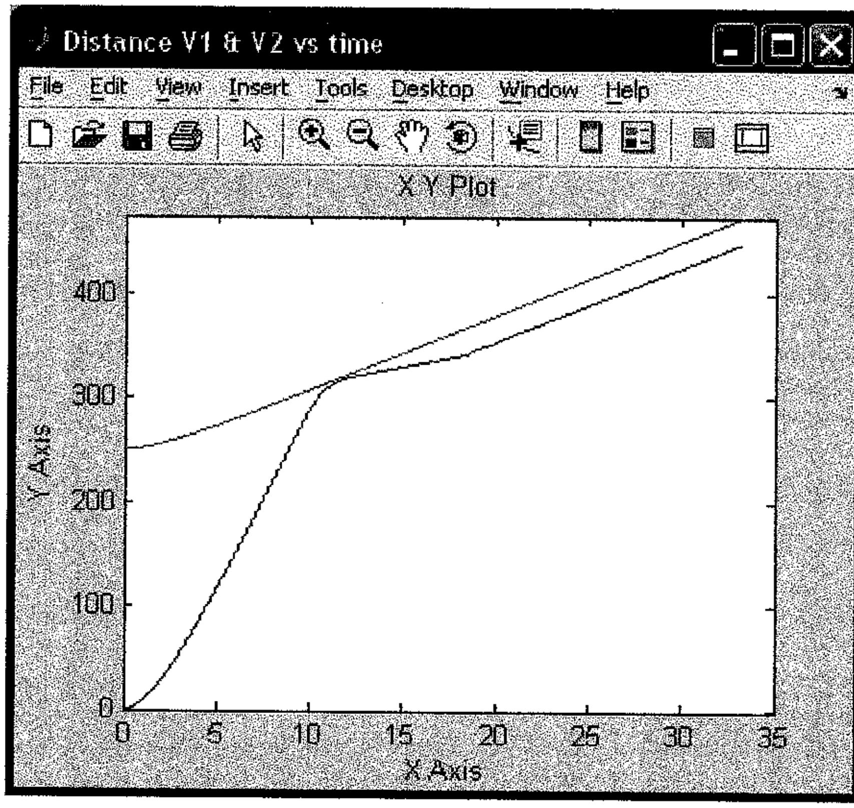


Figure 4.29: Position of vehicle 2(blue color) and vehicle 1(green color)

The figure above shows that vehicle 2 has slows down after sensing vehicle 1 and then maintain 50 meter distance.

4.7 Final Working Principle for the project

4.7.1 Case 1(enough distance to brake)

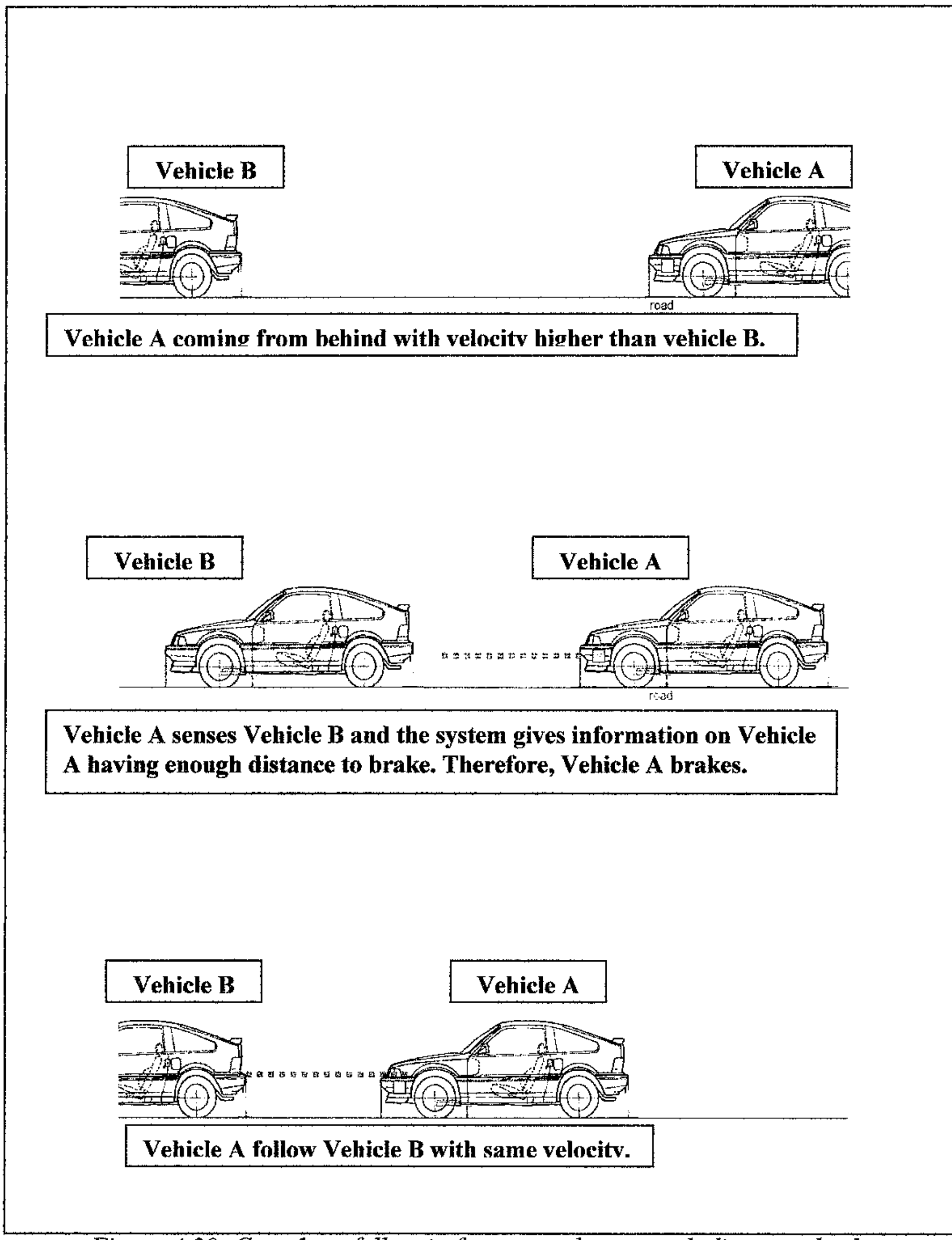


Figure 4.30: Case 1- to follow in front car when enough distant to brake

4.7.2 Case 2 (not enough distance to brake)

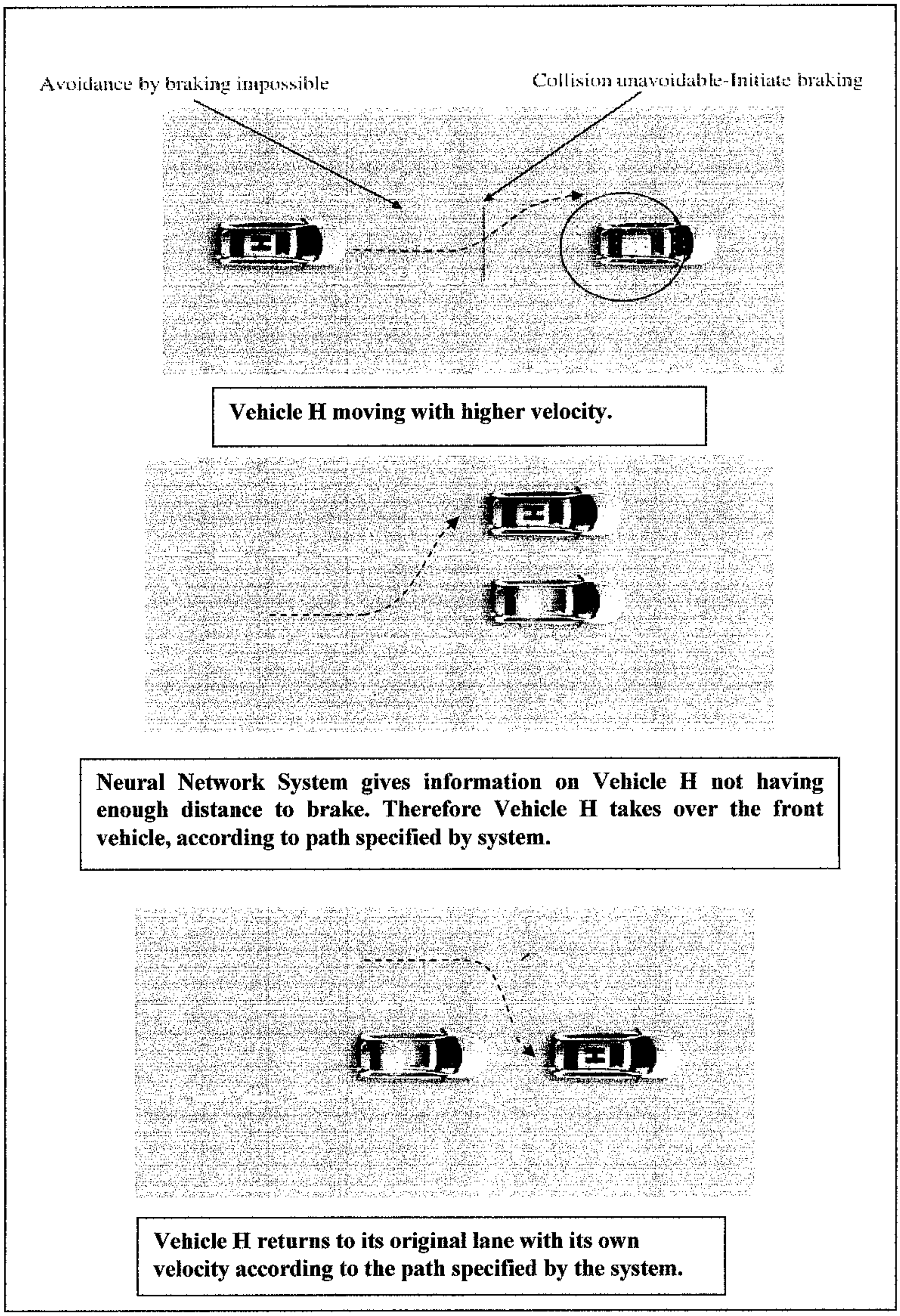


Figure 4.31: Case 2- to overtake front car when do not have enough distance to brake

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Summary about simulation results:

1. Modelings of steering and vehicle propulsion were completed.
2. Integrated of the steering and vehicle propulsion also completed.
3. Integrated of neural network controller only on propulsion and braking
4. Steering with neural network controller not complete. Default neural network controller required only one input, whereelse steering model which is use as plant has two outputs. So this problem cannot be solved. Therefore further study or modification required.

The simulation for braking model and steering model has got valid results compared to the calculation using equation and from literature review.

The development of an advanced crash avoidance system could help reduce the number of vehicle collisions in major highways. The project's results, together with appropriate sensors and equipment on the board of vehicles, could be used to assess the safety of lane changing maneuvers and provide warnings or take evasive actions to avoid collision.

5.2 Recommendations

Upon the accomplishment of this project, limitations and constraints had arisen, whether in terms of time, resources, knowledge or technology. For example, time constraint limits the project from having a greater and amazing feature. There are a few suggestions on the recommendations for the next enhancement of this project.

In enhancing this project, steering simulation needs to be changed from bicycle model to the 4-wheel model. Bicycle model only considers two tires in the analysis as it is simpler besides easy to calculate and implement into Matlab Simulink. From the research undergone, most analysis in automotive engineering uses bicycle model.

Inertia values are an important parameter to be considered in modeling vehicle. In this project, this parameter has been ignored. So, this is where CATIA comes into place, in which it is software used to calculate inertia values. This parameter can be used in modeling vehicle using Matlab to achieve a more precise result.

In addition to that, other engineering tools can be used, such as GT Power to determine the power required for vehicle in more accurate values. GT Power is an advanced software for engineering automotive, in which it can calculate the precise value for engine, such as horse power and torque.

Besides that, UTP should add a course specific on Matlab software, which will provide a lot of useful knowledge on the various application of this software to the students. Besides that it is widely used in engineering field, this software covers a wide scope of analysis such as in automotive, manufacturing and mathematics.

More related material, books and other references should be provided in the library. Besides that, the laboratories should provide the latest version of the software for the students to use.

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