ANKARA YILDIRIM BEYAZIT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ADVANCED DRIVER ASSISTANT SYSTEM: A SIMULATION OF PEDESTRIAN TRACKING AND DETECTION SYSTEM

M.Sc. Thesis by
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ANKARA

ADVANCED DRIVER ASSISTANT SYSTEM: A SIMULATION OF PEDESTRIAN TRACKING AND DETECTION SYSTEM

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by

Mustafa Emre CANSEV

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M.SC THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**Advanced Driver Assıstant System: A Simulation of Pedestrian Tracking and Detection System**" completed by Mustafa Emre CANSEV under supervision of Assoc. Prof. Dr. Remzi YILDIRIM and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ADVANCED DRIVER ASSISTANT SYSTEM: A SIMULATION OF PEDESTRIAN TRACKING AND DETECTION SYSTEM

ABSTRACT

In this research, I introduce general automotive electronic systems, automotive safety systems and advanced driver assistant systems. Additionally, pedestrian tracking and detection system, is one of the ADAS systems, are simulated.

The main reason why I got interested in this study is automotive industry`s showing progress more with the development of electronic systems. One of my objective is to make extensive literature research in this thesis. In this regard, this research will show the development of automotive technology from the beginning of the 21st century. This research will be helpful reference point for the field not only in terms of understanding the automotive electronic industry but also in terms of facilitating to understand the future developments of the automotive industry.

In this study, the automotive electronic systems are evaluated briefly by the researcher. The main purpose of this thesis is to introduce architecture of electronic systems and use of them in present. Desire to make safer vehicles and to build safer roads aiming to reduce the number of casualties caused by the traffic accidents, and the legislative arrangements prepared by the leading countries are the incentives for the demand of Automotive Electronics.

There are many factors that have influence on designing a vehicle, creating the controlling system and the well functioning of whole system in an automotive. For instance; many types of algorithm can be used in the controlling systems of the automotive. Hovewer, these systems do not accept any failure, because of that algorithm used in the systems must be error-free algorithm. Because, in case of any error, the risk of the fatal accident increases.

In this study, risky and riskless automotive electronic systems were examined. And it is targeted to show how these systems work and what their technological infrastructures are.

Keywords: Automotive electronics, safety system, braking system, ADAS, sensor and actuator, pedestrian tracking and detection system.

GELİŞMİŞ SÜRÜCÜ DESTEK SİSTEMİ:
YAYA TAKİP VE ALGILAMA SİSTEMİ SİMULASYONU

ÖZET

Bu araştırmada, genel otomotiv elektronik sistemleri, otomotiv güvenlik sistemleri ve gelişmiş sürücü destek sistemleri tanıtıldı. Ayrıca, ADAS sistemlerinden olan yaya algılama ve tespit sistemi simülasyonu yapılmıştır.

Bu çalışmayı yapmamızın ana sebebi, otomotiv endüstrisinin, elektronik sistemlerin gelişmesi ile beraber daha çok gelişim göstermesidir. Bu tezde hedeflerimden biri geniş literatür araştırması yapmaktır. Böylece, bu araştırma 21. yüzyılın başlarına kadar otomotiv teknolojisindeki gelişimi gösterecektir. Bu araştırma hem otomotiv elektronik sanayisinin anlaşılmasını hemde otomotiv sanayinin gelecekteki gelişiminin anlaşılmasını kolaylaştırılması açısından yararlı bir referans nokta olacaktır.

Bu tezde, otomotiv elektronik sistemleri araştırmacı tarafından kısaca değerlendirildi. Tezin temel amacı elektronik sistemlerin mimarisini ve mevcutta kullanımlarını tanıtmaktır. Önde gelen ülkelerin mevzuatında yol kazalarının sebep olduğu zayiatı azaltmak amacıyla güvenli araç ve yolların inşa edilmesinde otomotiv elektroniğine gerek duyulmuştur.

Araç dizaynını, kontrol sisteminin oluşturulmasını ve tüm otomotiv sistemlerinin iyi bir şekilde işleyebilmesini etkileyen birçok faktör vardır. Örneğin, otomotiv kontrol sistemlerinde birçok algoritma kullanılabilir. Ancak, bu sistemler hata kabul etmediğinden dolayı, kullanılan algoritmanın hatasız olması gerekmektedir. Çünkü herhangi bir hata durumda, ölümcül kaza riski artmaktadır.

Bu tezde riskli ve risksiz otomotiv elektronik sistemleri incelenmiştir. Ve bu sistemlerin nasıl çalıştığını ve teknolojik alt yapılarını göstermek hedeflenmiştir.

Anahtar Kelimeler: Otomotiv elektroniği, güvenlik sistemleri, frenleme sistemleri, ADAS, sensor ve aktuatörler, yaya algılama ve tespit.

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I certainly would have not started and completed this thesis without the constant support of my wife Fatıma, my parents Cafer and Mürüvvet, my sisters Gülten, Gülden and Hafize Gül, my brother M.S. Sabanca and my uncle Necip for being with me all the way.

Without you, I wouldn’t be here.

2016, 30 September **Mustafa Emre CANSEV**

CONTENTS

ABBREVATION

3G	Third Generation
4G	Fourth Generation
ABS	Antiblock Braking System
ADAS	Advanced Driver Assistance Systems
AVC	Active Vibration Control
BSDS	Blind Spot Detection System
D	Differential
DAS	Driver Assistant System
DSRC	Dedicated Short Range Communication
EBD	Electronic Brake Distributor
ECM	Engine Control Module
ECU	Electronic Control Unit
ESP	Electronic Stability Program
FCWS	Forward Collision Warning System
GPS	Global Position System
I	Integral
IPM	Inverse Perspective Map
ISA	Intelligent Speed Assistant
LDW	The Lane Departure Warning System
LKAS	The Lane Keeping Assistant System
LTPMS	Low Tire Pressure Monitoring System
NVS	Night Vision System
P	Proportional
RFID	Radio Frequency Identification
ROI	Region of Interest
RTD	Resistance Temperature Detector
SDARS	Satellite Digital Audio Radio Service
TCM	Transmission Control Module
TCS	Traction Control System
V2I	Vehicle to Infrustructure
V2R	Vehicle to Road
V2V	Vehicle to Vehicle

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CHAPTER 1

INTRODUCTION

The first self-propelled vehicle was invented by French engineer Nicolas Joseph Cugnot in 1769 [1]. The first steam engine vehicle patent was taken by Oliver Evans in U.S. in 1789 and the first electric vehicle was invented by Robert Anderson between 1832 and 1839 years in Scotland [1]. In the later years, electrical engine was converted to gasoline for the need of USA's long-range vehicle. Due to the increase of fuel prices in the world market, gasoline engine was converted to diesel engine in 1970’s [1]. In recent years, the studies for electrical vehicle have been focused on.

As a result of the development of the electronic industry, the automotive industry is growing and developing. The development of the automotive industry prevents potential accident situations. At the same time, in this case, use of the minimum standard features becomes compulsory in vehicles to ensure the safety of pedestrians, drivers and passengers. On the standard systems is thought to be primarily associated with safe driving and comfort.

Electronic systems that are used by automotive systems are sometimes used instead of function with other systems properly. For example, steering wheel is controlled by electrical system instead of mechanical system, the use of electrical mirror instead of flat mirror…etc.

Vehicle comprises of the wheel, engine and traction system [2]. Use of a vehicle is a complex activity. According to the researchers, only electronic systems constitute % 40 of the cost of the vehicles.

More than one hundred electronic systems are used in the automotive industry as shown in Figure 1.1.

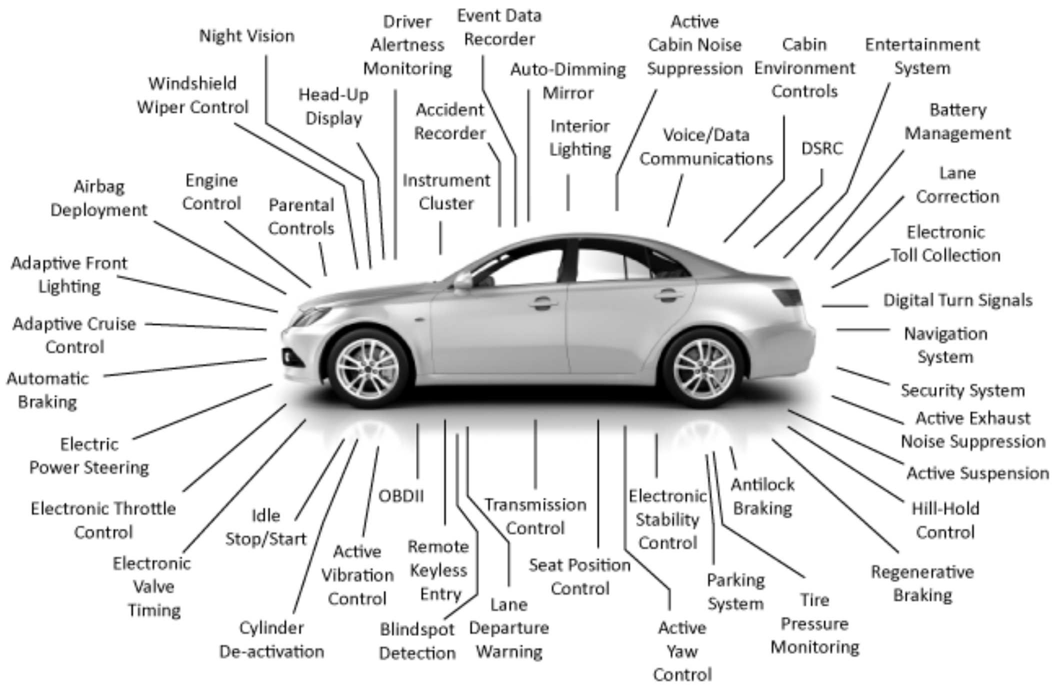


Figure 1.1 Automotive electronic systems [3].

Automotive electronic systems, as given in Figure 1.1;

1. Accident recorder,
2. Active Aerodynamics,
3. Active cabin noise suppression,
4. Active exhaust noise suppression,
5. Active suspension,
6. Active vibration control,
7. Active yaw control,
8. Adaptive cruise control,
9. Adaptive front lightening,
10. Airbag deployment,

11. Antilock braking,

12. Auto dimming mirrors,

13. Autonomous emergency braking,

14. Battery management,

15. Blind spot detection,

16. Cabin environment controls,

17. Communication systems,

18. Convertible top control,

19. Cylinders deactivation,

20. DSRC,

21. Driver alertness monitoring,

22. Electronic power steering,

23. Electronic seat control,

24. Electronics stability control,

25. Electronic throttle control,

26. Electronic toll collections,

27. Electronics valve timing,

28. Engine control,

29. Entertainment system,

30. Event data recorder,

31. Head up displays,

32. Hill hold control,

33. Idle stop starts,

34. Instrument cluster,

35. Intelligent turn signals,

36. Interior lighting,

37. Lane departure warning,

38. Lane keeping assist,

39. Navigation,

40. Night vision systems,

41. On-Board diagnostics,

42. Parental controls,

43. Parking systems,

44. Precrash safety,

45. Rear-view camera,

46. Regenerative braking,

47. Remote keyless entry,

48. Security systems,

49. Tire pressure monitoring,

50. Traction Control,

51. Traffic sign recognition,

52. Transmission control,

53. Windshield wiper control.

Automotive electronics are divided into three categories in terms of services [2].

1. Interior furnishing systems; radio, cd player, navigation,
2. Safety systems; cruise control, automatic parking system,
3. Engine systems.

On the other hands, automotive is divided into three categories in terms of technology that are general electronic systems, safety systems and advanced driver assistance systems. Automotive electronic system's categories are given in Figure 1.2.

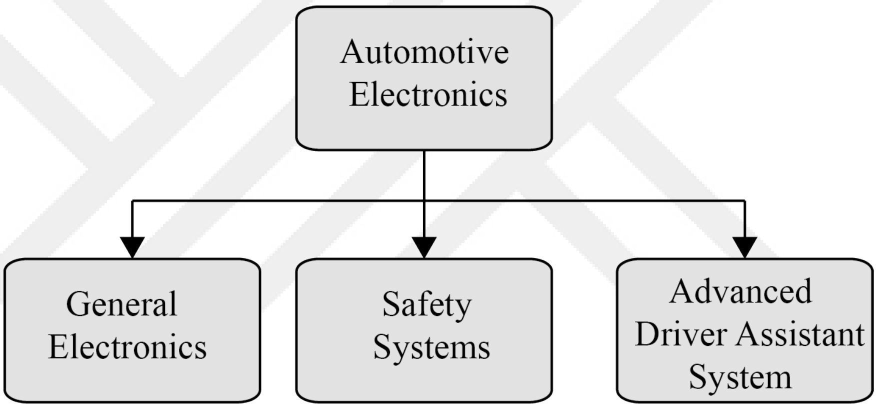


Figure 1.2 Automotive electronics.

Automotive electronics system uses control, measurement and communication systems [4]. Automotive Electronics control block system is given in Figure 1.3, measurement block system is given in Figure 1.4 and communication block system is given in Figure 1.5.

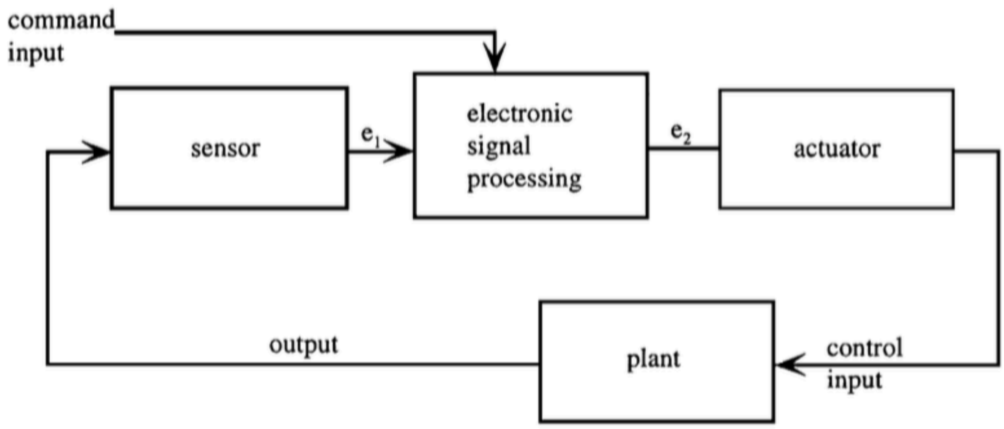


Figure 1.3 Control block system [4].

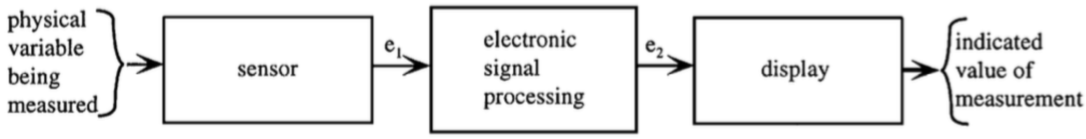


Figure 1.4 Measurement block system [4].

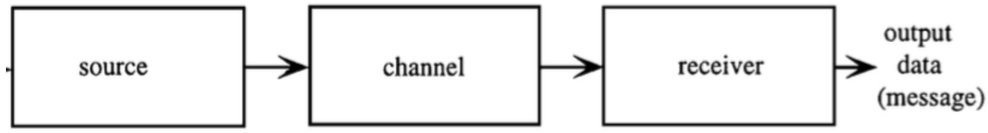


Figure 1.5 Communication block system [4].

This thesis is structured as follows. Suspension systems, vibration control, YAW control, battery management system, communication system, electronic seat control, electronic power steering, electronic throttle control, engine control system, navigation system, remote keyless control, security system, transmission control and airbag control are given in Chapter 2. In Chapter 3, safety system is given and advanced driver assistant system is given in Chapter 4. In addition, in Chapter 5, pedestrian tracking and detection system are simulated. Finally, automotive electronics conclusion is given in Chapter 6.

CHAPTER 2

GENERAL AUTOMOTIVE ELECTRONICS

One of the most important causes of developing in automotive and increasing competition between companies is electronic systems that used in the automotive industry. Electronic systems are used in many systems such as tire pressure monitoring system, navigation systems…etc.

In this thesis, electronic systems were given that used by some manufacturers in the automotive and it can be used as standard in the future. These are active suspension, active vibration control, active yaw control, battery management, communication systems, electronic throttle control, engine control, navigation, transmission control and airbag systems.

In this Chapter, electronic system's block diagram and control systems are given.

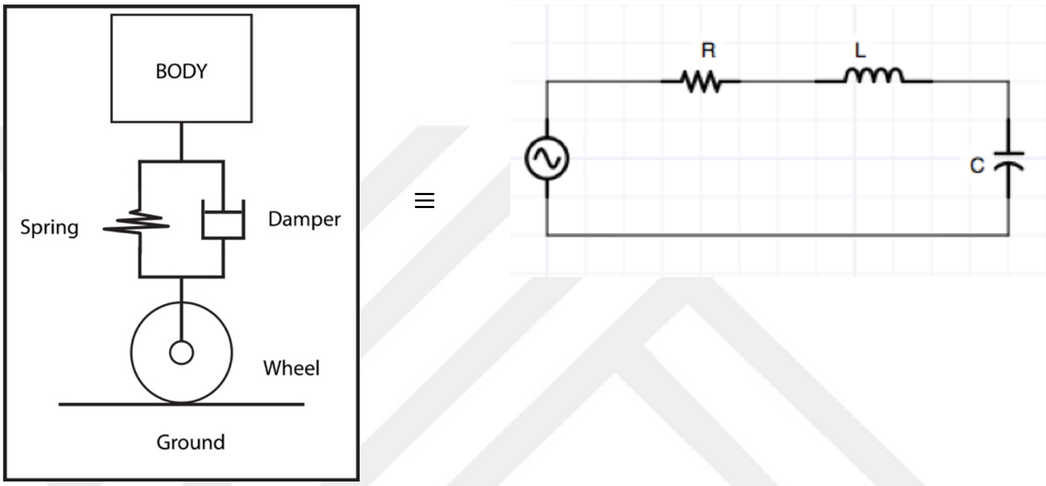
2.1 Active Suspension Systems

The suspension system protects chassis, driver and passengers from tremors caused by vertical replacement of drive shafts. This system increases the vehicle comfort and safety [4-7]. Generally, suspension system affects the vehicle performance and comfort [4]. Suspension system has spring and damper.

Nowadays, due to the development of computerized control systems, drivers have many options. Drivers can select the suspension response. For example, sport mode suspension system that gives dynamical response [7].

The active suspension system is examined under two main headings. These are semi active suspension system and active suspension system [7]. Semi active suspension system includes electrically controlled valve. Valve calibrates the flow of hydraulic in the damper. Thus, it can change the moistening quality [6]. On the other hand, active suspension system has some actuator and it controls the chassis for every wheel. Semi active suspension system is cheaper than active one [7]. Onboard computer senses body motion and choose which suspension system is better. After that, it controls the suspension system.

Suspension system and equivalent circuit is given in Figure 2.1. It consists of spring and damper. These are located between the car body and the wheel. System minimizes the response of road with using the spring and damper. The spring is widened or pressed according to the state of the tire on the road. Damper is used to prevent sustained release. Skyhook theorem regulates the semi active suspension system.



A **B**

Figure 2.1 A is suspension system and B is an equivalent circuit.

Where damper is D, spring is K, wheel mass is M, R is resistor, L is inductor and C is capacitor in Figure 2.1. Spring, damper and wheel in the mechanical system are represented to resistors, capacitors and inductors in the equivalent circuit [4]. Mechanical system transfer function is given in equation (2.13).

Transfer function of spring force velocity f(t);

$$f(t) = K\int_0^t v(\tau)d\tau \tag{2.1}$$

Transfer function of spring force displacement f (t);

$$f(t) = Kx(t) \tag{2.2}$$

Transfer function of damper force velocity f (t);

$$f(t) = f_v v(t) \quad \textbf{(2.3)}$$

Transfer function of damper force displacement f (t);

$$f(t) = f_v \frac{dx(t)}{dt} \quad \textbf{(2.4)}$$

Transfer function of damper impedance is $f_v s$. Transfer function of wheel mass force velocity f (t);

$$f(t) = M \frac{dv(t)}{dt} \quad \textbf{(2.5)}$$

Transfer function of wheel mass force displacement f (t);

$$f(t) = M \frac{d^2 x(t)}{dt^2} \quad \textbf{(2.6)}$$

Transfer function of wheel mass impedance is Ms^2.

Suspension system's output F(s);

$$F(s) = X(s)(Ms^2 + f_v s + K) \quad \textbf{(2.7)}$$

Suspension system's transfer function G(s);

$$G(s) = \frac{X(s)}{F(s)} = \frac{1}{(Ms^2 + f_v s + K)} \quad \textbf{(2.8)}$$

In equivalent circuit transfer function of capacitor V(s);

$$V(s) = \frac{1}{Cs} I(s) \quad \textbf{(2.9)}$$

In equivalent circuit transfer function of resistor V(s);

$$V(s) = RI(s) \quad \textbf{(2.10)}$$

In equivalent circuit transfer function of inductor V(s);

$$V(s) = LsI(s) \tag{2.11}$$

Equivalent circuit's Kirchhoff law time variables V(τ);

$$V(\tau) = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int_0^t i(\tau)d\tau \tag{2.12}$$

Equivalent circuit's transfer function G(s);

$$G(s) = \frac{V_c(s)}{V(s)} = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{1}{LCs^2 + RCs + 1} \tag{2.13}$$

The input curves of the suspension system are considered like a sine curve [4]. Thus, the final curve is considered like a sin curve. In addition, system makes optimization the curves for road disorders [4].

The input curve x(t);

$$x(t) = X\sin(2\pi ft) \tag{2.14}$$

Where X is input amplitude, f is frequency, t is time.

Final curve y(t);

$$y(t) = Y\sin(2\pi f(t - d)) \tag{2.15}$$

Where Y is final amplitude, d is time delay.

Suspension system's force F (t);

$$F(t) = F_0\sin(\omega t) \tag{2.16}$$

Where F_0 is force amplitude, ω is $2\pi f$ and f is frequency.

Spring movement in the system x (t);

$$x(t) = X\sin(2\pi ft - \phi) \quad \textbf{(2.17)}$$

Where ϕ is phase angle.

Shock absorber has four answers in the standard system. Answer of the graph is given in Figure 2.2. Response frequency to the damping coefficient is much higher when it is near the resonance frequency. In addition, response for many systems is used in critical damping.

Resonance frequency f_0;

$$f_0 = \sqrt{W/K} \quad \textbf{(2.18)}$$

Critical damping D_c;

$$D_c = \sqrt{WK} \quad \textbf{(2.19)}$$

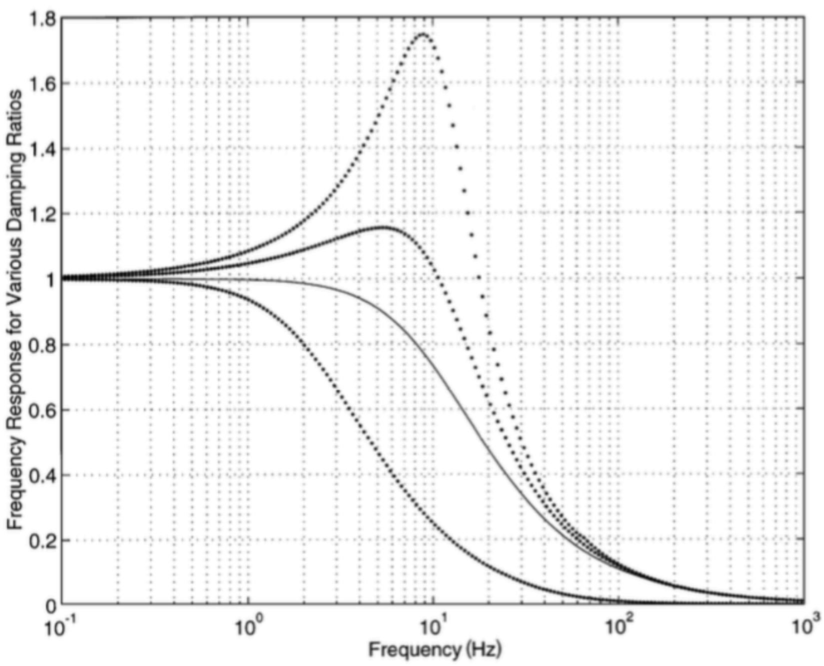


Figure 2.2 Suspension system's response graph [4].

Skyhook control needs velocity of spring and unspring mass [8]. Skyhook theorem and equivalent circuit are given in Figure 2.3.

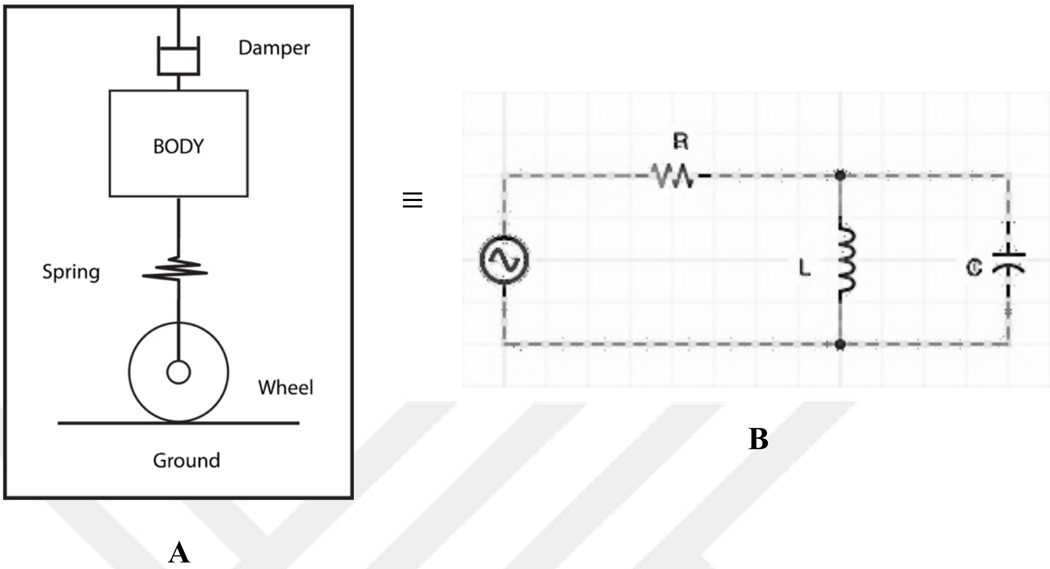


Figure 2.3 A is Skyhook theorem and B is equivalent circuit.

Suspension system's transfers function with Skyhook Theorem G(s);

$$G(s)=\frac{X(s)}{F(s)}=\frac{K}{s(WDs^2+KWs+KD)} \tag{2.20}$$

Equivalent circuit's transfer function G(s);

$$G(s)=\frac{\frac{1}{RC}s}{s^2+\frac{1}{RC}s+\frac{1}{LC}} \tag{2.21}$$

Equivalent of spring and damper are given in equation (2.17) and (2.19).

2.1.1 Detection System

System uses acceleration sensor system for detection. Acceleration sensor block system is given in Figure 2.4.

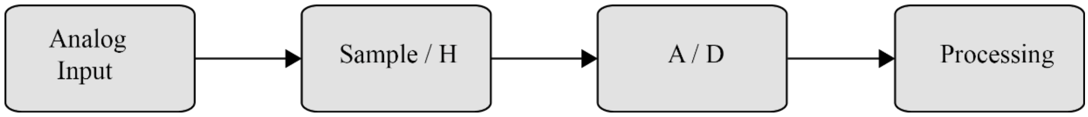


Figure 2.4 Acceleration sensor block system.

Acceleration sensor system uses the force of gravity for detection. The force of gravity is equal to zero in steady state. Acceleration is calculated according to a different gravitational force. System creates a sample for using response force and converts it to digital. Finally, it finds how many gravitational forces are applied. Moreover, it sends this information to the Electronic Control Unit (ECU). Mathematical model of g;

$$g \approx V_{dd} / 2 \tag{2.22}$$

Where V_{dd} is drain supply voltage.

The transformation of the force applied to (R_x, R_y, R_z) axis;

$$R_x = \frac{V_x - g}{s} \tag{2.23}$$

$$R_y = \frac{V_y - g}{s} \tag{2.24}$$

$$R_z = \frac{V_z - g}{s} \tag{2.25}$$

Where V_x is velocity in the x-axis, V_y is velocity in the y axis, V_z is velocity in the z axis.

Sensitivity (S);

$$S = \frac{V_{out,1g} + V_{out,-1g}}{2g} \tag{2.26}$$

2.1.2 Electronic Control System

Suspension electronic control block system is given in Figure 2.5.

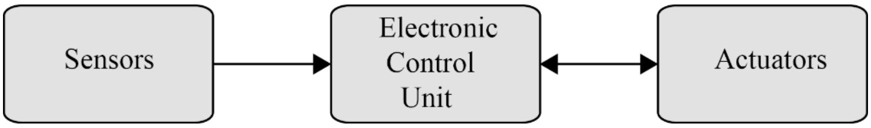


Figure 2.5 Suspension electronic control block system [4].

ECU compares to sensor's last data and actuator's previous data. After that, it determines the actuator movement. In theory, if the damper parameter is finite, vehicle is not0 swung. Electronic suspension system uses variable resistor and damper as an actuator.

2.2 Active Vibration Control (AVC)

The most important causes of vibration in automotive are engine, transmission system and road disorders [9, 10]. Vibration system is one of the most important factors for vehicle safety and comfort. AVC system, is given Figure 1.1, is the best method for vibration controls [11]. AVC block system is given Figure 2.6.

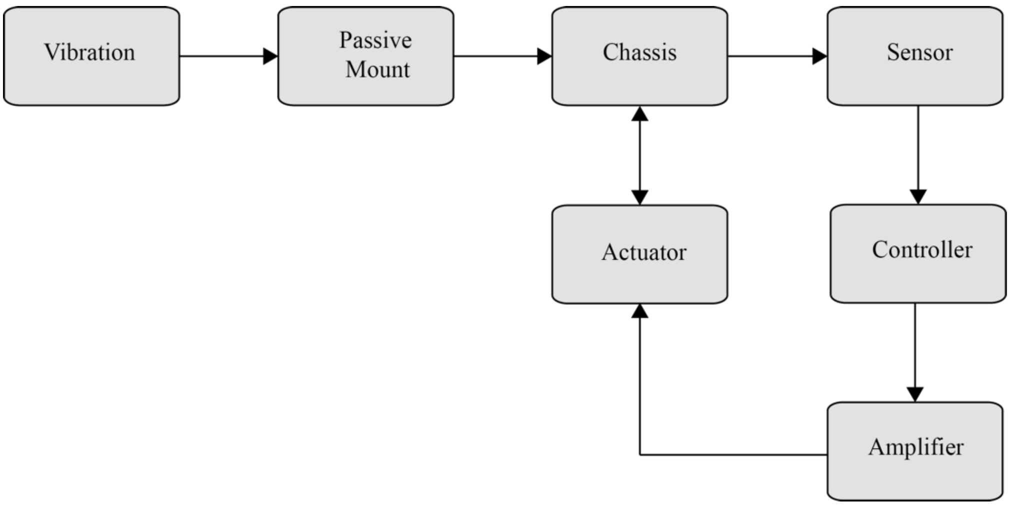


Figure 2.6 AVC block system.

AVC system consists of four main systems. These are actuator, ECU, amplifier and sensor systems [12, 13]. AVC system operates over a wide frequency range, so it prevents from the vibration [12]. System's schematic is given in Figure 2.7. Engine vibration is transmitted to passive mount from chassis. Sensors detect the vibration on the chassis. After that, ECU takes sensor data and uses the amplifier and actuator for decreasing the vibration [9].

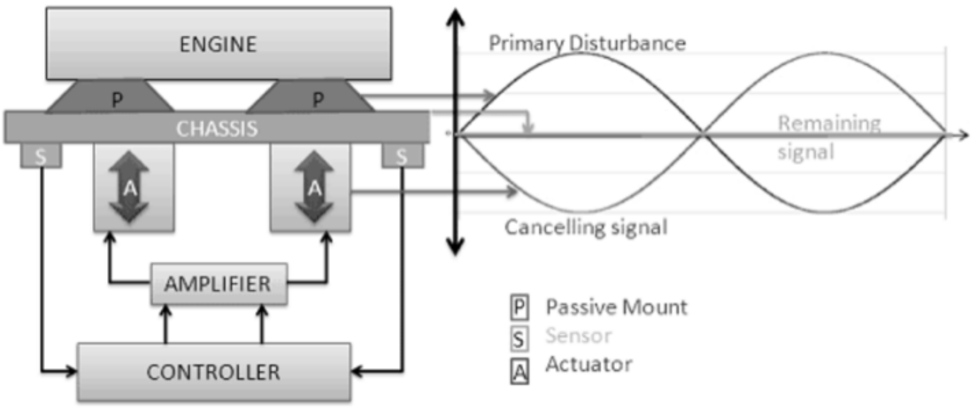


Figure 2.7 Active vibration system [9].

Acceleration sensor system is used by active vibration control system and it is given in Chapter 2.1. System makes damping for isolating vibration at maximum level. Firstly, restrictions on the passive vibration isolation system are detected for determining the relationship between insulation and damping [9]. AVC system uses ECU for determining.

Vibration isolation varies according to the degree of damping. Because of that, firstly, the degree of damping is determined [9]. If the damping is strong, vibration isolation is low. Good damping and isolation is the subject of the classical design [9]. The relationship between frequency and vibration isolation is given in Figure 2.8.

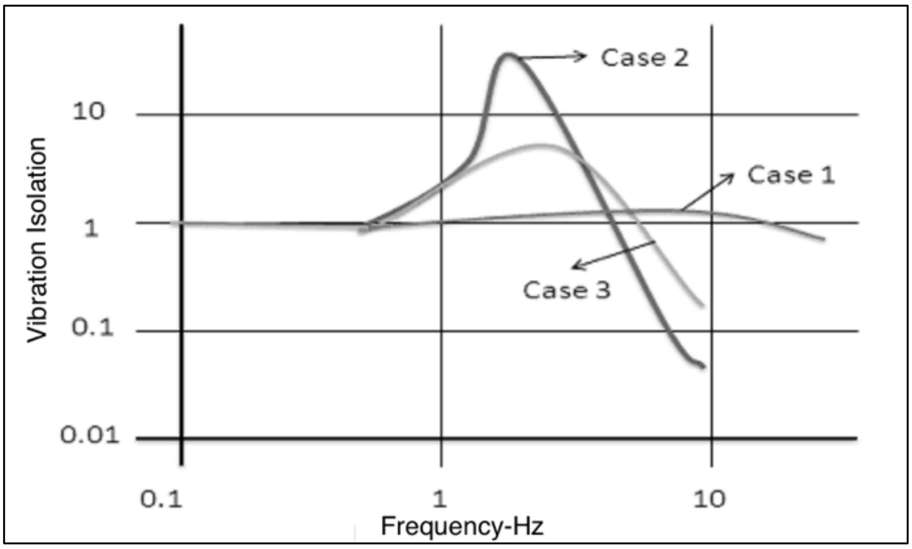


Figure 2.8 The relationship between frequency and vibration isolation [12].

AVC system uses inertia-mass actuators. These are electro-mechanic, hydraulic and pneumatic inertia-mass actuators [13-15]. Electro-mechanic actuator uses the magnetic field force, hydraulic actuator uses the fluid force and pneumatic actuator uses the air force.

Inertia-mass actuator operates with a moveable mass that is connected fixedly with spring and damper [15, 16]. Actuator transmits the electrical power into mechanical movement [17]. This process is achieved by the movement of a coil in a magnetic field. Electromagnetic field force is given in Figure 2.9.

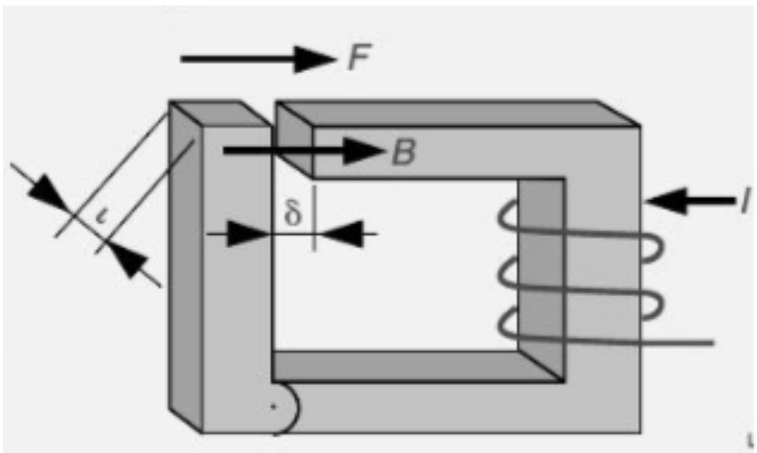


Figure 2.9 Electromagnetic field force [13].

Where F is force, B is magnetic flux density and I is current in Figure 2.9. Actuators are put to the appropriate spot and it synchronizes the vibration with the signal in the opposite phase [11]. Actuator system is given in Figure 2.10.

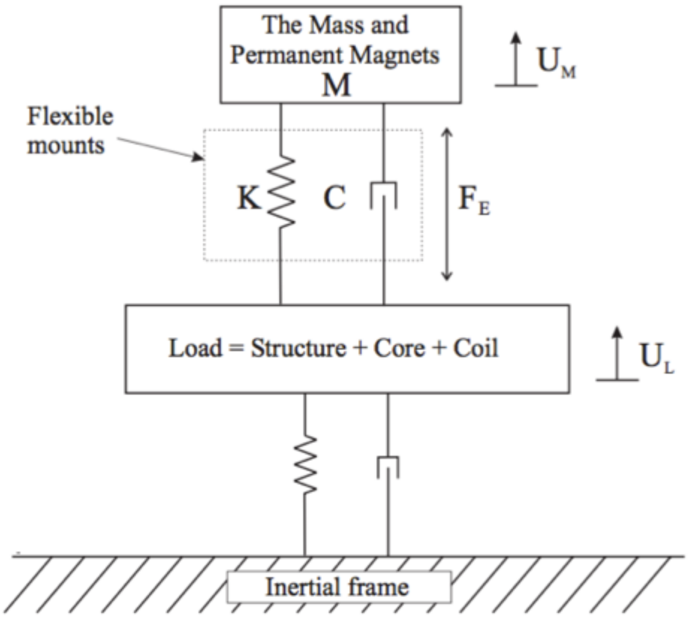


Figure 2.10 Inertia-mass actuator [17].

Where U is speed and F is force in Figure 2.10. Mobility (Y_M) of a mass M;

$$Y_M = \frac{1}{j\omega M} \quad \textbf{(2.27)}$$

Spring mobility Y_S;

$$Y_S = \frac{1}{C + \frac{K}{j\omega}} \quad \textbf{(2.28)}$$

Where K is spring, C is damper.

Equation circuit of actuator system is given in Figure 2.11.

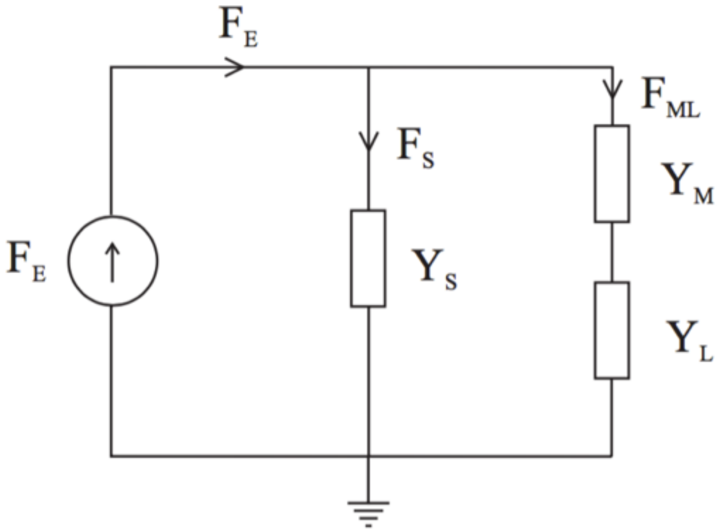


Figure 2.11 Equivalent circuit of actuator system [17].

Transmitted force F_{ML};

$$F_{ML} = F_E \frac{Y_s}{Y_s + Y_M + Y_L} \qquad \textbf{(2.29)}$$

Where Y_L is mobility load, Y_M is mobility mass, Y_S is flexible mount. If the spring and damper mobility is large, transmitted force equal to current. Feedback controller is given in Figure 2.12. Feedback controller uses equation K.

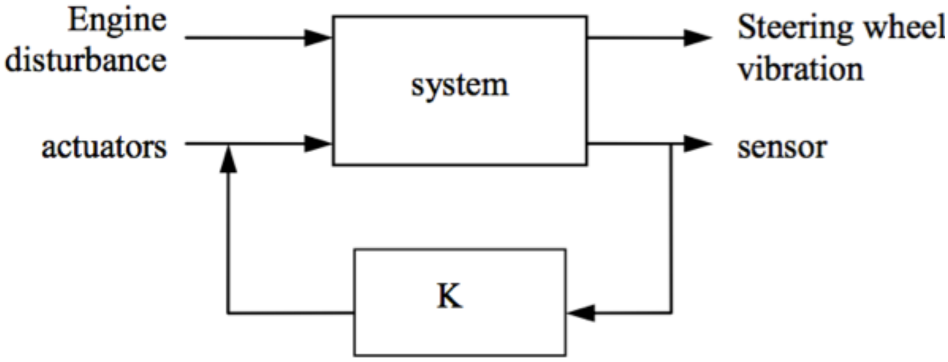


Figure 2.12 Feedback controller loop [11].

Equation K;

$$K = \frac{k}{s^2 + 2\xi\omega_p s + \omega_p^{\ 2}} \quad \textbf{(2.30)}$$

Where k is constant, ω_p is natural frequency, ξ is dimensional damper damping. AVC system is given in Figure 2.13.

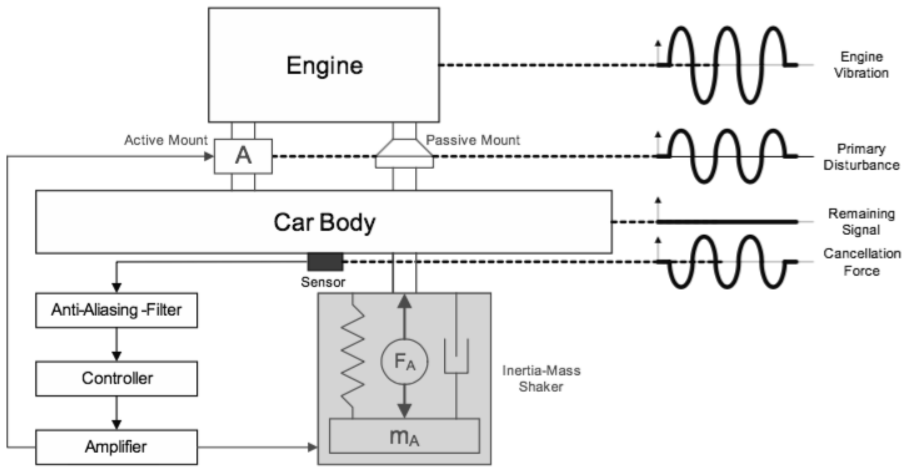


Figure 2.13 Active vibration system [13].

Firstly, anti-aliasing filter is used. After that, controller and amplifier are used. Controller determines the damping degree and it uses actuator for decreasing the vibration.

2.3 Active YAW Control

Active YAW control system is the most important system for safety system in the automotive industry [18]. Active YAW control prevents the skidding in the vehicles and it increases the cornering speed. System uses some active differential components but this system is not same stability control system [18]. YAW control system uses acceleration sensor for splitting torque to the rear wheels [19]. Thus, it is creating a relative wheel speed [19]. YAW control block system is given in Figure 2.14. ECU interprets the engine control module (ECM), transmission control module (TCM) and sensor data. In addition, it generates the differential between the rear tires. In this way, torque in the rear wheel is changed and system prevents the vehicles from the skidding.

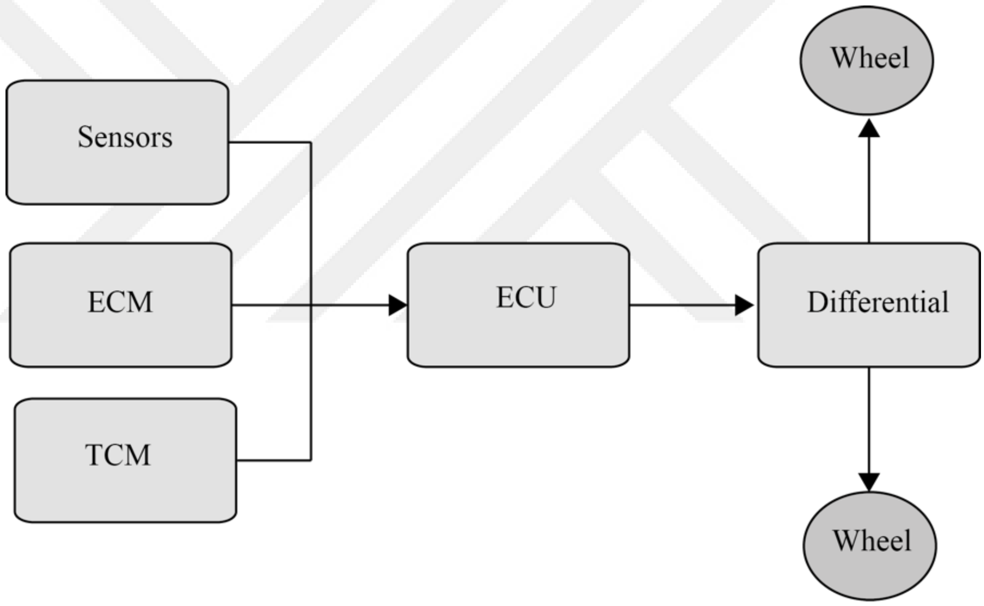


Figure 2.14 YAW control block system.

2.3.1 Detection System

Active YAW control system uses accelerometer, wheel speed, steering wheel position, yaw rate and throttle position sensors [19]. Accelerometer sensor system is given in Chapter 2.1. Wheel speed and steering wheel position sensor is a kind of magnetic sensor. Magnetic sensors have two type sensor systems. These are crankshaft and Hall Effect sensors. The magnetic sensors are divided into four sections. These are rotor, magnet, core and coil. Rotor has some protrusions and magnetic flux may move in the core.

Magnetic sensors consist of current, voltage and resistor like electrical circuit. Magnetic flux is equal to current, magnetic field is equal to voltage and reluctance is equal to resistor [8]. Equation circuit is given in Figure 2.15.

Magnetic field in the equivalent circuit V;

$$V = I \times R \tag{2.31}$$

Where I is magnetic flux and R is reluctance.

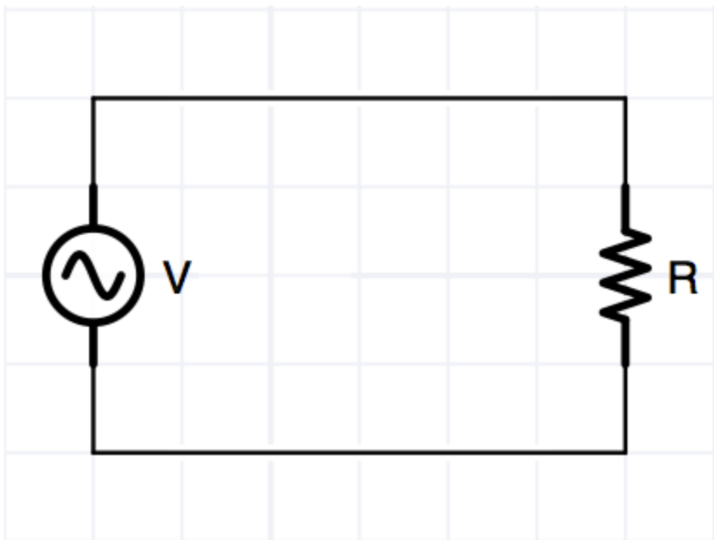


Figure 2.15 Equation circuit for magnetic [8].

Rotor gap generates the air gap in the magnetic circuit. The air gap causes the changing the flux. It induces voltage on the coil. When the changing of the magnetic flux is increased, the voltage is increased on the coil. If the rotor gap is near the magnetic circuit's air gap, the voltage value is equal to zero. While the tab is near the magnetic circuit's air gap, the flux begins to increase and voltage takes the maximum value. On the other hand, when the tab is far from the magnetic circuit's air gap, the flux begins to decrease and voltage begin to decrease. When the tap opposites from the magnetic circuit, voltage is equal to zero. This process is repeated but in the first case, system takes positive value. In the second case, system takes negative value [5, 8, 20, 21]. Because of the rotor's movement.

2.3.1.1 Crankshaft Sensor

The wheel speed and the steering wheel position are fund with crankshaft sensor system. Magnet, pole piece and sensor coil are placed on the cylinder block for determining the steering wheel position. Every metal piece on the rotor disk passes from the pole piece voltage [20, 21]. This voltage depends on the engine speed. It becomes a low voltage at low engine speeds. Therefore, wave velocity is proportional to wheel speed [8, 20, 21]. The absence of voltage is generated to create a reference area. Because of this, the gap is put on the reluctor [8, 20, 21]. There are 34 tabs on the reluctor disk. Every tab was opened at 10-degree intervals [20]. Two tabs are missing on the disk and this missing tab is reference area. The missing tab generates the lost output wave, thereby the position of the engine is determined [8]. Magnetic sensor calculates the wheel speed with the number of rotations of crankshaft. Sensor finds the number of tour of the shaft. For instance, the number of tour of the shaft is 100 and tire diameter is 1.5 m. That is mean, wheel speed is 150 m/sec. Therefore, wheel speed is 9 km/h.

Wheel speed V;

$$V = R \times N \quad \textbf{(2.32)}$$

$$V = R \times N \times 60\,(\text{Km/h}) \quad \textbf{(2.32a)}$$

Where R is tire diameter and N is number of tour.

2.3.1.2 Hall Effect Sensor

Hall Effect is a kind of magnetic sensor. This sensor finds the wheel speed and steering wheel position. This sensor system uses semiconductor plate for measuring the voltage. On the semi conductive plaque with the movement of electrons, an electromagnetic force perpendicular to magnetic flux is formed. This force canalizes electrons to one side of the plate. Increasing of the electrons creates negative polarized. And also, decreasing of the electrons creates positive polarized. This kind of polarizations creates magnetic voltage and it is called Hall Effect voltage. This voltage depends on the current supply and magnetic field intensity. The output force produces a constant power. Magnetic sensor block system is given in Figure 2.16.

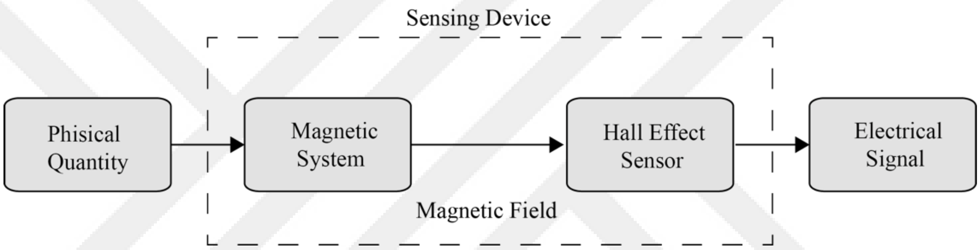


Figure 2.16 Magnetic sensor block system [21].

Hall Effect sensor equivalent circuit is given in Figure 2.17.

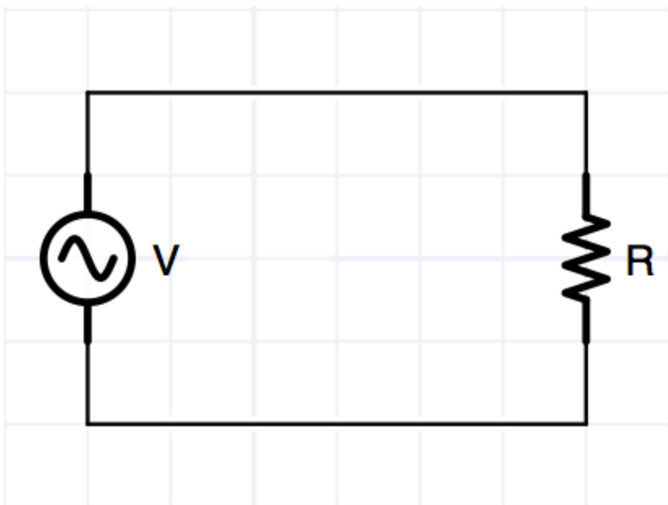


Figure 2.17 Hall Effect sensor equivalent circuit.

In the equivalent circuit is given in Figure 2.17, the voltage increases or decreases in proportion to the magnetic field. The same way, current is proportional to the voltage. The sensor makes the magnetic detection. After that, it converts the magnetic signal to the electrical signal.

For wheel speed and steering wheel position, this sensor works such as crankshaft sensor.

2.3.1.3 YAW Rate Sensor

YAW rate sensor system finds vehicle's direction according to the axis. Yaw rate sensor block system is given in Figure 2.18.

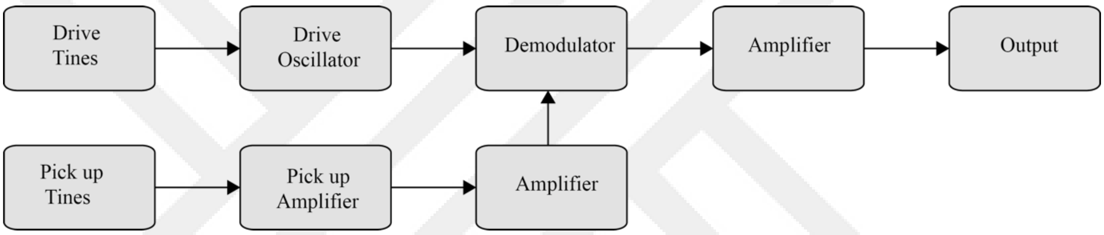


Figure 2.18 Yaw rate sensor block system.

Drive tines creates DC voltage with direction of movement and vehicle position is find with this voltage. Throttle Position sensor system sets the gas flow amount. This kind of sensor system works as potentiometer. Resistance value changes according to the position of the throttle. The throttle position is adjusted according to the resistance value.

2.3.2 Electronic Control System

Active YAW ECU interprets the ECM, TCM and sensor data. Moreover, it detects the differential between the rear tires. In this way, torque in the rear wheel is changed and system prevents the skidding in the vehicles. ECM system gives the instant engine status data and TCM gives the gear data. ECM system is given in Chapter 2.9 and TCM system is given in Chapter 2.13.

Torque differences depend on the position between the steering wheel and the vehicle status. According to the centrifugal laws, vehicle moves outward on the curve way. As a result, the vehicle stability is increased by the active YAW control system.

2.4 Battery Management System

Battery systems are used like electrical system in vehicle. This system knows as device or accumulator, it stores the electrical energy as chemical energy and it feeds the vehicle system.

Battery management system is a kind of electronic system, it controls the batteries charging system and it protects from damage [23, 24]. Generally, system protects the battery cell from the damage and it controls the vehicle energy system and feeds it [23]. Battery management system occurs the cell protecting, charging control, energy demand management, cell for balancing, battery history, cell voltage, cell health data, state of voltage and communication [22, 24]. Battery charging block system is given in Figure 2.19.

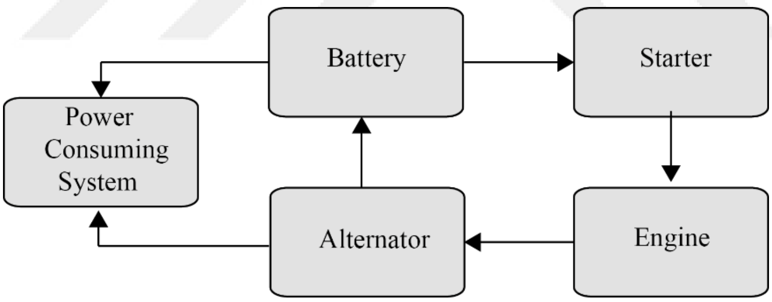


Figure 2.19 Battery charging block system.

Battery is used as an energy source for the starter. Same way, the starter is used for engine and the engine is used for alternator. The alternator is used for battery. Battery and alternator system are used as an energy source for power consuming system. After lithium-ion battery production, battery management system began to use.

Battery management system is a kind of battery brain system [25]. The most important feature of the system protects the battery cell [25]. Because of the battery life. That is mean, battery life depends on the battery cell. For instance, battery is the most important system for stop and start system. System gives the electricity for vehicle restart. If the battery is dead, start and stop system does not work. Battery management block system is given in Figure 2.20. ECU takes data about battery cell and gives it to equalizers and display.

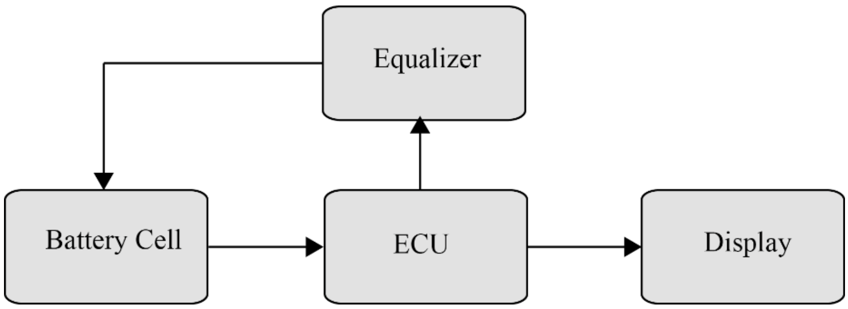


Figure 2.20 Battery management block system [23].

2.4.1 Detection System

System measures the battery occupancy rate by sensor data. BMW battery sensor is given in Figure 2.21.

Index	Explanation
1	Battery Ground Lead
2	B+ Connection for IBS
3	Bit Serial Data Interface (BSD)
4	Intelligent Battery Sensor (IBS)

Figure 2.21 BMW battery sensor systems [26].

Sensor finds the battery output current. Moreover, it finds the charging level. For example, if the battery is full charging, it gives 100 A outputs. Output current decreases with time and approximately 5 hour later, it finishes. So charging level is proportional with time [26, 27].

2.5 Communication System

Communication system ensures exchange of data among the electronics. All electronic systems can use it. System is divided into two sections. These are wired communication system and wireless communication system.

Communication can be done in four different ways. These are vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to road (V2R) and inside the vehicle. Vehicle communication system uses wired system, cellular phone network and global position system (GPS) for communicating with the other systems [28]. Sounds and images are transmitted and received from the communication systems. Some communication applications are given in Figure 2.22.

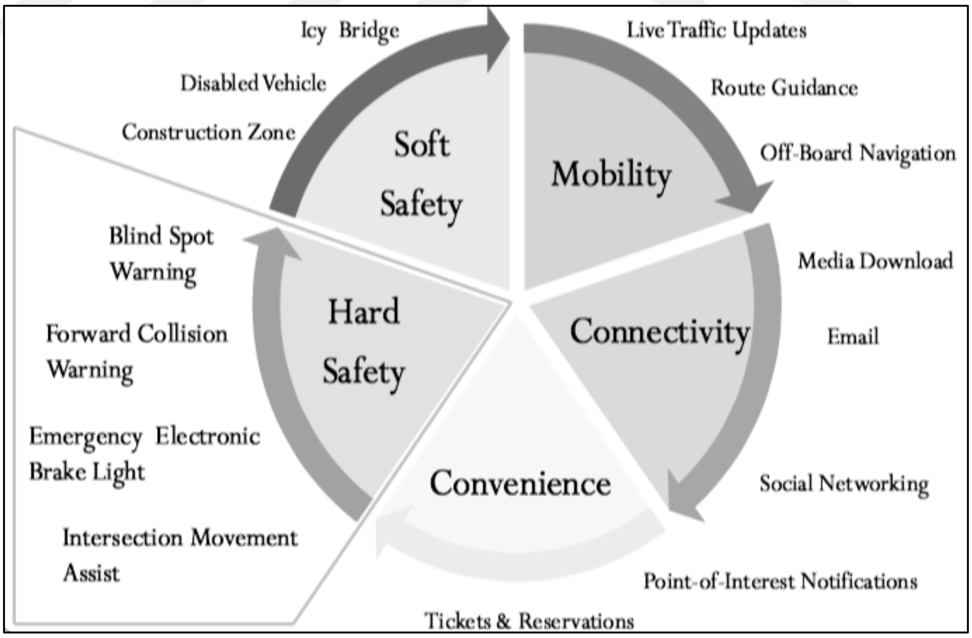


Figure 2.22 Some communication applications [29].

Wired communication system uses CAN-BUS system and wireless communication system uses Bluetooth, Wi-Fi, dedicated short range communication (DSRC), 3 generation (3G), 4 generation (4G) and satellite digital audio radio service (SDARS). These systems are the communication system for using the vehicle communication system. Wireless communication systems are given in Table 2.1.

Table 2.1 Wireless communication systems [29].

	DSRC	Wi-Fi	Bluetooth	3G	4G LTE	SDARS
Range	100s meters	100s meters	Up to 100 meters	10s Km	10s meters to 100 Km	Countrywide
End to End Delay	10ms	10ms	10 ms	50-100 ms	10s ms	10-20 sec.
Call Setup Time	Not needed	3-5 s	3-4 sec.	100s ms to seconds	~50 ms	Not applicaple
V2V local broadcast	Yes	Yes	Impractical	With a server	With a server	No
V2V multi-hop	Yes	yes	Impractical	With a server	With a server	No
I2V local broadcast	Yes	Yes	Impractical	Not offered by all network operators	Not offered by all network operators	Yes
V2I Bidirectional	Yes	No	Impractical	Yes	Yes	No

Dedicated Short Range Communications (DSRC): Nearby is the distance communication system [30]. System communicates between V2V and V2I fcommunication. It is administered by IEEE 802.11p protocol [30].

Wi-Fi: System communicates between V2V communications. It has IEEE 802.11 standard [29].

Bluetooth: It is used nearby (max 10m), lower power consumption [29]. It is 2.4 Ghz.

Third Generation (3G): 3. Generation cellular network.

Fourth Generation (4G): LTE and it is so powerful and fast.

Satellite Digital Audio Radio Service (SDARS): It is 2.3-GHz and makes broadcast the S band.

Wired communication system uses CAN-BUS system for safety. This kind of communication system uses one cable wire. Robert Bosh invented it. Many vehicle systems use it. CAN-BUS block system is given in Figure 2.23.

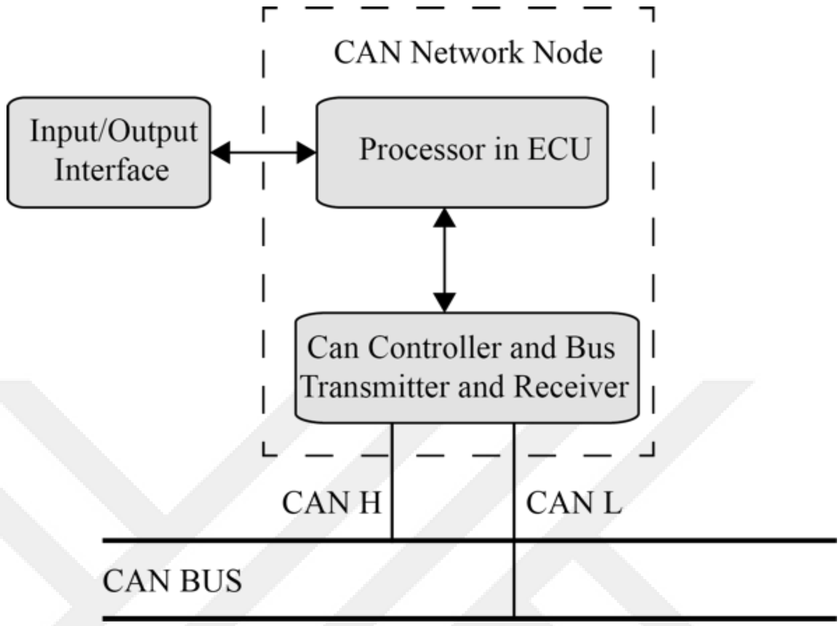


Figure 2.23 CAN-BUS block system [31].

There is a single bus in the CAN-BUS and other systems use it [31, 32]. Every system controls the bus and if the bus is not busy, all systems in the vehicle forward own data in there [31-32]. CAN-BUS system numerates the system that will send data. Which system data is the most important than the others, this system number is one. They line up in this way. For instance, braking system is the more important system than the other systems. Because, if driver wants to stop the vehicle, braking system works instantly. Thus, braking system number is one. Because of this, braking system uses the can-bus system before the others.

CAN network system is given in Figure 2.24. There are two-bus systems. These are low CAN-BUS system and high CAN-BUS system. CAN H is meaning of the high and CAN L is meaning of the low bus system. Breaking system, engine temperature system and similar systems use high bus and seat control, rear view mirror and similar systems use low bus system [31].

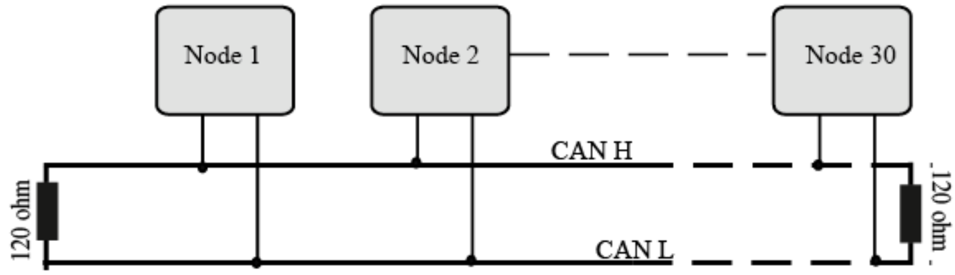


Figure 2.24 CAN network organization [31].

The ends of the CAN-BUS system have 120 Ω resistors. This resistor is put for protecting the bus from reflected signal energy like capacitance and inductance [31].

2.6 Electronic Power Steering

The steering wheel is a system of designed to make the maneuver for vehicles. This system provides to be controlled the vehicle by driver. Steering wheels have different technologies for facilitate the driving of car in the automotive industry. One of them is electronic power steering. Electronic power steering block system is given in Figure 2.25.

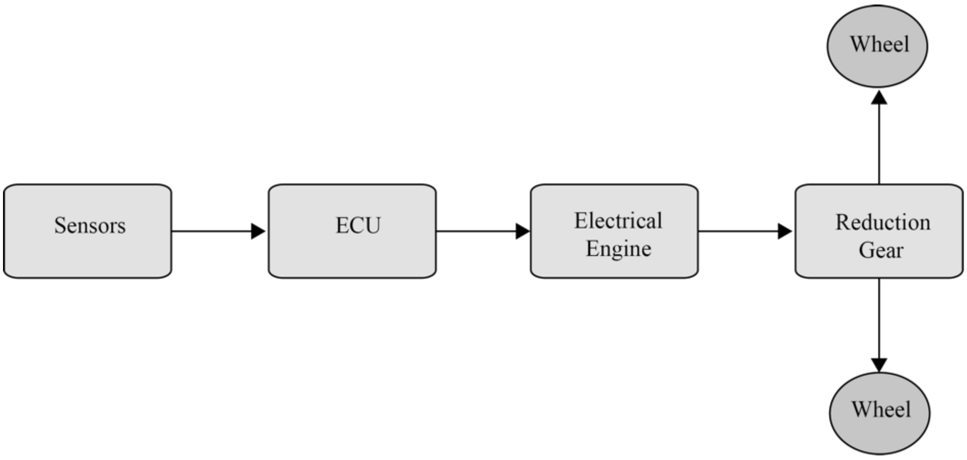


Figure 2.25 Electronic power steering block system [33].

Conventional steering wheel is hydraulic system but nowadays, use of the electronic power steering has increase. The main reason for this, hydraulic steering wheel is heavier and electronic steering wheel works with less system in the vehicle [34].

ECU calculates the torque for steering wheel according to the vehicle speed, the driver position and the steering wheel position. Electrical engine uses the torque for steering wheel and the driver arm force decreases [33].

System uses steering wheel torque sensor, steering wheel position sensor and wheel speed sensor and electrical engine is used as an actuator.

2.7 Electronic Seat Control

Conventional seats use the mechanical control, but nowadays, use of the electronic seat control increases. This technology is a new system in the automotive industry. In generally, system is applied to front seat but it can be applied the all seats.

Electronic seats can move the 4, 6, and 8 directions. In generally, these movements are controlled with the help of joystick or remote control. Direction of system movement is given in Figure 2.26.

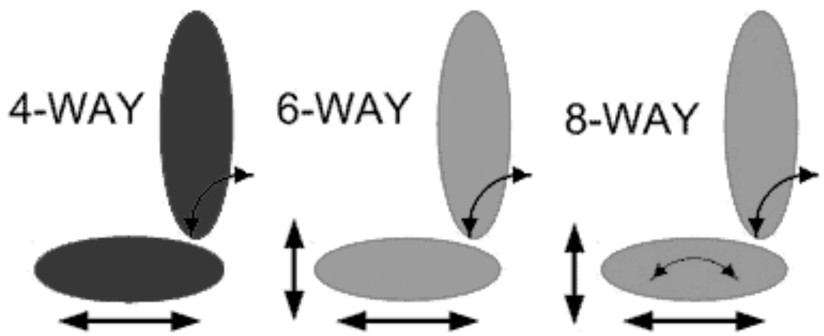


Figure 2.26 Direction of system movement [34].

Drivers prefer the electronic seat control. Because, system is an easiest way of the using the vehicle and more comfortable [35]. System uses position sensor and electrical engine actuator. Block system is given in Figure 2.27.

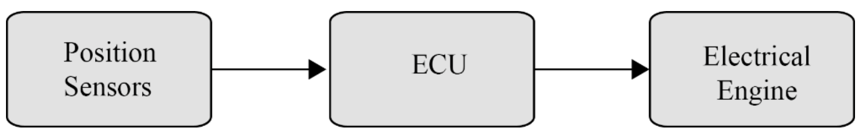


Figure 2.27 Electronic seat control block system.

2.8 Electronic Throttle Control

Pedals in the conventional automotive are connected with the wire to the throttle [36]. So, it is controlled with the mechanical system. Nowadays, throttle can be controlled with electronic system. System has three steps. These are gas pedal, throttle and engine control module [37]. Throttle control block system is given in Figure 2.28.

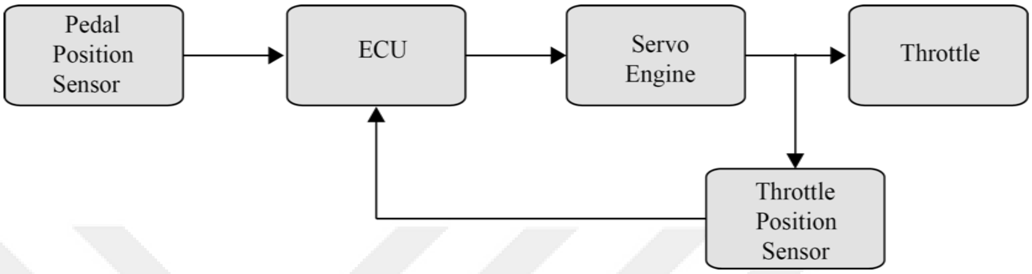


Figure 2.28 Electronic throttle control block system.

Gas pedal and throttle position are converted to the electrical signal with sensors and it sends to ECU. System is controlled by the control system according to the sensor data.

2.8.1 Detection System

System uses pedal position sensor and throttle valve position sensor.

2.8.1.1 Pedal Position Sensor

Gas and braking pedal sensors are used for position of the pedals.

Gas pedal position sensor is given in Figure 2.29.

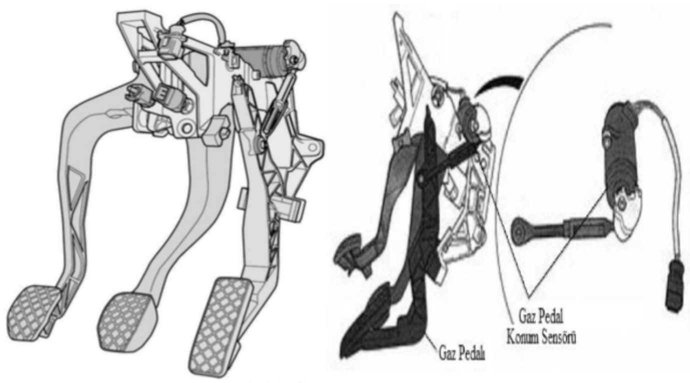


Figure 2.29 Gas pedal position sensor system [38].

Pedal position sensor is two types. These potentiometric and Hall Effect sensor are given in Chapter 2.3.1. This sensor sends two-type pulse. It determines the pedal position with signal width. Gas pedal position sensor and its signal are given in Figure 2.30.

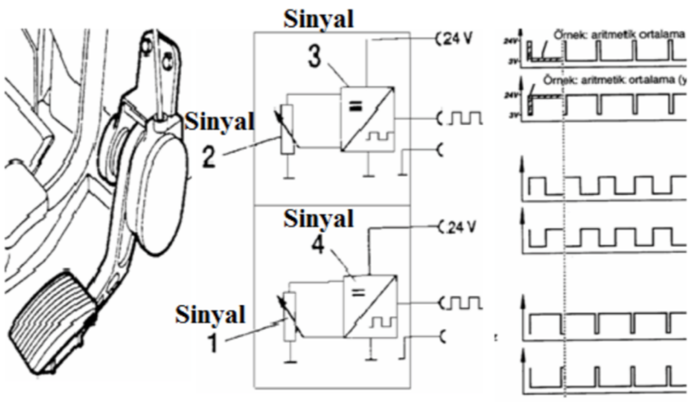


Figure 2.30 Gas pedal sensor and its signal [38].

Signal 1 shows gas pedal position. Impulse width modulation changes, when the pedal is being pressed but frequency remains the same.

2.8.2 Electronic Control System

Generally, throttle control system uses PID control. PID controller block system is given in Figure 2.31. It compares between instant pedal position and position sensor data. PID controller decides to amount of gas and sends this data to the throttle engine.

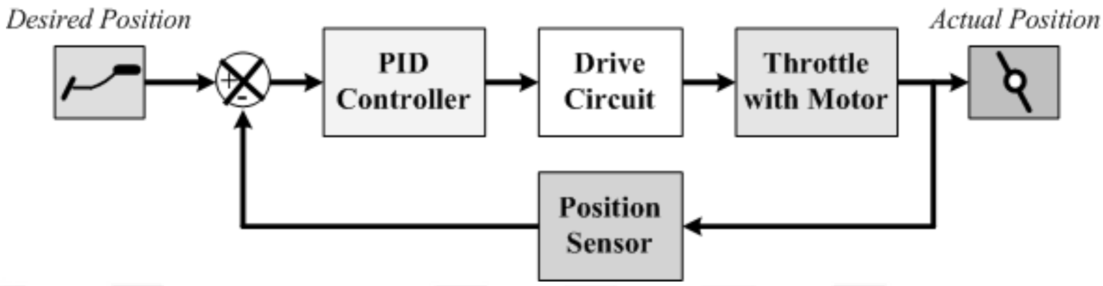


Figure 2.31 PID controller block system [39].

PID controller system is given in Chapter 3.2.1.3.

2.9 Engine Control System

Engine control is a system of controlled the air- fuel ratio, the ignition's time, the idling speed and the valve [40]. Engine control block system is given in Figure 2.32.

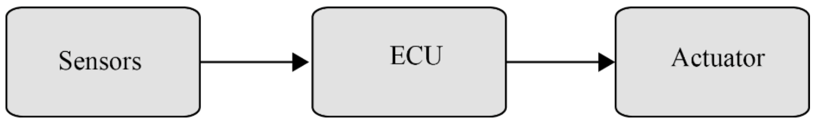


Figure 2.32 Engine control block system.

The system works with sensors and actuators. It controls the all engine system. Engine control system uses pedal position sensor, throttle valve position sensor, engine oil temperature sensor, oxygen sensor, oil pressure sensor, fuel level sensor, wheel speed sensor, torque sensor, knock sensor, air flow sensor, crankshaft position sensor, camshaft position sensor. And it uses fuel injectors actuator, spark plugs actuator, EGR valve, fuel tank venting, cooling fan, starter motor, throttle position motor and check engine light [40].

The most important sensors and actuators that used in the engine system are given in Figure 2.33.

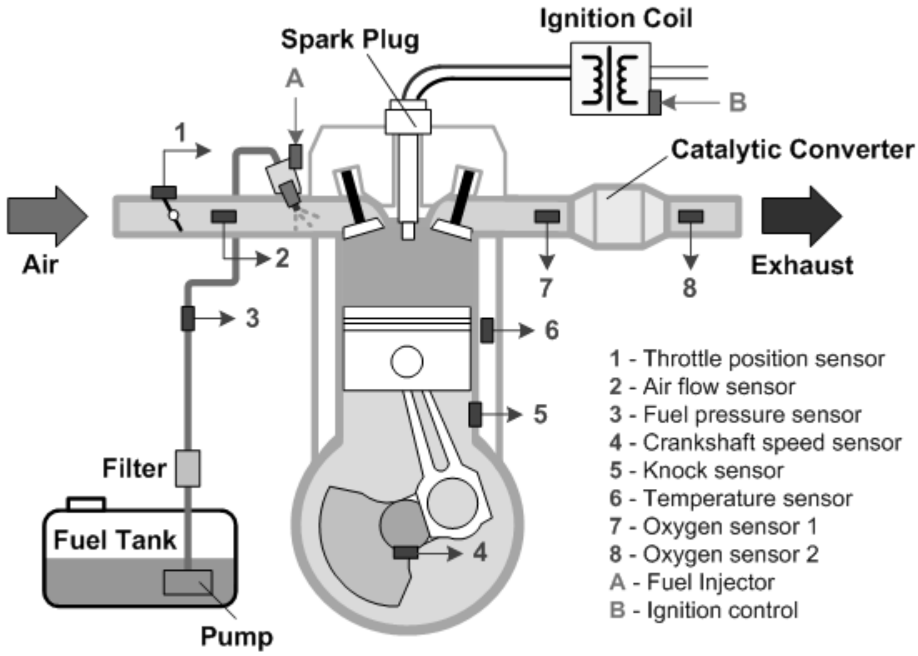


Figure 2.33 The most important sensor and actuators [40].

- Gas pedal position is detected by pedal position sensor. Also, this sensor measures the vehicle's acceleration and controls the fuel. This sensor is given in Chapter 2.
- Throttle valve position sensor controls the gas flow.
- Engine oil temperature sensor measures the oil of the engine for any fault.
- Engine uses oxygen for burning the gas. However, it uses mixture. Because of this, sensor detects the amount of oxygen.
- Oil pressure sensor detects the oil pressure.
- Fuel level sensor detects the amount of gas and if it is less than the normal, system gives warning,
- System measures the amount of the air with air flow sensor,

- It measures the engine position with crankshaft position sensor,
- Camshaft position sensor measures the ignition timing.

Engine control system controls the engine status, fuel consumption according to the sensors data.

2.10 Navigation System

Navigation system helps the driver for making the guidance of the road with global position system (GPS) [41]. GPS uses satellite and electronic maps [41]. Navigation system takes data from satellite and it processes this data on the map. Finally, information of road is shown on the monitor. Generally, system works with 12V energy supply. Navigation block system is given in Figure 2.34.

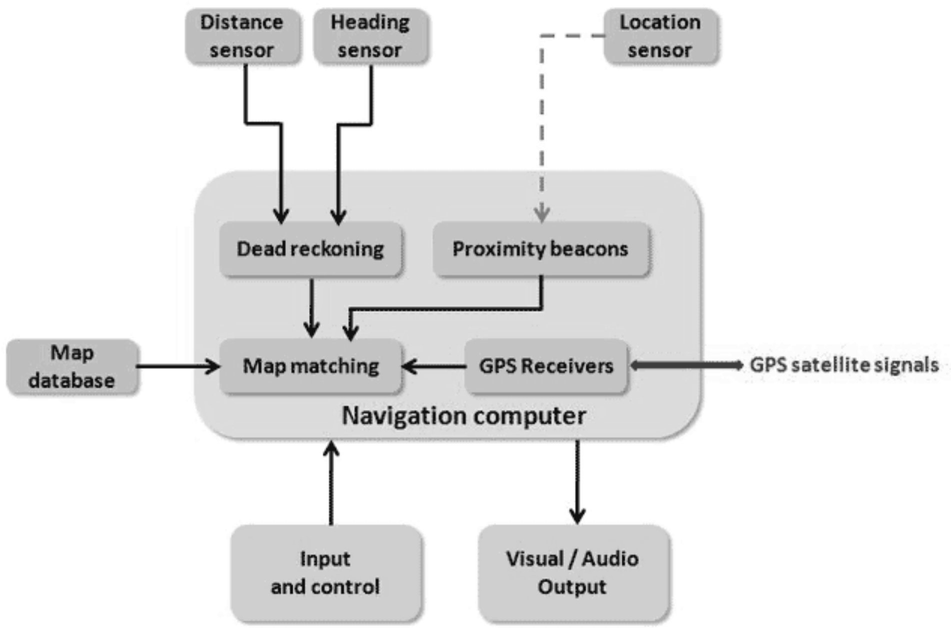


Figure 2.34 Navigation block system [41].

System detects position, location and distance of the vehicle with some sensor. In addition, it processes the all sensor data on the map. Moreover, it gives the information about guidance of the road. GPS system works with 24 satellite [42]. These satellites work all time and every weather forecast. Navigation system uses GPS receiver sensor, gyrocompass sensor, accelerometer and vehicle speed sensors [41, 42].

2.11 Remote Keyless Entry

Remote keyless entry helps the driver for opening or closing the vehicle door and for running the vehicle without the key [43]. System automatically detects the drivers' position and if the driver is closest the vehicle, system opens the vehicle door or vise verse. Same way, if there is not key, driver can start the vehicle and stop it using this system.

System works with radio frequency identification (RFID) technology and system-working diameter is approximately 16 meters [43]. Remote keyless entry block system is given in Figure 2.35.

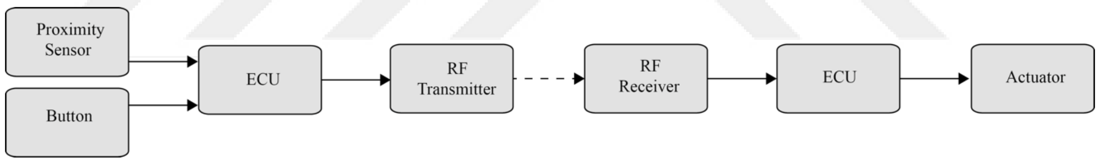


Figure 2.35 Remote keyless entry block system.

System uses proximity sensor for detecting the distance of the key. In addition, it controls the distance that is good or bad. If the key distance is acceptable and driver pushes the button, system sends the code with RFID. Detecting system in the car takes this code and if the code is correct, vehicle door is opening.

System works with the other helping system. For instance, vehicle-warning system, stop start system and open or close the vehicle's windows system and similar systems [43].

Stop and start system works as remote keyless technology. If the key is in the vehicle and driver pushes the start button, vehicle is starting. System uses radio frequency receivers, proximity detectors sensors and door locks actuator, speaker, trunk latch, window and sunroof motors, door and trunk motors, interior and exterior lights, engine ignition button and horn systems [43].

2.12 Security System

The automotive security problems increase with the development of the electronic industry. Vehicles are protected against the thieves by this system. Security block system is given in Figure 2.36.

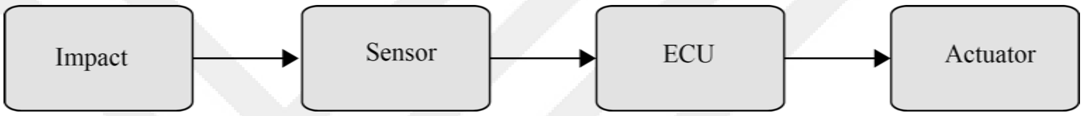


Figure 2.36 Security block system.

Systems determine the vehicle situation. There are two options. If there is not damage, system warns the driver immediately. Moreover, if there is damage, system detects the impact on the vehicle with impact sensors and this data is send the ECU. Force of the impact is detected and if it is highest, system uses the actuator and warns the driver [44]. Systems use warning system, immobilizer system and tracking system [44]. Nevertheless, they may change as manufacturer.

Immobilizer system locks the door, closes the ignition system and prevents fuel coming at the time of theft [44]. Immobilizer block system is given in Figure 2.37.

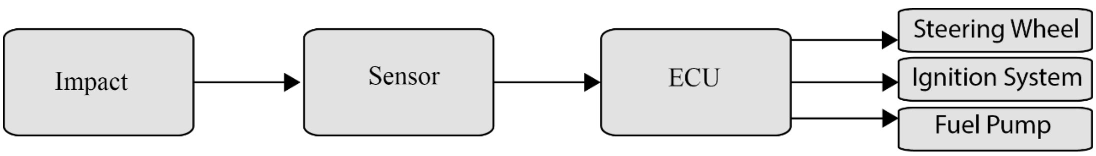


Figure 2.37 Immobilizer block system.

Tracking system uses GPS system. If the vehicle is stolen, system tracks the vehicle and warns the authorities.

Security system uses pressure sensors, switches, microphones, tilt sensors, vibration sensors, acceleration sensors, proximity sensors, GPS position sensor. Moreover, it uses audible alarms, lights and RF link to telephone network [44].

2.13 Transmission Control System

Transmission system transmits the torque data to the shaft or the differential according to sensor data and engine control module data. There are two types transmission system. These are manual and automatic. Driver decides when and which direction the gear is change on the manual transmission system in the manual system. However, automatic system decides this choice [45]. Generally, automatic transmission system is design to controls the fuel consumption [45]. Automatic transmission block system is given in Figure 2.38.

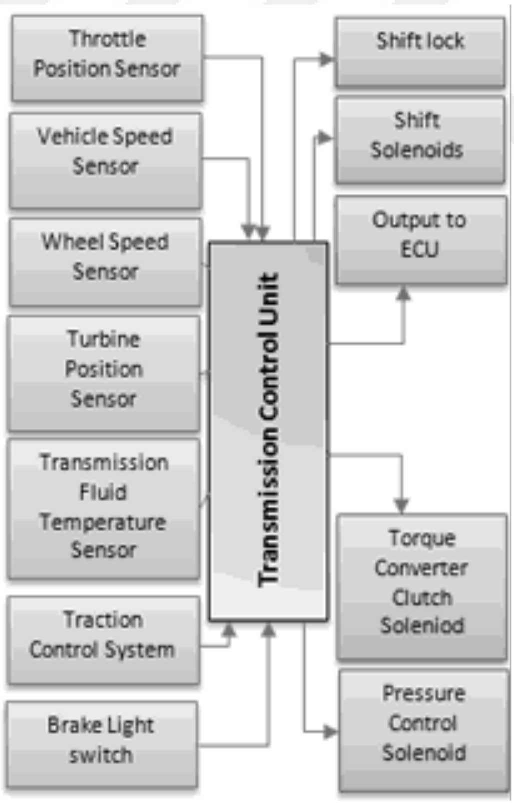


Figure 2.38 Automatic transmission control block system [45].

System uses wheel speed sensor, throttle position sensor, transmission fluid temperature sensor, turbine speed sensor as given in Figure 2.38 [45]. Except of them, it uses vehicle speed sensor, crankshaft position sensor, gear position sensor, engine coolant temperature sensor [46].

Wheel speed sensor and crankshaft sensor are given in Chapter 2.3.1. Gear position sensor gives information about vehicle gear. The engine coolant temperature sensor measures the engine temperature that is normal or not. Transmission control system makes the controlled shifting for using these sensors [45]. And system makes the optimum transmission control. Some sensor data is given in Table 2.2.

Table 2.2 Sensor data [45, 46].

No	Sensor or System	Description	Transmission Control Module
1	Turbine Speed Sensor	Speed of the torque converter’s informatıon.	Activate the torque converter lockup clutch.
2	Throttle Position Sensor	how far the throttle is open	the best time to change a gear.
3	Transmission Fluıd Temp. Sensor	Correct temperature	Hot- down shift / Cold- up shift
4	Traction Control Sys.	Losing traction	Down shift

System uses some actuators. These are solenoid-actuated valves, pressure regulating or control solenoids, shift solenoids, shift lock and torque converter clutch solenoids [45, 46].

2.14 Airbag System

Airbag system is one of the passive safety systems. System protects the driver and passenger’s upper bodies from the accidents [47]. It is made from nylon fabric and sensors [47]. Airbag block system is given in Figure 2.39.

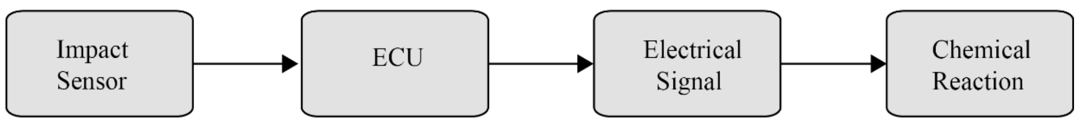


Figure 2.39 Airbag block system.

System detects the impact of the vehicle with the sensors. ECU decides which airbag should work and give the first electrical signal [47]. System performs a chemical reaction with the first electrical signal. After that, airbag inflates. This event occurs in the short time. Active and passive airbag system is given in Figure 2.40.

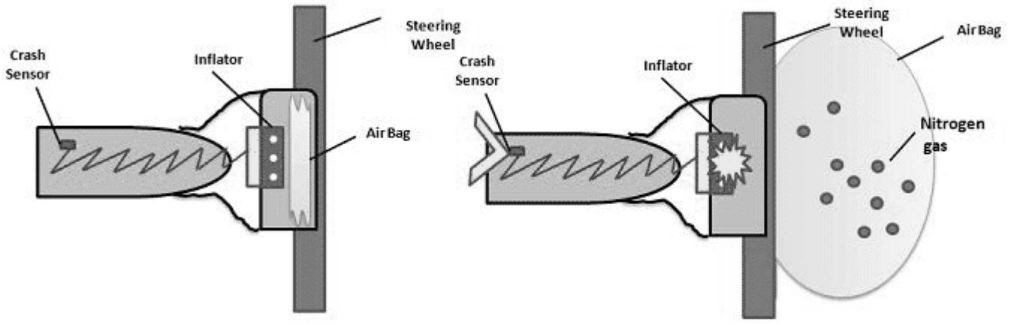


Figure 2.40 Active and passive airbag system [47].

Sodium gas comes out from chemical reaction that provides the inflation of air bags. Because that gas is reactive gas [48], the suppliers by making it enter reaction with potassium-nitrate chemical, manage to minimize that reactivity level. From the final reaction, nitrogen also comes out.

The chemical reaction;

$$2NaN_3 \rightarrow 2Na + 3N_2$$

Sodium is a reactive gas,

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

$$K_2O + Na_2O + SiO_2 \rightarrow \text{alkaline acid (glass)}$$

Gas pressure P;

$$P = F / A \quad \textbf{(2.33)}$$

Where A is area and F is force.

Total force F;

$$F = ma \tag{2.34}$$

Where a is acceleration, m is mass.

Volume V;

$$V = V_f^{\,2} - V_i^2 = 2ad \tag{2.35}$$

Where V_f is first volume, V_i is inflator volume, d is displacement.

Acceleration a;

$$a = \frac{V_f^{\,2} - V_i^2}{2d} \quad (m/s^2) \tag{2.36}$$

Ideal gas pressure P;

$$PV = nRT \rightarrow P = \frac{nRT}{V} \tag{2.37}$$

Where n is number of moles gas, R is constant value and T is temperature.

The number of airbags in the vehicle are variable according to the manufacturer. System uses acceleration sensor, wheel speed sensor, brake pressure sensor, seat occupancy sensor. In addition, it uses some actuators. These are airbag inflation device, passenger airbag ON/OFF indicator [47].

CHAPTER 3

SAFETY SYSTEMS

Safety systems prevent to the vehicle skidding, slipping and to get out of control. And also, it ensures the safety braking. Supported security systems with existing technologies are not used for the faster and irregular manner by the driver, they have been developed for the safe journey. Systems provide support to the drive for the safe journey and driving in limits.

In this thesis, conventional braking system is given in Chapter 3.1 and safety systems are given in Chapter 3.2. These are low tire pressure monitoring system (JTPMS), antilock braking system (ABS), traction control system (TCS), electronic brake distributor (EBD) and electronic stability program (ESP).

3.1 Conventional Braking Systems

Braking system is driving control system and it is used to slow down or stop the vehicle. The force applied by the driver from the brake pedal is transmitted to the wheels with different braking system. When the braking, brake shoe or pad opens the against the drum or it frictions to the disk. So frictional force is created [50]. Conventional braking block system is given in Figure 3.1. Disk brake and drum brake are given in Figure 3.2.

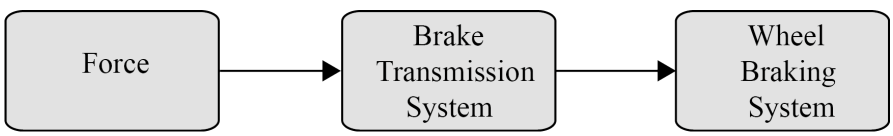


Figure 3.1 Conventional braking block system [50].

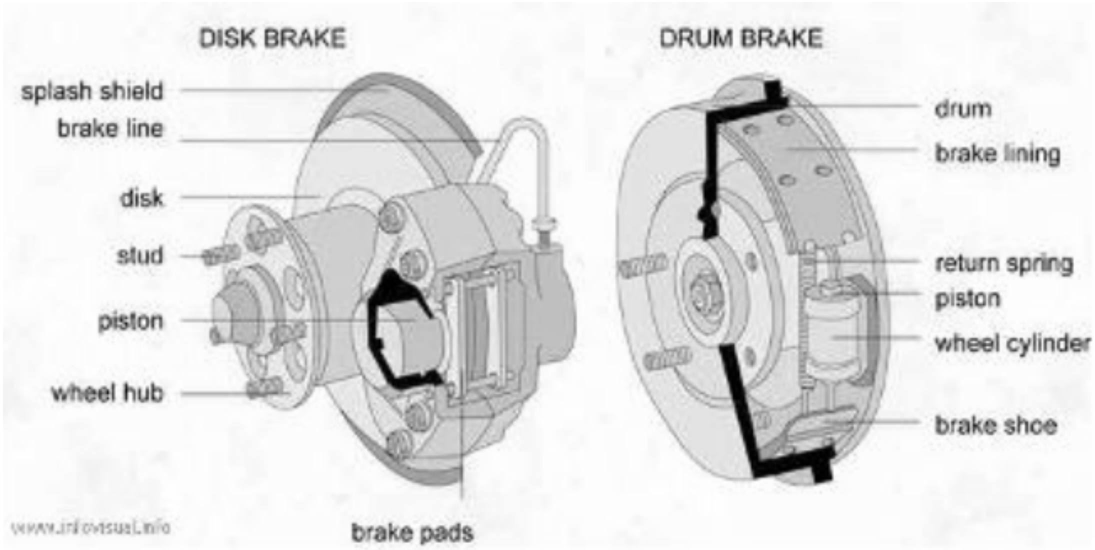


Figure 3.2 Types of brakes [51].

The rule of braking system involves the conversion of kinetic energy into heat energy [52]. Because of that, system must have the heat absorption capability [51]. Brake system has two kinds of friction brakes [51]. These are disk brakes and drum brakes. Disk brake uses a clamping, so it creates friction between the rotor and pads. These are mounted in caliper [51]. Drum brake is also used brake shoe as distinct from disk brakes.

3.1.1 Brake Transmission Systems

There are four different way of brake transmission. These are hydraulic, pneumatic, mechanic and magnetic [50]. These systems have advantages and disadvantages. Not every system is used to every vehicle. For instance, long trailer vehicle does not use the hydraulic system but the small trailer vehicle uses it.

3.1.1.1 Mechanic Braking Transmission Systems

This system uses mechanical equipment for transmitting the force. It is used as handbrake system in the vehicle. The force applied by the driver from the handbrake's lever is transmitted to the wheels.

3.1.1.2 Hydraulic Braking Transmission Systems

Hydraulic braking system operates according to the Pascal law. The force applied by the driver is increased to use to the principle of leverage and transmitted to wheel system. Wheel uses the brake lining and vehicle is slow down or stopped. Pascal law and equation circuit is given in Figure 3.3.

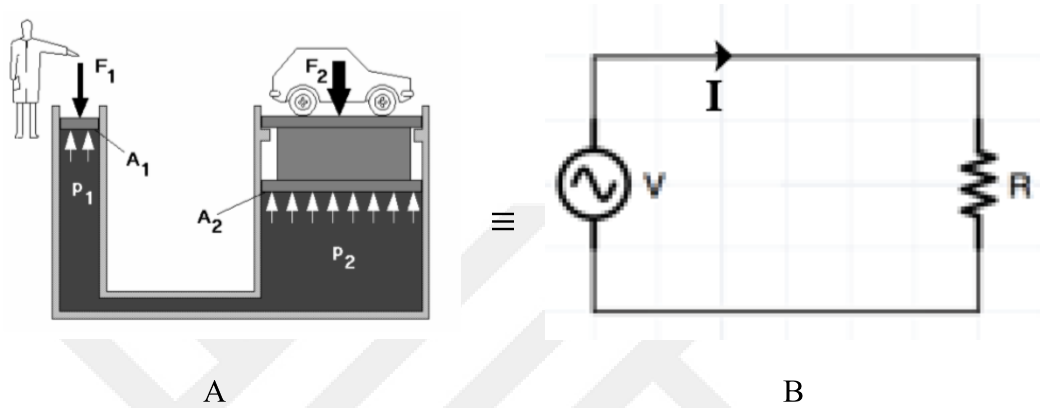


Figure 3.3 A is pascal law and B is equation circuit [49].

In hydraulic system, fluid pressure, pipe diameter and force is equal to current, resistor and voltage in the equation circuit.

Left side fluid pressure P_1;

$$P_1=F_1/A_1 \quad \textbf{(3.1)}$$

Right side fluid pressure P_2;

$$P_2=F_2/A_2 \quad \textbf{(3.2)}$$

$$P_1=P_2 \text{ and } F_1/A_1 = F_2/A_2 \quad \textbf{(3.3)}$$

Where F_1 and F_2 are force, A_1 and A_2 are pipe diameter.

Current I_1;

$$I_1=V_1/R_1 \quad \textbf{(3.4)}$$

Current I_2;

$$I_2=V_2/R_2 \quad \textbf{(3.5)}$$

$$I_1= I_2 \text{ and } V_1/R_1 = V_2/R_2 \quad \textbf{(3.6)}$$

Where R is resistor.

Hydraulic system composes of three parts. These are command system, hydraulic system and wheel mechanism [49]. Command system is distance between the center and the brake pedal, hydraulic system transmits the force, the first force is applied to wheel system with hydraulic system and the vehicle is slowed down or stopped by the mechanical system [49]. Hydraulic braking transmission block system is given in Figure 3.4.

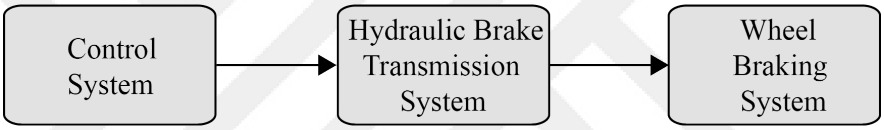


Figure 3.4 Hydraulic braking transmission block system.

3.1.1.3 Pneumatic Braking System

This kind of system uses the pneumatic braking system for transmission. This system uses compressor but the other systems do not use it [49]. In addition, this system is used for heavy vehicle and long trailer vehicle. For instance, underground vehicles.

3.1.1.4 Electromagnetic Braking System

Electromagnetic brake is one of the most important braking system in automated industrial development. This system is used for heavy vehicles. This system is mounted in the transmission line of vehicles [51, 52]. Electromagnetic brake system working principle is based on the Eddy currents [51-56]. Magnetic field is given in Figure 3.5 and electromagnetic disk brake circuit is given in Figure 3.6.

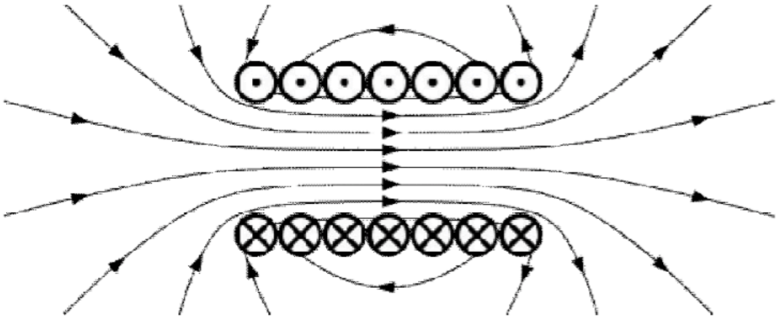


Figure 3.5 Magnetic field [52].

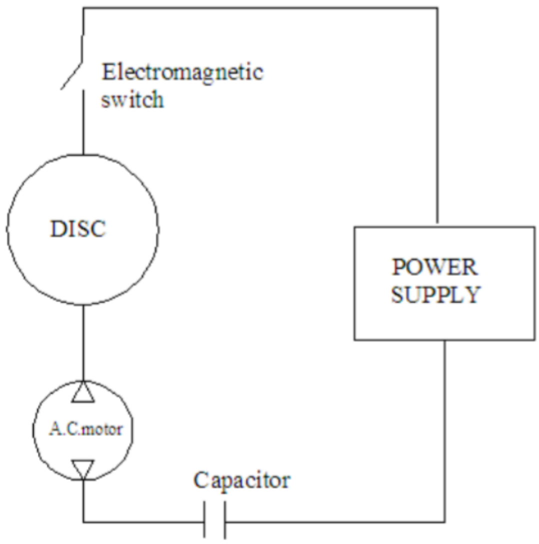


Figure 3.6 Electromagnetic disk brake [52].

As mention above, Eddy current is used in the electromagnetic braking system. This braking system basically consist of a disc and a magnet [55]. Eddy current braking is given in Figure 3.7.

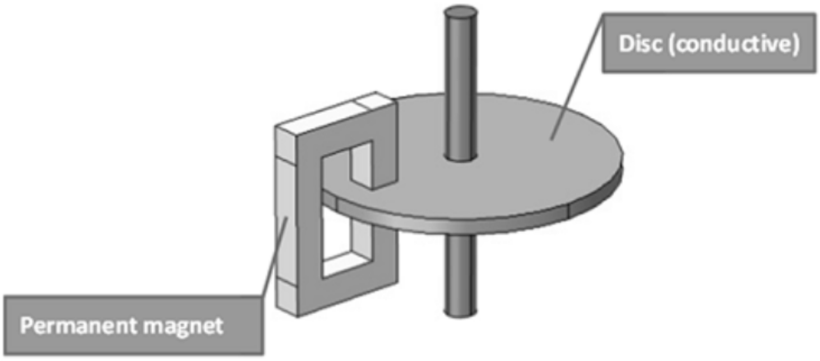


Figure 3.7 Eddy current braking system [55].

The permanent magnet generated spin of disk and the Lorentz forces slow down the disc [55]. This working principle's name is Eddy current. Likewise, magneting braking working principle is as same as Eddy current. But, magnetic braking system consist of magnetic steel plate, a permanent magnet and a current coil [56]. Full geometry of the brake model is given in Figure 3.8.

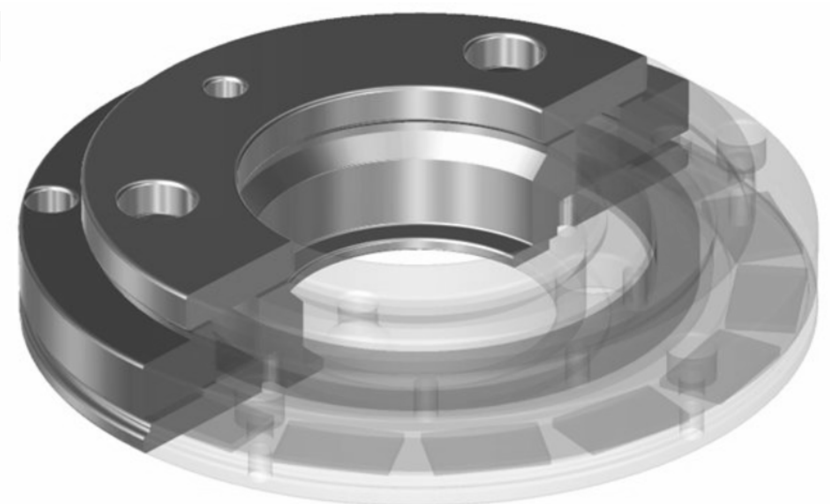


Figure 3.8 Full geometry of the brake model [56].

Magnetic braking system consists of magnetic steel plate, a permanent magnet and a current coil in Figure 3.8. The coil generates a magnetic field against the field of the magnet [54,56]. When the coil current is zero, vehicle starts to slow down. If the coil current starts to increase, vehicle starts to movement [54,56]. Braking force is a function of coil current.

3.1.2 Wheel Systems

Disc brake, drum brake and magnetic brake systems are used in the wheel system. Results of the pedal force, the caliper tightens to the wheel lining and disc brake creates the frictional force that is opposite to the direction of rotation of the wheel between the disc and the tire lining [49]. Results of the pedal force, the lug tightens to the tire lining, drum brake creates the frictional force that is opposite to the direction of rotation of the wheel between the drum and the tire lining [49]. The tire's lateral and vertical movement speeds are stopped by the braking system. Force of the tire and effects of the braking pressure are given in Figure 3.9.

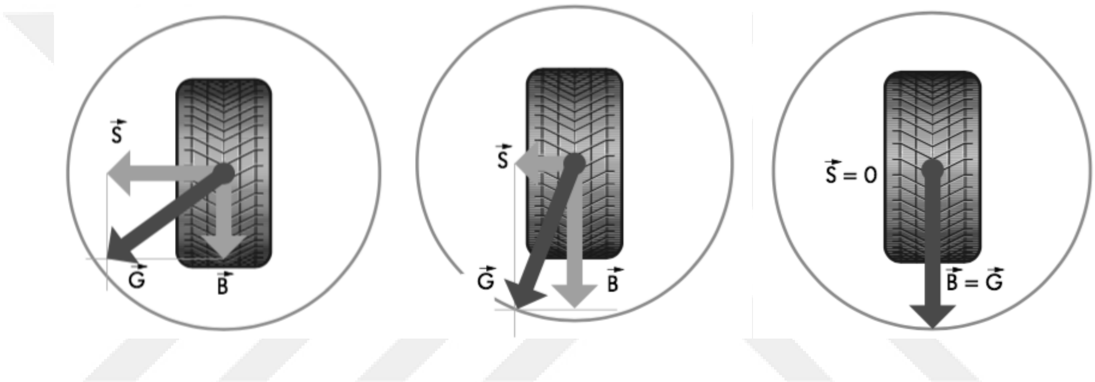


Figure 3.9 Force of the tire and effects of the braking pressure [50].

Total force $\vec{G}$;

$$G = S + B \quad \textbf{(3.7)}$$

Where $\vec{B}$ is braking force, $\vec{S}$ is lateral force. When the braking force increases, lateral force increases and timely total force increases. When the braking force is equal to total force, lateral force is equal to zero and tire speed is equal to zero.

3.2 Safety Systems

Purpose of the conventional braking system slow down or stop the vehicle. The brake force applied by the driver from the brake pedal and it is transmitted to the wheels. However, conventional braking system facilitates to slipping or locking the wheel. On the other hands, safety system compares the all tire speed.

3.2.1 Low Tire Pressure Monitoring System (LTPMS)

The most development tire pressure measuring system is low tire pressure monitoring system. It shows the tire pressure and temperature [57]. This system measures at the reel time [57, 58]. LTPMS block system is given in Figure 3.10.

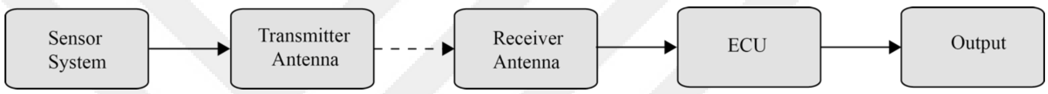


Figure 3.10 LTPMS block system.

TPMS, is an electronic system, is put in the rim [57, 58]. System measures the tire pressure with pressure sensor and if the tire pressure is lower than the normal value, system sends this data to the ECU with RF communication system.

TPM system has been mandatory since 2007 in the United States [57]. In the Turkey, it has been mandatory since 2014 [59].

System uses air pressure sensor, temperature sensor, wheel speed sensor and low tire pressure display actuator is used [4, 57].

3.2.1.1 Mathematical Model

Mathematical model uses vehicle model and tire model. The change of the gravity, the air resistance, the rolling resistance and suspension system was ignored in this model.

3.2.1.1.1 Tire Model

Tire is made of different rubber materials. Because of this, tire model is change according to the type of tire. But in this thesis, rubber material was ignored. Tire mathematical model is given in Figure 3.11.

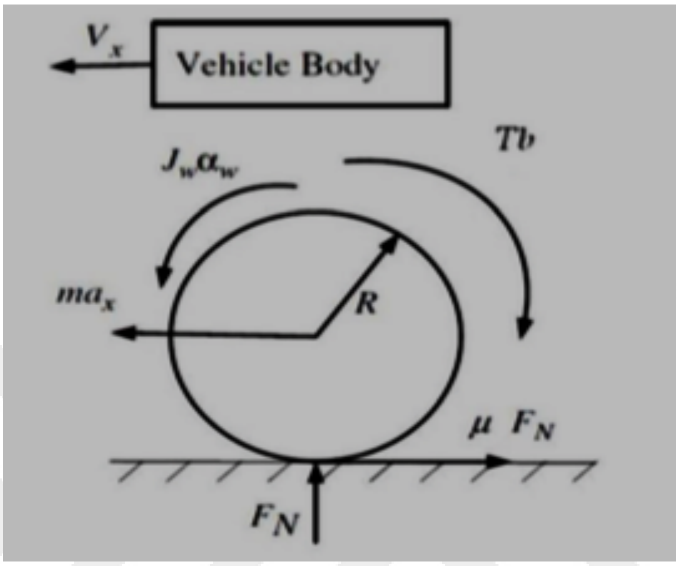


Figure 3.11 Tire mathematical models [60].

Lateral force F_s;

$$F_s = -ma_x = \mu F_N = -m\frac{dV_x}{dt} \tag{3.8}$$

Where m is vehicle mass, a_x is vehicle acceleration, μ is friction coefficient, F_N is road reaction force, V_x is wheel speed and t is time.

Total torque in the tire center T_b;

$$T_b = \mu F_N R - J_\omega \alpha_\omega \tag{3.9}$$

$$T_b = \mu F_N R - J_\omega \omega \tag{3.10}$$

Where α_ω is tire angular acceleration and R is tire diameter.

The rate of tire slip λ;

$$\lambda = \frac{V_x - \omega R}{V_x} \tag{3.11}$$

Where ω is tire speed. Both sides derivative is taken;

$$\lambda = \frac{V_x(1-\lambda) - \omega R}{V_x} \tag{3.12}$$

Friction coefficient μ [63];

$$\mu = \frac{\mu_h}{\lambda_0}\lambda, \ \lambda \leq \lambda_0 \tag{3.13}$$

$$\mu = \frac{\mu_h - \mu_g \lambda_0}{1-\lambda_0} - \frac{\mu_h - \mu_g}{1-\lambda_0}\lambda \ , \ \lambda > \lambda_0 \tag{3.14}$$

Where μ_h is high friction coefficient, μ_g is angular friction coefficient, μ_0 is slip friction coefficient.

3.2.1.2 Detection System

System uses air pressure sensor, temperature sensor and wheel speed sensor. Wheel speed sensor is given in Chapter 2.3.1. It detects the tire pressure, temperature and speed with these sensors. It sends sensor's data to the ECU with RF communication system. End of the measuring, pressure is low and low-pressure warning is send the display.

Sensor system creates the electrical output. This output is compared with the nominal value. Sensor measuring block system is given in Figure 3.12.

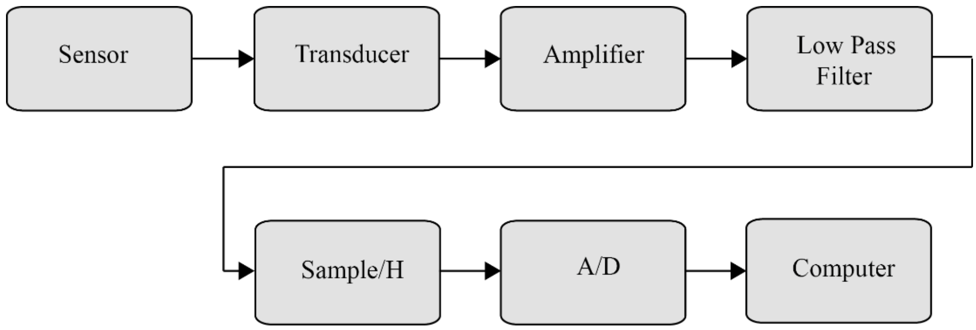


Figure 3.12 Sensor measuring block system [61].

If the signal distorted, low pass filter is used and it optimizes the signal. After that, sample/H and A/D are used for process [61].

3.2.1.2.1 Temperature Sensor

Temperature sensor measures the reel time temperature of the tire. Many sensors are used for measuring the temperature. These are resistance temperature detector (RTD), thermistors, thermocouples and integrated circuit temperature sensors [62]. RTD sensor is mostly used.

RTD sensor consists of metal conductors (iron, platinum, nickel). When the temperature increases, metal resistor increases. This system is used for measuring the engine temperature and tire temperature.

Integrated circuit temperature sensor consists of germanium and silicon [61]. If the system temperature increases, current of the circuit increases. System is separated two main categories. These are generating of the voltage or current for measuring the temperature [61].

3.2.1.2.2 Tire Pressure Sensor

Tire pressure system measures the tire pressure and data is converted to the electrical signal. Tire pressure sensor is given in Figure 3.13.

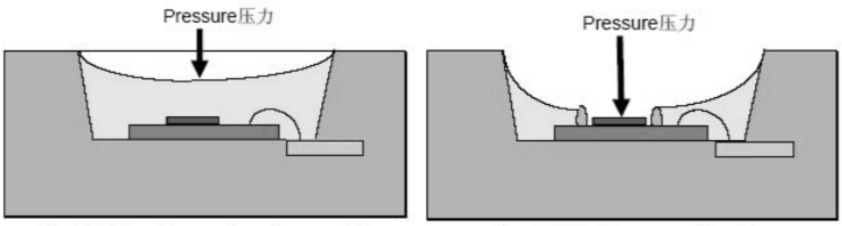


Figure 3.13 TPM system [58].

Piezoelectric and diaphragm type sensors are used as pressure sensor [61]. Diaphragm type sensor consists of metal plate. Metal plate is swelled by the pressure. Mechanical system is moved with this way. This movement is converted to the electrical signal and system measures the pressure on the diaphragm. This system measures the pressure between 0.1 and 10000 bar [61]. Diaphragm type sensor is given in Figure 3.14.

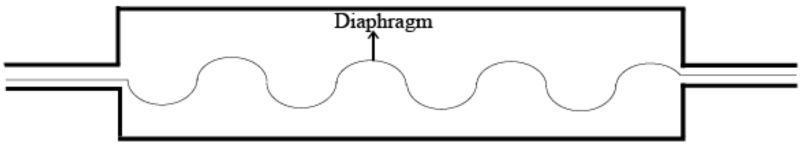


Figure 3.14 Diaphragm type sensor [61].

Piezoelectric sensor consists of metal plate and crystals. Metal plate is swelled by the pressure and crystal is moved. End of this movement, current is created and when the pressure increases, the current increases [61]. This system measures the pressure between 1N and 1mN bar [61].

3.2.1.3 Electronic Control System

Control systems evaluate the sensor data and in the low pressure, it warns. System saves the nominal tire pressure when the tire stops and tire has enough temperature. System proportions the relation between low pressure and temperature with nominal pressure data. System determines the pressure in the rotating tire, but this data is wrong. Because, temperature increases and pressure is change.

LTPM system uses lots of algorithm for control. The most used systems are P, PI and PID controller. P is proportional, I is integral and D is differential. In this thesis, PID controller is given. PID control uses all control types. Firstly, it uses P, secondly it uses I and thirdly, it uses D controller. LTPM PID controller block system is given in Figure 3.15.

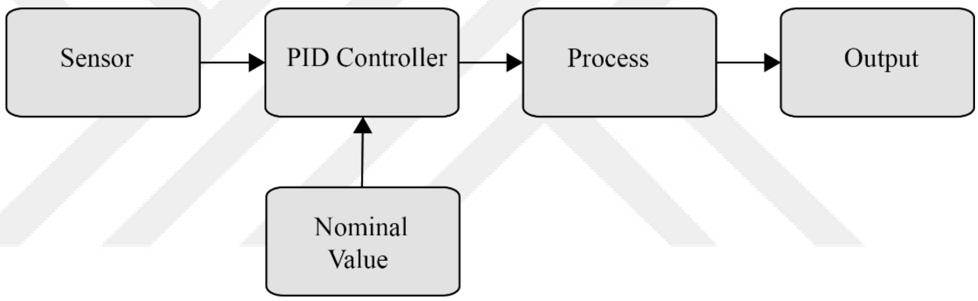


Figure 3.15 LTPM PID controller block system.

PID controller block system is given in Figure 3.16.

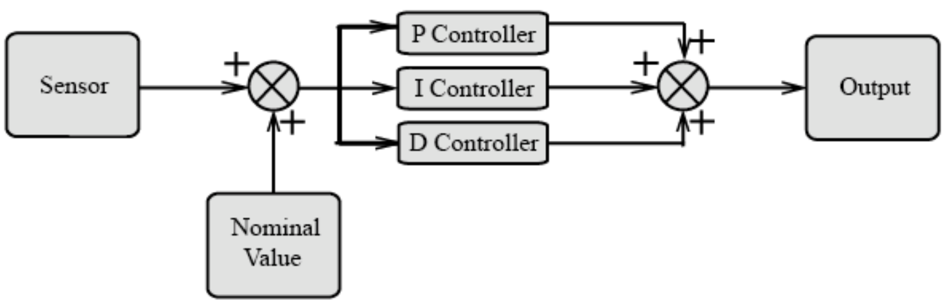


Figure 3.16 PID controller block system.

Equation of PID controller, final situation u:

$$u = K_p e + K_i \int e dt + K_d \frac{de}{dt} \quad \textbf{(3.15)}$$

Where K_p is error rate coefficient, K_d is differential error coefficient, K_i is integral error coefficient and e is error.

3.2.2 Antilock Braking System (ABS)

Antilock braking system (ABS) is avoided the wheel lockup. And it is modulating the braking pressure [64]. System helps the driver for safety driving. This system has sensors that detects the speed of each wheel. When sudden braking, system detects the wheel traction decrement. After that, it sends this data to ECU. ECU sends the command to the hydraulic control module for changing the braking pressure. System pumps the brakes at approximately 18 Hz per second. So, it prevents the wheel lockup and helps the driver [19]. ABS block system is given in Figure 3.17.

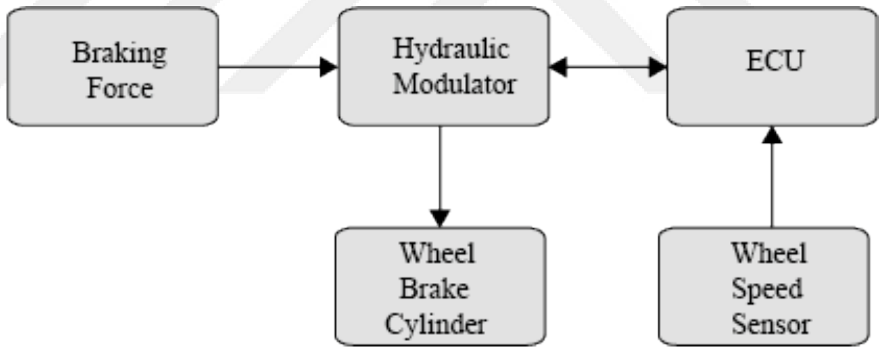


Figure 3.17 ABS block system.

ABS may use four different brake systems in the wheel. These are 4 channel 4 sensor, 3 channel 4 sensor, 3 channel 3 sensor, 2 channel 4 sensor, 1 channel 1 sensor [64,65].

- **4 channel - 4 sensors;** This system is the best braking system. Every wheel has speed sensor and valve [64, 65].

- **3 channel – 4 sensors;** Every wheel has sensors but front wheels have 2 valve and rear wheels have 1 valve [64, 65].

- **3 channel – 3 sensors;** Front wheels have 2 sensors and 2 valve but rear wheels have 1 sensor and 1 valve [64, 65].

- **2 channel – 4 sensors;** every wheel has sensors but front wheel has 1 valve and rear wheel has 1 valve [64, 65].

- **1 channel – 1 sensor;** There are only 1 sensor and 1 valve [64, 65].

ABS has four main systems. These are speed sensor, valves, pump, and ECU. Speed sensor detects speed of the wheel. A valve adjusts the fluid inlet and outlet. In addition, it sets the hydraulic pressure. Pump sets the hydraulic braking pressure. Last system ECU pumps the brakes and controls the other system. ABS system firstly uses hydraulic module system. This system is given in Figure 3.18.

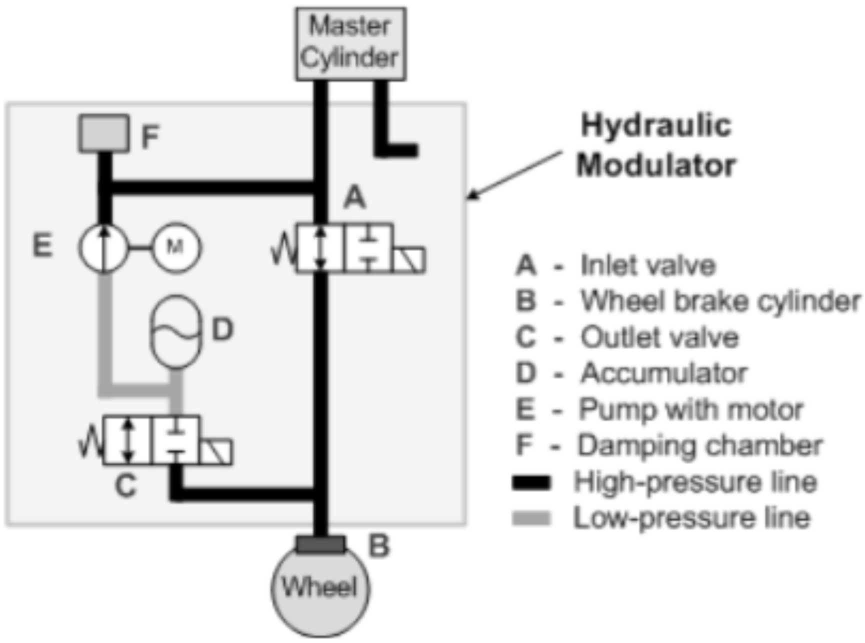


Figure 3.18 Hydraulic module system [64].

3.2.2.1 Mathematical Model

System creates the torque and the friction force, after that vehicle is stopped or slowed by this system. The most important mathematical model is wheel model. Tire model is given in Chapter 3.2.1.1. In this model uses 2 DOF ABS system vehicle model.

Many factors affect the ABS system. These factors are separated intra-system and non-system. Delay is the most effective factor for intra system. Road condition and wheel system is the most effective factor for non-system. ABS system applies the torque for each wheel [64, 66]. Friction force changes according to road conditions and wheel. Tire slip rate changes at certain intervals for not wheel lockup [64, 66]. Tire slip rate is given in equation 3.11. If slip rate is equal to “1”, wheel acceleration speed is equal to “0”. This mean, vehicle is slipping and chasses moves forward direction [64, 67, 68]. If the slip rate is equal to “0”, vehicle is not slipping [64, 67]. When vehicle is slipping, ABS system controls the rate and rate changes between 0.1 and 0.3. In addition, system prevents the wheel lockup and vehicle starts to slow [64, 67]. State space model should be calculated. State space model is given in equations (3.17, 3.18, 3.19).

Stopping distance derivative S_x;

$$S_x = V_x \tag{3.16}$$

Derivative of linear acceleration V_x;

$$V_x = \frac{-\mu F_N}{m} \tag{3.17}$$

Where F_N is reaction force, μ is friction coefficient and m is mass.

Derivative of slip rate λ;

$$\lambda = \frac{-\mu F_N}{V_x} - \left(\frac{1-\lambda}{m} + \frac{R^2}{J\omega} \right) + \frac{R}{J\omega V_x} T_b \tag{3.18}$$

Where T_b is braking torque, ω is rotational tire speed and R is wheel radius.

Friction coefficient varies widely. The principal reasons are road condition, tire condition, friction coefficient and tire road harmony. Slip rate is given in equation 3.20. Friction coefficient is a function of slip rate and speed.

Friction coefficient μ;

$$\mu(\lambda, V_x) = \left[c_1\left(1 - e^{-\lambda c_2}\right) - c_3\lambda\right]e^{-V_x c_4} \qquad \textbf{(3.19)}$$

Where C_1 is max value of slip graph, C_2 is friction curve graph, C_3 is differences between friction rate 1 and maximum value and C_4 is wetness value of the place.

Optimum slip rate is given in Figure 3.19 and friction coefficient is given in Figure 3.20.

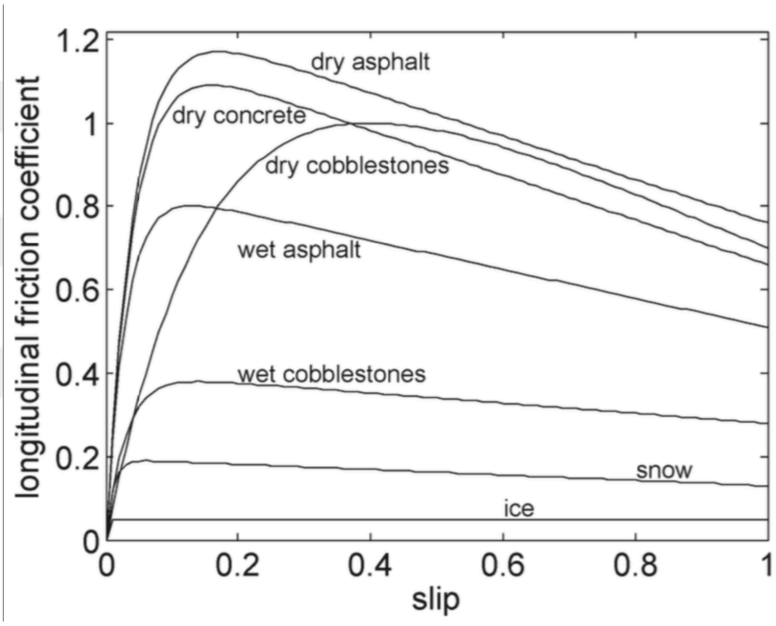


Figure 3.19 Slip rate graph [66].

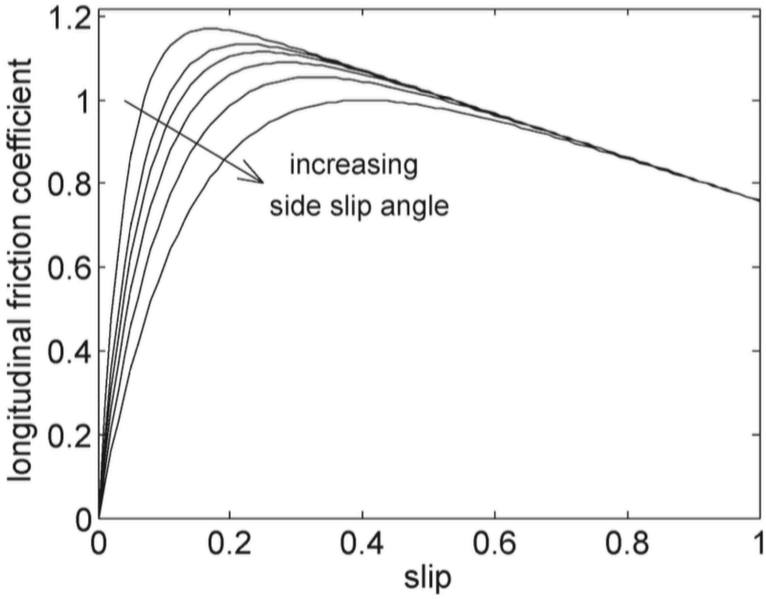


Figure 3.20 Friction coefficient [66].

Firstly, friction coefficient, friction rate, vehicle speed and tire speed is detected. After, system calculates the front and rear torque. Braking is irregular, so saturation and torque is calculated as equations (3.21, 3.22, 3.23) [69].

Saturation S;

$$s = \mathrm{sat}\left(\frac{\lambda - \lambda_b}{\sigma}\right) \quad \textbf{(3.20)}$$

Torque of front wheel T_{bf};

$$T_{bf} = \frac{2J_f}{r}\left(\lambda_b v - \left(\frac{w_r r v}{v} - \frac{r}{2J_f}\left(M_b + \mu m_1 r g - \mu m_3 r v\right)\right)\right) - k\,sat\left(\frac{\lambda - \lambda_b}{\sigma}\right) \quad \textbf{(3.21)}$$

Torque of rear wheel T_{br};

$$T_{br} = \frac{2J_r}{r}(\lambda_b v - (\frac{w_r rv}{v} - \frac{r}{2J_r}(M_b + \mu m_2 rg - \mu m_3 rv))) - ksat(\frac{\lambda - \lambda_b}{\sigma}) \quad \textbf{(3.22)}$$

Where J_f is front wheel moment, J_r is rear wheel moment, M_f is total mass, v is vehicle speed and w is angular velocity.

3.2.2.1.1 Hydraulic Model

Hydraulic brake pressure modulator creates a connection between the master cylinder and the wheel brake cylinder [62, 64]. Modulator has pump, engine, battery and reservoir [62]. Hydraulic model is separated four systems. These are valve model, pump model, engine model and accumulator model.

3.2.2.1.2 Valve Model

The change of the valve current with time $\frac{di}{dt}$;

$$\frac{di}{dt} = \frac{1}{L(x,i) + i.\frac{\partial L(x,i)}{\partial i}}\left[U - R.i - \frac{\partial L(x,i)}{\partial i}.i.v\right] \quad \textbf{(3.23)}$$

Where U is solenoid valve drive voltage, L is valve coil inductance, R is valve coil resistance, I is current in the valve, x and v are displacement and speed of the spool shifts. The change of the spool shifts speed with time $\frac{dv}{dt}$;

$$\frac{dv}{dt} = \frac{1}{m}\left[F_m(x,i) - k.(x + G_0) - F_p(x) - b.v^3 - F_f\right] \quad \textbf{(3.24)}$$

Where m is spool quality, F_m is electromagnetic force, F_f is friction, k is return spring stiffness, F_p is spool components suffered fluid power, b is speed damping and G_0 is spring preload.

Displacement with time $\frac{dx}{dt}$;

$$\frac{dx}{dt} = v \tag{3.25}$$

3.2.2.1.3 Pump Model

Pump model is related to engine traction system. Pump and accumulator systems are given in Figure 3.21.

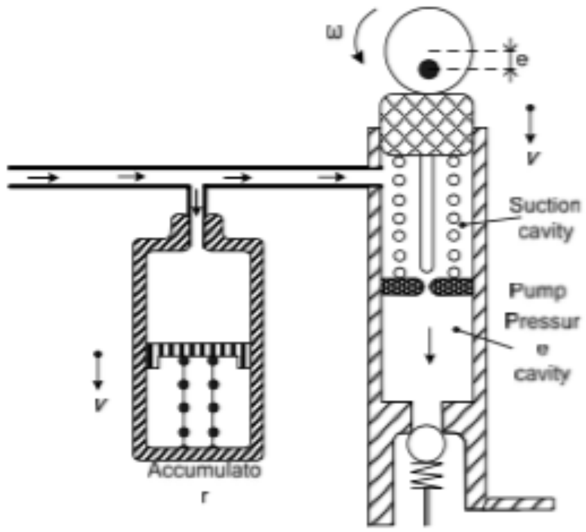


Figure 3.21 Accumulator and pump system [70].

System volume V;

$$V = A \cdot e \cdot \sin(\varphi_0 + \omega \cdot t) \tag{3.26}$$

Where A is pump piston area, e is eccentric, φ_0 is eccentric wheel angle, ω is engine angular velocity and t is time.

Flow q;

$$q = \dot{V} = A \cdot e \cdot \cos(\varphi_0 + \omega \cdot t) \cdot \omega \tag{3.27}$$

Pump pressure p;

$$p = p_{out} - fp_{in} \quad \textbf{(3.28)}$$

Where P_{out} is channel pressure, P_{in} is absorption channel pressure, f is rate of pressure gap and absorption gap.

Resistance moment M;

$$M = qp \quad \textbf{(3.29)}$$

3.2.2.1.4 Engine Model

Dc engine coil current $\frac{di}{dt}$;

$$\frac{di}{dt} = (U - i \cdot R - k_{-\varphi} \cdot \omega) / L \quad \textbf{(3.30)}$$

Where U is switch voltage, i is engine coil current, R is engine coil resistance, ω is engine angular velocity, $k_{-\varphi}$ is electromagnetic coefficient, L is engine coil inductance.

Engine angular velocity;

$$\omega = [k_{-\varphi} i - (M + m_0)] / J \quad \textbf{(3.31)}$$

Where M is pump moment resistance, m_0 is engine friction moment and J is moment of inertia.

3.2.2.1.5 Accumulator Model

Cavity length is related to accumulator volume. Accumulator cavity length I_e ;

$$I_e = x_0 \ \ x_1 \quad \textbf{(3.32)}$$

$$V = l_e \cdot \pi \cdot d^2 / 4 \quad \textbf{(3.33)}$$

Where X_0 is accumulator cavity first length, X_1 is piston movement, d is piston radius.

Flow rate of the brake fluid in the accumulator q;

$$q = v \cdot \frac{\pi}{4} \cdot d^2 \cdot \frac{\rho(P)}{\rho(0)} \quad \textbf{(3.34)}$$

Where v is piston speed, $\rho(P)$ is liquid density pressure, P is accumulator pressure, d: diameter.

Piston dynamic F;

$$F = l_e \cdot k - \frac{\pi}{4} \cdot d^2 \cdot P \quad \textbf{(3.35)}$$

$$F = mv = mx_1 \quad \textbf{(3.36)}$$

Where k is spring stiffness and m is piston mass.

3.2.2.2 Detection System

ABS system detects the speed of each wheel with wheel speed sensor. Wheel speed is measured by Crankshaft and Hall Effect sensor that are given in Chapter 2.3.1.

3.2.2.3 Electronic Control System

Sensor signal is raised and filtered for calculates the required torque of each wheel and acceleration by ECU [60]. ECU takes the median speed of the front and rear wheels and accepts as reference value. System determines to use this reference which wheel is slipping. When the wheel is slipping, ECU triggers the valve and it raises the pressure of wheel. In addition, ECU defines the errors of all system.

Many algorithms are used for ABS controller. Some of them are logic threshold control, PID control, optimal control, synovial variable structure control, fuzzy control, neural network control and genetic algorithm [66].This controller algorithm has some advantages and disadvantages. Advantage and disadvantage situations are defined as vehicle stopping distance, cost and reference measuring system. The most useful algorithm is PID controller algorithm for ABS. PID controller is given in Chapter 3.2.1.3. Controller block system is given in Figure 3.22.

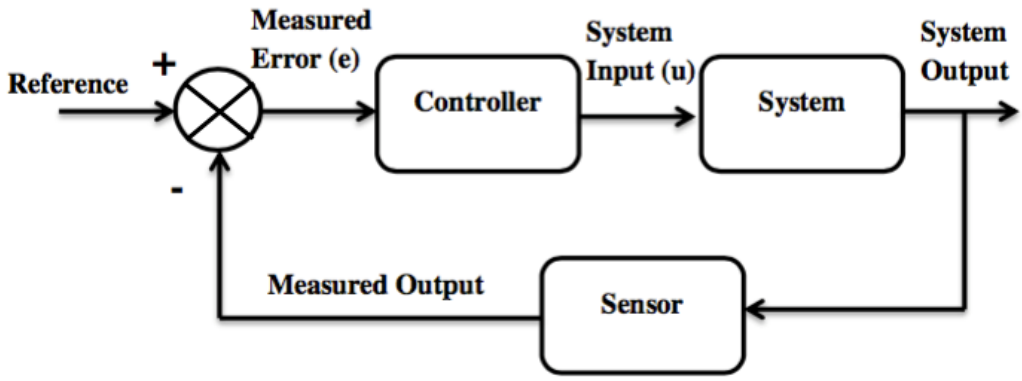


Figure 3.22 Controller block system [60].

PID controller equation is given in equation 3.16. ABS system is designed to use this equation. For designing, manual set and simulation method is used. Also, control system controls hydraulic pressure modulator.

As a result, ABS system is a kind of passive safe system. In sudden cases, system uses sensors, actuators, hydraulic system and ECU and the vehicle is slowed or stopped wherever driver want. System operates the greater speed than 7 km per hour [21]. ABS system and normal braking system are given in Figure 3.23.

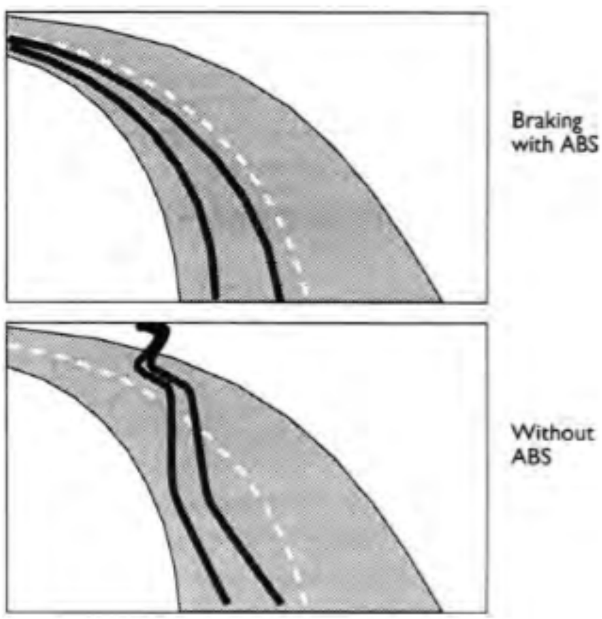


Figure 3.23 ABS and normal braking system [20].

3.2.3 Traction Control System (TCS/ASR)

Traction control is a system that prevents the skidding at the time of acceleration [19, 66]. Skidding consists of due to the loss of traction [20, 71]. ABS system may be used for preventing the skidding as traction control system by some manufacturer. However, traction system is used for preventing the skidding at the time of acceleration, antilock system is used at the time of braking [71, 72]. When front left wheel makes spin, front right wheel torque is increased [71, 72]. TCS block system is given in Figure 3.24.

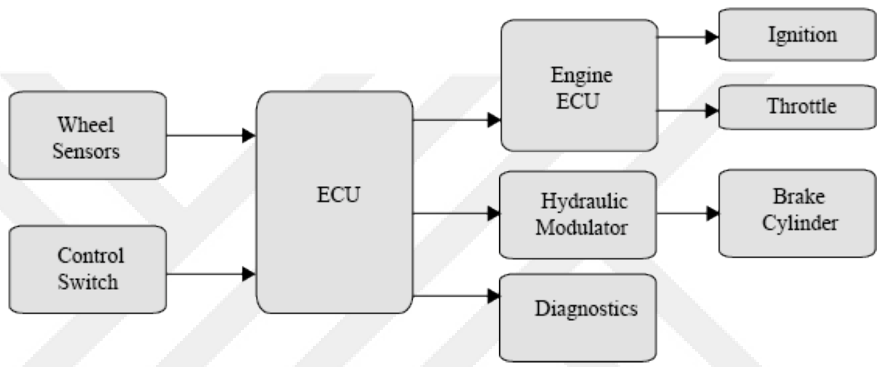


Figure 3.24 Traction control block system [20].

Firstly, TCS system controls the switch. If the switch is on, system works. Secondly, system uses sensors for detecting the wheel condition. In addition, if the wheel makes spin, sensors detect it and send this data to ECU. After that, system may use engine ECU, hydraulic modulator and diagnostics. If the system uses engine module, it operates the ignition system or throttle. If the system uses hydraulic modulator, it operates brake cylinder. Third option is diagnostics.

Engine system is given in Chapter 2.9 and hydraulic system is given in Chapter 3.2.2.1. TCS uses third options for preventing the skidding. These are ignition, throttle and brakes. These technics are given in Figure 3.25.

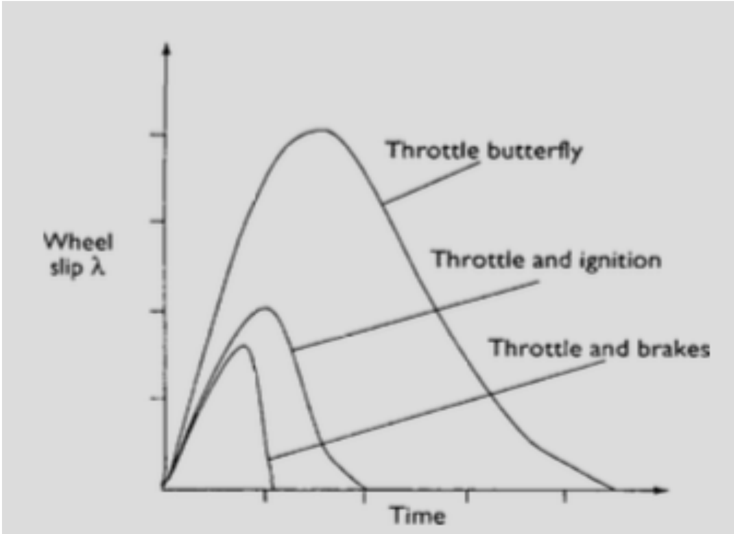


Figure 3.25 Comparison of three techniques used to prevent wheel spin: throttle, ignition and brake control [20].

The system may work in different road conditions. TCS system with different road conditions is given in Figure 3.26.

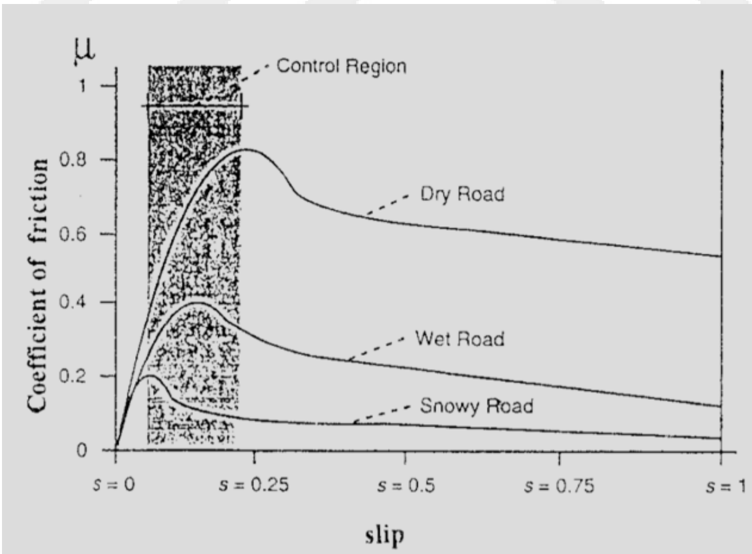


Figure 3.26 TCS system with different road conditions [73].

3.2.3.1 Mathematical Model

TCS uses vehicle model, wheel model and engine model as mathematical model.

3.2.3.1.1 Vehicle Model

Derivative of vehicle velocity v;

$$v = v_y r + \frac{1}{m}[(F_{xfl} + F_{xfr})\cos\delta - (F_{yfl} + F_{yfr})\sin\delta + F_{xfl} + F_{xrr} + F_{dx}] \quad \textbf{(3.37)}$$

Where F_x, F_y are longitudinal and lateral force, m is vehicle mass, r is yaw rate, δ is steering wheel angle.

Derivative of tire angular velocity ω;

$$\omega_{fl} = \frac{1}{I_\omega}(-R_W F_{xfl} + T_{dfl} - T_{rolfl}) \quad \textbf{(3.38)}$$

$$\omega_{fr} = \frac{1}{I_\omega}(-R_W F_{xfl} + T_{dfl} - T_{rolfl}) \quad \textbf{(3.39)}$$

$$\omega_{rl} = \frac{1}{I_\omega}(-R_W F_{xrl} + T_{drl} - T_{rolrl}) \quad \textbf{(3.40)}$$

$$\omega_{rr} = \frac{1}{I_\omega}(-R_W F_{xrr} + T_{drr} - T_{rolrr}) \quad \textbf{(3.41)}$$

Where T_{rol}, T_d are rolling resistance and traction torque, I_w is tire inertia and R_w ia tire diameter.

3.2.3.1.2 Tire Model

Tire system is one of the most important systems in the braking system. Tire tolerance value effects all system. Because of this, tire model is important. This model is given in Chapter 3.2.1.

3.2.3.1.3 Engine Model

Engine model has two important cases. These are intake manifold air mass and engine rotational dynamics. These includes absorption torque and ignition torque delay [71].

Derivative of intake manifold $m_a(t)$ [74];

$$m_a(t) = m_{ai}(t) - m_{ao}(t) \quad \textbf{(3.42)}$$

Where m_{ao} is out of the air mass ratio. Derivative of intake manifold air mass ratio $m_{ai}(t)$;

$$m_{ai}(t) = \text{MAX TC(t) PRI (t)} \quad \textbf{(3.43)}$$

Where MAX is maximum flow, TC is throttle features, PRI is normal pressure. Throttle feature is a function of angle. PRI is a function of manifold pressure. Throttle features TC;

$$TC(t) = \begin{cases} 1 - \cos(1{,}144\alpha), \alpha \leq 79{,}46 \\ 1, \alpha \geq 79{,}46 \end{cases} \quad \textbf{(3.44)}$$

Normal pressure PRI;

$$PRI(t) = 1 - \exp(9\frac{P_m}{P_{aim}} - 1) \quad \textbf{(3.45)}$$

$$PRI(t) = 1 - \exp(2808m_a - 9) \quad \textbf{(3.46)}$$

Derivative of air mass flow entering the combustion chamber $m_{a0}(t)$;

$$m_{a0}(t) = c\eta_{vol}(t)m_a(t)\omega_e(t) \quad \textbf{(3.47)}$$

Where ω_e is engine speed, c is physical coefficient, η_{vol} is measurement of engine induction effect.

Engine rotational dynamics $I_{eff}\omega_e$;

$$I_{eff}\omega_e = T_{ind} - T_{fric} - T_{aero} - T_{roll} - T_L \quad \textbf{(3.48)}$$

Where T_{ind} is engine net torque, T_{fric} is engine friction torque, T_{aero} is aerodynamic drag torque, T_{roll} is rolling friction torque, T_L is load torque and I_{eff} is effective inertia of the engine. Engine torque is discrete process. And continuous process ($T_{ind}(t)$) is given in equation 3.50.

$$T_{ind}(t) = c_T \frac{m_{a0}(t-\Delta t_{it})}{\omega_e(t-\Delta t_{it})} AFI(t-\Delta t_{it})SI(t-\Delta t_{st}) \quad \textbf{(3.49)}$$

3.2.3.2 Detection System

System uses crankshaft and Hall Effect sensor for detecting. These sensors are given in Chapter 2.3.1.

3.2.3.3 Electronic Control System

TCS ECU compares speed of each wheel. When it determines which wheel speed is bigger than the others, system makes braking [75, 76]. Braking algorithm is same as ABS system and ABS system is given in Chapter 3.2.2. On the other hand, when the system determines which wheel speed is bigger than the others, system calculates the degree of shift and engine torque is decreased [75, 76].

Many controller is used for maintain stability, reducing the yaw moment reaction and providing optimum power at all speed in the TCS system [20]. PI control, sliding mode controller, fuzzy logic controller, self-tuning fuzzy logic controller and model predictive controller are used for TCS controller algorithm [73]. Nevertheless, PID controller is the most useful algorithm for TCS system. PID controller is given in Chapter 3.2.1. TCS system provides the improved traction force for safe driving [20].

3.2.4 Electronic Brake Distributor (EBD)

Electronic brake distributor (EBD) is a kind of braking system. This system makes the balanced power distribution to the front and rear axles at the time of braking. Most important factor is the axles mass for balanced power distribution. System applies different brake force and prevents the slipping. EBD changes braking pressure. The slipping shows how close all tires to lock [77].

EBD is more developed system than ABS. Prime reason for this, EBD system provides to be same speed of all wheels. That is mean, the front of the vehicle is heavier than the rear of the vehicle. Because of this, the rear of the vehicle is slipping. However, system applies different braking force for all axes and the rear of the vehicle does not slip. EBD block system is given in Figure 3.27.

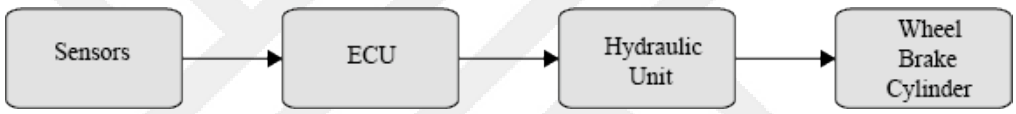


Figure 3.27 EBD block system.

System uses sensors, brake force modulators (hydraulic) and ECU for controlling the wheel. Tire friction system is important for EBD system. Because of which wheel is slipping or not, system analyzes with tire friction system [77].

3.2.4.1 Mathematical Model

System applies the different torque with vehicle mass and wheel speed. Vehicle free body is given in Figure 3.28.

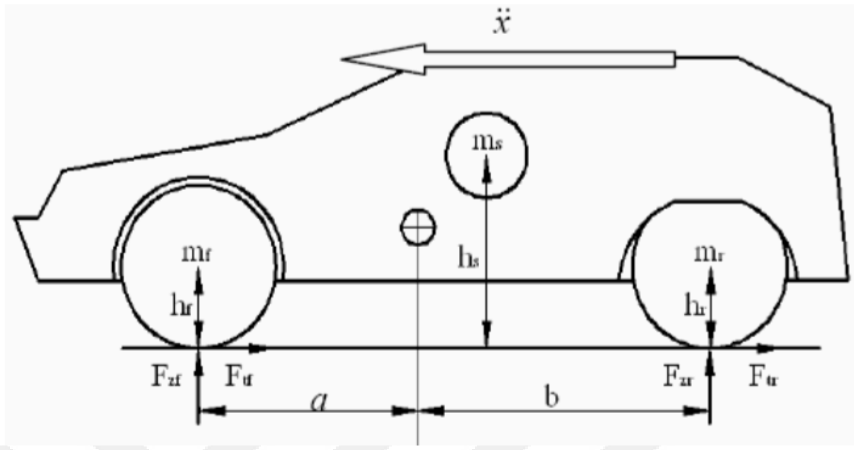


Figure 3.28 Vehicle free body [77].

In vehicle model, vehicle speed v;

$$v = x \tag{3.50}$$

Where *x* is vehicle position. And derivative of vehicle speed v;

$$v = -g\frac{\mu(\lambda_f)m_1 + \mu(\lambda_r)m_2}{m_{tot} - \mu(\lambda_f)m_3 + \mu(\lambda_r)m_3} \tag{3.51}$$

Where λ_f is front angular velocity, λ_r is rear angular velocity, m_{tot} is vehicle total mass and g is gravity force. Derivative of front and rear angular velocity ω_f and ω_r;

$$\omega_f = \frac{1}{2J_f}(-T_{bf} + \mu(\lambda_f)m_1 R_\omega g - \mu(\lambda_f)m_3 R_\omega x) \tag{3.52}$$

$$\dot{\omega}_r = \frac{1}{2J_r}(-T_{br} + \mu(\lambda_r)m_1 R_\omega g - \mu(\lambda_r)m_3 R_\omega x) \tag{3.53}$$

Where T_{bf} and T_{br} are front and rear torque, J_f and J_r are front and wheel moment of inertia, R_ω is tire radius.

Different mass value m_1, m_2, m_3;

$$m_1 = \frac{b}{a+b} m_{tot} \tag{3.54}$$

$$m_2 = \frac{a}{a+b} m_{tot} \tag{3.55}$$

$$m_3 = \frac{m_f h_f + m_s h_s + m_r h_r}{a+b} \tag{3.56}$$

Where a is distance between front wheel and center of gravity, b is distance between rear wheel and center of gravity, h_f is front wheel high, h_r is rear wheel high, h_s is center of gravity high, m_f is front mass, m_r is rear mass, m_s is vehicle center mass.

Friction coefficient and tire slipping are calculated. These relations are given in Chapter 3.2.1.1.

3.2.4.1.1 Braking Model

Hydraulic braking system is used in the EBD system. High-speed on-off valve is controlled for wheel cylinder pressure. Hydraulic braking system is given in Chapter 3.2.2.

High speed on-off valve $\bar{q}$;

$$\bar{q} = I_{PWM} q_n = \frac{t_p}{T} C_d A \sqrt{\frac{2\Delta P}{\rho}} \tag{3.57}$$

Where t_p is effective width, T is signal period, C_d is flow coefficient, A is high speed on-off valve flow profile, ΔP is high speed on-off valve differential pressure, q_n is flow rate and ρ is oil density.

Brake wheel cylinder Q;

$$Q = \frac{V_w}{K_W}\frac{dP_w}{dt} \tag{3.58}$$

Where V_w is tire cylinder braking module, P_w is tire cylinder pressure, K_w is tire cylinder volume module.

Disc brake

Tire braking torque and disk brake T_μ and F_μ;

$$T_\mu = GA_W P_W \tag{3.59}$$

$$F_\mu = \frac{T_\mu}{R} = \frac{GA_W P_W}{R} \tag{3.60}$$

Where G is constant value, P_w is tire cylinder pressure, A_w is cylinder piston cross-sectional area and R is tire radius.

3.2.4.2 Detection System

EBD system uses magnetic sensor for detecting the speed of vehicle. Speed sensor system is given in Chapter 2.3.1.

3.2.4.3 Electronic Control System

Many controllers are used in EBD ECU. For instance, PID control and Fuzzy control. In this thesis, Fuzzy control is given.

In EBD controller design;

$E \in$[-0.1,+0.1], $EC \in$[-0.8,+0.8] and $U \in$[-1000000,+1000000].

Input and output variables are NB, NM, NS, ZO, PS, PM, PB. Variables are given in Figure 3.29, 3.30, 3.31 and Fuzzy controller is given in Table 3.1.

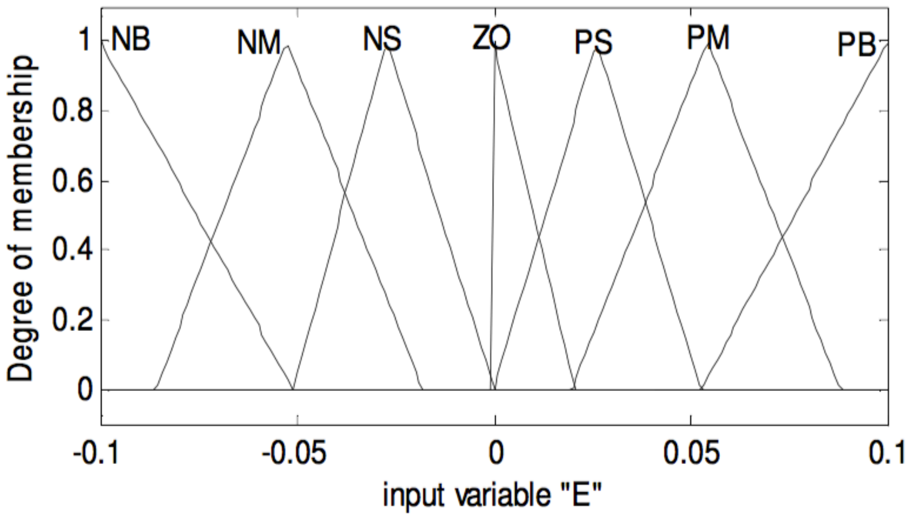


Figure 3.29 Membership function of input variable E [77].

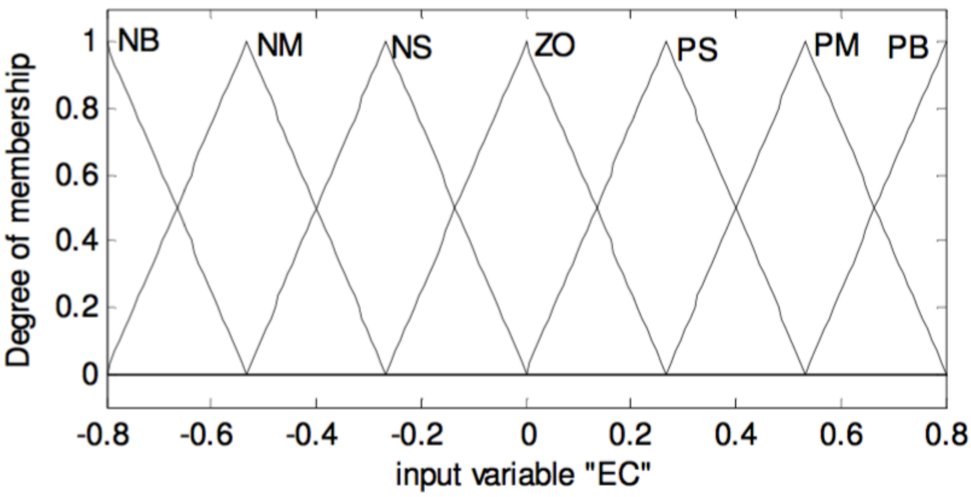


Figure 3.30 Membership function of input variable EC [77].

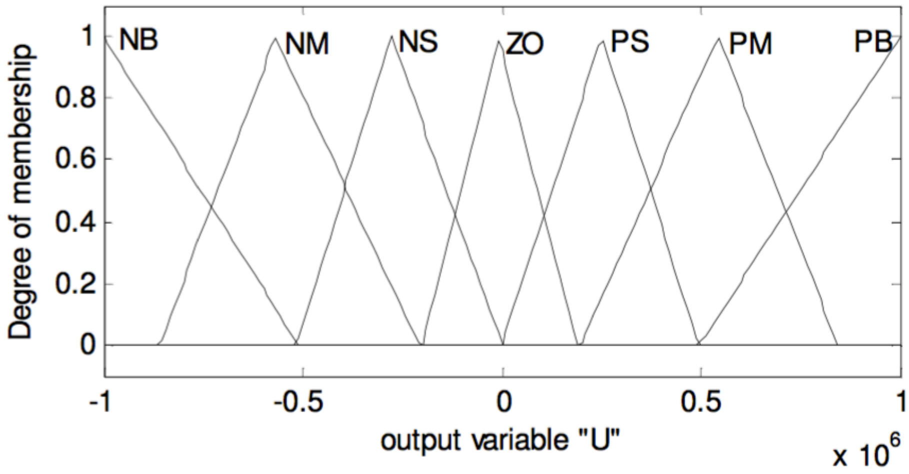


Figure 3.31 Membership function of output variable U [77].

Table 3.1 Fuzzy controller [77].

U		**EC**						
		NB	NM	NS	ZO	PS	PM	PB
E	NB	NB	NB	NB	NB	NM	NM	NS
	NM	NB	NB	NB	NM	NC	ZO	ZO
	NS	NM	NM	NM	NS	ZO	ZO	ZO
	ZO	NM	NS	NS	ZO	PS	PS	PM
	PS	ZO	ZO	ZO	PS	PM	PM	PM
	PM	ZO	ZO	PS	PM	PB	PB	PB
	PM	PS	PM	PM	PB	PB	PB	PB

Where E is front and rear wheel slip ratio, EC is the rate of change of the input error, U is the increase of the target wheel cylinder pressure.

3.2.5 Electronic Stability Program (ESP)

Electronic stability program (ESP) is a passive safety system [78-80]. System prevents skidding, slipping and protects the vehicle stability. ESP system detects steering wheel position and wheel speed. Thus, system learns driver behavior. On the other hand, it calculates lateral acceleration and rotational velocity and it learns vehicle behavior. Finally, system compares two behaviors and it analyses vehicle position. If the vehicle stability changes, ESP intervenes the vehicle system. ESP block system is given in Figure 3.32.

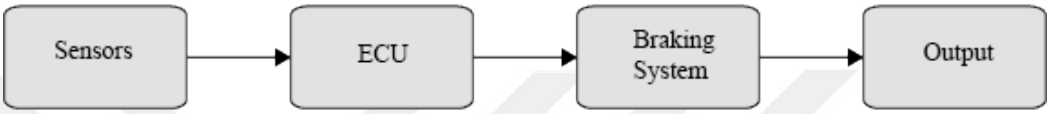


Figure 3.32 ESP block system.

ESP system intervenes wheel system and this is determined according to the road condition and vehicle position. Oversteer and understeer conditions are given in Figure 3.33. ESP system characteristics are given in Table 3.2 and 3.3.

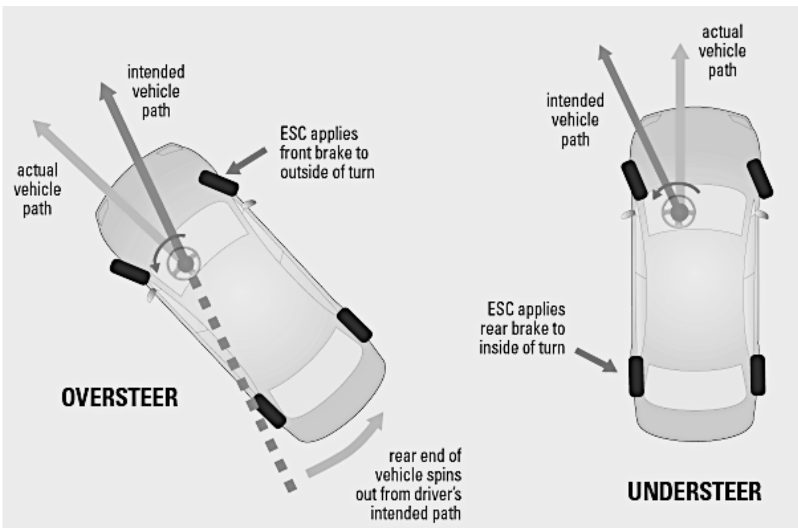


Figure 3.33 Oversteer and understeer conditions [81].

Table 3.2 Oversteer vehicle conditions.

	Road Conditions	Driver Behavior	Vehicle Behavior	ESP System
1	Right-hand bend	y=x	$z < x$	Brake applied to front left tire.
2	Left-hand bend	y=x	$z < x$	Brake applied to front right tire.

Table 3.3 Understeer vehicle conditions.

	Road Conditions	Driver Behavior	Vehicle Behavior	ESP System
1	Right-hand bend	y=x	$z > x$	Brake applied to rear right tire.
2	Left-hand bend	y=x	$z > x$	Brake applied to rear left tire.

Where x is bend angle, y is steering wheel angle, z is vehicle angle in Table 3.2 and 3.3. ESP system uses yaw moment and ABS system for controlling the vehicle [78,79].

3.2.5.1 Mathematical Model

System protects vehicle stability in the case of understeer condition or oversteer condition. Vehicle body may move at six directions. These are Euler angles (pitch, roll, yaw) and spherical coordinates (x, y, z) [82, 83]. In addition, each tire can move at two directions, these are rotational and vertical directions [82]. Nonlinear systems are resolved with the numerical integration. ESP system model is made with 2 DOF model. Reference coordinate system is given in Figure 3.34.

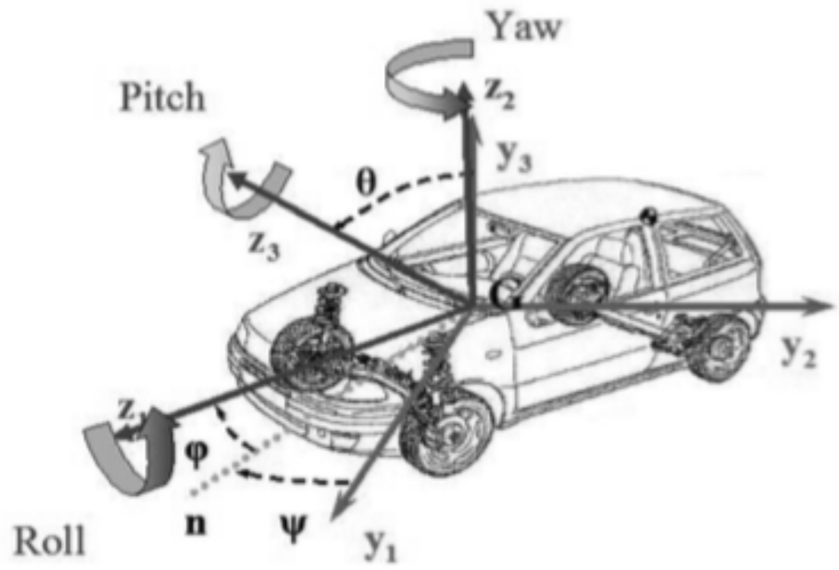


Figure 3.34 Reference coordinate system [82].

Euler angle; represents 3D movement that is given in Figure 3.34. For the movement of a vehicle in three dimensions, it is necessary to have a change on the angle of at least one of those; pitch, roll and yaw. These angles are formed with the axis of rotation of the vehicle. The axis of Roll; imaginary line connecting between vehicle rear and vehicle nose. On the left or right tipping angle on this axis. The axis of Pitch; imaginary line connecting between vehicle left side and vehicle right side. Vehicle nose may move up or down and this case is on this axis. The axis of Yaw; the axis that is 90^0 perpendiculars to Roll and Pitch axis, and the movements from right to left and left to right that determines the direction of the vehicle takes place on this axis.

Rotation matrix;

$$R_x(\phi) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & \sin\phi \\ 0 & -\sin\phi & \cos\phi \end{pmatrix} \quad \textbf{(3.61)}$$

$$R_y(\theta) = \begin{pmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{pmatrix} \quad \textbf{(3.62)}$$

$$R_z(\psi)=\begin{pmatrix}\cos\psi & \sin\psi & 0\\ -\sin\psi & \cos\psi & 0\\ 0 & 0 & 1\end{pmatrix} \quad \textbf{(3.63)}$$

Where R is rotation matrix. There are six different movements.

$$R_{xyz}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_x(\phi)R_y(\theta)R_z(\psi)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.64)}$$

$$R_{yxz}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_y(\theta)R_x(\phi)R_z(\psi)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.65)}$$

$$R_{yzx}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_y(\theta)R_z(\psi)R_x(\phi)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.66)}$$

$$R_{xzy}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_x(\phi)R_z(\psi)R_y(\theta)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.67)}$$

$$R_{zyx}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_z(\psi)R_y(\theta)R_x(\phi)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.68)}$$

$$R_{zxy}\begin{pmatrix}0\\0\\1\end{pmatrix}=R_z(\psi)R_x(\phi)R_y(\theta)\begin{pmatrix}0\\0\\1\end{pmatrix} \quad \textbf{(3.69)}$$

Spherical coordinate system x, y, z;

$$x = r\sin\alpha\sin\beta \quad \textbf{(3.70)}$$

$$y = r\sin\alpha\sin\beta \quad \textbf{(3.71)}$$

$$z = r\cos\alpha \quad \textbf{(3.72)}$$

Where r is diameter, α is angle between z-axis and diameter, β is angle between x-axis and projection of the diameter of the xy-plane.

3.2.5.1.1 Vehicle Model

Track model of the vehicle is given in the case of understeer and oversteer in Figure 3.35.

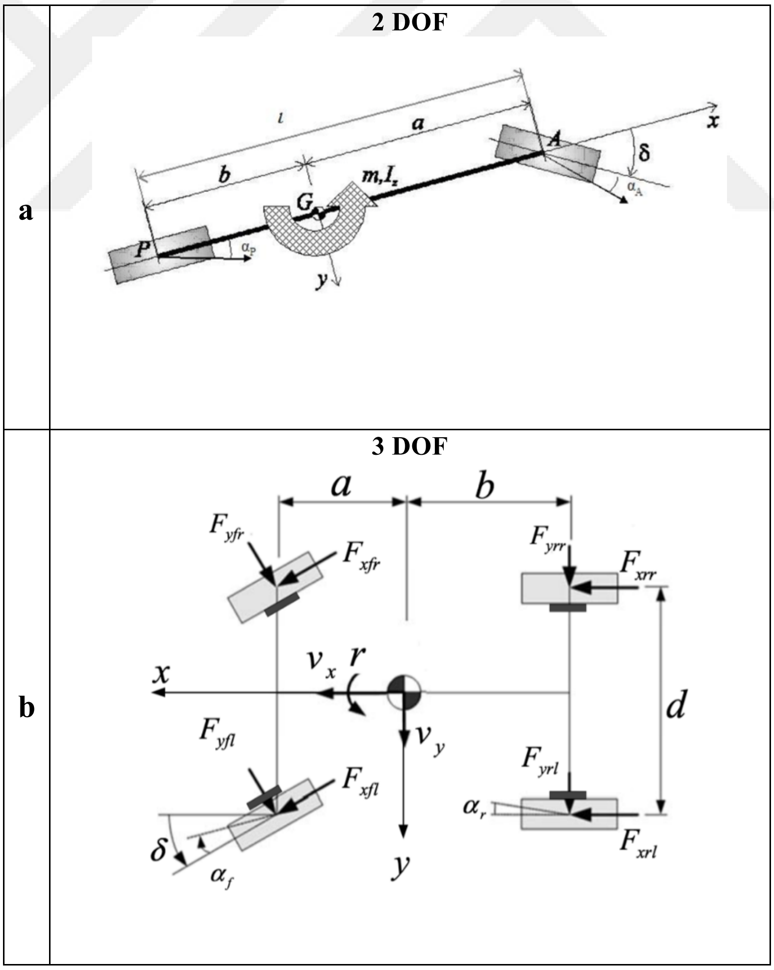


Figure 3.35 Track model of the vehicle [82,83].

Movement equation in Figure 3.35a, Lateral velocity V_y;

$$V_y = \frac{V_x^{\ 2}}{\rho} \quad \textbf{(3.73)}$$

Where V_x is linear velocity, ρ is pitch angle. Movement equation in Figure 3.35b;

Total force in the x direction $\sum F_{xi}$;

$$\sum F_{xi} = m\left(V_x - V_y r\right) \quad \textbf{(3.74)}$$

Where m is vehicle mass and r is yaw rate.

Total force in the y direction $\sum F_{yi}$;

$$\sum F_{yi} = m\left(V_y - V_x r\right) \quad \textbf{(3.75)}$$

Total force in the z direction $\sum M_{zi}$;

$$\sum M_{zi} = I_z r \quad \textbf{(3.76)}$$

Where I_z is moment of inertia. Total force in the linear x direction $\sum F_{xi}$;

$$\sum F_{xi} = \left(F_{xfl} + F_{xfr}\right)\cos\delta - \left(F_{yfl} + F_{yfr}\right)\sin\delta + \left(F_{xrl} + F_{xrr}\right) \quad \textbf{(3.77)}$$

Where F_{fr} is front right force, F_{lr} is left right force, F_{rr} is rear right force and F_{rl} is rear left force.

Total force in the lateral y direction $\sum F_{yi}$;

$$\sum F_{yi} = \left(F_{yfl} + F_{yfr}\right)\cos\delta - \left(F_{xfl} + F_{xfr}\right)\sin\delta + \left(F_{yrl} + F_{yrr}\right) \quad \textbf{(3.78)}$$

Total force in the z direction $\sum F_{zi}$;

$$\sum F_{zi} = \left(-F_{xfl}\cos\delta + F_{yfr}\sin\delta - F_{xrl} + F_{xrr} + F_{xfr}\cos\delta - F_{yfr}\sin\delta\right)\frac{d}{2} - \left(F_{yrl} + F_{yrr}\right)b + \left(\left(F_{yfl} + F_{yfr}\right)\cos\delta + \left(F_{xfl} + F_{xfr}\right)\sin\delta\right)a \quad \textbf{(3.79)}$$

Where δ is steering wheel angle, a and b are distance between rear axle and vehicle mass center.

3.2.5.2 Detection System

There are many different types of sensors and detection methods. Some of them are wheel speed, vehicle speed and steering wheel angle sensors. Steering wheel angle, wheel speed and vehicle speed is detected with magnetic sensors. Steering wheel angle and wheel speed is given in Chapter 2.3.1. In this Chapter, vehicle speed is given.

Magnetic sensor calculates wheel speed with numbers of crankshaft rotation. In here, beginning from the reference point, in every turn, the shaft had gathered momentum that equals to diameter of the tire. The sensor calculates how many full tours did the shaft turn in one minute [4, 19, 20, 49]. For instance; shaft turns around 100 times, and the diameter of the tire is 1.5 m. With those two data, the sensor calculates how many meters does the vehicle go in every minute and calculates how many kilometers does the vehicle go. 150.60=9000 meters. As a result, we find that our vehicle's speed is 9 km\hr.

Vehicle speed V;

$$V = R \times N \quad \textbf{(3.80)}$$

Where R is tire diameter, N is rotation of crankshaft per second. In terms of Hall Effect sensor, on the magnetic field power that is used to detect the speed of vehicle, there is a resistor change on the semiconductor plate. This resistor change calculates the number of tab on the disc and calculates how many tab passes from the disc in every minute. Hall Effect sensor by using the formula used in the crankshaft sensor calculates the speed of vehicle.

3.2.5.3 Electronic Control System

Many controller algorithms is used for ESP. Some of them are Fuzzy controller, PID controller, Sliding mode control, Kalman filtering. Generally, Fuzzy controller is used for 2 DOF, sliding mode controller is used for 3 DOF and Kalman filtering is used for 6 DOF. 2 DOF ESP block system is given in Figure 3.36.

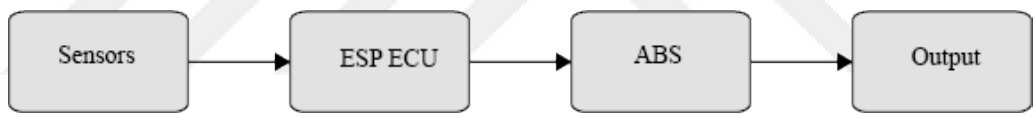


Figure 3.36 2-DOF ESP block system.

System uses many sensors, ABS and actuators. ESP block system is given in Figure 3.37.

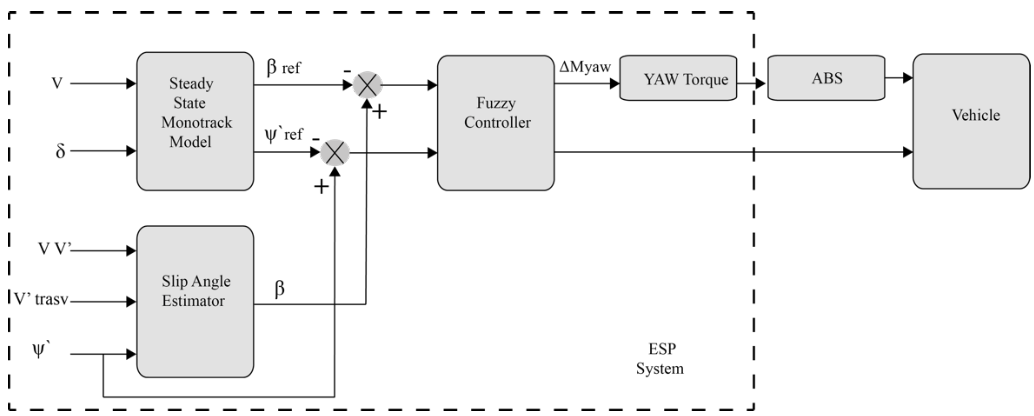


Figure 3.37 ESP block system.

ESP system controls the engine torque power with Fuzzy control and it uses the ABS system for braking. Controller equation is given above equation according to Figure 3.25A and 3.37.

Steering angle δ;

$$\delta = \arctan\left(\frac{1}{\rho}\right) \tag{3.81}$$

Reference yaw angle ψ_{ref};

$$\psi_{ref} = \frac{\tan\delta}{L\left(1 + k_{us}V^2\right)}V \tag{3.82}$$

Where k is positive coefficient, l is wheelbase.

And slipping reference angle β_{ref};

$$\beta_{ref} = \frac{b}{\rho} - \alpha_p \cong \frac{\tan\delta}{L\left(1 + k_{us}V^2\right)}\left(b - k_{ps}V^2\right) \tag{3.83}$$

$$V_y = V_x^{\,2} / \rho = \psi V_x \tag{3.84}$$

Lateral speed can't be greater than the friction force. So equation;

$$V_y \le \mu_{y\_max} g \tag{3.85}$$

$$\psi_{lim.} \le \mu_{y\_max} g / V_x \cong \mu_{y\_max} g / V \tag{3.86}$$

Nominal parameter value is known and system behavior is examined with this value. Reference value is nominal value. In this system, Fuzzy controller is used. This controller uses two-type algorithm. These are ΔM_{yaw} (yaw moment) and the interruption of torque power. ΔM_{yaw} uses slip rate error (e_β) and yaw rate error (e_ψ).

Slip rate errorSlip rate error e_β;

$$e_\beta = \beta - \beta_{ref} \quad \textbf{(3.87)}$$

Yaw rate error e_ψ;

$$e_\psi = \psi - \min\left(\psi_{ref}; \psi_{lim.}\right) \quad \textbf{(3.88)}$$

Limit values are important for interruption of torque power. Limit values can be 0, 30, 60, 90 [77].

$$\text{Limit} = \psi_{ref} - \psi_{lim} \quad \textbf{(3.89)}$$

$$\text{Limit} = \frac{\tan\delta}{L\left(1 + k_{us}V^2\right)} V - \mu_{y\_max} g / V \quad \textbf{(3.90)}$$

Firstly, yaw moment is calculated [83]. The braking force is determined for each wheel according to the tire position. Yaw moment is separated to two parts. These are front moment (M_F) and rear moment (M_R) [83].

Front yaw moment M_F;

$$M_F = \frac{F_{V\_FL} + F_{V\_Fr}}{F_{V\_tot}} \Delta M_{yaw} \quad \textbf{(3.91)}$$

Rear moment M_R;

$$M_R = \frac{F_{V\_RL} + F_{V\_Rr}}{F_{V\_tot}} \Delta M_{yaw} \quad \textbf{(3.92)}$$

Total Force F_{v_tot};

$$F_{v\_tot} = F_{V\_Asx} + F_{V\_Adx} + F_{V\_Psx} + F_{V\_Pdx} \quad \textbf{(3.93)}$$

Rear and front braking is calculated (ΔM_{brake_F} and ΔM_{brake_R});

$$\Delta M_{brake\_F} = (2r_w)/c_F M_F \quad \textbf{(3.94)}$$

$$\Delta M_{brake\_R} = (2r_w)/c_R M_R \quad \textbf{(3.95)}$$

System determines which moment is negative. Thus, system determines which wheel is applied to braking. Front moment of EBS system is given in Table 3.2. If the front moment is negative, braking is applied left front tire and if the front moment is positive, braking is applied right front tire. Rear moment of EBS system is given in Table 3.3. If the rear moment is negative, braking is applied right rear tire and if the rear moment is positive, braking is applied left rear tire.

CHAPTER 4

ADAS

(ADVANCED DRIVER ASSISTANT SYSTEM)

Nowadays, advanced driver assistant system is one of the most developed systems in automotive electronics. System is considered as an advanced version of the driver assistant system (DAS) [84]. DAS gives data, warning and feedback about road and driver. In addition, comfort, stability is increased, so the driver reasoning is increased [84]. In addition, ADAS processes complex algorithm and makes evaluation about vehicle, related to the status and positions [84]. DAS and ADAS block system is given in Figure 4.1.

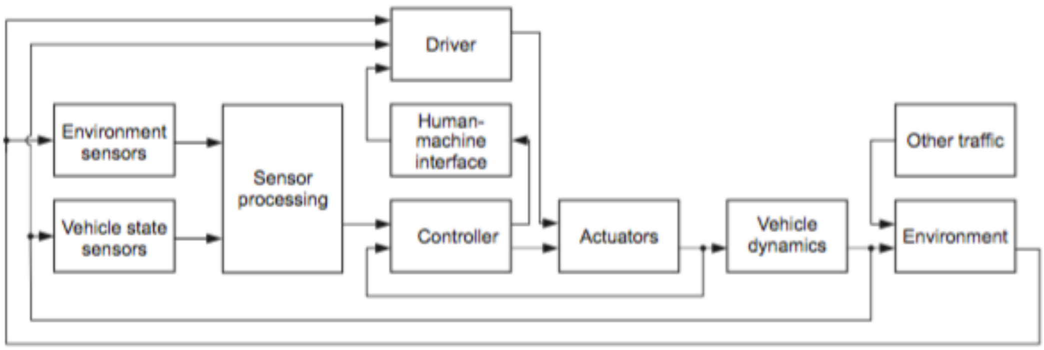


Figure 4.1 DAS and ADAS block system [85].

Assistant system has three stages. These are data entry, data processing and warning. Data entry is made by sensors, data processing is made by ECU and warning is made by actuators.

Safety and efficiency systems in vehicle are divided into two main categories. These are driver support systems and vehicle support systems. Support systems have the driver information, driver perception, driving ability and tracing [86]. Vehicle support systems have general vehicle control, lateral and longitudinal control, collision avoidance and vehicle imaging [86]. DAS and sub systems are given in Figure 4.2.

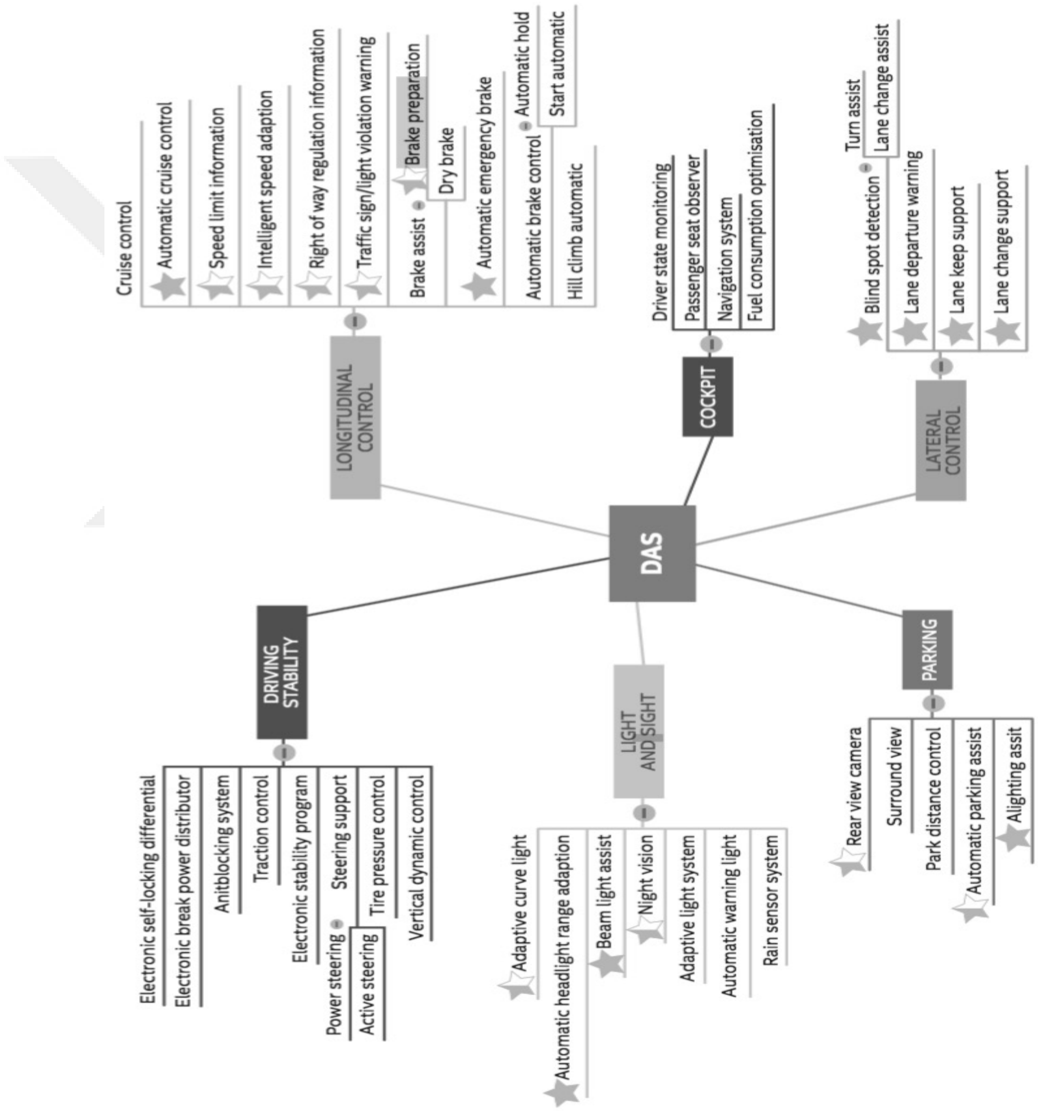


Figure 4.2 DAS and sub systems [84].

ADAS detection systems are given in Figure 4.3.

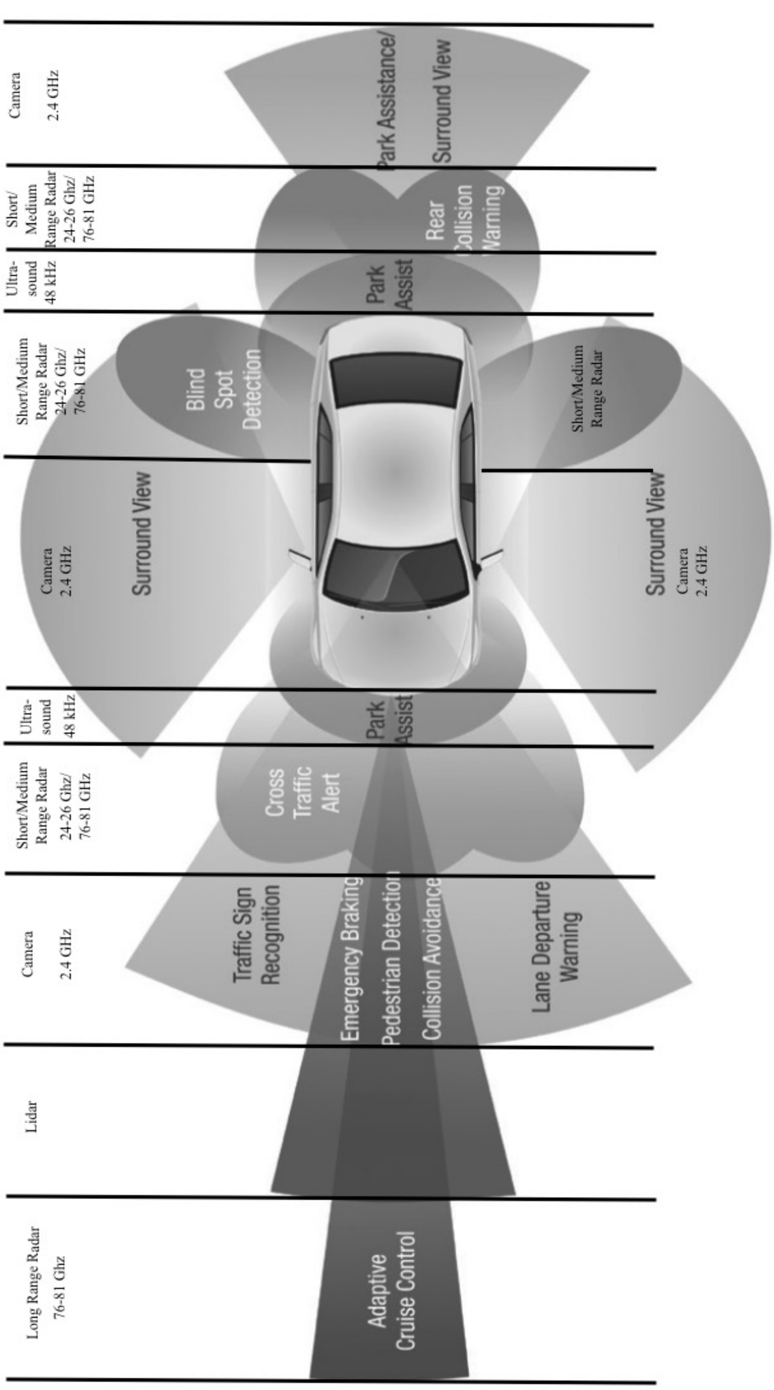


Figure 4.3 ADAS detection systems [87].

Advanced driver assistance is a system that supports the driving to achieve safety. The purpose of the system is to reduce potential collisions or accidents and solves potential problems for safe driving [2, 86, 88].

Causes of accidents are high speed, adverse weather conditions, missing traffic lamp, wrong turning and pedestrian error [86, 89]. According to the research, the relationship between driver assistance systems and road accidents is given in Figure 4.4. System avoids the traffic accident by 40 % [6].

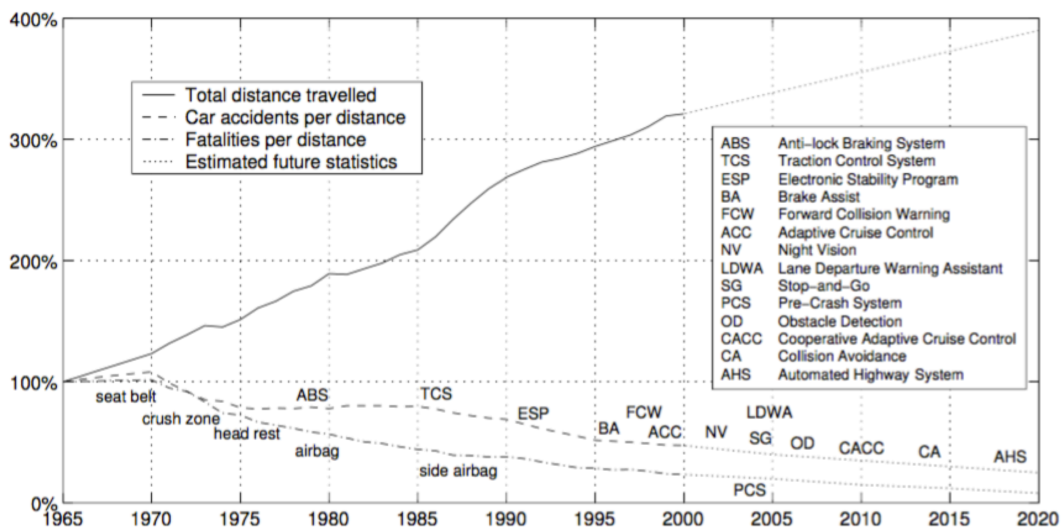


Figure 4.4 DAS vs road accidents [90].

Driver assistant system includes cruise control, speed assistance, automate lighting, provide adaptive cruise control, automate braking, incorporate GPS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots, collision avoidance system, driver drowsiness detection system, adaptive light control, automotive navigation system, emergency driver assistant and similar systems [2, 89, 90].

ADAS uses sensor systems, camera systems, vehicle networks, communication systems (vehicle to vehicle or vehicle to infrastructure) [86, 90, 91]. This technology must provide certain security criteria (ISO 26262). In addition, system must provide high system performance, low energy requirements and safety rates (NCAP, NHTSA) [87].

ADAS systems, with the use of smart sensors that are located four sides of the vehicle shown as fig. 4.3, detects the events occur outside of vehicle that the sensor is adjusted to detect and sends the data to the control unit (ECU) via using the communication protocols which it has them in its hardware. The control unit evaluates all those data, calculates the ultimate data and it sends the data to the main screen to warn the driver or by controlling the vehicle through using the brake safety systems such as ABS and ESP, it minimizes the possible errors. ADAS system uses unique hardware system and this hardware system is given in Figure 4.5.

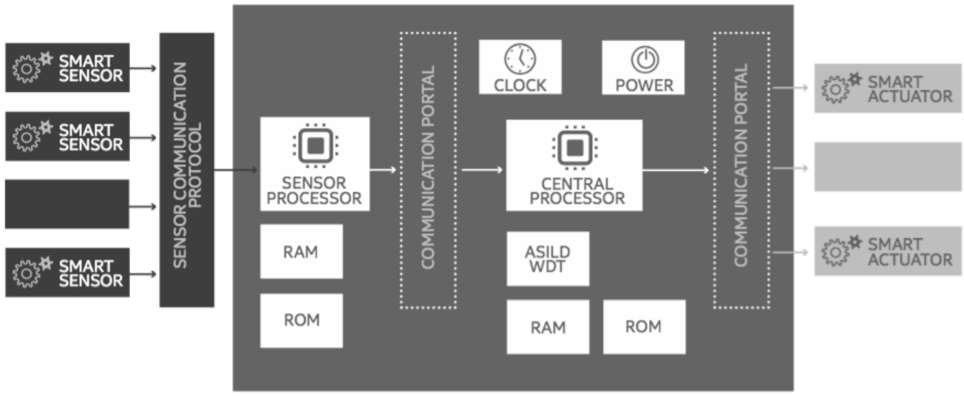


Figure 4.5 Unique hardware system for ADAS [84].

ADAS reaches to outside of the status data. Same time, system reaches to vehicle status data using sensors. Thus, system uses some data about vehicle and it calculates other data.

ADAS is divided into four main categories [84, 92]. These are longitudinal, lateral, lightening and other systems [2, 84, 87, 89].

Longitudinal control is associated with front and rear of the vehicle [2, 84, 92]. These systems;

1. Adaptive Cruise Control (ACC) or distance keeping systems,
2. The collision warning system (CWS),
3. Stop and Start systems,
4. Pedestrian Collision Warning system (PCWS),
5. Intelligent Speed Assistance (ISA).

Lateral control is associated with side of the vehicle [2, 84, 92]. These systems;

1. The lane keeping assist systems (LKAS),
2. Lane Departure Warning(LDW),
3. The blind spot detection systems (BSDS).

The most important lightening system [2, 84];

1. Night vision (NV),
2. Adaptive front lightening (AFL).

The other system;

1. Driver Alertness Monitoring.

Some systems are mandatory for vehicle. Because, ADAS gives support for drivers, pedestrians, passengers and vehicles. For instance, vehicle rear camera system will become mandatory in the United States in 2018.

In this Thesis, ADAS detection systems are given in Chapter 4.1 and ADAS systems are given in Chapter 4.2. And other ADAS system is given in Chapter 4.3.

4.1 Detection Systems

ADAS systems determine the position, the distance and the images of the vehicles, the pedestrians and the passengers with using radio detecting and ranging (radar), lidar, ultrasonic and camera systems [85]. Camera system is used for images, radar and lidar system is used for object detection. Radar uses radio frequency but lidar uses light. Ultrasonic is used for object detection and it uses sound (frequency is above the limit of hearing people). ADAS system may use these all sensor systems.

4.1.1 Radar Sensor System

Radar system uses radio frequency for object distance, height, speed and direction. It works with the global position system. It occurs long range and short range. Radar block system is given in Figure 4.6.

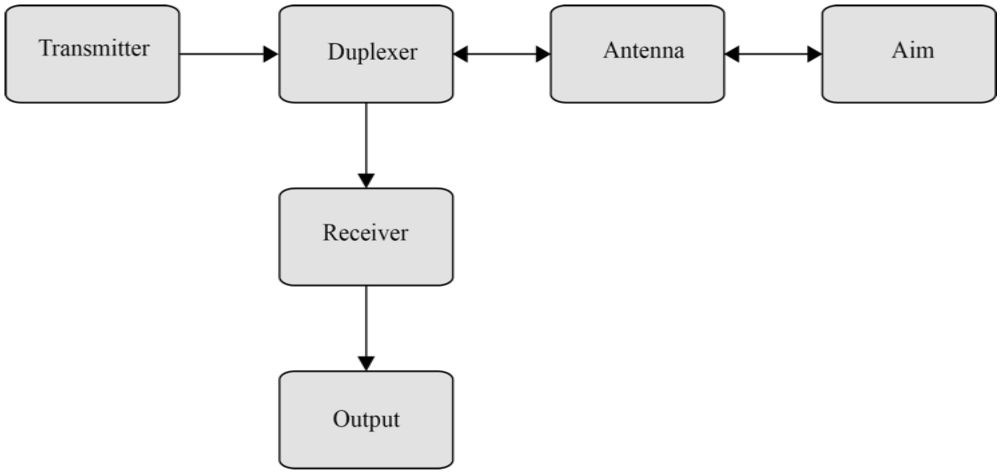


Figure 4.6 Radar sensor block system.

System occurs two functions. These are normal radar function and signature analysis & inverse scattering. Normal radar function measurements range (from pulse delay), velocity (from Doppler Effect) and angular direction (from antenna pointing). System detects target size (from magnitude of return), target shape and components (return as a function of direction), moving parts (modulation of the return), material composition. System operates that sprawling electromagnetic wave (antenna to aim) by the system hits to object and it is spread (aim to antenna). Wavelength of returning wave into the antenna varies. Therefore, system calculates the object distance, highest, speed and direction. However, firstly returning wave is strengthened by system. Because this wave is weak.

Distance R_0;

$$R_0 = \frac{t_0 C}{2} \tag{4.1}$$

Where C is propagation velocity and t_0 is time.

Waveform of radar classification is given in Figure 4.7

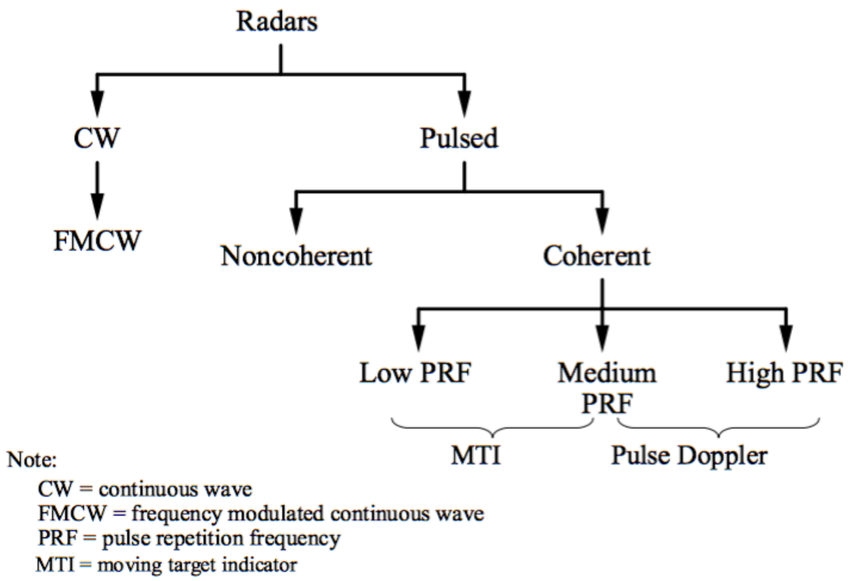


Figure 4.7 Classification of waveform [93].

Plane wave is given in Figure 4.8.

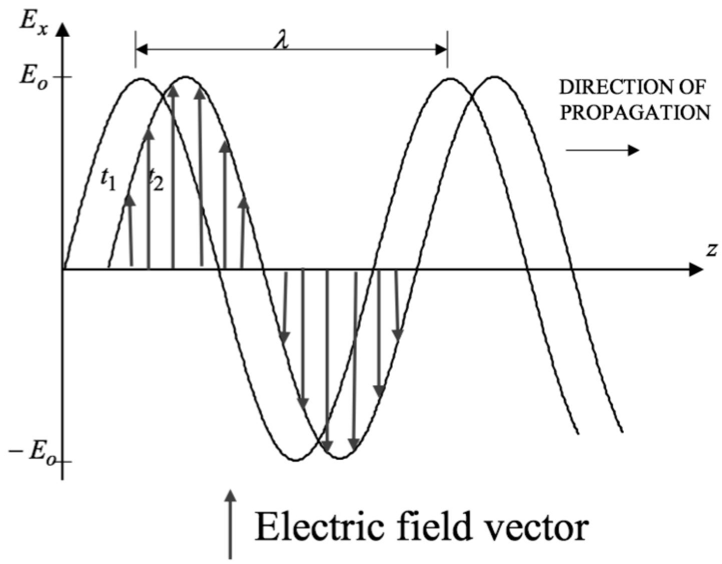


Figure 4.8 Plane wave [93].

In Figure 4.8, wave propagates in the z direction. Electric field vector direction is x polarized. Where λ is wavelength, f is frequency, c is phase velocity, maximum amplitude of the wave is E_0.

Frequency ω;

$$\omega = 2\pi f \tag{4.2}$$

Wave fronts are given in Figure 4.9.

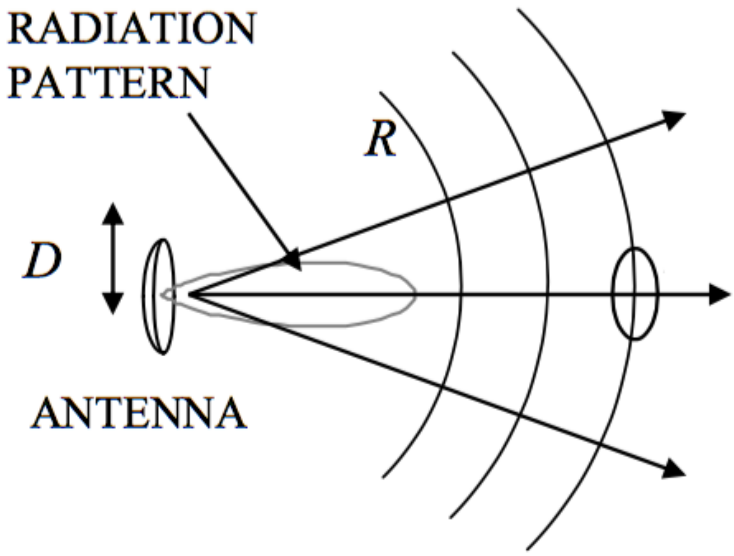


Figure 4.9 Wave fronts [93].

Where D is antenna diameter and R is distance.

Distance R;

$$R > \frac{2D^2}{\lambda} \tag{4.3}$$

Wavelengt λ;

$$\lambda = c / f \tag{4.4}$$

Radar system use superposition of waves. There is multiple signal or multiple paths, the total signal at a location is the sum.

Antenna gain is the radiation intensity relative, and it depands on the lossless isotropic reference [93].

Antenna gain G;

$$G = \frac{4\pi A_e}{\lambda^2} \quad \textbf{(4.5)}$$

Where A_e is effective area, A is apperture area. If the beamwidht decreases, antenna gain increase.

Radar system received power P_r;

$$P_r = \frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 R^4} \quad \textbf{(4.6)}$$

Where P_t is transmitting power (W), G_t is transmitting antenna gain, G_r is received antenna gain and σ is radar cross section (RCS, m^2). Maximum detection range is a function of proportional of minimum detectable signal (S_{min}).

Maximum detection range R_{max};

$$R_{max} = \left(\frac{P_t G_t G_r \sigma \lambda^2}{(4\pi)^3 S_{min}} \right)^{\frac{1}{4}} \quad \textbf{(4.7)}$$

Radar display types are given in Figure 4.10.

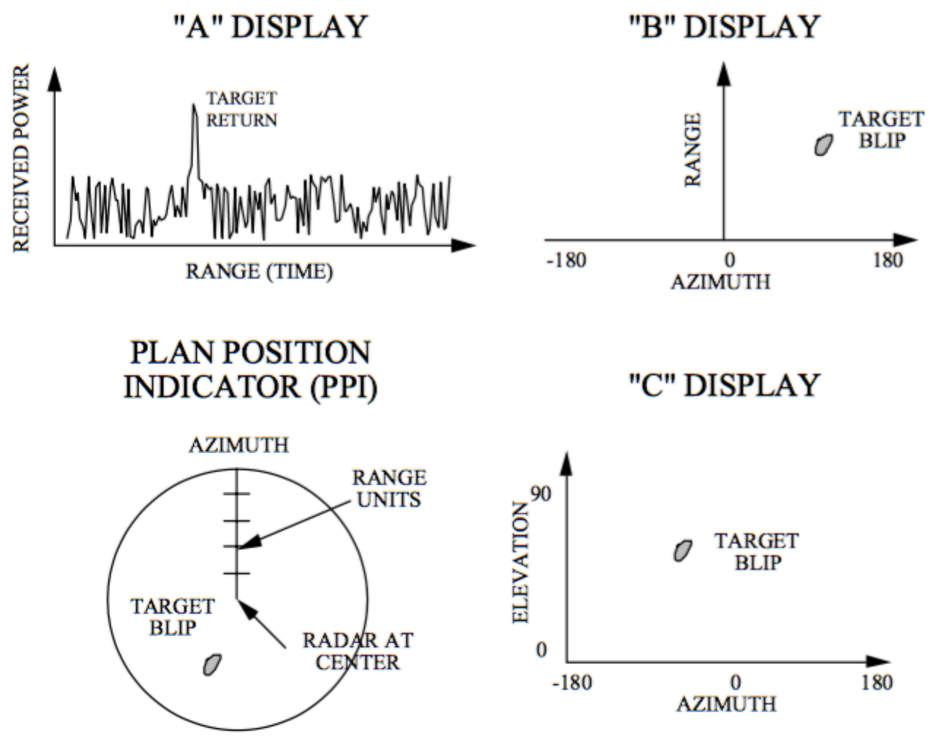


Figure 4.10 Radar display types [93].

Pulse is a kind of waveform and multiple pulses are transmitted to cover search patterns, track moving target and integrate several target returns to improve detection. Pulse train is given in Figure 4.11.

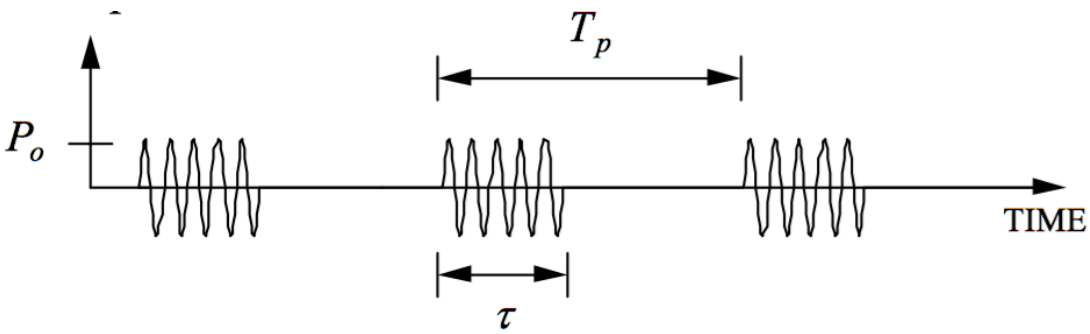


Figure 4.11 Pulse train [93].

Where P_0 is peak instantaneous power (W), τ is pulse width (sec), T_p is interpulse period (sec) and N is number of pulse.

As indicated in equation 4.1, range is equal to $t_0 C$ divided by 2. However, in equation 4.8, distance R;

$$R_u = \frac{cT_p}{2} = \frac{c}{2f_p} \tag{4.8}$$

Where f_p is pulse repetition frequency (PRF, Hz). Some signal has noise, and system corrupts it. Typical return trace appears is given in Figure 4.12.

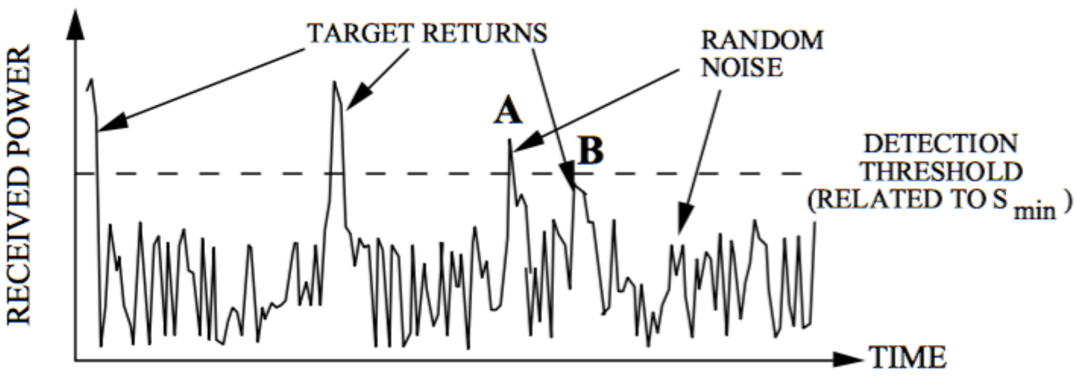


Figure 4.12 Typical return trace appears [93].

In Figure 4.12, A is a false alarm, there is no target in there and B is miss alarm, because target signal is smaller than threshold value.

Signal to noise ratio SNR;

$$SNR = \frac{P_r}{N_0} = \frac{P_t G_t G_r \sigma \lambda^2 G_p L}{(4\pi)^3 R^4 k_B T_s B_n} \tag{4.9}$$

Where N_0 is noise power, k_B is boltzman constant that is 1.38×10^{-23} (Joules/K), T_s is system noise temperature, B_n is bandwitdh. Frequency and wavelength varies from one another for moving objects. Therefore, Doppler Effect is used [4].

Doppler frequency f_d;

$$f_d = \frac{-2v_r}{\lambda} \tag{4.10}$$

System uses Doppler filter for knowing the target’s velocity range that is given in Figure 4.13.

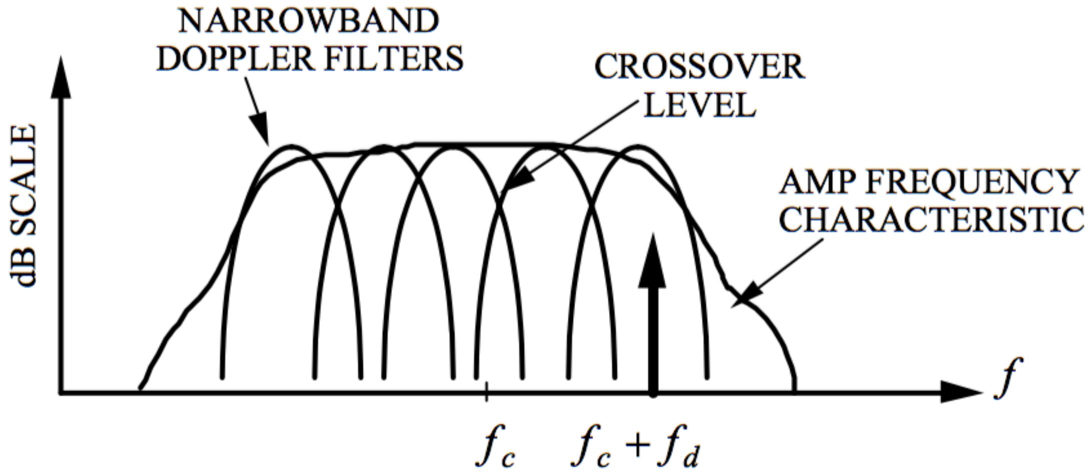


Figure 4.13 Target’s velocity range [93].

4.1.2 Lidar Sensor System

Light Detection and Ranging (Lidar) works as radar system (Figure 4.6). However, lidar system uses laser for measurement. Laser is meaning of Light Amplification by Stimulated Emission of Radiation system [94]. Lidar system uses laser, high precision clock, global positioning system (GPS), data storage-management system and inertial measurement unit (IMU) [95]. The main advantage of Lidar system is cost [94]. It is cheaper than Radar system.

GPS system determines the position and time in the open field. UMI detects position, speed and orientation with accelerometer and gyroscope sensors. To decrease the noise, Kalman filter is used. The system uses pitch, yaw and roll axis. This axis is given in Chapter 3.2.1. Nominal relative GPS to IMU to sensor relationship is given in Figure 4.14.

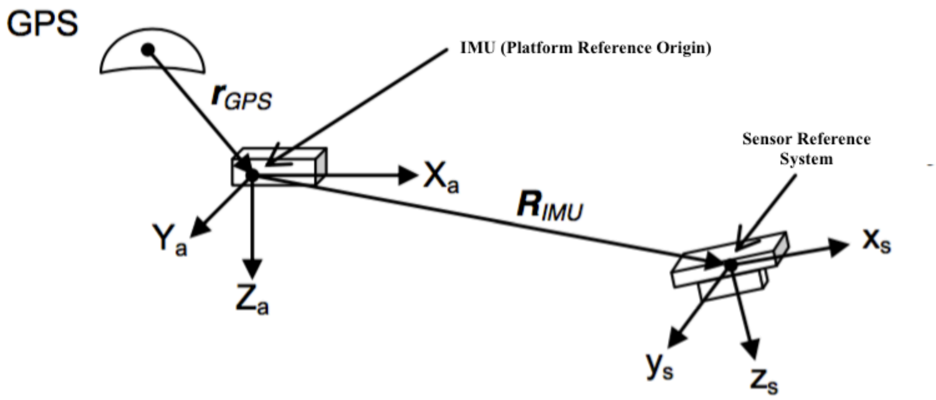


Figure 4.14 Nominal relative GPS to IMU to sensor relationship [96].

Data storage and management system interprets information of reflected laser [95]. System uses equation (4.11) for distance of the object. If continuous wave is laser, phase angle is added.

Distance R;

$$R = \frac{C}{2}\frac{\varphi}{2\pi f} \quad \textbf{(4.11)}$$

$$\Delta R = \frac{C}{2}\frac{\Delta\varphi}{2\pi f} \quad \textbf{(4.11a)}$$

Lidar coordinate system and their relationship are given in Figure 4.15.

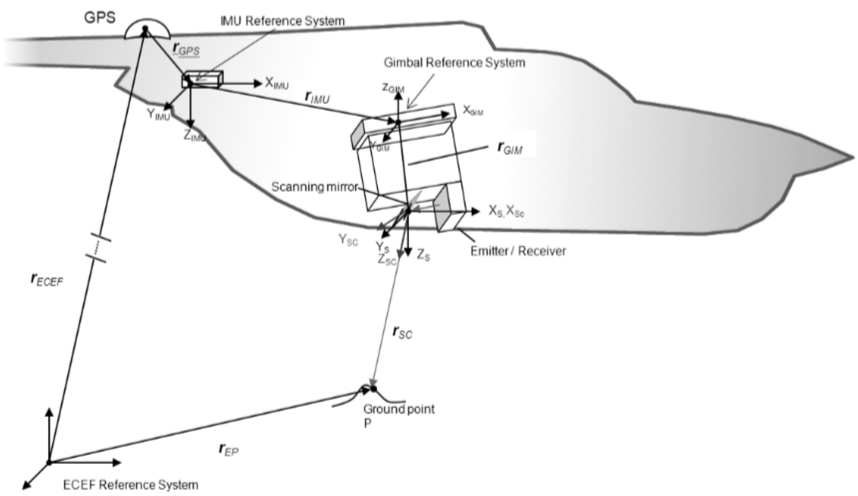


Figure 4.15 Lidar coordinate system and their relationship [96].

System uses geocentric ECEF coordinate system. ECEF coordinate system equation is given in equation 4.12.

Vector from the ECEF origin to the ground point in the ECEF reference frame r_{EP};

$$r_{EP} = r_{ECEF} + M_{ECEF} M_{ELL} M_{VER} \left(M_{PLA} M_{GIM} \left(M_{SEN} r_{SCA} + r_{GIM} \right) + r_{INSMU} + r_{GPS} \right) \tag{4.12}$$

Where

r_{SCA} : vector from the scanner to the ground point in the scanner reference frame (range),

r_{GIM} : vector from the gimbal center of rotation to the sensor in the gimbal reference frame,

r_{INSMU} : vector from the IMU to the gimbal center of rotation in the platform reference frame,

r_{GPS} : vector from the GPS antenna phase-center to the IMU in the platform reference frame,

r_{ECEF} : vector from the ECEF origin to the GPS antenna phase-center in the ECEF reference frame (GPS observations),

M_{SEN} : rotation matrix from scanner reference frame to sensor reference frame (scan angles),

M_{GIM} : rotation matrix from the sensor reference frame to the gimbal reference frame (gimbal angles),

M_{PLA} : rotation matrix from the gimbal reference frame to the platform reference frame (boresight angles),

M_{VER} : rotation matrix from the platform reference frame to the local-vertical reference frame (IMU observations),

M_{ELL} : rotation matrix from the local-vertical reference frame to the ellipsoid-tangential reference frame,

M_{ECEF} : rotation matrix from the ellipsoid-tangential (NED) reference frame to the ECEF reference frame,

r_{INSMU}, r_{GPS} : constant [96].

Lidar sensors have short wavelengths. So it is used for a region of the image. System's resolution is higher than Radar system. However, it is limited by weather conditions [97].

4.1.3 Camera Sensor System

Firstly, camera system makes detection, after that it makes determination. Camera sensor block system is given in Figure 4.16.

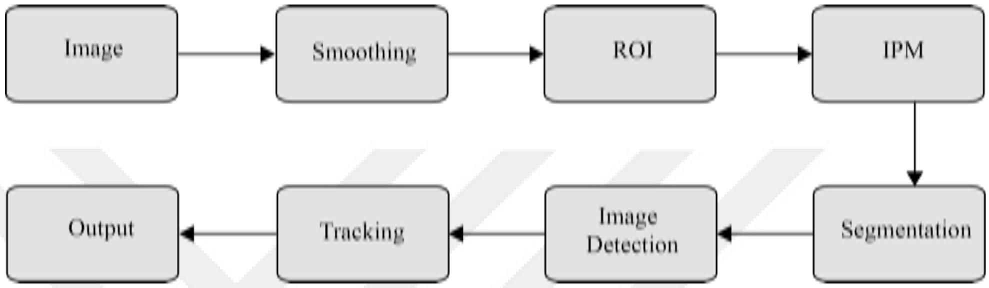


Figure 4.16 Camera sensor block system.

4.1.3.1 Smoothing

Firstly, snapshot images are achieved and smoothing is done for every image. Some filters are used for smoothing. Some of them are Median filter, Gaussian filter, 2D high-pass filter or dilation and erosion filters [98-100].

4.1.3.1.1 Median Filter

For instance, the masks get 3 of 3 matrixes. Neighbor mask matrix is given in Table 4.1. After that, median filter is used for this kind of mask matrix and filter fixes it. These are 1,2,3,4,5,6,7,8,9. Median value is five. As a result, median value is put median matrix and image is clearest than before.

Table 4.1 Mask Matrix [101].

4	5	6
1	7	8
3	2	9

Same way, if the mask gets 4 of 3 matrixes. Median filter is used [98].

4.1.3.2 Region of Interest (ROI)

The area of interest is region of interest [99]. It has three parts. These are detection the vanishing point, perspective analysis/projection model and takes subsample [99]. For detection the vanishing point, Hough transform is used. Perspective analysis and projection model is important factor for ROI. Image perspective creates different visual. Image plane, actual plane and camera plan is different. Because of that, sub sampling detects size of region of interest [99].

4.1.3.2.1 Hough Transform

This transform has some point in the line image (x_i, y_i) [100,102,103].

$$y_i = mx_i + c \tag{4.13}$$

Where m is line slop and c is intercept. P_1 and P_2 values are given in Figure 4.17.

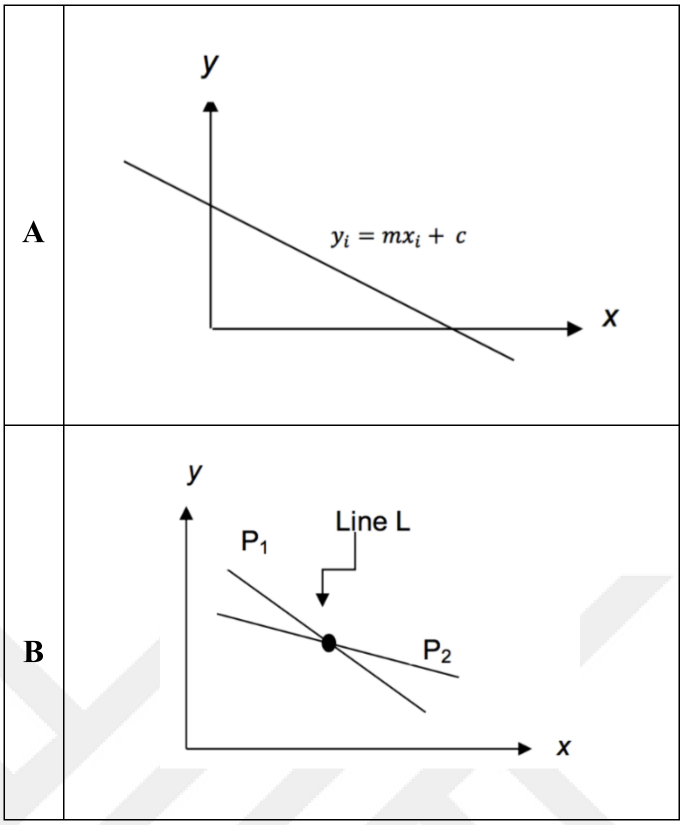


Figure 4.17 Ais equation (yi), B is in the (m, c) space, P1 and P2 lines [100].

Hough transform’s step [100,102-104];

1- Created on the edges of the source image,

2- Image is converted to black-and-white color,

3- All edges of dots are created,

4- m, c is calculated in the H matrix,

5- H matrix is beginning with zero,

6- H matrix value is increased 1 value,

7- Which value is bigger than others, this image is most prominently.

4.1.3.3 Inverse Perspective Map (IPM)

Inverse perspective map uses bird eye method [99].

4.1.3.4 Segmentation

Last optimization step has three main sections. These are edge, color and MSER Based segmentation. Segmentation types are given in Figure 4.18 [98, 99]. Edge based and color based is more useful method than MSER based segmentation.

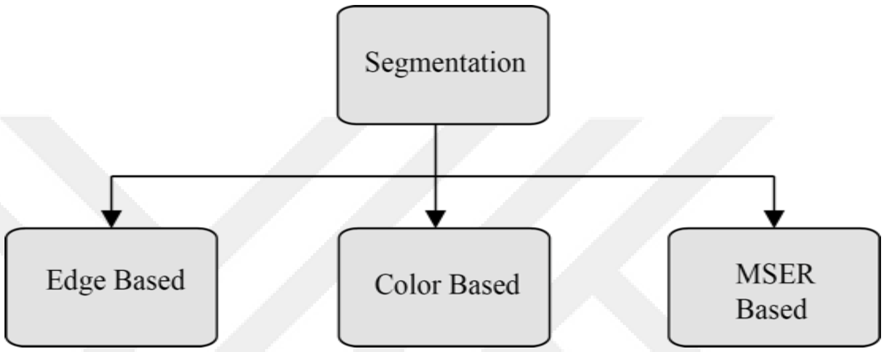


Figure 4.18 Segmentation.

4.1.3.4.1 Color Based Segmentation

This segmentation is known as gray scale imaging. Color image is converted to gray image in this segmentation [99]. Color image is 24 bit, 3 channels and gray image is 8 bit, 1 channel [98,100]. Gray scale value GSV;

$$GSV= (0.2989\ R) + (0.5870\ G) + (0.1140\ B) \quad \textbf{(4.14)}$$

Where R is red comp, G is green comp, B is blue comp.

This method is used by many researchers. On the other hand, some researchers use own algorithm [99]. For example, RGB to HSV or RGB to HSI. HSI is more useful method than HSV [99].

4.1.3.4.2 Edge based segmentation

Canny, Sobel and Prewire systems are used. This segmentation uses information of Figure and Slope.

4.1.3.4.3 Canny

This segmentation analysis maximum slope function [100,105]. Median filter is used.

F (x, y) is a 2D function. Function vector $\nabla^2 f(x,y)$;

$$\nabla^2 f(x,y) = \begin{vmatrix} G_x \\ G_y \end{vmatrix} = \begin{vmatrix} \frac{\delta^2 f}{\delta x^2} \\ \frac{\delta^2 f}{\delta y^2} \end{vmatrix} \quad \textbf{(4.15)}$$

Gradyan operator mag(∇f);

$$\nabla^2 f(x,y) = mag(\nabla f) = \left[(\frac{\delta^2 f}{\delta x^2})^2 + (\frac{\delta^2 f}{\delta y^2})^2 \right]^{\frac{1}{2}} \quad \textbf{(4.16)}$$

Gradyan operator angle α(x,y);

$$\alpha(x,y) = \tan^{-1} \left(\frac{\frac{\delta^2 f}{\delta x^2}}{\frac{\delta^2 f}{\delta y^2}} \right) \quad \textbf{(4.17)}$$

4.1.3.5 Image Detection

After the segmentation, analysis of image is done. There are three different methods. These are edge, color and hybrid (edge and color) methods. Generally, edge based method is more useful. However, color based methods are used for unstructured or village roads [99]. Nevertheless, color based method is not a good solution for night, rainy and other complex situation [99].

4.1.3.5.1 Edge Based Method

Hough Transform, Steerable Filter or Frequency Domain systems are used in edge based method [98-100]. Hough Transform and Steerable filter are more useful methods than the others. However, steerable filter does not work in rainy day [99]. Because of that, Hough transform is method that is more convenient. Nevertheless, it gets some error. Some researchers change Hough transform to parallel Hough transform or probabilistic Hough transform (PHT) or adaptive random Hough transform (ARHT) [99, 106].

4.1.3.6 Image Tracking System

This system is used for decreasing the wrong detection and tracking the image [99,107]. Extended Kalman filter and Particle filters are used in it [99,107]. However, Kalman filter is method that is more useful. After the using Kalman filter, image is made linear.

Every time ADAS system tracks the image. That is mean, when there is an inverted situation, ADAS warns the driver. General state space model is given in Figure 4.19.

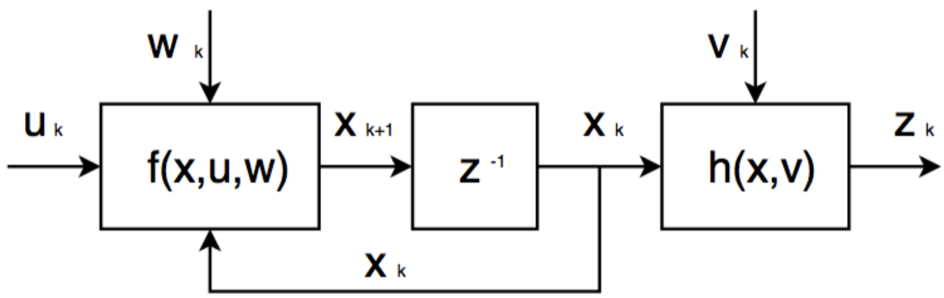


Figure 4.19 General state space model of image tracking [108].

There are two functions in Figure 4.20. These are f and h.

$$f(x_k, u_k, w_k) = x_{k+1} \quad \textbf{(4.18)}$$

$$h(x_k, v_k) = z_k \quad \textbf{(4.19)}$$

Where u is process input, w is state noise vectors, v is measurement noise vectors, k is the discrete time, x is mathematical model of state and z is the unit delay function. Linear state space model is given in Figure 4.20.

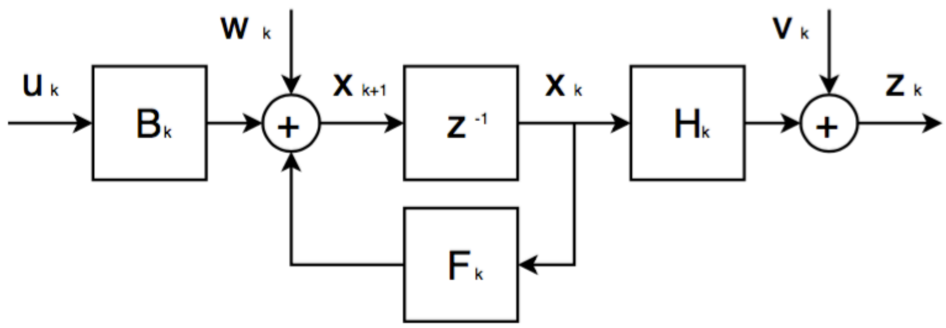


Figure 4.20 Linear state space model of tracking [108].

$$x_{k+1} = F_k x_k + B_k u_k + w_k \quad \textbf{(4.20)}$$

$$z_k = H_k x_k + v_k \quad \textbf{(4.21)}$$

Where F, B and H are matrices.

The problem of estimating the probability density function is a subject for state estimation that includes the predicting the next state and updating/correcting on noisy measurements taken. This estimation is applied two different method. These are recursive bayesian estimation and Kalman filter. When the problem of state estimation is put certain constrains, state is easily solved. Certain constrains are linear functions, the noise terms w and v to be uncorrelated, Gaussian and white with zero mean.

Mathematical notation of linear functions f and h;

$$f(x_k, u_k, w_k) = F_k x_k + B_k u_k + w_k \quad \textbf{(4.22)}$$

$$h(x_k, v_k) = H x_k + v_k \quad \textbf{(4.23)}$$

$w_k \sim N(0, Q_k)$, $v_k \sim N(0, R_k)$

$$E(w_i w_j^T) = Q_i \delta(i - j) \quad \textbf{(4.24)}$$

$$E(v_i v_j^T) = R_i \delta(i - j) \quad \textbf{(4.25)}$$

$$E(w_k v_k^T) = 0 \quad \textbf{(4.26)}$$

Where Q and R are covariance matrices.

Put the contrains;

$$x_{k+1} = F_k x_k + B_k u_k + w_k \quad \textbf{(4.27)}$$

$$z_k = H_k x_k + v_k \quad \textbf{(4.28)}$$

Kalman filter block system is given in Figure 4.21.

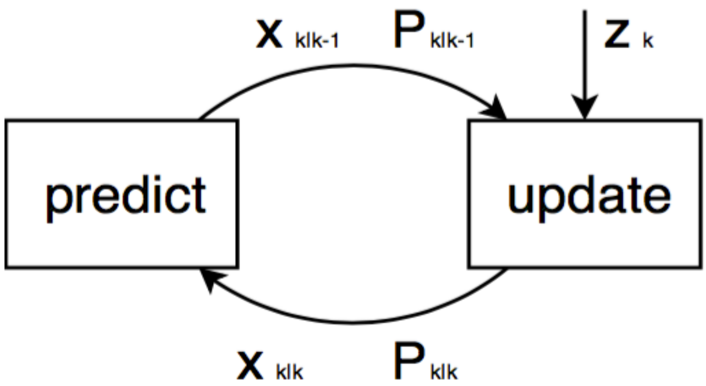


Figure 4.21 Kalman filter loop [108].

Where x and P are covariance matrix.

Two Bayesian approach is used in Kalman filter. These are predicted and update. Predict next state, before measurements are taken $x_{k|k}$ and $P_{k|k-1}$;

$$x_{k|k-1} = F_k x_{k-1|k-1} + B_k u_k \quad \textbf{(4.29)}$$

$$P_{k|k-1} = F_k P_{k-1|k-1} F_k^T + Q_k \quad \textbf{(4.30)}$$

Update state, after measurements are taken;

$$K_k = P_{k|k-1} H_k^T \left(H_k P_{k|k-1} H_k^T + R_k \right)^{-1} \quad \textbf{(4.31)}$$

$$x_{k|k} = x_{k|k-1} + K_k \left(z_k - H_k x_{k|k-1} \right) \quad \textbf{(4.32)}$$

$$P_{k|k} = \left(I - K_k H_k \right) P_{k|k-1} \quad \textbf{(4.33)}$$

Where K is Kalman gain matrix, P is covariance matrix.

4.1.4 Ultrasonic Sensor System

Ultrasonic sensor uses audio signal between 20 KHz and 1 GHz. There is a waiting time among each signal for do not mix the signals. Ultrasonic sensor system is given in Figure 4.22.

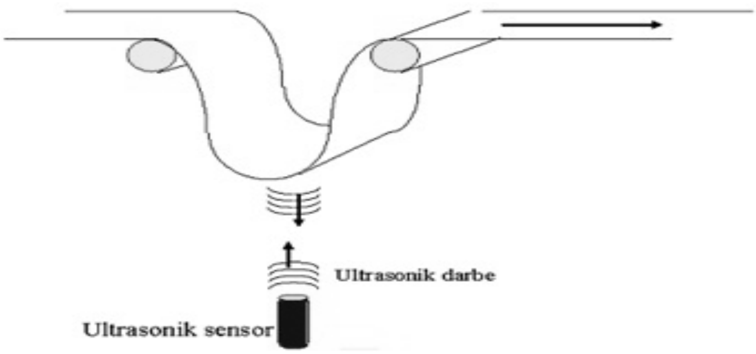


Figure 4.22 Ultrasonic sensor system [109].

Distance equation is as equation 4.1. Return time of the signal is proportional to the distance. Distance is changed with ultrasonic intensity [110]. Ultranic sensor block system is given in Figure 4.23.

Figure 4.23 Ultrasonic sensor block system.

Sensor system's equation, ultrasonic intensity I;

$$I(s,\alpha) = I_0 \times \exp(-\alpha \times s) \quad \textbf{(4.34)}$$

Where s is transmission distance, α is factor of the medium attenuation.

Transmitted direction angle $I(\theta_\alpha)$;

$$I(\theta_\alpha) = I_0 \left(\frac{2J(K\sin\theta_\alpha)}{K\sin\theta_\alpha}\right)^2 \quad \textbf{(4.35)}$$

$$K = 2\pi D / \lambda \quad \textbf{(4.36)}$$

Where θ is direction angle, J is Bessel function, D is diameter and λ is wavelength.

Transmitted signal power F_t [111];

$$F_t = F_{ct}\left(\frac{x_t - x_2}{d_t}\bar{x} + \frac{y_t - y_0}{d_t}\bar{y}\right) \quad \textbf{(4.37)}$$

Where F_{ct} is target signal power constant, d_t is distance of transmitted, (x_t, y_t) are coordinate system.

Total power R;

$$R = F_r + F_t \quad \textbf{(4.38)}$$

4.2 ADAS Longitudinal System

Longitudinal system is associated with the front and the rear of the vehicle. That is mean, system detects and tracks the objects behind the vehicle. Five different ADAS system are given in this Chapter.

4.2.1 Adaptive Cruise Control System (ACC)

Cruise control systems control the speed of vehicle at the desired speed. This kind of systems is developed and its name is adaptive cruise control system (ACC). Main difference between cruise control and adaptive cruise control is cruise control (CC) holds to specified speed but adaptive cruise control system controls four situations. ACC calculates the own speed and front vehicle speed. After that, if the stopping distance is less than actual distance, vehicle speed is decelerated by the system [90]. On the other hand, if specified speed is more than actual speed and the distance between the vehicle and front vehicle is acceptable value, vehicle speed is increased [90]. That is mean, ACC system is more improve than CC system [90]. There are some standard safe rules for ACC. One of them is ISO 26262 [90]. This standard is used for automotive electronics and electrical safety system since 2011. Speed must be greater than 30 km/h for ACC and CC systems [90].

CC system technology stands DAS system but ACC system technology stands ADAS system. ACC block system is given in Figure 4.24.

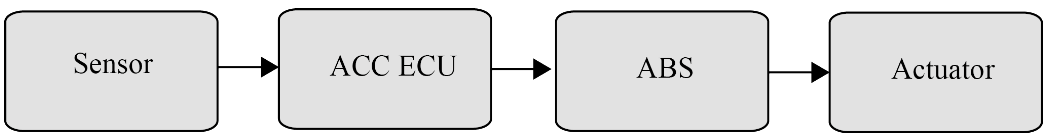


Figure 4.24 ACC block system.

ACC control block system is given in Figure 4.25.

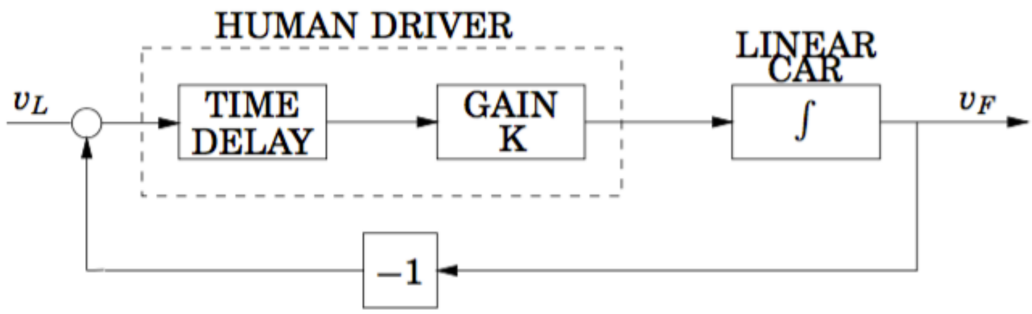


Figure 4.25 ACC control block system [90].

Where V_L is speed of front vehicle, V_F is speed of rear vehicle in Figure 4.25.

Rear vehicle ACC system controls the front vehicle speed and rear vehicle tracks the front vehicle at the following distance, as shown in Figure 4.25.

By Gazis [112], vehicle tracking model, acceleration a;

$$a_F(t) = \frac{b}{\Delta Y(t-\tau)}(v_L(t-\tau) - v_F(t-\tau)) \quad \textbf{(4.39)}$$

Where ΔY (t-τ) is headway gap at the (t-τ) time, b is sensitivity constant, and V is velocity.

By Edie [112], vehicle-tracking model have some limits in low-density traffics [112].

$$a_F(t) = b\frac{v_L(t-\tau)}{\Delta Y(t-\tau)^2}(v_L(t-\tau) - v_F(t-\tau)) \quad \textbf{(4.40)}$$

By General Motor [112], linear vehicle tracking model;

$$a_F(t) = \alpha\frac{v_L(t)^p}{\Delta Y(t-\tau)^\gamma}(v_L(t-\tau) - v_F(t-\tau)) \quad \textbf{(4.41)}$$

Where α is constant value, β and γ are model parameter.

By Chandler [112], linear vehicle tracking model;

$$a_F(t)=\frac{\lambda}{M}[v_L(t-\tau)-V_F(t-\tau)] \quad \textbf{(4.42)}$$

Where λ is sensitivity factor of control system and M is vehicle mass. If the angle increases between the vehicles, new equation is used. The angle among to the vehicles is given in Figure 4.26.

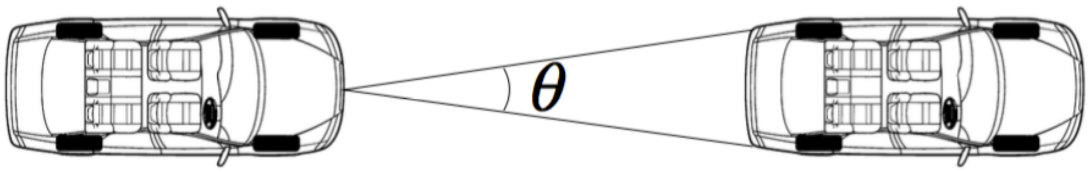


Figure 4.26 Angle between vehicles [112].

$$a_F(t)=b\frac{(v_L(t-\tau)-v_F(t-\tau))}{\Delta Y(t-\tau)^2} \quad \textbf{(4.43)}$$

System nonlinear model, acceleration of the rear vehicle $a_F(t)$;

$$a_F(t)=\alpha\frac{v_f(t)^{\beta}\Delta v(t-\tau)}{(\Delta Y(t-\tau))^{\gamma}}\eta(\Delta Y(t-\tau)-D_n)^3 \quad \textbf{(4.44)}$$

Where D_n is desired headway, η is constant value and ΔY is distance. ACC system is given in Figure 4.27.

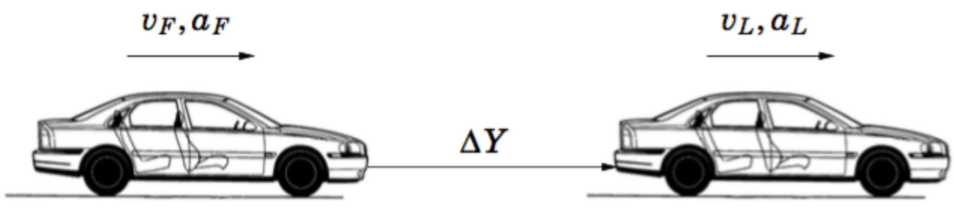


Figure 4.27 ACC system [112].

4.2.1.1 Detection System

System uses radar sensor systems and it was given in Chapter 4.1.1.

4.2.1.2 Mathematical Model

This model occurs from vehicle model, driver model and engine model. So all model will be given respectively.

4.2.1.2.1 Vehicle Model

The vehicle mass and the tire diameter is known by the system. Vehicle model is occurred according to 2-track model [112]. Vehicle model is given in Figure 4.18.

In vehicle model, first derivative is equal to vehicle speed, second derivative is equal to vehicle acceleration and third derivative is equal to function.

First derivative of nth vehicle position $\frac{dy_n(t)}{dt}$;

$$\frac{dy_n(t)}{dt} = V_n(t) \tag{4.45}$$

Where $V_n(t)$ is nth vehicle speed. Second derivative of nth vehicle position $\frac{dy_n(t)}{dt}$;

$$\frac{dy_n(t)}{dt} = a_n(t) \tag{4.46}$$

Where $a_n(t)$ is nth vehicle acceleration.

Third derivative of nth vehicle position $\frac{dy_n(t)}{dt}$;

$$\frac{dy_n(t)}{dt} = b\left(y_n, y_n\right) + \alpha(y_n)u_n(t) \tag{4.47}$$

Where $u_n(t)$ is nth vehicle engine input, b is sensitivity constant.

Constant $\alpha(y_n)$;

$$\alpha(y_n) = \frac{1}{m_n \tau_n (y_n)} \quad \textbf{(4.48)}$$

Where m_n is nth vehicle mass, τ_n is is reaction time for nth driver.

Constant $b(y_n, y_n)$;

$$b(y_n, y_n) = -2\frac{k_{dn}}{m_n} y_n y_n - \frac{1}{\tau_n y_n}[y_n + \frac{k_{dn}}{m_n} y_n^2 + \frac{d_{mn} y_n}{m_n}] \quad \textbf{(4.49)}$$

Where k_{dn} is nth aerodynamic friction coefficient and d_{mn} is nth vehicle mechanical friction. Vehicle engine input in control model u_n;

$$u_n = \frac{1}{\alpha y_n}[c_n(t) - b(y_n, y_n)] \quad \textbf{(4.50)}$$

$$c_n = C_p \delta_n(t) + C_u \delta_n(t) + K_v v_n(t) + K_a a_n(t) \quad \textbf{(4.51)}$$

Where C_p, C_v, K_v, K_a are design constants.

Deviation from the desired headway $\delta_n(t)$;

$$\delta_n(t) = y_{n-1}(t) - y_n - (L_n + S_{0n} + \lambda_2 v_2(t)) \quad \textbf{(4.52)}$$

Where L_n is nth vehicle length, S_{0n} is first headway.

Derivative $\delta_n(t)$;

$$\delta_n(t) = v_{n-1}(t) - v_n - \lambda_2 a_n(t) \quad \textbf{(4.53)}$$

System makes report the potential for flowing traffic. Thus, if properly implemented, traffic flow rates increase [112].

4.2.1.2.2 Driver Model

Driver model control block system is given in Figure 4.28.

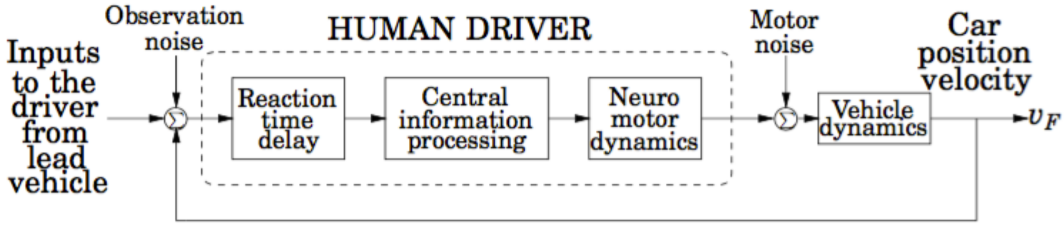


Figure 4.28 Driver model control block system [112].

Reaction time was determined to be about 1.5 second and mass sensitivity ratio was determined to be about 0.37 seconds [112]. This research was made with 8 male drivers by General Motor [108]. Sensitivity factor depends on the distance among the vehicles [112]. To applied speed at the time of t for nth driver $r_n(t)$;

$$r_n(t) = k_n(t-\tau_n) \cdot s_n(t-\tau_n) \quad \textbf{(4.54)}$$

Where k_n is sensitivity, S_n is warning, t is observation time and τ_n nth vehicle's engine time constant.

4.2.1.2.3 Engine Model

When the distance is less than following distance, vehicle speed must be reduced. Because of that, ACC system uses engine torque power. Engine model control block system is given in Figure 4.29.

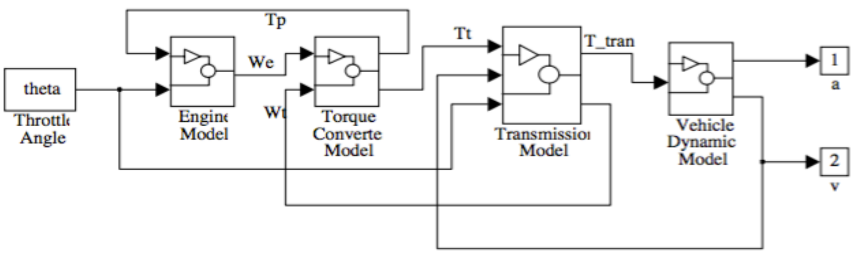


Figure 4.29 Engine model control block system [113].

Engine speed equation ω_e;

$$\omega_e = \frac{1}{J_e}(T_e(\omega_e,\theta_{th}) - T_a(\omega_e) - T_p(\omega_e,\omega_t)) \quad \textbf{(4.55)}$$

Where ω_t is torque converter turbine speed, T_p is load torque from torque converter pump, J_e is engine inertia, θ_{th} is throttle angle, T_e is an engine combustion torque and T_a is engine accessory and load torque.

Turbine and pump torque T_p and T_t;

$$T_p = m_1\omega_p^{\ 2} + m_2\omega_t\omega_p + m_3\omega_t^{\ 2} \quad \textbf{(4.56)}$$

$$T_t = n_1\omega_p^{\ 2} + n_2\omega_t\omega_p + n_3\omega_t^{\ 2} \quad \textbf{(4.57)}$$

Where m_1, m_2, m_3, n_1, n_2, and n_3 are parameter mode and values.

Speed rate, SR;

$$\text{SR}=\omega_t / \omega_p \quad \textbf{(4.58)}$$

Modes are changed according to SR.

SR<0.842: converter mod,

0.842<SR<1: coupling mode,

SR>1: overrun mod.

Torque power and mode are determined with the engine model. Torque power is used for braking. In addition, this power depends on the transmission. When the transmission increases, torque power is change.

This situation is given in equations (4.59, 4.60, 4.61, 4.62).

$$1 \leftrightarrow 2'de, \omega_t = 0.77 \cdot \theta + 89.2 \quad \textbf{(4.59)}$$

$$2 \leftrightarrow 3'de, \omega_t = 2.77 \cdot \theta + 163.1 \quad \textbf{(4.60)}$$

$$3 \rightarrow 4'de, \omega_t = 4.62 \cdot \theta + 224.8 \quad \textbf{(4.61)}$$

$$3 \leftarrow 4'de, \omega_t = 7.85 \cdot \theta + 91.6 \quad \textbf{(4.62)}$$

Where ω_t is transmission output speed and θ is throttle angle.

4.2.1.3 Electronic Control System

ACC system interferes in the vehicle braking system with the information received from the sensor. This is made with control algorithm. ACC system uses many algorithms. Some of them are PID, PI and fuzzy control. Fuzzy control algorithm is used in this research. ACC control block system is given in Figure 4.30. This algorithm is Germann and Isermann's algorithm [112].

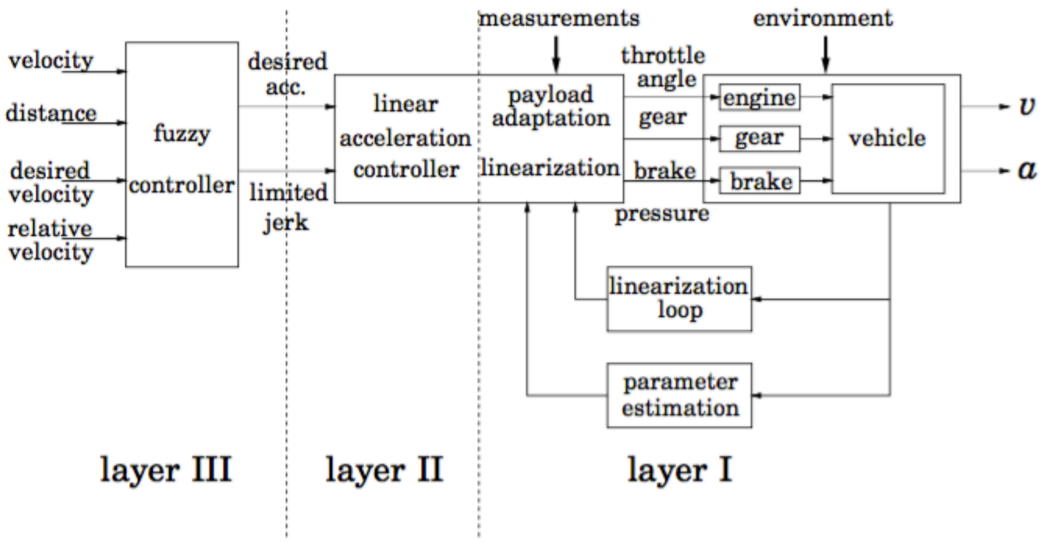


Figure 4.30 Germann and Isermann ACC control block system [112].

Fuzzy logic control block system is given in Figure 4.31.

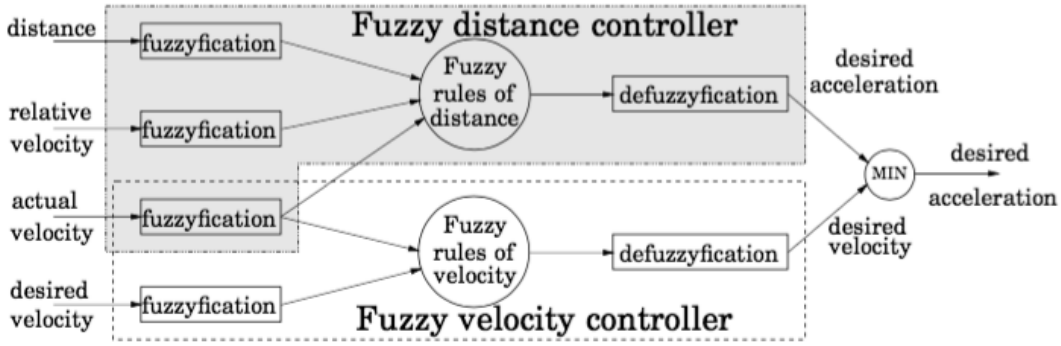


Figure 4.31 Fuzzy logic control block system [112].

Output acceleration a;

$$a = \min[a(\text{velocity}), a(\text{distance})] \quad \textbf{(4.63)}$$

ACC system control structure is given in Figure 4.31. In this Figure, vehicle speed, distance, desired speed and relative speed information is provided by sensor systems. After this information, system compares them. Subsequently, linear control application is applied. Finally, system interferes in the vehicle system with driver model, vehicle model and engine model. Fuzzy controller algorithm is given in Chapter 3.2.4.3.

ACC system uses ABS for braking.

4.2.2 Forward Collision Warning System (FCWS)

Forward collision warning system calculates the speed of vehicle and front vehicle. After that, it measures distance among the vehicles. Thus, it finds probability of collision. Then, if there is a probability of collision, system warns the driver [89]. Collision warning system algorithm is more important for warning time [114].

System detects front vehicles with sensors. It controls the following distance. If the distance is less than following distance, system warns the driver [92].

FCWS block system is given in Figure 4.32.

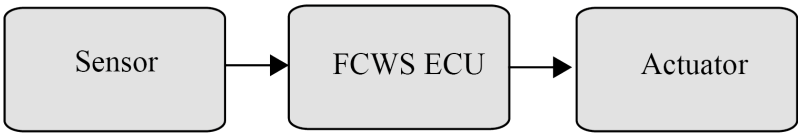


Figure 4.32 FCWS block system.

FCWS system reduces the probability of collision, but it does not classify the object that is a tree or a bridge or a vehicle [2]. The average age is important factor for the system. According to the research, reaction time for young person is fewer than older age's [91]. Because of that, the limit values are formed according to the reaction time in older people [91]. This system uses some icon for warning. FCWS icons are given in Figure 4.33.

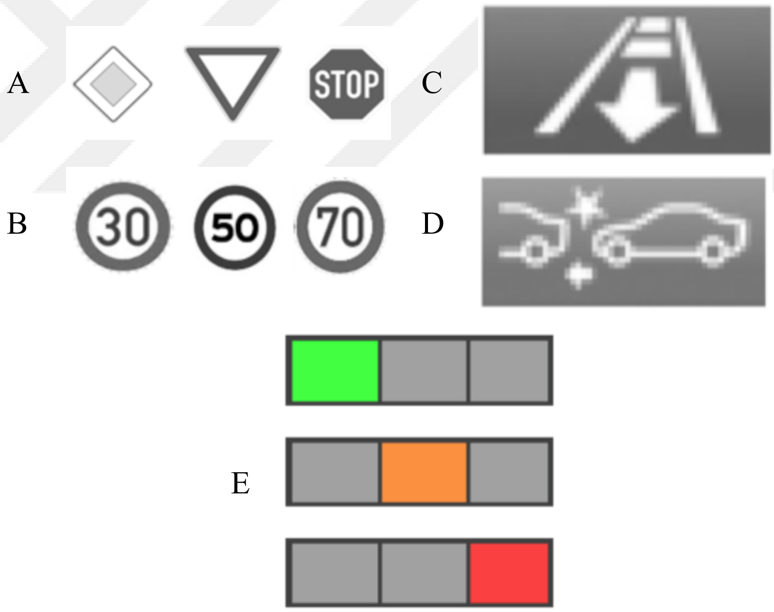


Figure 4.33 FCWS system's icons [86].

In Figure 4.33A shows traffic sign, in Figure 4.33B shows legal speed limit, in Figure 4.33C shows that distance is bigger than 2 second, in Figure 4.33D shows the collision, in Figure 4.33E shows that distance is bigger than 5 second, 2 second to 5 second and smaller than 2.5 second.

4.2.2.1 Detection System

FCWS uses radar, lidar sensors for measuring the speed and distance of front vehicle. These sensors are given in Chapter 4.1. Information of own vehicle speed and acceleration is calculated with wheel speed sensor. Wheel speed sensor is given in Chapter 2.3.1. The system controls the distance among the vehicles with these sensors and algorithm systems. If there is a probability of collision, system warns the driver.

4.2.2.2 Mathematical Model

Vehicle model of FCWS system is same as ACC system vehicle model. Because of that, ACC system vehicle model is used in this research. ACC system vehicle model is given in Chapter 4.2.1.2

4.2.2.3 Electronic Control System

Electronic control system compares information of speed, position and distance among the vehicles. If maximum braking capability (a_d) value is less than front value (a_{Fmin}), system warns the driver for the collision in equation 4.64.

$$a_d = \begin{cases} \dfrac{a_L v_F^2}{2a_L(\tau v_F - \Delta Y + S_0) + v_L^2} & \text{If } t_{stop,F} \leq t_{stop,L} \text{ and } t_{stop,F} \neq 0; \\ \dfrac{a_L(\Delta Y - S_0) - \frac{1}{2}(\Delta v)^2}{\tau(\frac{1}{2}\tau a_L + \Delta v) + \Delta Y - S_0} & \text{If } t_{stop,F} > t_{stop,L} \text{ or } t_{stop,F} = 0; \end{cases} \quad \textbf{(4.64)}$$

Where a_L is leader vehicle acceleration, v_L is leader vehicle speed, a_F is forward vehicle acceleration, v_F is forward vehice acceleration, τ is reaction time, ΔY is distance between vehicles, ΔV is speed differences, S_0 is initial headway.

System can make two possible misinformation about vehicle situation. These are false alarm and missed the alarm. "θ" is a cluster of system all parameter. There are two possible situations according to this parameter. These are safe and threat zone [115].

Cluster is given in Figure 4.34. Safe and threat zone is given in Figure 4.35. False alarm is related to safe zone [115]. Missed alarm is related to threat zone [115]. Error situations are given in Figure 4.36.

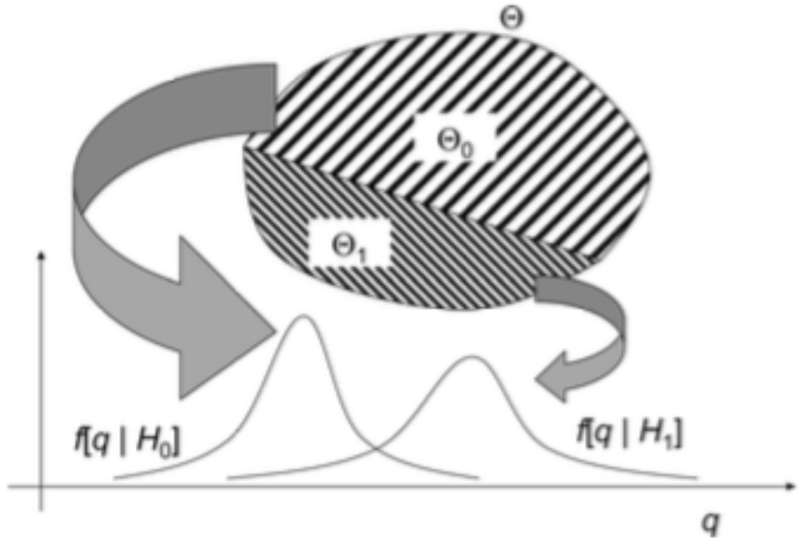


Figure 4.34 θ cluster [115].

Where θ_0 is safe zone and θ_1 is threat zone in Figure 4.34.

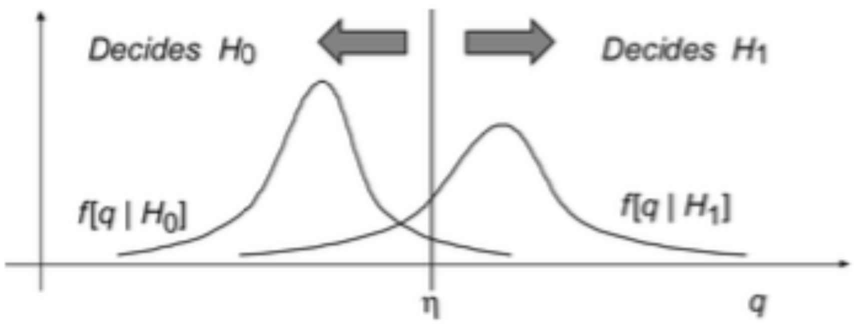


Figure 4.35 Safe and threat zone graph [115].

Where η is limit value and q is a function in Figure 4.35.

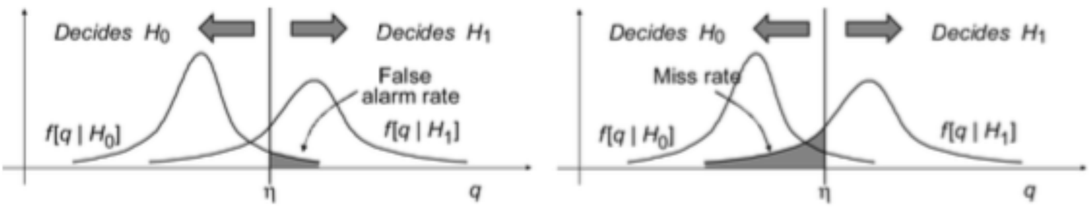


Figure 4.36 Error graph [115].

H1 is threat zone in Figure 4.36. Confusion matrix fixes tolerance value. Confusion matrix is given in Table 4.2 and calculation is given in Table 4.3.

Table 4.2 Confusion matrix [115].

Number of prediction		Actual data	
		Negative (safe)	Positive (threatening)
Prediction	Negative (safe)	a	c
	Positive (threatening)	b	d

Table 4.3 Rates calculated from confusion matrix [115].

Rate	**Definition**
Accuracy	(a+d)/(a+b+c+d)
P (Precision)	d/(b+d)
TP (True Positive Rate)	d/(c+d)
FN (False Negative Rate)	c/(c+d)
TN (True Negative Rate)	a/(a+b)
FP (False Positive Rate)	b/(a+b)
Geometric Mean	$\sqrt{TP * P}$

FCWS calculates possible collision between vehicles and if there is a problem, it warns the driver. On the other hand, it is just warning system for collision situation.

4.2.3 Stop and Start System

Stop and start system is started to use in vehicles in recent times. This system aim is to reduce to the fuel consumption and to increase the emission rate. System stops the engine when vehicle stopped. After that, when the driver pushes any pedals, engine starts to work automatically. By this method, emission rate increases at a rate of 5-7 percent [116]. Also, extends the vehicle's maintenance intervals [86]. System is given in Figure 4.37.

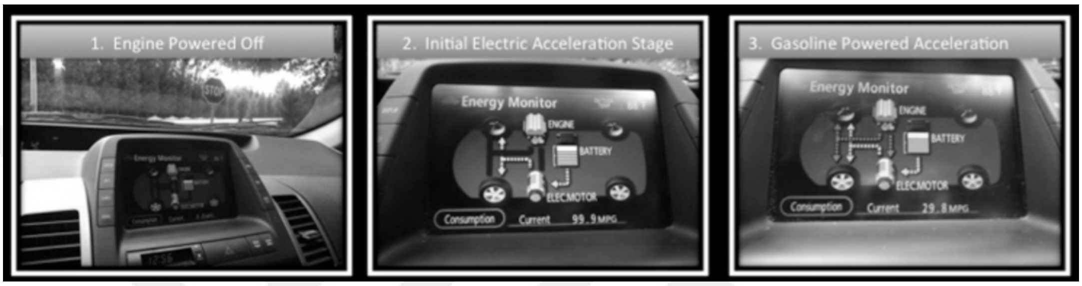


Figure 4.37 Stop and start systems [116].

In Figure 4.37;

1. Vehicle engine is off, so the vehicle is parking.
2. Vehicle is waiting position and battery gives energy for the vehicle.
3. Vehicle starts to working. Vehicle engine starts with electrical engine and engine gives energy for all vehicle system [116].

Stop and start control block system is given in Figure 4.38. System uses lots of sensor system for measuring.

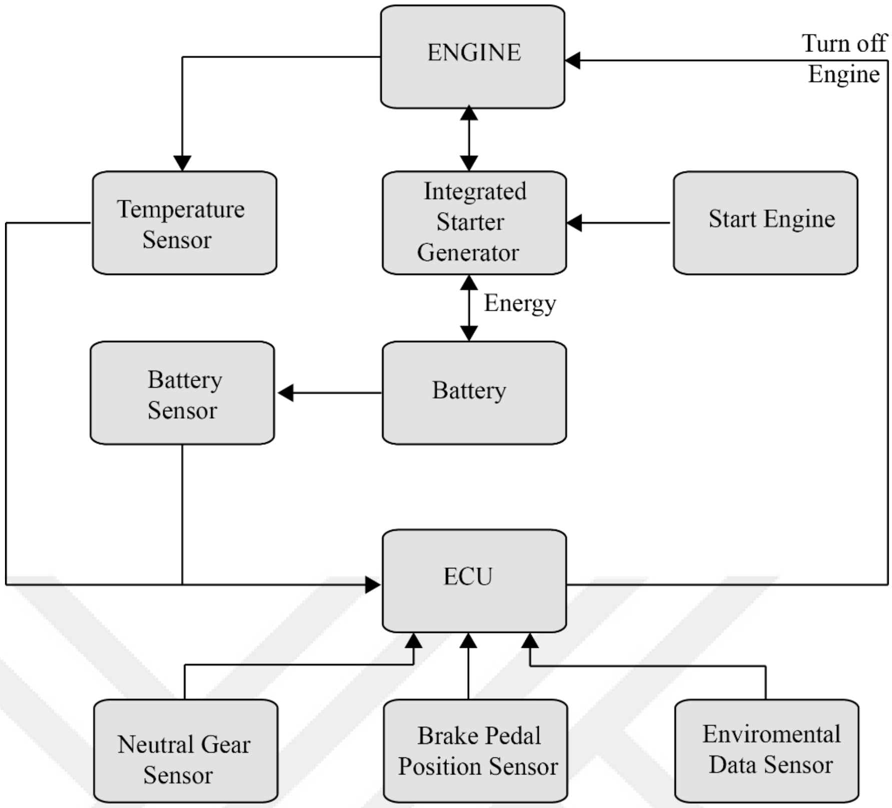


Figure 4.38 Model of start and stop control systems [117].

System uses engine temperature sensor, battery level sensor, brake pedal position sensor, throttle pedal position sensor and wheel speed sensor [116,117]. Firstly, system examines the speed of wheel. If the speed of wheel is not equal to zero, vehicle does not stop. Because of that, system does not do anything. If the speed of wheel is equal to zero, gas pedal and braking pedal is equal to zero and one. After that, system controls the battery level. Lastly, engine temperature is controlled. If battery level is higher than nominal value and engine temperature is normal, system stops the engine and it uses a battery to provide the necessary low energy [116,117]. The battery is the energy source for the electrical engine [117]. When the driver pushes any pedal or if it drops a certain amount of engine temperature or if battery power is very low, engine starts to work automatically [116,117].

Stop and start system depends on the battery level [118]. Because of that, the battery must be charged quickly. According to the research, AGM battery is more useful [118].

4.2.3.1 Detection System

Stop and start system uses temperature sensor, wheel speed sensor, battery sensor and pedal position sensor. Temperature sensor is given in Chapter 3.2.1.2. Wheel speed sensor is given in Chapter 2.3.1. Battery sensor is given in Chapter 2.4 and pedal position sensor is given in Chapter 2.8.1.

4.2.3.2 Electronic Control System

Controller starts or stops the engine according to the vehicle situation. Control system uses some information for stopping the vehicle. These are given in below [119].

1. Wheel speed= 0,
2. Vehicle is stopped,
3. Brake pedal position =1,
4. Battery status > threshold rate,
5. Engine temperature > threshold rate,
6. Turn off engine.

If one of these steps changes, engine restarts. That is mean, if the wheel speed is not equal to zero, if the brake pedal position is not equal to one, if the battery status is not higher than threshold rate, or if the engine temperature is not higher than threshold rate, the engine restart. As another method, if the gas pedal position is changed, the engine restarts [119].

4.2.4 Pedestrian Collision Warning System (PCWS)

According to the 2009 data, 65 percent of all fatal traffic accidents have been sourced from pedestrian [120]. Pedestrian collision warning system is designed to reduce the likelihood of accidents.

Pedestrian collisions are given in Figure 4.39.

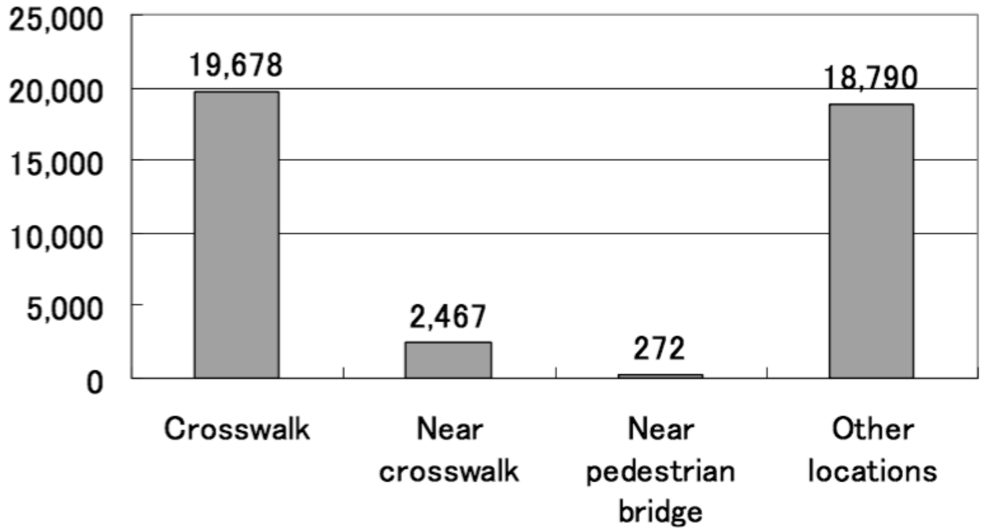


Figure 4.39 Location of pedestrian accidents (2007 Japan) [121].

PCWS system is given in Figure 4.40.

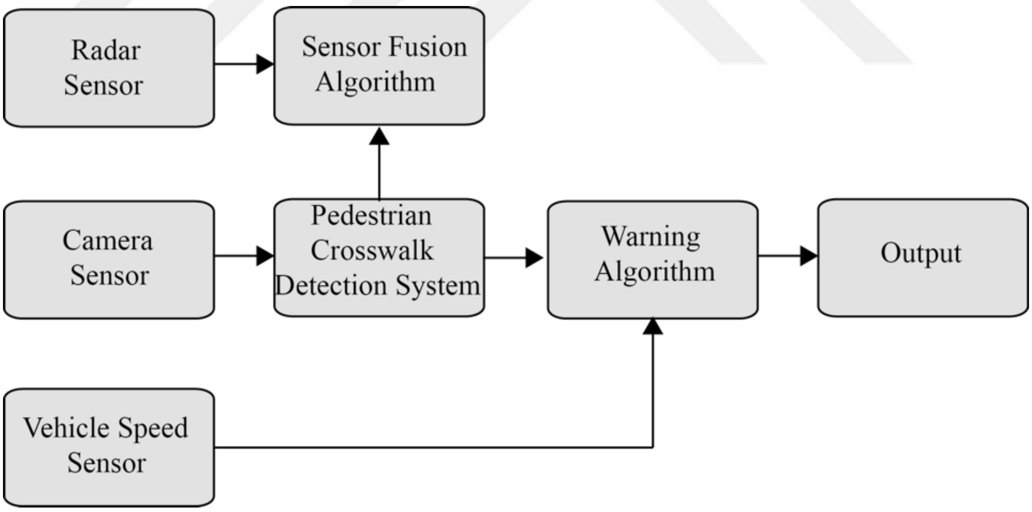


Figure 4.40 PCWS block system.

System determines the pedestrian with radar and camera sensor systems. Generally, twelve parameters are used for determination. Pedestrian crosswalk and sensor fusion algorithm are used for them. These parameters are given in Table 4.4.

Table 4.4 PCWS Feature definition [122].

N	Feature	Description
1	Distance Collision Point	Lateral Distance between the pedestrian and the collision point (CP), where pedestrian and ego-vehicle will intersect.
2	Time Ped Collision Point	Time for the pedestrian to reach the collision point
3	Diff Time Collision	Time for the ego vehicle to reach the collision point minus time for the pedestrian to reach the collision point.
4	Distance to Curbstone	Lateral distance between the pedestrian and the curbstone.
5	Time to Curbstone	Time for the pedestrian to reach the curbstone
6	Time to EgoLine	Time for the pedestrian to reach the ego lane
7	Global Orientation	Moving direction as the angle between the pedestrian and the road
8	Facing Road	Pedestrian is walking towards the road parallel or away to it.
9	Relative Orientation	Moving direction as the angle between the pedestrian and the ego vehicle.
10	Distance to Ego Lane	Lateral distance between the pedestrian and the ego lane
11	Distance to Zebra	Lateral distance between the pedestrian and the zebra crossing.
12	Time to Zebra	Time for the pedestrian to reach the zebra model.

Pedestrian detection sensors had produced too many false alarms in the first years [120]. Because of that, drivers close the warning system or they did not take into account [123]. New generation PCWS system uses different sensor system. So accurate detection systems have been created.

According to the research, there are visual, auditory and sensory warning systems [120]. Sensory warning system is useful system for near collisions [123]. Visual and auditory warning system is useful systems for conditions of low probability of collision. In the warning systems can be alteration according to the situation of hardware and pedestrian.

Firstly, system detects pedestrian and it finds where the pedestrian walks [120]. It is so important factor for PCWS. Because, the pedestrian can walk on the bridge or on the crosswalk or on the sidewalk. Each of them is detected with different signal.

This system is important system for ADAS. It has three main categories. These are detection, tracking and warning [120,121,123-125]. Pedestrian and vehicle position are given in Figure 4.41.

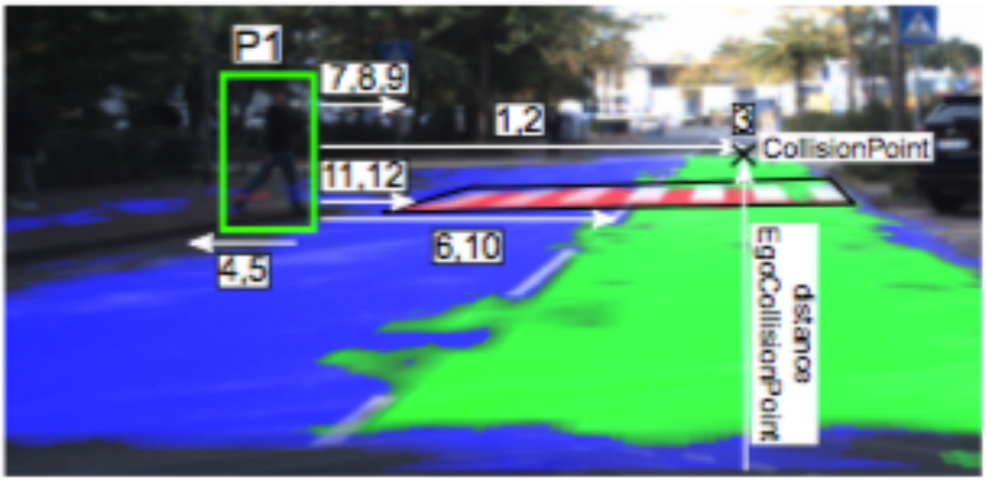


Figure 4.41 Pedestrian and vehicle position [122].

Where green area is EGO strip, blue area is road, red-white area is crosswalk lines in Figure 4.41.

Pedestrian collision warning system uses three-algorithm system. Firstly, it uses crosswalk algorithm with camera information. After that, it uses lidar sensor fusion algorithm. Lastly, it uses warning algorithm.

4.2.4.1 Detection System

System uses vehicle speed sensor, camera sensor system and radar-lidar sensors. Wheel speed sensor is given in Chapter 2.3. Radar, lidar and camera sensor system are given in Chapter 4.1.1.

4.2.4.2 Electronic Control System

Control system calculates where the pedestrian is, pedestrian position and their speeds with sensor systems. After that, if there is a problem on the road, system warns the driver. In this Chapter, speed of vehicle and pedestrian are considered stable.

4.2.4.2.1 Crosswalk Detection Algorithm

The system is used as a cross ratio on the crosswalk [121]. Cross ratio is a perspective view. Cross ratio is given in Figure 4.42.

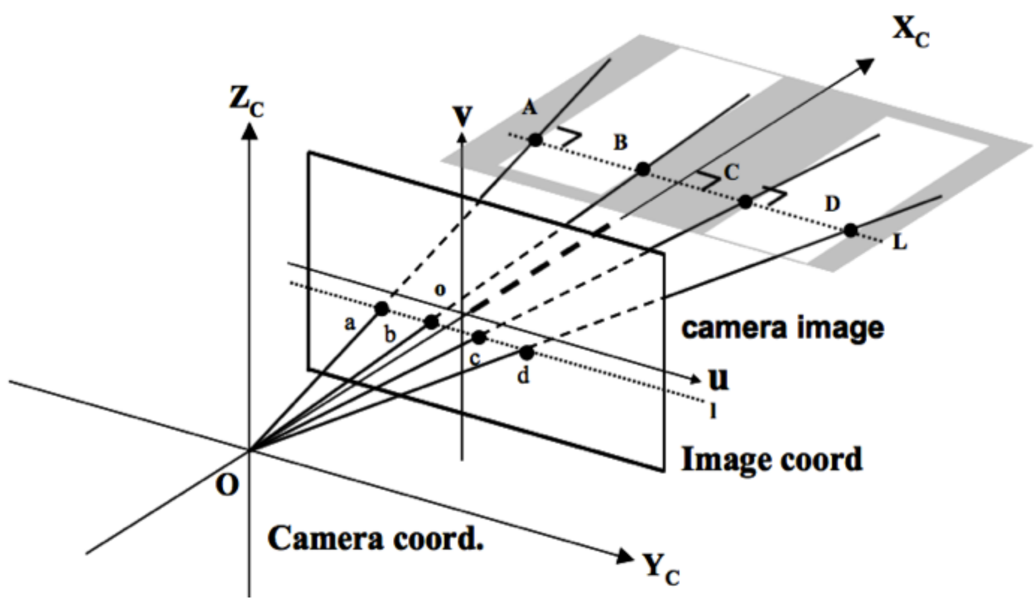


Figure 4.42 Cross rate [121].

This algorithm calculates four points. System uses [a b c d] points and $\overline{a\,b}$ symbol. [a b c d] are points. $\overline{a\,b}$ is a symbol of cross ratio. $\overline{a\,b}$ is the distance between a and b.

General equation [abcd];

$$[abcd] = \frac{\overline{ac}}{\overline{bc}} \frac{\overline{bd}}{\overline{ad}} \qquad \textbf{(4.65)}$$

System uses camera system for pedestrian detection, determination and tracking. Camera system is given in Chapter 4.1.3. Crosswalk detection algorithm is given in Figure 4.43.

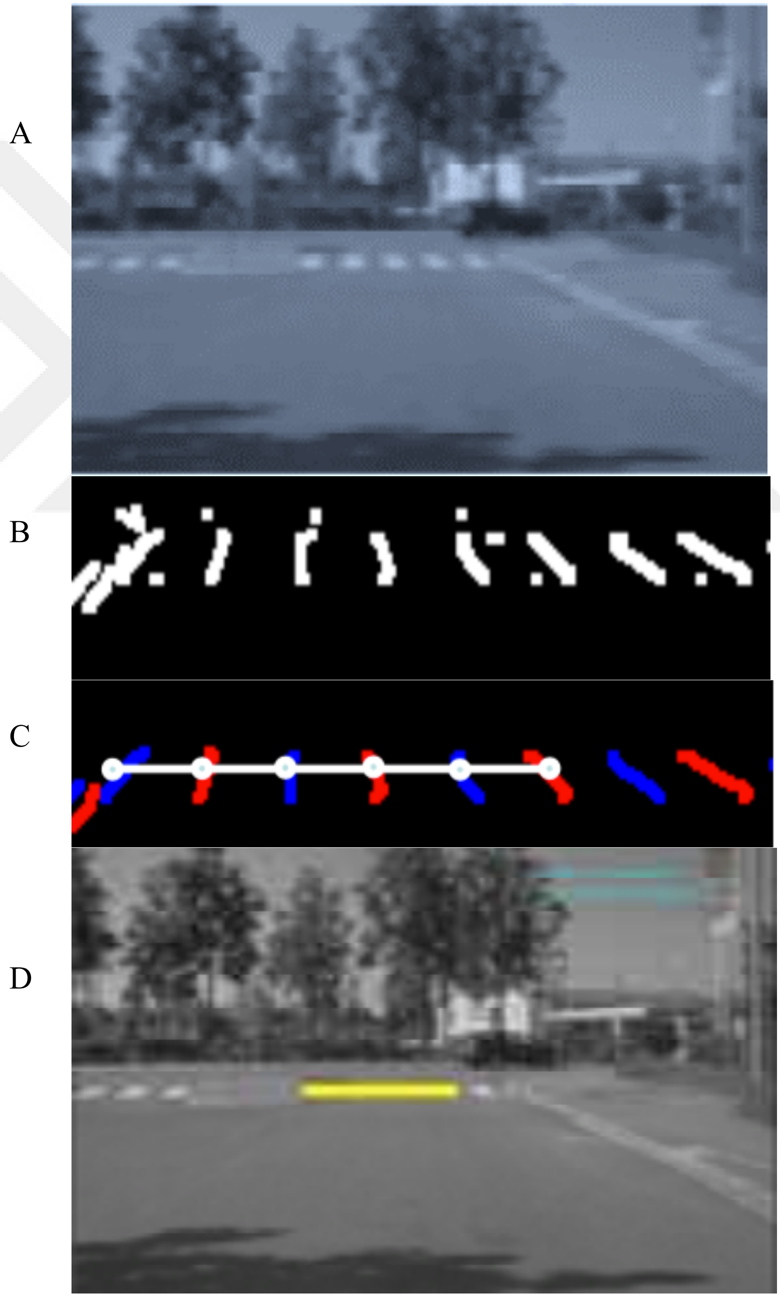


Figure 4.43 Crosswalk detection algorithm [121].

Where A is a first image, finds white lines in B, calculates the cross ratio is C and detects the crosswalk is D.

4.2.4.2.2 Sensor Fusion Algorithm

System assumes that the vehicle moves parallel to the road [121]. Sensor fusion system detects the pedestrian using coordinate system and camera system. Coordinate system is given in Figure 4.44.

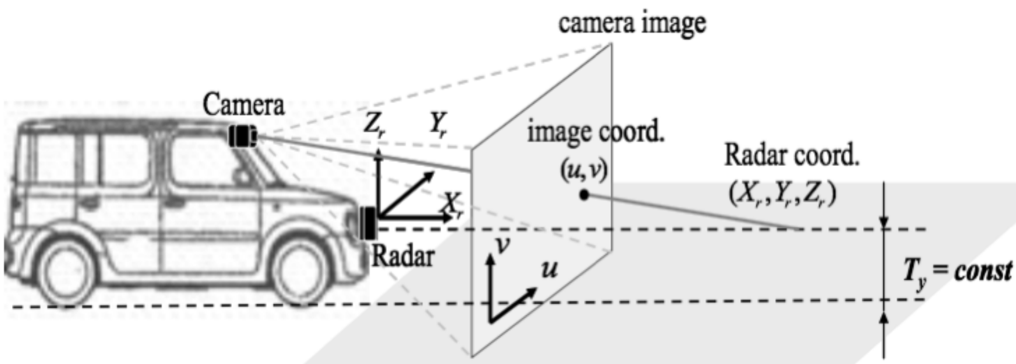


Figure 4.44 Coordinate system [121].

Equation of coordinate system (u, v, l);

$$\begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{14} \\ P_{21} & P_{22} & P_{23} & P_{24} \\ P_{31} & P_{32} & P_{33} & P_{34} \end{pmatrix} \begin{pmatrix} X_r \\ Y_r \\ Z_r \\ 1 \end{pmatrix} \tag{4.66}$$

Where u,v are camera coordinate system, X_r, Y_r, Z_r are radar coordinate system $P_{11} \dots P_{34}$ *are* perspective projection matrix for coordinate system.

Coordinate axis of the camera system and the radar system are combined in the pedestrian detection. In addition, system focuses on pedestrian in limit value. Last step, system determines the ROI. So ROI area is mean of pedestrian for system. And system calculates pedestrian speed using to the ROI area movement. ROI is given in Figure 4.45.

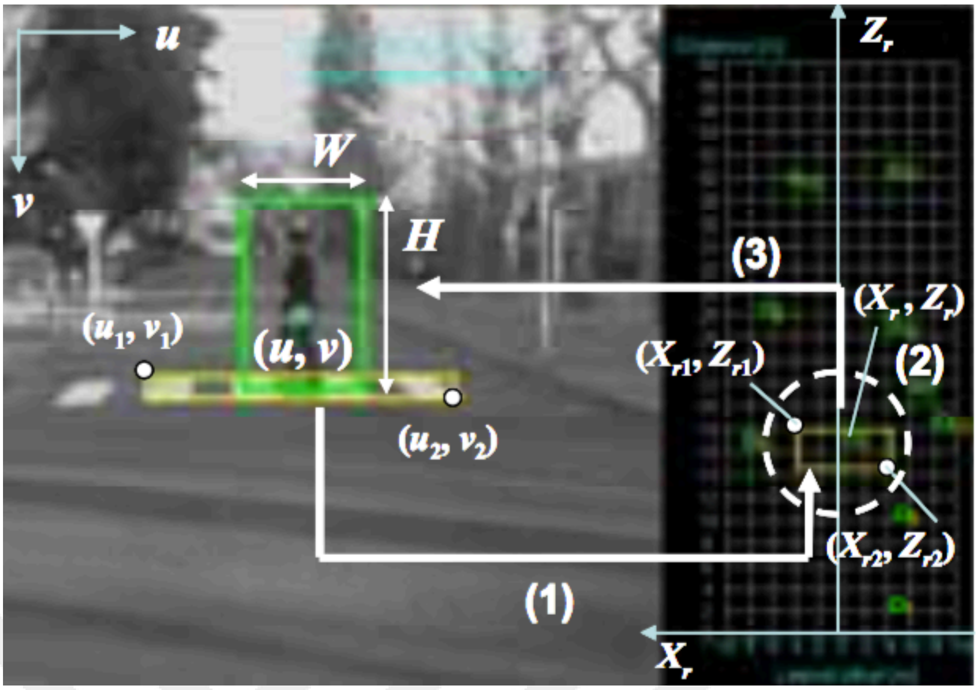


Figure 4.45 Detects ROI [121].

Where H is high and W is width.

System uses camera and radar system for detecting the pedestrian movement. Radar system is given in Chapter 4.1.1.

4.2.4.2.3 Warning Algorithm

The most useful algorithms are TTC (time to collision) and RDP (Required Deceleration Parameter) in the warning algorithm [121,126].

Predicted time T_p;

$$T_p = \left(X_{ped}(t) - X_{car}(t)\right) / V_{car} \qquad \textbf{(4.67)}$$

$$RDP = \frac{V_{car}^{\ 2}}{2T_p g} \qquad \textbf{(4.68)}$$

Where $X_{ped}(t)$ is pedestrian speed at the x direction, $X_{car}(t)$ is vehicle speed at the x direction, V_{car} is vehicle speed and g is the gravitational acceleration constant.

TTC system is given in Figure 4.46.

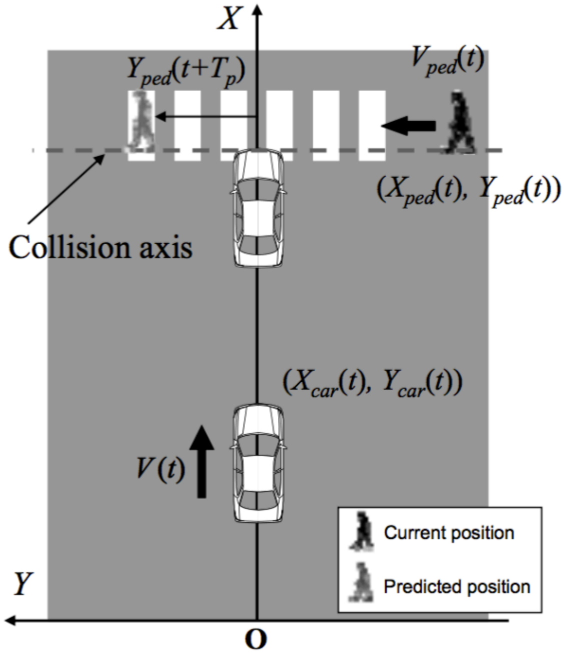


Figure 4.46 TTC system [121].

Possible pedestrian position speed Y_{ped};

$$Y_{ped}\left(t+T_p\left(t\right)\right)=Y_{ped}\left(t\right)+V_{ped}\left(t\right)T_p\left(t\right) \tag{4.69}$$

PCWS system application was given in Figure 4.47.

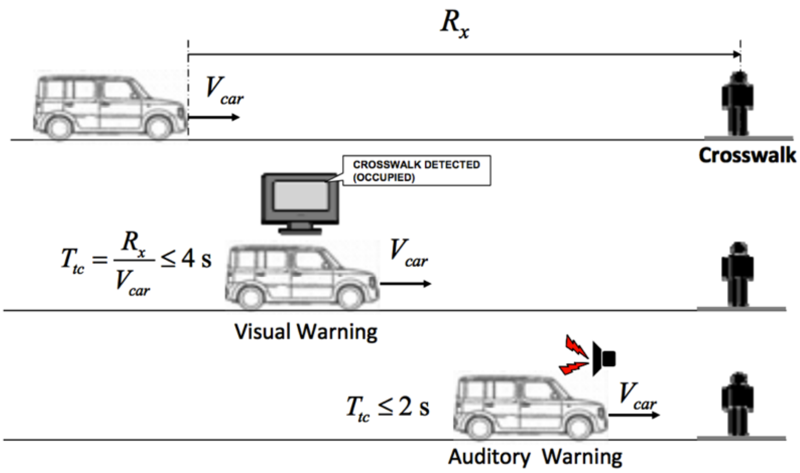


Figure 4.47 PCWS system application [121].

Where R_x is distance between the pedestrian and vehicle, T_{tc} is collision time, V_{car} is vehicle speed in Figure 4.47.

The system detects the pedestrians from R_x distance. If the collision time is much more than four second, system gives a visual warning. On the other hand, it gives an auditory warning.

4.2.5 Intelligent Speed Assistant (ISA)

Intelligent speed assistant controls the speed of the vehicle with road information [127]. Each location has different speed limit. Therefore, system uses Global Position System (GPS) and it determines the vehicle position. Thus, system determines the speed limit [127]. ISA block system is given in Figure 4.48.

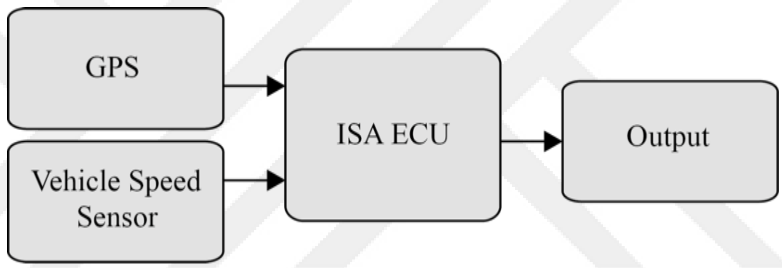


Figure 4.48 ISA block system.

System uses data of static speed limit, dynamic speed limit and location speed limit [127]. Static speed limit is determined according to the traffic signs, dynamic speed limit is determined according to the actual road and traffic conditions and location speed limit is determined according to the vehicle location limit [129].

ISA method is given in Figure 4.49. Methods are general and specific inductors. General inductors are gender, age, education level and income. Specific inductors are efficiency, effectiveness, usability, usefulness and satisfaction [129,130].

Different speed area and their effects are given in Figure 4.50. For example, ISA mostly affects the traffic safety. On the other hands, system reduces the fuel consumption.

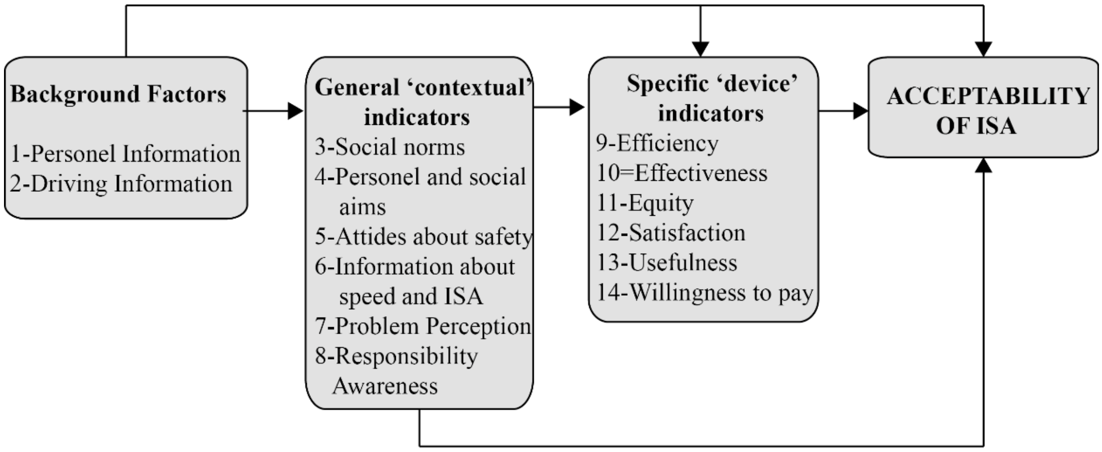


Figure 4.49 Method of ISA [130].

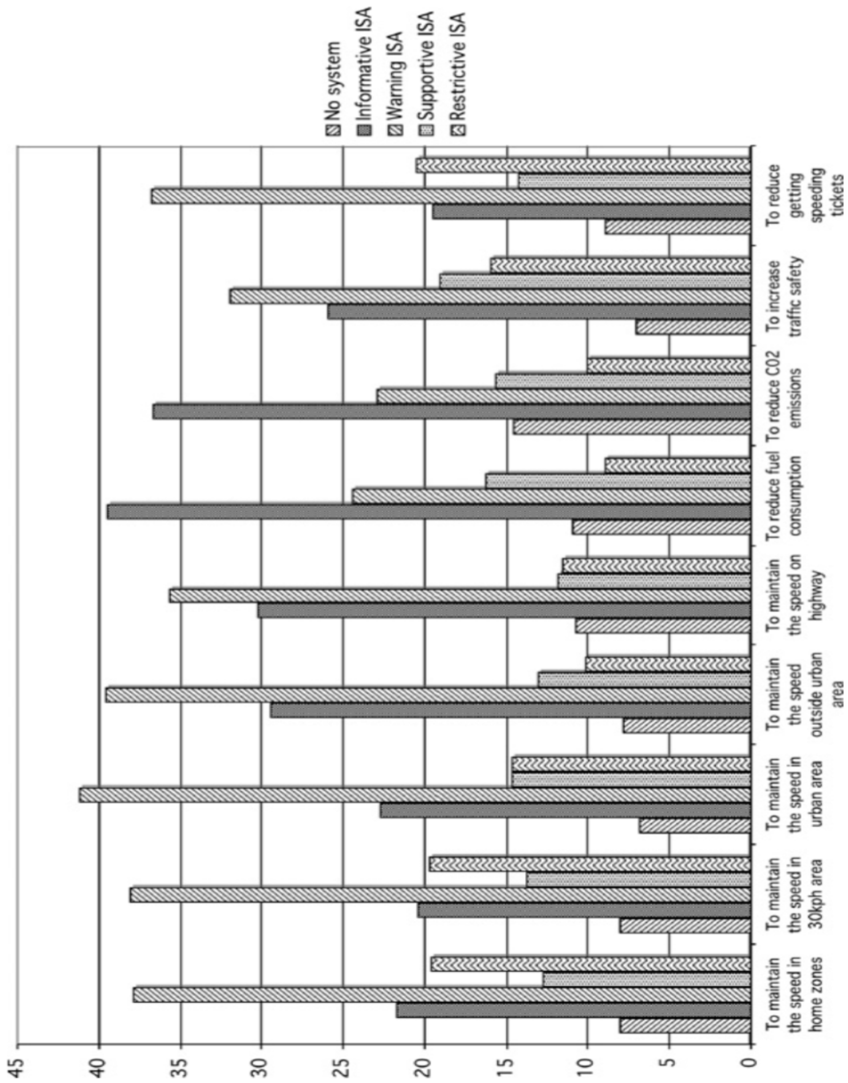


Figure 4.50 Using ISA for different speed area [129].

Firstly, system determines which speed limit is using. This system compares between the speed limit and the vehicle speed.

4.2.5.1 Detection System

System uses vehicle speed sensor and GPS system. Vehicle speed sensor is given in Chapter 2.3.1.

4.2.5.1.1 Global Position System (GPS)

GPS system uses 24 satellite systems. This system technic is same as general satellite technology. It determines the coordinates with GPS receivers. Each satellite has L1 and L2 frequency. System works with low radio signal. For instance, L1 signal works with 20 to 50-watt power.

GPS system sends random encrypted code to the receiver. Distance is measured with this signal between satellite and the receiver. Signal speed is considered to the speed of light. Received signal includes the orbit information, time information, and system status and ionosphere delay time.

GPS data is used together with digital road mapping. Digital road mapping has speed data of school area, street, avenue, boulevard and similar places. Therefore, GPS data gives position of vehicle and system compares between GPS data and digital road mapping data.

4.2.5.2 Electronic Control System

GPS does not send the data at some places. For instance, high-rise buildings, tunnels, urban area. If the vehicle is that zone, system does not work. In real time algorithm, map-matching algorithm is used in generally. This method works online. However, if the vehicle passed through from some region previously, map matching saves that data. Therefore, system can work offline.

System uses GPS data and vehicle speed sensor data in the map matching. If converting data is bigger than 5 km/h, system makes rotation of angle. Map matching block system is given in Figure 4.51.

Change of direction × vehicle speed < 1000.

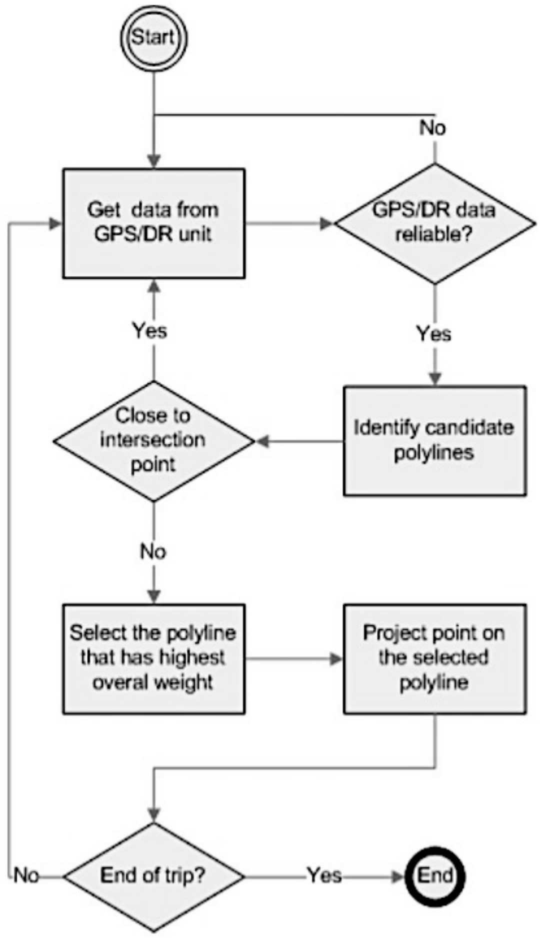


Figure 4.51 Map matching block system [131].

4.3 ADAS Lateral Control System

Lateral control is associated with side of the vehicle. This system is used for detection, determination and warning for that kind of vehicle. This control system includes the lane keeping assist, the lane departure warning and the blind spot detection systems. Lateral control block system is given in Figure 4.52.

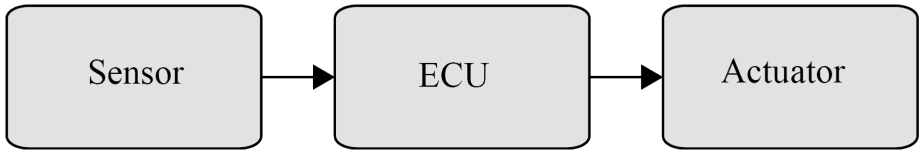


Figure 4.52 Lateral control block system.

4.3.1 The Lane Departure Warning System (LDW)

The lane departure warning system makes lane control [98]. When the vehicle exits the lane, system warns the driver [89]. System uses vehicle position angle, braking time calculation system and vehicle speed. Then, it scans the road. These data are input information for the system. Also, system determines the lane detection, road status analyze and the deflection [2, 89]. LDW block system is given in Figure 4.53.

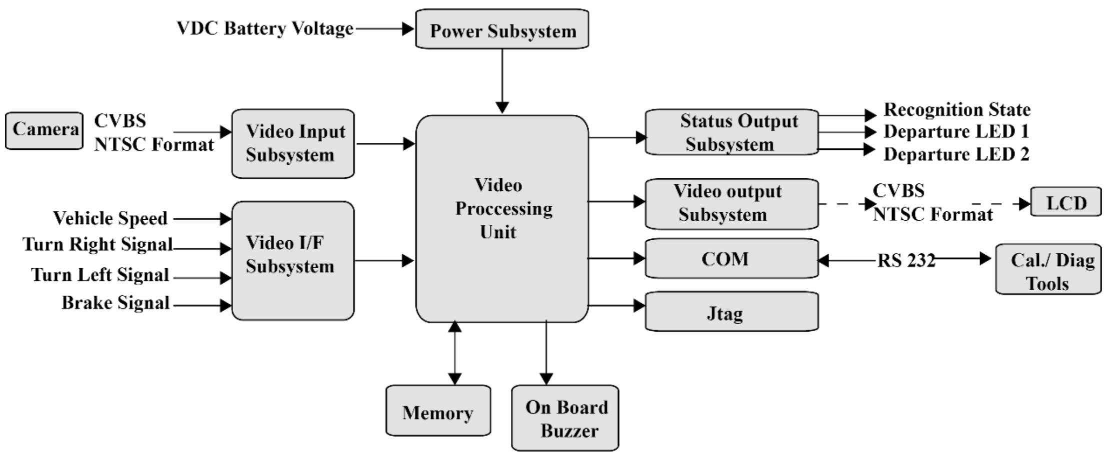


Figure 4.53 LDW system's block diagram [98].

System processes camera data and vehicle dynamic data. Then, it generates the warning on the LCD panel [98,106].

4.3.1.1 Detection System

System uses camera system and vehicle speed sensor. Camera system is given in Chapter 4.1.3 and vehicle speed sensor is given in Chapter 2.3.1

4.3.1.2 Electronic Control System

System includes five-step control algorithm. Firstly, it softens the camera data with median filter. After that, it uses ROI, IPM, segmentation, image detection algorithm and Image tracking algorithm.

LDW ROI is given in Figure 4.54.

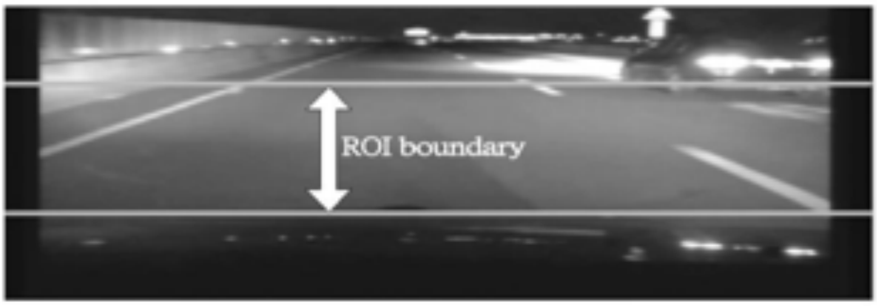


Figure 4.54 LDW ROI [99].

ROI and birds eye view is given in Figure 4.55.

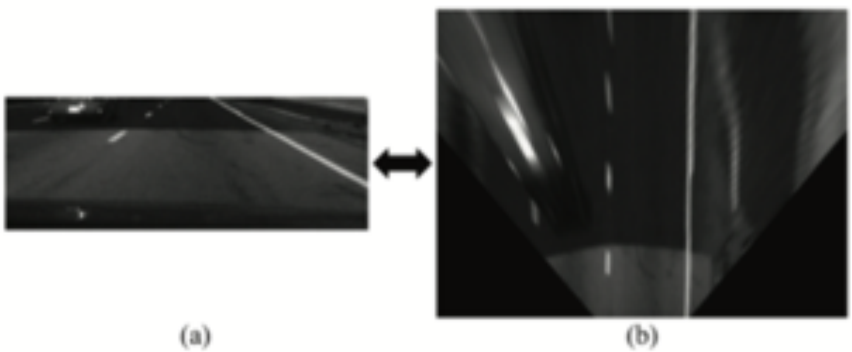


Figure 4.55 ROI (a), Bird's eye view (b) [99].

Image, image processing and Hough transform is given in Figure 4.56.

Figure 4.56 Image, image processing and Hough transform [100].

Finally, LDW system detects the lane with camera system. It processes this image. It tracks the vehicle and the lane. When the vehicle exits the lane, system warns the driver [89].

4.3.2 The Lane Keeping Assistant System (LKAS)

Lane keeping assistant system is a kind of tracking and warning system [132, 133]. This lane keeping assistant system is more advanced version of the lane departure warning system [134]. System is used since 2010 [133]. System is developed for reducing the collision in the traffic. LKAS block system is given in Figure 4.57.

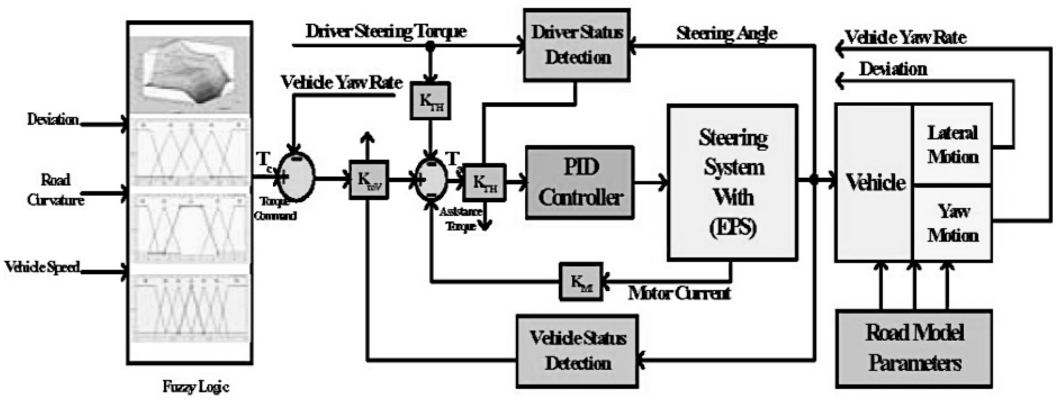


Figure 4.57 LKS block diagram and configuration [135].

LKAS control the lane and road with camera and sensors [135]. If it is a necessary, it uses electrical hydraulic steering wheel (EPS) [135].

4.3.2.1 Detection System

System uses camera system, yaw rate sensor, steering wheel sensor and vehicle speed sensor. Camera system is given in Chapter 4.1.3. Vehicle speed sensor, Yaw rate and steering wheel position sensor are given in Chapter 2.3.1.

Detection system for lane is given in Figure 4.58.

Figure 4.58 Detection system for lane [136].

4.3.2.2 Electronic Control System

LKAS system processes data of some sensors and it determines the lane. System can calculate the engine torque power, so it can control the vehicle system. LKAS control system algorithm is same as pedestrian collision warning algorithm. The main differences between LKAS and PCWS are that LKAS automatically can control the steering wheel, and system uses ABS system for braking. LKAS block system is given in Figure 4.59.

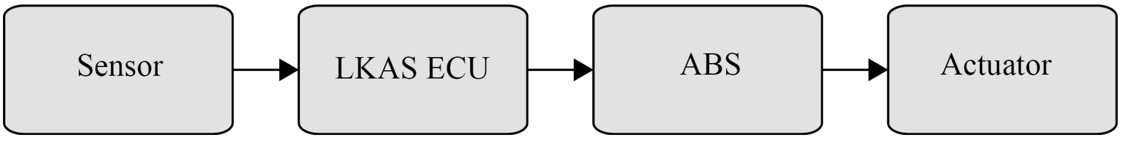


Figure 4.59 LKAS block system.

LKAS system calculates the torque power for steering wheel according to yaw angle, cornering information and vehicle speed information. Vehicle speed, Yaw angle sensor and cornering information are given in Chapter 2.3.

System respectively makes the lane detection, coordinate transformation, road parameter estimation and lastly it finds the viewpoint parameters.

Image coordinates u;

$$u = \frac{ke_u e_v H}{e_v m_\theta - v} + me_u + \frac{be_u}{He_v}\left(e_v m_\theta - v\right) \quad \textbf{(4.70)}$$

Where v is image coordinate, e_u, e_v are focal ratio of the horizontal and vertical pixel sensor size, H is camera high, m_θ is road slope and k, m, b are road model parameters.

Road model 2nd equation, lateral displacement Y_d;

$$Y_d = kx^2 + mx + b \quad \textbf{(4.71)}$$

Road slope ε_d;

$$\varepsilon_d = 2kx + m \quad \textbf{(4.72)}$$

Curvature ρ_d;

$$\rho_d = \frac{2k}{\left(1+(2kx+m)^2\right)^{3/2}} \quad \textbf{(4.73)}$$

Vehicle mass lateral acceleration in movement My;

$$My = C_f\left(\delta - \beta - \frac{l_f \gamma}{V}\right) - C_r\left(\beta - \frac{l_f \gamma}{V}\right) \quad \textbf{(4.74)}$$

Where C_f and C_r are front and rear cornering stiffness, δ is steering wheel angle, β is angle of slipping, V is vehicle speed, γ is yaw rate and, l_f is the distance of the front wheels of the vehicle center of gravity center.

Distance times derivative Yaw rate $I\dot{\gamma}$;

$$I\dot{\gamma} = I_f C_f \left(\delta - \beta - \frac{I_f \gamma}{V} \right) - I_r C_r \left(\beta - \frac{I_f \gamma}{V} \right) \quad \textbf{(4.75)}$$

Where l_r are the distance of the rear wheels of the vehicle center of gravity center.

System uses fuzzy controller for calculation torque power. In addition, fuzzy controller is given in Chapter 3.2.4.3. When the vehicle exits the lane, LKAS system controls the vehicle [135]. Also, system can activate with the speeds between 65 and 180 km/h [134]. LKAS image is given in Figure 4.60.

Figure 4.60 LKAS controls systems [133].

4.3.3 Blind Spot Detection System (BSDS)

Blind spot detection system is a designed system to help the driver of a possible collision or accident [137]. For example, when the driver wants to change the lane, the driver may not see the side of the vehicle. At this time, system warns the driver for blind spot [137]. Blind spot detection system must have some standards and test procedure. These are ISO 17387:2008 [138].

System is divided into two different working principles [139]. These are daytime and nighttime detection. The main difference between daytime and nighttime detection is different method of detection. Daytime detection is related to the shadow edges, but nighttime is related to the headlight [140]. General system is given in Figure 4.61.

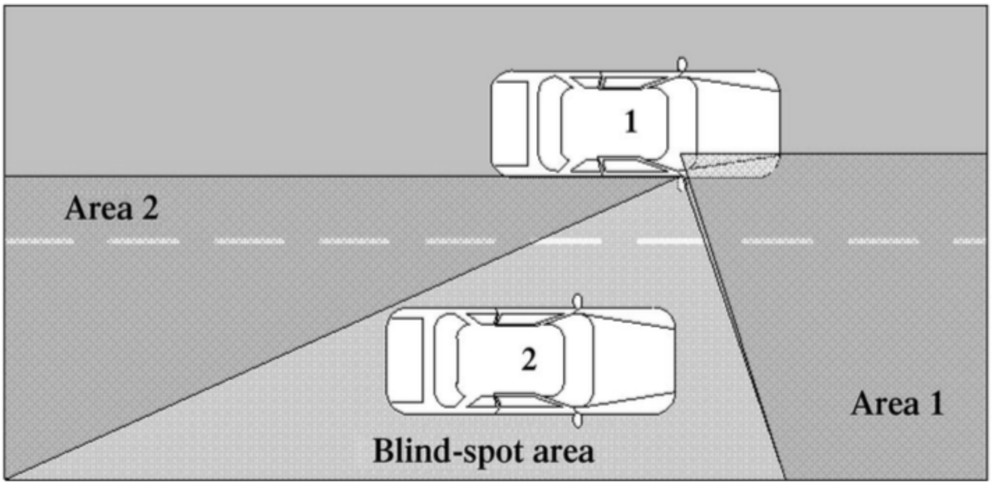


Figure 4.61 Blind Spot Area [141].

In this Figure 4.61, first vehicle's driver sees the area 1 and 2. Second vehicle position is blind spot area for first vehicle. Therefore, this area is a blind spot area.

4.3.3.1 Detection System

System uses lidar sensor, radar sensor, ultrasonic and/or camera sensor and vehicle speed sensor [138, 142, 143]. Lidar sensor, radar sensor, ultrasonic and/or camera sensor are given in Chapter 4.1 and vehicle speed sensor is given in Chapter 2.3.1.

4.3.3.2 ***Electronic Control System***

System uses two different algorithms for two different time period. These algorithms are nighttime and daytime algorithm. The camera detection system is used for daytime algorithm, but different algorithm is used for nighttime algorithm.

ROI on the nighttime is given in Figure 4.62. Vehicle image is not used for this. Actually, headlight image processing has different method. For instance, the system can mix lights. That is mean, system detects the lights of vehicle or not. Because of this, nighttime algorithm is different from daytime algorithm [139].

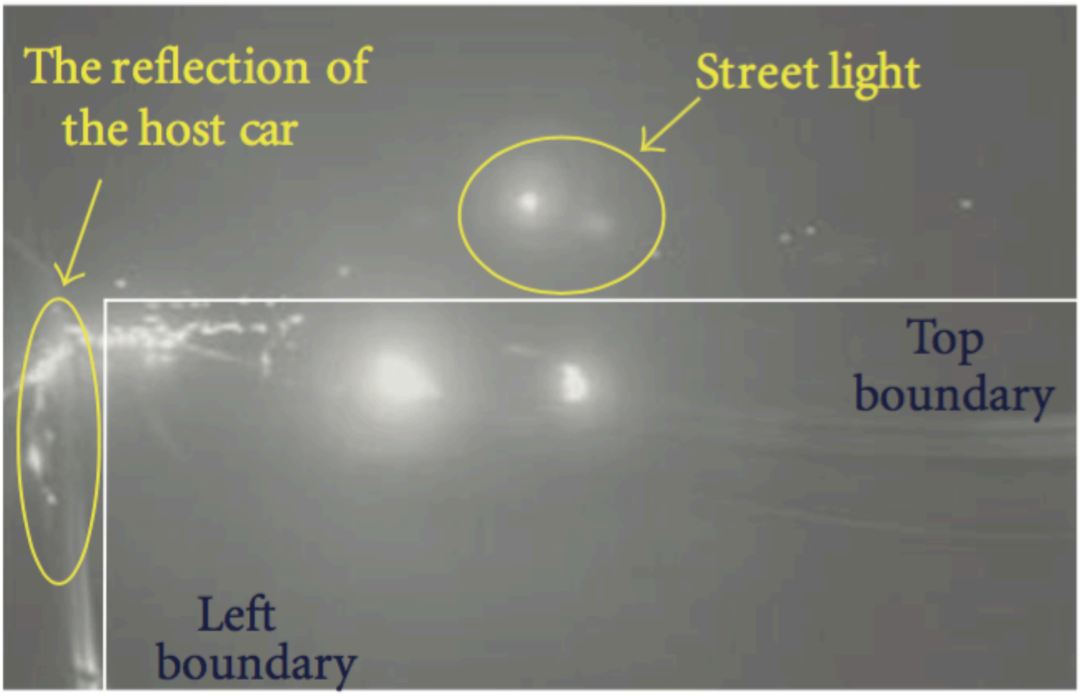


Figure 4.62 ROI on the night time [139].

Gray level to number of pixels are given in Figure 4.63.

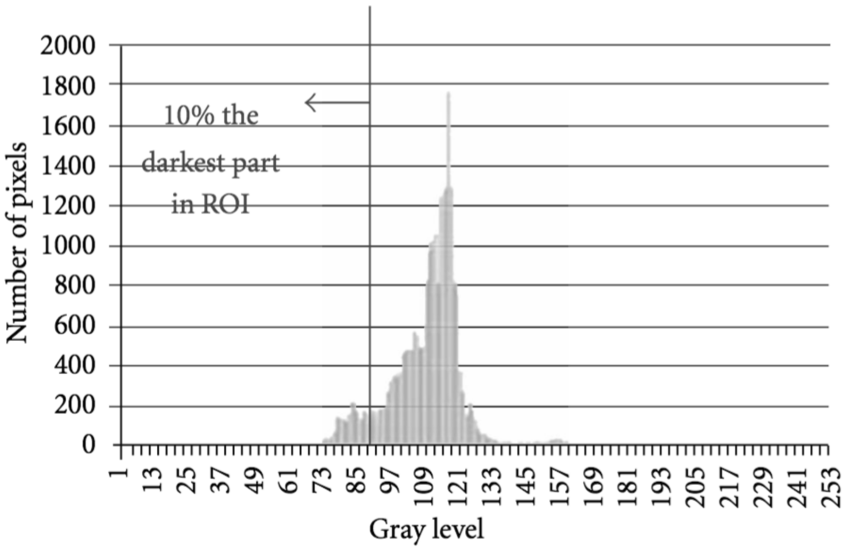


Figure 4.63 Gray level to number of pixels [139].

Nighttime has some threshold value in the gray level. Threshold value is calculated as equation 4.76.

Threshold value g^*;

$$g^* = \arg(\sum_{g=0}^{255} h(g) > \delta N) \quad \textbf{(4.76)}$$

Where g is gray level, N is number of pixels and δ is 0.99.

When calculates the gray level, threshold value uses previous gray level value for reference value [139]. Because, brightness can be as same as lighting.

Previous gray level value g(t);

$$g(t) = \frac{7}{8} g^*(t) + \frac{1}{8} g(t-1) \quad \textbf{(4.77)}$$

Vehicle detection system works with coordinate system. Vertical and horizontal pixels are given in Figure 4.64.

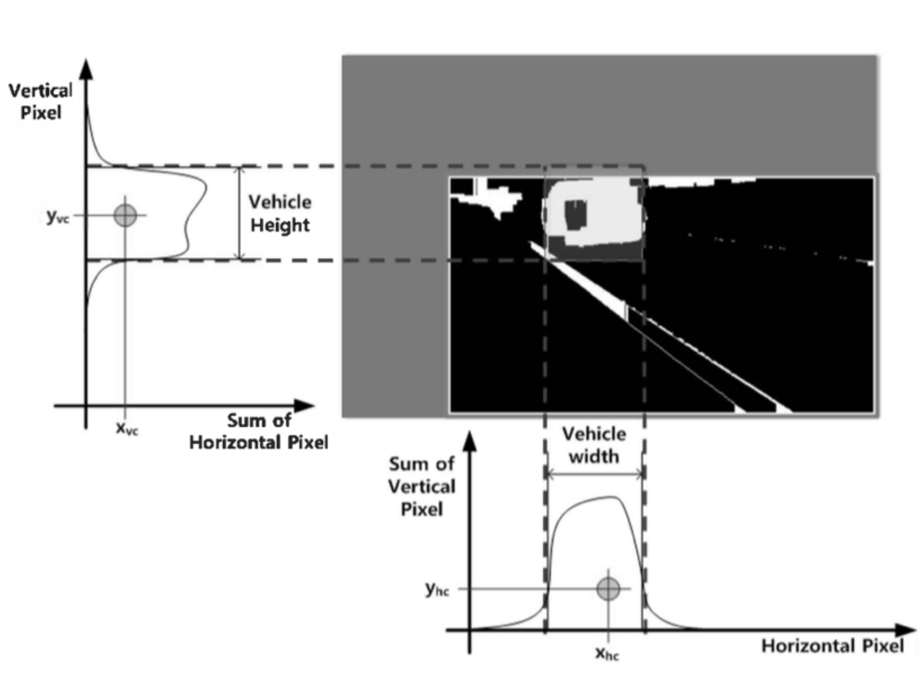


Figure 4.64 Projection Data [143].

Central of vertical and horizontal are found from vehicle imaging [143].

Sum of the projection data (horizontal) Y_{total};

$$y_{total} = \sum_{i=1}^{n} y_{hi} \tag{4.78}$$

X axis center of mass (Horizontal) x_{hc};

$$x_{hc} = \frac{\sum_{i=1}^{n} (y_{hi} x_{hi})}{y_{total}} \tag{4.79}$$

Y axis center of mass (Horizontal) Y_{hc};

$$y_{hc} = \frac{y_{total}}{n} \tag{4.80}$$

Standart deviation (horizontal) σ_x;

$$\sigma_x = \sqrt{\frac{1}{3} \sum_{i-1}^{n} (y_{hi} - y_{hc})^2} \tag{4.81}$$

Sum of the projection data (vertical) X_{total};

$$x_{total} = \sum_{i=1}^{n} X_{vi} \tag{4.82}$$

Center of mass (Vertical) Y_{vc};

$$Y_{vc} = \frac{\sum_{i=1}^{n} (Y_{vi}\ X_{vi})}{X_{total}} \tag{4.83}$$

Standart deviation (vertical) σ_y;

$$\sigma_y = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (X_{vi} - X_{vc})^2} \tag{4.84}$$

System finds vehicle position for using the vehicle image and it decides that are there any vehicles or not? Firstly, system detects the headlight from first camera image. When this determination, system uses some threshold value for does not mix with other lights. After that, the headlight is tracked for blind spot detection. Nighttime tracking algorithm is different from daytime tracking algorithms. Nighttime tracking algorithm;

$$|H_L-H_c|< T_H \quad \textbf{(4.85)}$$

$$|W_L-W_c|< T_w \quad \textbf{(4.86)}$$

$$L_R \leq (H_L/W_L)/(Hc/W_c) \leq U_R \quad \textbf{(4.87)}$$

$$d_{if}= |x_i-x_j|+|y_i-y_j| \quad \textbf{(4.88)}$$

Where H_C, W_C, H_L, and W_L are the height and width of the same lamp, T_H, T_w, U_R, and L_R are Threshold values, i th is current frame lamp values, j th is the last frame lamp values, a and y are column and row. If there is any vehicle to blind spot area, system detects and warns the driver.

Example of blind spot area and tracking are given in Figure 4.65.

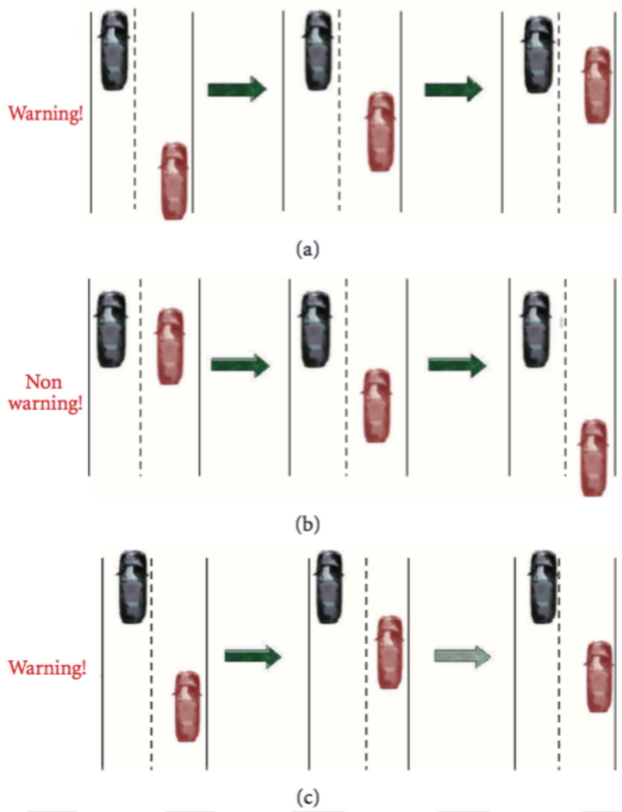


Figure 4.65 (a) Relative approaching, (b) Relative backing, (c) Relative static [139].

In Figure 4.65, black vehicle is the host car and red car is the tracked vehicle in the blind spot area.

4.4 ADAS Lightening System

Lightening system is one of the most important systems for driving. Lightening system are adaptive front lightening and night vision system. These systems are examined in this thesis.

4.4.1 Night Vision System (NVS)

Night vision is a system of helps the driver for driving [89]. The drivers cannot see clearly pedestrian, animal and other objects at night. There are lots of factor for effects the night vision system. Some night vision system detects only human beings or animals or traffic signs. Detection of the night vision system has different technologies.

The system is analyzed in two categories [144-147]. These are active (near infrared) and passive (far infrared) night vision algorithm. Active night vision is used at the 0.7 to 3.0-micron wavelength meter and passive night vision is used at the 8-12 micron wavelength meter [144,145]. Active night vision system uses infrared and passive night vision system uses thermal infrared [144,145,147]. Active night vision system is analyzed in two main categories. These are gated and non-gated system. Gated system is used with emit pulse, non-gated system works with emit constant [144].

Night vision system generally consists of six parts. These are control unit, controller display, controller, instrument cluster, and button in light switch center and camera systems [139]. NVS block system is given in Figure 4.66.

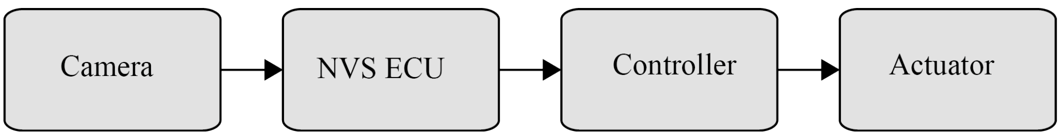


Figure 4.66 NVS block system.

Camera system is the most important section in this system. Because system detects the objects with camera system [148]. After the detection, system analyzes the vehicle situation and system warns the driver if any need.

4.4.1.1 Detection System

System uses thermal camera sensor system.

4.4.1.1.1 Thermal Imaging

Eyes and normal lightening system do not detect the objects. However, if thermal system is used, all objects can be detected. Thermal imaging block system is given in Figure 4.67.

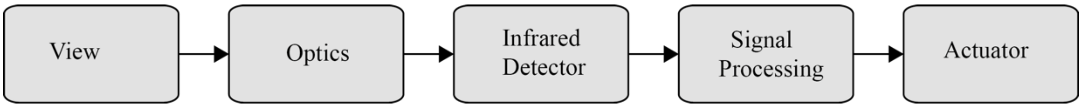


Figure 4.67 Thermal Imaging block system.

Infrared detector detects the energy of the objects. After that, system processes the energy signal and the image is found [145]. Differences between thermal camera and normal camera are given in Figure 4.68. Upper side is visual image and bottom side is thermal image.

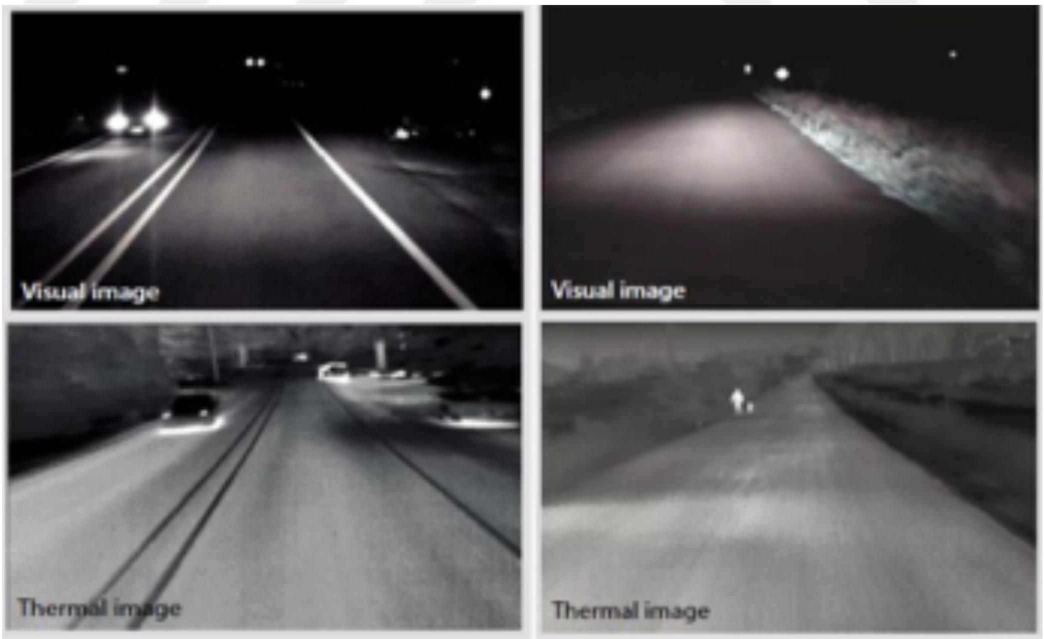


Figure 4.68 Visual and thermal image [147].

Thermal camera includes thermal sensors and heated optical elements [147]. Every object has infrared energy and they radiate this energy. Thermal camera detects radiating energy and it creates images with this energy [148].

4.4.1.2 Electronic Control System

Night vision electronic control system works like the lane keeping warning system. The only difference is method of detection. Thermal camera algorithm is like camera sensor system algorithm.

4.4.2 Adaptive Front Lightening

Adaptive front lightening system adjusts the angle of the lightening system [150]. The most important lightening system is curve-lightening system. Adaptive front lightening system is given in Figure 4.69.

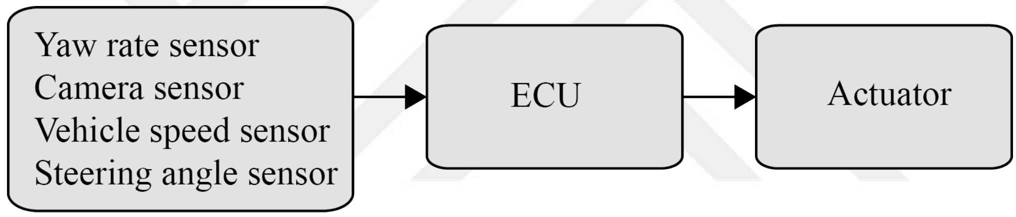


Figure 4.69 Adaptive front lightening block system.

Curve lightening system is given in Figure 4.70.

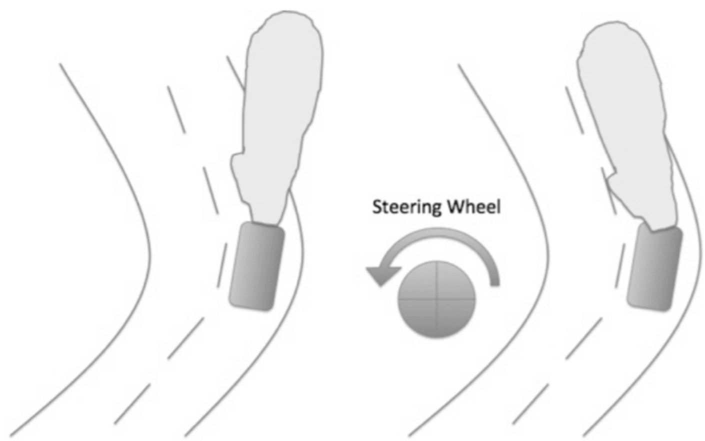


Figure 4.70 Curve lightening system [150].

4.4.2.1 Detection System

System uses vehicle speed sensor, steering wheel angle sensor, yaw rate sensor, radar, lidar and camera sensor system. Vehicle speed sensor, steering wheel angle sensor and yaw rate sensor are given in Chapter 2.3.1. Radar, lidar and camera sensor systems are given in Chapter 4.1.

4.4.2.2 Electronic Control System

Adaptive front lightening system provides movement of right, left, up and down direction according to the vehicle direction and vehicle yaw moment. System makes the line control for not to impress the other drivers. Line control data is taken from the line tracking system. Adaptive front lightening system algorithm is fuzzy control algorithm. It is given in Chapter 3.2.4.3.

On the other hands, some manufacturers develop new technology for front lightening. For instance, Mercedes develops new technology and its name is dipped beam system [151]. This system detects the vehicle and they use five different methods for lightening [151]. Dipped beam system is given in Figure 4.71.

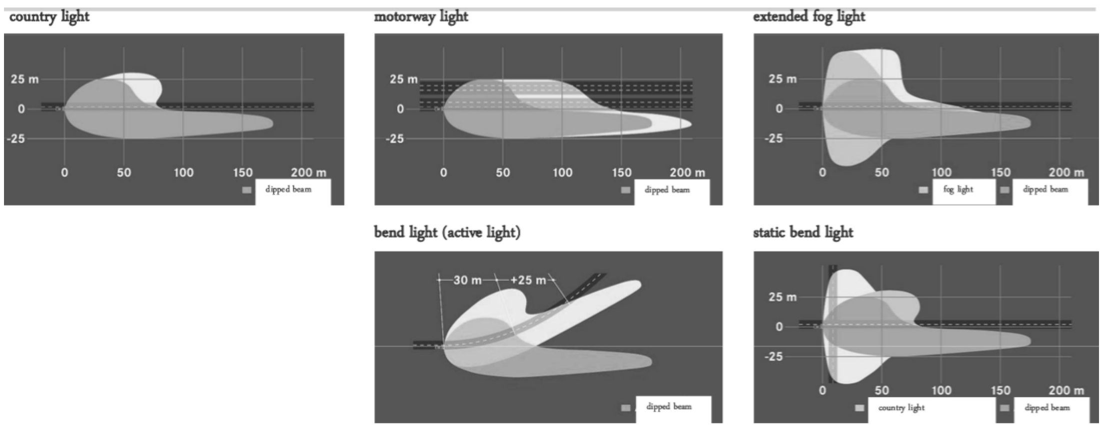


Figure 4.71 Adaptive dipped beam system [151].

Four samples for adaptive dipped beam system is given in Figure 4.72.

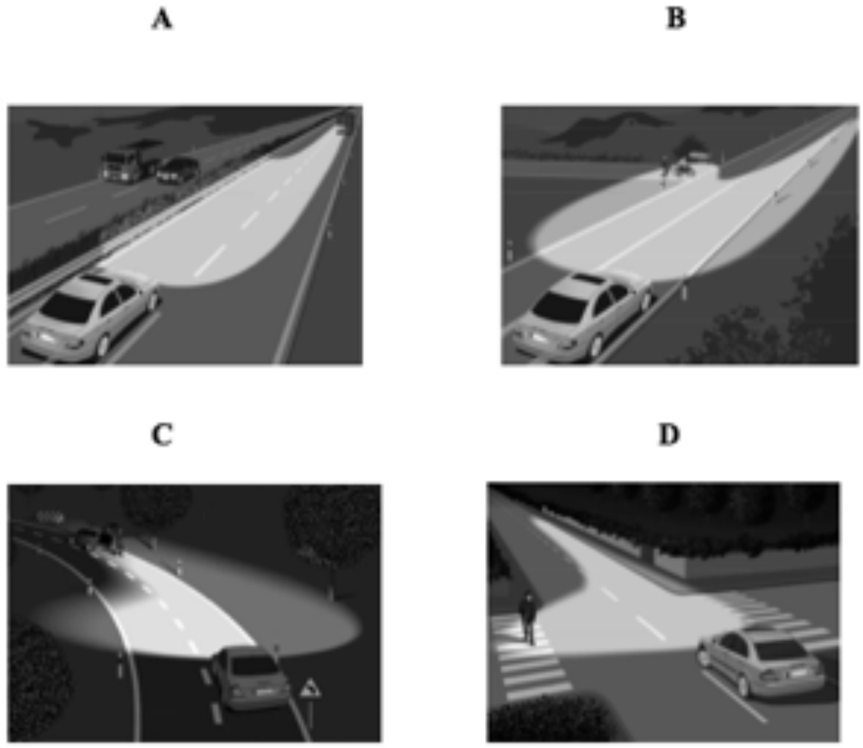


Figure 4.72 Mercedes adaptive dipped beam sample [151].

(A: Country light, B: Motorway light, C: Bend lighting,

D: Bend lighting due to additional light source.)

4.5 Other Driver Assistance System

4.5.1 Driver Alertness Monitoring

Driver state is one of the most important cases for driving. Accidents occur due to the fatigue, stress, sleepiness and similar systems. Sleepiness is one of the most important driver states. Because, if the driver sleeps, the risk of accidents increases. Therefore, it effects the safe driving. According to the International Traffic Safety Institution, the number of accident is 100000 due to the sleepiness and 1550 people died in 2008 [152].

Driver alertness monitoring system detects the driver's sleepiness and if there is a problem, system warns the driver. Some secondary systems can be used in case of sleepiness, for instance, lane departure warning system is a kind of sleep control system [153]. Driver alertness monitoring block system is given in Figure 4.73. System detects and analyzes with camera system. If there is a critical condition, system warns the driver with RF transceiver and monitor.

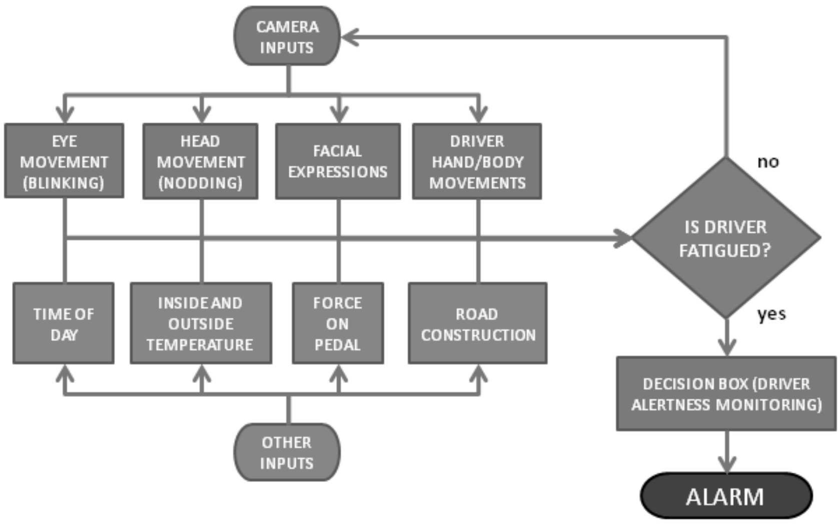


Figure 4.73 Driver alertness monitoring block system [153].

System detects eye movements, head movements, body movements and facial expressions with head. In addition, system finds day information, internal and external temperature, pedal power and road condition information. Finally, system analyzes the all information together and sleepiness is determined.

4.5.1.1 Detection System

System uses camera, steering angle sensor, pedal position sensor and vehicle speed sensor. Camera system is given in Chapter 4.1.3. Vehicle speed sensor and steering angle sensor are given in Chapter 2.3. Pedal position sensor is given in Chapter 2.8. System uses display, speaker, lights, seat belt tensioner, steering wheel vibrator, seat vibrator, hot air blower.

4.5.1.2 Electronic Control System

Driver alertness monitoring system uses many algorithms. Each technic has different assumption. For instance, steering control is the most important factor for some systems. However, vehicle speed data is not important for them. On the other hands, some system measures of the heart rhythm [152]. In this section, only eye and head movement algorithm are used.

Primarily, Adaboost technic is used for detects the eye movement. This technic uses Viola-jones algorithm. The sum of the images S (x,y);

$$S(x,y)=\frac{\sum_{x,y}[T(x,y)-I(x+x,y+y)]^2}{\sqrt{\sum_{x,y}T^2(x,y)\sum_{x,y}I^2(x+x,y+y)}} \qquad \textbf{(4.89)}$$

Where $T(x,y)$ is brightness intensity, $I(x,y)$ is brightness intensity for source image, T is template image and I is second image.

Every image is compared. Image is used for detection to the pupil. Therefore, every image is divided into four parts. Pupil is sign with limit pixel value. Generally, BioID technic is used for detection to the pupil.

BioID technic d_{eye};

$$d_{eye} = \frac{\max(\left|C_{left} - \bar{C}_{right}\right|\left|C_{right} - \bar{C}_{left}\right|}{\left|C_{left} - C_{right}\right|} \tag{4.90}$$

Where C_{left} and C_{right} are reel center position, $\bar{C}_{right}$ and $\bar{C}_{left}$ are estimated center position. Sample pupil position is given in Figure 4.74.

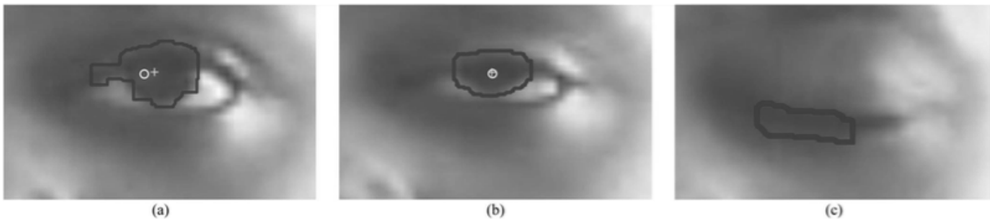


Figure 4.74 Sample pupil position [152].

Euler angles are used to estimate the position of head. 3D and 2D head model is used. When the case against each other. Scale factor s;

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} r_{11}\cdots & r_{13} & t_1 \\ r_{21}\cdots & r_{23} & t_2 \\ r_{31}\cdots & r_{33} & t_3 \end{pmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \tag{4.91}$$

Where X, Y, Z are 3D coordinate system, u,v are pixel coordinate, c_x, c_y are center of image, f_x, f_y are focal length, r_{ij} and t_i are dissal parameter. Lucas-Kanade technic is used for head position change. This method finds common points between the two video image. Limit value must be between 20 and 40. Three-way movement's equality. Rotation matrix R;

$$R = R_z(\varphi)R_y(\theta)R_x(\gamma) \tag{4.92}$$

Where φ, θ, γ are head position angles. In this detection system, driver does not use glasses.

CHAPTER 5

SIMULATION OF PEDESTRIAN TRACKING AND DETECTION SYSTEM

In this Chapter, we will simulate the pedestrian tracking and detection system with using the Matlab program. I examined Pedestrian Collision Warning System in Chapter 4. Pedestrian collision warning system has three main part. These are detection, tracking and warning [120, 121, 123-125]. In this regard, the best system detects the pedestrian on the crosswalk to reduce the error rate. Because of this, system must calculates lots of factor. For instance, vehicle velocity, pedestrian velocity... etc. However, in this Chapter, I will not focus on the pedestrian velocity, vehicle velocity and crosswalk. Just I will focus on the pedestrian on the road and the sidewalk.

Firstly, I will take the video images of the road. After that, I will analyze this video with global parameter. Simulation algorithm system has four main section. These are main system functions, system objects, initialize tracks, and people detection.

In this study, I used cell phone camera and Matlab R2016A program. I simulate pedestrian detection and tracking system in a video from a moving camera. I created a main function algorithm, after that I defined the sub category function. Firstly, I defined tracking system with global parameter and detected the objects who are pedestrian or not. After that, I controlled the objects that are right or not. If detection people is wrong, system deletes the file or if detection people is right, system shows the pedestrian on the display.

5.1 Algorithm of Main System Function

Firstly, I defined the video and scaled different pixels. For scaling pixels, ‘pedScaleTable’ parameter is used. Scale data stored in this command. The approximate Y-coordinate is calculated. Every data gives the best result for estimated person heigh. The approximate Y coordinate of the pedestrian's feet is reference point in this algorithm.

System functions are given in below.

```
function PedestrianTrackingDetection()
videoFile       = 'pedestrian.m4v';
scaleDataFile   = 'pedScaleTable.mat';
```

System detects and tracks with some parameter. These are ROI, scThresh, gating Thresh, gating Cost, cost Of Non Assignment, time Window Size, confidence Thresh, age Thresh, vis Thresh [154].

- *ROI;* ROI is the meaning of region of interest. That’s mean we define the region. After that we tracks and detects the pedestrian. This parameter blocks the analyze in unrelated fields. ROI in the form of [x y w h]. x and y are image starting coordinates, w is width and h is high of the image. In this example, maximum value of (w+x) is 1280 and maximum value of (h+y) is 720. Thus, we chose that x is equal to 40, w is equal to 1200, h is equal to 400 and y is equal to 200. ROI is given in Chapter 4. System ROI is given in Figure 5.1.

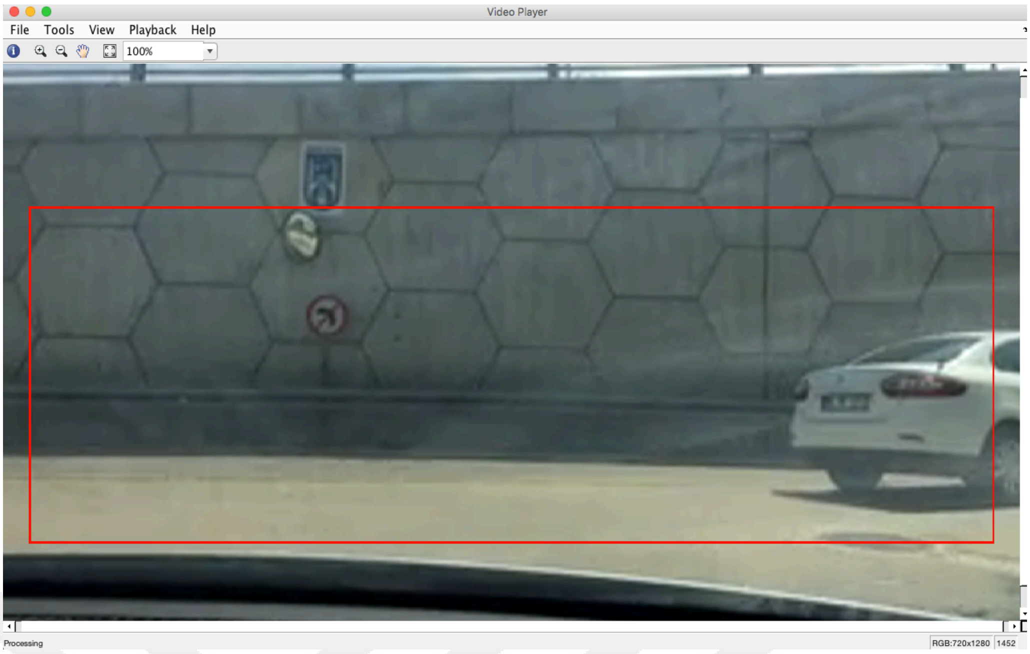


Figure 5.1 System ROI.

- *scThresh;* It is the meaning of scale treshold. Scale treshold helps us scale approaches. And it provides to the control of error tolerance for pedestrian detection and tracking.

- *gatingThresh;* This parameter is used for the distance measure. If detected bounding box and predicted bounding box exceeds the treshold value, data is wrong. So this data is deleted.

- *gatingCost;* This parameter is a matrix value for detection assignment. If this value can be higher, detection assignment is easier.

- *costOfNonAssignment;* With this parameter is tuned the control for a new track. It increases too low, system creates new track.

- *timeWindowSize;* This parameter is related to the reliability for the track.

- *confidenceThresh;* Level of reliability.

- *ageThresh;* Minimum length threshold of a track reliability.

- *visThresh;* Minimum visibility threshold.

Main system function is given in below [154].

```
function PedestrianTrackingDetection()
    videoFile       = 'pedestrian.m4v';
    scaleDataFile   = 'pedScaleTable.mat';

    obj = setupSystemObjects(videoFile, scaleDataFile);
    tracks = initializeTracks();


    nextId = 1;
    option.ROI                    = [40,200,1200,400];
    option.scThresh               = 0.3;
    option.gatingThresh           = 0.9;
    option.gatingCost             = 100;
    option.costOfNonAssignment    = 10;
    option.timeWindowSize         = 16;
    option.confidenceThresh       = 2;
    option.ageThresh              = 8;
    option.visThresh              = 0.6;
    while ~isDone(obj.reader);
          frame    = readFrame();
          [centroids, bboxes, scores] = detectPeople();
          predictNewLocationsOfTracks();
          [assignments, unassignedTracks, unassignedDetections] =
                detectionToTrackAssignment();
          updateAssignedTracks();
          updateUnassignedTracks();
          deleteLostTracks();
          createNewTracks();
          displayTrackingResults();
    ~isDone(obj.reader) && isOpen(obj.videoPlayer);
    End
```

5.1.1 System Objects

This system analyzes the video frame and reads the data source. At the same time, it detects the pedestrian and the result of detection will showed on the screen. System objects function uses some parameter. These are UprightPeople parameter, MinSize parameter, MaxSize parameter, Classification Threshold parameter, Scale Factor parameter, Window Stride parameter, Merge Detection parameter and ROI.

- *UprightPeople;* We set the people size. Matlab has two type people size. These are (128, 64) pixels and (96, 48) pixels. We used (96, 48) pixels [154].

- *MinSize;* It is minimum pixel value for the people. This pixel value is related to the processing time. We use minimum size (96, 48) pixels.

- *MaxSize;* It is maximum pixel value fort he people. And also, it is related to the processing time. We use maximum size (576, 384) pixels.

- *ClassificationThreshold;* For the multiscale detection, sub category classification is controlled by this parameter. For the people detection, threshold value is set higher than nominal value. Classification threshold parameter is used for the error detetction. Nominal value is 1 in Matlab program [154].

- *Scale Factor;* This parameter is used on the image scaling. It is set lowest value for reliability. But it is higher than 1.0001. Nominal value is 1.05 in Matlab program [154].

- *Window Stride;* It is used to scroll the images. Step size is shown as (x,y). If the step size is short, sensitivity increases. We use [8 8] step size.

- *Merge Detection;* This parameter combines similar detection footage. Because of that, it is closed. When it is opened, detection is low.

System objects functions are given in below.

```
function obj = setupSystemObjects(videoFile,scaleDataFile)
            obj.reader = vision.VideoFileReader(videoFile,
        'VideoOutputDataType', 'uint8');
            obj.videoPlayer = vision.VideoPlayer('Position',
        [2, 370, 1290, 750]);
            obj.peopleDetector = vision.PeopleDetector
        ('UprightPeople_96x48','MinSize',[96,48],...
            'MaxSize',[576,384], 'ClassificationThreshold', 1,
        'ScaleFactor', 1.12,'WindowStride',[16 16],...
        'MergeDetections',false,'UseROI', true);
        ld = load(scaleDataFile, 'pedScaleTable');
        obj.pedScaleTable = ld.pedScaleTable;
end
```

5.1.2 Initialize Tracks

This function creates an array of tracks. It stores the tracks data. And it uses some parameter for it. These are id, color, scores, kalman filter, age, totalVisibleCount, confidence, predPosition.

- *id;* Tracking number.

- *color;* Tracking color.

- *scores;* Total detection number.

- *kalman filter;* It is a filter for moving object. It is given in Chapter 4.

- *age;* Number of frames since initialize tracks.

- *totalVisibleCount;* Total number of visible detection.

- *confidence;* It stored last data and it is related to reliability.

- *predPosition;* The predicted bounding box in the next frame.

Initialize tracks function is given in below.

```
function tracks = initializeTracks()
    tracks = struct('id', {}, 'color', {}, 'bboxes', {},...
    'scores', {}, 'kalmanFilter', {}, 'age', {},...
    'totalVisibleCount', {}, 'confidence', {}, ...
    'predPosition', {});
end
function frame = readFrame()
      frame = step(obj.reader);
end
```

5.1.3 People Detection and Tracking

Firstly, image is read from the recorded video.

~isDone(obj.reader)

After that, detection and tracking system are created with while loop. This while loop's steps are given in below.

- Read frame,

- People is detected,

- Predict new location of existing tracks,

- Assign detection to tracks,

- Assigned tracks are updated,

- Unassigned tracks are updated,

- Lost tracks are deleted,

- New tracks are created,

- Display.

5.1.3.1 Read Frame On The Recorded Video

This parameter uses ‘readFrame’ command.

```
frame    = readFrame();
```

5.1.3.2 People is Detected

Three different algorithm are used in Matlab for detect people. These are centroids, bboxes and scores.

- *centroids*; It is a N by 2 matrix and it’s formed is [x,y]. It gives information of object center.

- *bboxes;* It is the meaning of bounding box. Bboxes is a N by 4 matrix and it’s formed is [x, y, width, heigh].

- *scores;* It is classification score at the corresponding frame and it is a N by 1 vector.

ROI and gray scale are used in this system for detect people. Also, approximation calculation and estimation methods are used. Pedestrian ROI is given in Figure 5.2.

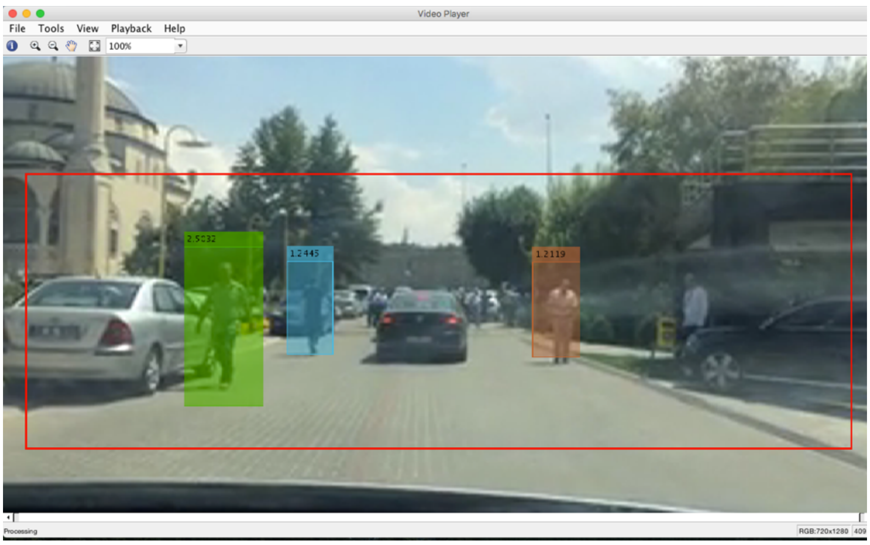


Figure 5.2 Pedestrian ROI.

System function is given in below.

```
function [centroids, bboxes, scores] = detectPeople()
      resizeRatio = 4;
      frame = imresize(frame, resizeRatio);
      [bboxes, scores] = step(obj.peopleDetector, rgb2gray(frame),
      option.ROI);
      height = bboxes(:, 4) / resizeRatio;
      y = (bboxes(:,2)-1) / resizeRatio + 1;
      yfoot = min(length(obj.pedScaleTable), round(y + height));
      estHeight = obj.pedScaleTable(yfoot);
      invalid = abs(estHeight-height)>estHeight*option.scThresh;
      bboxes(invalid, :) = []; scores(invalid, :) = [];
      [bboxes, scores] = selectStrongestBbox(bboxes, scores, ...
                          'RatioType', 'Min', 'OverlapThreshold',
                         0.1);
      if isempty(bboxes)
          centroids = [];
      else
          centroids = [(bboxes(:, 1) + bboxes(:, 3) / 2), ...
              (bboxes(:, 2) + bboxes(:, 4) / 2)];
      end
 end
```

5.1.3.3 Predict New Locations of Existing Tracks

Pedestrian is detected in previous Chapter. Now, we estimate the pedestrian's movement direction. Kalman filter is used. Kalman Filter is given in Chapter 4.

System algorithm is given in below.

```
function predictNewLocationsOfTracks()
      for i = 1:length(tracks)
          bbox = tracks(i).bboxes(end, :);
          predictedCentroid = predict(tracks(i).kalmanFilter);
          tracks(i).predPosition = [predictedCentroid -
          bbox(3:4)/2, bbox(3:4)];
      end
end
```

5.1.3.4 Assign Detections to Tracks

System calculates the overlap ratio between the predicted bounding box and the detected bounding box. Command of bboxOverlapRatio is used. Algorithm consists of two steps.

a- Calculate the cost of assign detection to track with using bboxOverlapRatio. If people move towards or away from the camera, this movement is not explained by center point. It is an M by N matrix. M is the number of tracks and N is the number of detection.

b- The assignment problem represented is solved by |assignDetectionsToTracks| function.

If function value is set too low, lots of new tracks are created and it causes in track fragmentation. If function is set too high, just one track is created. Because of that value must be medium.

Hungarian algorithm is used in this function. It is used to solve the problem of assignment algorithm. A M by 2 Hungarian matrix is used.

System algorithm is given in below.

```
function [assignments, unassignedTracks, unassignedDetections] =
         detectionToTrackAssignment()
         predBboxes = reshape([tracks(:).predPosition], 4, [])';
         cost = 1 - bboxOverlapRatio(predBboxes, bboxes);
         cost(cost > option.gatingThresh) = 1 +
         option.gatingCost;
         [assignments, unassignedTracks, unassignedDetections] =
         assignDetectionsToTracks(cost,
         option.costOfNonAssignment);

end
```

5.1.3.5 - Assigned Tracks are Updated

Each assigned track data updates. Correct the location estimate is made by Kalman filter. Kalman filter is given in Chapter 4. After the correct the location estimate, the average of the previous 4 bounding box are taken. So new bounding box is created. System updates the time of tracking, sum of the tracking, total visible count and time window size datas. According to these values are determined the reliability of the system.

Update assigned tracks function are given in below.

```
function updateAssignedTracks()
        numAssignedTracks = size(assignments, 1);
    for i = 1:numAssignedTracks
        trackIdx = assignments(i, 1);
        detectionIdx = assignments(i, 2);
        centroid = centroids(detectionIdx, :);
        bbox = bboxes(detectionIdx, :);
        correct(tracks(trackIdx).kalmanFilter, centroid);
        T = min(size(tracks(trackIdx).bboxes,1), 4);
        w = mean([tracks(trackIdx).bboxes(end-T+1:end, 3);
        bbox(3)]);
        h = mean([tracks(trackIdx).bboxes(end-T+1:end, 4);
        bbox(4)]);
        tracks(trackIdx).bboxes(end+1, :) = [centroid - [w,
        h]/2, w, h];
        tracks(trackIdx).age = tracks(trackIdx).age + 1;
        tracks(trackIdx).scores = [tracks(trackIdx).scores;
        scores(detectionIdx)];
        tracks(trackIdx).totalVisibleCount = ...
        tracks(trackIdx).totalVisibleCount + 1;
        T = min(option.timeWindowSize,
        length(tracks(trackIdx).scores));
        score = tracks(trackIdx).scores(end-T+1:end);
        tracks(trackIdx).confidence = [max(score), mean(score)];
    end

  end
```

5.1.3.6 Unassigned Tracks are Updated

This function marks the unassigned tracks as invisible and their number starts one. System functions are given in below.

```
function updateUnassignedTracks()
      for i = 1:length(unassignedTracks)
          idx = unassignedTracks(i);
          tracks(idx).age = tracks(idx).age + 1;
          tracks(idx).bboxes = [tracks(idx).bboxes;
          tracks(idx).predPosition];
          tracks(idx).scores = [tracks(idx).scores; 0];
          T = min(option.timeWindowSize,
          length(tracks(idx).scores));
          score = tracks(idx).scores(end-T+1:end);
          tracks(idx).confidence = [max(score), mean(score)];
      end
end
```

5.1.3.7 Lost Tracks are Deleted

This system should delete invisible tracks if it has too many consecutive frames. In this way, some wrong tracks are deleted. That's mean, short time tracking and lots of consecutive frames for one tracks are deleted.

Delete lost tracks functions are given in below.

```
function deleteLostTracks()
      if isempty(tracks)
          return;
      end
      ages = [tracks(:).age]';
      totalVisibleCounts = [tracks(:).totalVisibleCount]';
      visibility = totalVisibleCounts ./ ages;
      confidence = reshape([tracks(:).confidence], 2, [])';
      maxConfidence = confidence(:, 1);
      lostInds = (ages <= option.ageThresh & visibility <=
      option.visThresh) | (maxConfidence <=
      option.confidenceThresh);
      tracks = tracks(~lostInds);

end
```

5.1.3.8 New Tracks are Created

New tracks are created for unassigned detection. System functions are given in below.

```
function createNewTracks()
      unassignedCentroids = centroids(unassignedDetections, :);
      unassignedBboxes = bboxes(unassignedDetections, :);
      unassignedScores = scores(unassignedDetections);
      for i = 1:size(unassignedBboxes, 1)
          centroid = unassignedCentroids(i,:);
          bbox = unassignedBboxes(i, :);
          score = unassignedScores(i);
          kalmanFilter = conFigureKalmanFilter('ConstantVelocity',
                         centroid, [2, 1], [5, 5], 100);
          newTrack = struct(...
              'id', nextId, ...
              'color', 255*rand(1,3), ...
              'bboxes', bbox, ...
              'scores', score, ...
              'kalmanFilter', kalmanFilter, ...
              'age', 1, ...
              'totalVisibleCount', 1, ...
              'confidence', [score, score], ...
              'predPosition', bbox);
          tracks(end + 1) = newTrack;
          nextId = nextId + 1;
      end

  end
```

5.1.3.9 Display

Pedestrian detection and tracking are determined. Finally, these datas are shown on the display. Display functions are given in below.

```
function displayTrackingResults()
      if ~isempty(tracks),
          ages = [tracks(:).age]';
          confidence = reshape([tracks(:).confidence], 2, [])';
          maxConfidence = confidence(:, 1);
          avgConfidence = confidence(:, 2);
          opacity = min(0.5,max(0.1,avgConfidence/3));
          noDispInds = (ages < option.ageThresh & maxConfidence <
```

```
            option.confidenceThresh) |(ages < option.ageThresh / 2);
            for i = 1:length(tracks)
                if ~noDispInds(i)
                    frame = insertShape(frame, ...
                    'FilledRectangle', tracks(i).bboxes(end, :), ...
                    'Color', tracks(i).color, ...
                    'Opacity', opacity(i));
                    frame = insertObjectAnnotation(frame, ...
                    'rectangle', tracks(i).bboxes(end, :), ...
                     num2str(avgConfidence(i)), ...
                     'Color', tracks(i).color);
                end
            end
        end

        frame = insertShape(frame, ...
       'Rectangle', option.ROI, ...
       'Color', [255, 0, 0], 'LineWidth', 3);
        step(obj.videoPlayer, frame);

    end
```

5.2 End of the Simulation

I created all algorithm step by step in this simulation. Firstly, system function is wrote. After that pedestrian detection and tracking algorithms are created.

This simulation shows how the pedestrian detects and tracks. I get some error in this simulation. Because, used filters are not enough for this detection and tracking. System must know people behavior in society for minimum error rate. Moreover, maybe I can use some different filters, thus error rate will be decrease.

In Chapter 4, pedestrian collision warning system is given. This collision warning system has lots of main section. For instance, system needs to calculate lots of factor on the road. Hovewer, in this Chapter, I just analyze detection and tracking of the pedestrian. Because of that, I could not use many filter and algorithm. Image of pedestrian tracking and detection system are given in Figure 5.3a and Figure 5.3b.

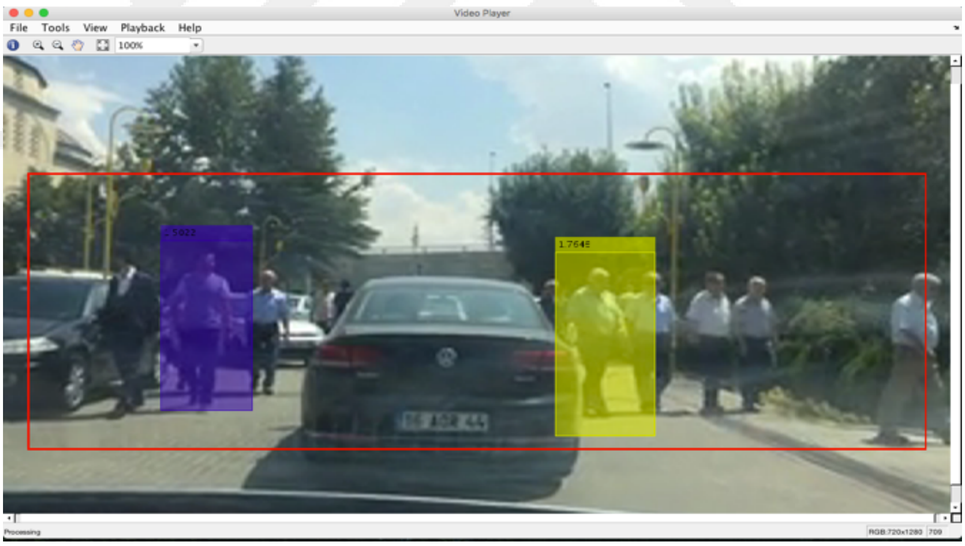


Figure 5.3a Pedestrian tracking and detection system sample image.

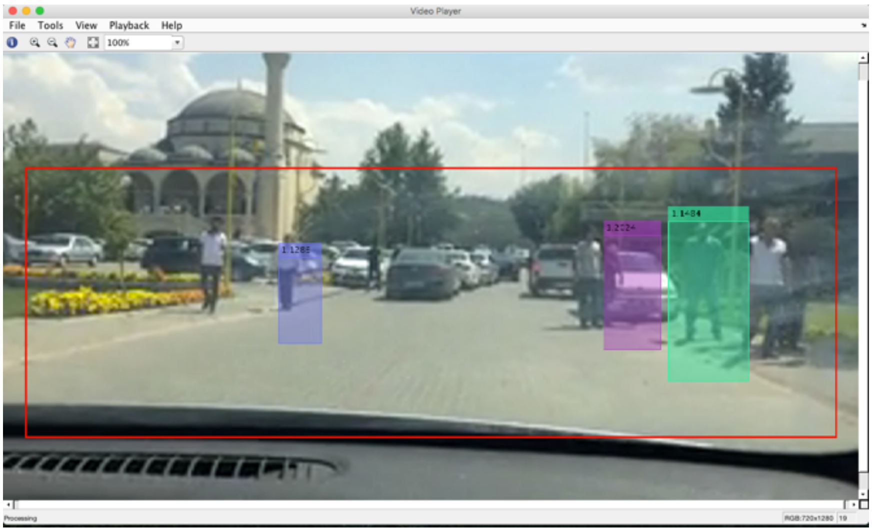


Figure 5.3 Pedestrian tracking and detection system sample image.

CHAPTER 6

CONCLUSION AND FUTURE WORK

Considering development process of automotive industry, the most important role appears to play of electronic system. Vehicles were developed with the use of mechanical parts until the first half of the 20th century. However, according to the research, electronic systems have played an important role in the development of automotive in the last quarter of century. Nowadays, almost all the mechanical parts of the vehicle are automized. A major role in this automation process is played by general electronic systems. Because, electronic systems are more useful systems than mechanic systems.

In this research, important systems of the automotive electronics are examined. Generally, automotive electronics are composed of three main sections. These are general systems, safety systems and ADAS system. Similarities of these systems are their depanding on comfort and safety. In this thesis, suspension system, vibration system, engine system, navigation system and similar systems are examined as general systems. These systems generally help the driver to use basic comfort applications such as; electronic steering wheel. ABS, ASR, ESP and similar braking systems are given as safety systems. Safety systems must have high level standarts. Because, if the safe system have error, the safety of vehicle will jeopordise. Thus safety systems are the most important systems of vehicles. Third system is ADAS system. These systems assist the driver for safety driving. And there are four main parts of them. They are lateral system, longitudinal system, lightening system and other systems. Actually, ADAS consists of sensor systems, control system, braking system and actuators. Electronic sensors can be used in almost all mechanical and electronic systems. Sensors detect the distance, temperature, speed, position, tracking and similar measurement statement. Control systems are used to make calculation, to to operate determination system, to check line control and to conduct similar control processes. Braking systems are used as to control the vehicle. Braking system is the most important system for vehicle. Because, if there is any error in operating system of the brake system, risk of the fatal accident increases. Finally, above mentioned system uses actuators for warning the driver.

Additionally, automatic systems are used in automotive in the future. Nowadays, BMW, Tesla, Google and Mercedes work to use developing this technology and they want to make autopilot. Because of that, in the future, electronic systems mostly are used. Autopilot system uses hdyraulic, mechanic and electronic system. Actually, autopilot uses advanced artificial intelligence.

As a result, in this study, the researcher examine the detection system, control system, warning system and how these systems work in automotive electronic systems. One of the most developing system in the automotive industry is ADAS system. In near future, it should be said that many ADAS systems will be mandatory to use in the automotive industry. Developed countries therefore attach great importance to these system. Because, the field of automotive electronics are developing industry and future of the automotive industry depands on the development of electronic system. However, in the developing countries, exactly the opposite situation occurs with respect to the developed countries.

Finally, it should be emphasized that the future studies should consider conducting research on each aspect of the automotive electronic systems, because each system needs to be examined seperately due to sweeping nature of the field to explore.

REFERENCES

[1] Bellis, Mary., " *The History of the Automobile [online*]", http://inventors.about.com/library/weekly/aacarssteama.htm?p=1, [Ziyaret tarihi: 13.12.2015].

[2] Thalen, J.P., "*ADAS for the Car of the Future- Interface Concepts for Advanced Driver Assistant Systems in a Sustainable Mobility Concept of 2020",* Bachelor of Assignment, Faculty of Engineering Technology Industrial Design University of Twente, 2006.

[3] Clemson Vehicular Electronics Laboratory, *"Automotive Electonics [online]",* http://www.cvel.clemson.edu/auto/systems/auto-systems.html, [Ziyaret tarihi: 05.04.2015].

[4] Ribbens William B., *"Understanding Automotive Electronics"*, (6th ed.), Butterworth–Heinemann, United States of America, 1998.

[5] Hailong, ZHANG, & Enrong, WANG, & Fuhong, MIN, & Rakheja, SUBASH, & Chunyi, SU, *"*Skyhook-based Semi-active Control of Full-vehicle Suspension with Magneto-rheological Dampers*"*, "Chinese journal of mechanical engineering", Vol.26, No 3, page 498-505, 2013.

[6] Clemson Vehicular Electronics Laboratory, *"Active Suspension [online]",* http://www.cvel.clemson.edu/auto/systems/active_suspension.html, [Ziyaret tarihi: 07.04.2015].

[7] Akhtar Munaim, & Alam Shahnawaz, & Mohd Faiz, *"Fuzzy rules incorporated skyhook theory based vehicular suspension design for improving ride comfort", "Int. Journal of Engineering Research and Applications",* Vol. 5, Issue 5, (Part -2), Page 30-36, May 2015.

[8] Nguyen Le Hoa, & Park Seonghun, & Turnip Arjon, & Hong Keum-Shik, "*Application of LQR Control Theory to the Design of Modified Skyhook Control Gains for Semi-Active Suspension Systems",* ICROS-SICE International Joint Conference, 2009, Fukuoka International Congress Center, Japan, August 18-21, 2009.

[9] Clemson Vehicular Electronics Laboratory, *"Active Vibration Control [online]",* http://www.cvel.clemson.edu/auto/systems/active_vibration_control.html, [Ziyaret tarihi: 05.03.2015].

[10] Accurion Scientific Instruments, *"Passive and active vibration isolation systems [online]"*, http://physics-animations.com/Physics/English/spri_txt.htm, [Ziyaret tarihi: 10.03.2015].

[11] Bianchini Emanuele, *"Active Vibration Control of Automotive Steering Wheels"*, SAE International, 01-2546, 2005.

[12] Contitech, *"Actively Compensating for Vibrations [online]"*, http://www.contitech-megi.com/pages/current/press/2008/080527_schwingung/presse_en.html, [Ziyaret tarihi: 02.04.2015].

[13] Svaricek, Ferdinand., & Fueger, Tobias, & Karkosch, Hans-Juergen., & Marienfeld, Peter., & Bohn, Christian., *Automotive Applications of Active Vibration Control,* Habitability of Combat and Transport Vehicles: Noise Vibration and Motion, October 2004, Prag, Croatia: Sciyo, 303-318, 2010.

[14] Yildiz Teknik Universitesi, *"Aktuatorler [online]"*, http://www.yildiz.edu.tr/~sandalci/dersnotu/alg/7Aktuator.pdf, [Ziyaret tarihi: 04.04.2015].

[15] Firdaus, Mohd.,*"The Inertial Electromagnetic Actuator [online]",* Malaysia, http://asivr.ump.edu.my/index.php?option=com_content&view=article&id=126:the-inertial-electromagnetic-actuator&catid=50:list-of-articles&Itemid=97 [04.04.2015].

[16] Cinquemani Simone, and Resta Ferruccio, and Monguzzi Massimo, *"Limits on the use of inertial actuators in active vibration control"*, Politecnico di Milano, 2007.

[17] Winberg, Mathias., & Johansson, Sven., & Claesson., Ingvar, "Inertial mass actuators, understanding and tuning", Department of Signal Processing, Sweden.

[18] Anwar Sohel, "*Yaw Stability Control of an Automotive Vehicle via Generalized Predictive Algorithm",* American Control Conference, June 8-10, 2005. Portland, OR, USA, 435-440,2005.

[19] Clemson Vehicular Electronics Laboratory, *"Active YAW Control [online]",* http://www.cvel.clemson.edu/auto/systems/yaw-control.html, [Ziyaret tarihi: 05.03.2015].

[20] Denton Tom, *"Automobile Electrical and Electronic Systems",* (3th Edition), Butterworth-Heinemann, Great Britain,2004.

[21] Bonnick Allan, *"Automotive Computer Controlled Systems",* Butterworth-Heinemann, Great Britain, 2001.

[22] Ozcetin Gokhan., *"Batarya Yönetim Sistemi Nedir? [online]"*, http://www.volrad.com.tr/volblog/batarya-yonetim-sistemi-nedir/, [Ziyaret tarihi: 10.03.2015].

[23] Clemson Vehicular Electronics Laboratory, *"Battery Management System [online]",* http://www.cvel.clemson.edu/auto/systems/battery_management.html, [Ziyaret tarihi: 10.03.2015].

[24] Electropaedia, *"Battery Management System [online]"*, United Kingdom, http://www.mpoweruk.com/bms.htm, [Ziyaret tarihi: 10.03.2015].

[25] Engineering, *"Battery Management System [online]"*, http://www.engineering.com/ProductShowcase/BatteryManagementSystems.aspx, [Ziyaret tarihi: 11.03.2015].

[26] BMW, *"Intelligent Battery Sensor (IBS)[online]",* http://www.bimmerscan.com/bmw-intelligent-battery-sensor-ibs/, [Ziyaret tarihi: 11.03.2015].

[27] Lohmeier Christopher, and Veik, Tom, *"Battery Management With an Intelligent Battery Sensor is Vital to the Success of Future Automotive Designs[online]",* http://www.batterypoweronline.com/main/articles/battery-management-with-an-intelligent-battery-sensor-is-vital-to-the-success-of-future-automotive-designs/), [Ziyaret tarihi: 11.03.2015].

[28] Clemson Vehicular Electronics Laboratory, *"Communication Systems [online]",* http://www.cvel.clemson.edu/auto/systems/communications.html, [Ziyaret tarihi: 15.03.2015].

[29] Delgrossi Luca, *"The Future of the Automobile Vehicle Safety Communications[online]"*, http://docplayer.net/2410000-The-future-of-the-automobile-vehicle-safety-communications-stanford-university-me302-luca-delgrossi-ph-d-april-1-2014.html, [Ziyaret tarihi: 22.06.2015].

[30] Clemson Vehicular Electronics Laboratory,*"Dedicated Short Range Communications [online]",*http://www.cvel.clemson.edu/auto/systems/dsrc.html, [Ziyaret tarihi: 12.05.2015].

[31] Automobile electrical system, *"Basics of Controller Area Network (CAN)bus [online]"*, https://autoelectricalsystems.wordpress.com/2015/11/10/basics-of-controller-area-network-can-bus-part-1/, [Ziyaret tarihi: 11.12.2015].
[32] Samanci Baris, *"CAN Bus nedir? CAN protokolü incelemesi [online]"*, http://www.barissamanci.net/Makale/15/can-bus-nedir-can-protokolu-incelemesi/, [Ziyaret tarihi: 2.12.2015].
[33] BOSH, *"Steering systems [online]"*, http://products.bosch-mobility-solutions.com/en/de/driving_safety/driving_safety_systems_for_passenger_cars_1/steering_systems/steering_systems_1.html, [Ziyaret tarihi: 13.12.2015].
[34] Clemson Vehicular Electronics Laboratory, *"Electronic Power Steering [online]",* http://www.cvel.clemson.edu/auto/systems/ep_steering.html, [Ziyaret tarihi: 10.10.2015].
[35] Clemson Vehicular Electronics Laboratory, *"Seat Position Controls [online]"*, http://www.cvel.clemson.edu/auto/systems/seat_position_control.html, [Ziyaret tarihi: 14.10.2015].
[36] Clemson Vehicular Electronics Laboratory, *"Electronic Throttle Control [online]",* http://www.cvel.clemson.edu/auto/systems/throttle_control.html, [Ziyaret tarihi: 14.10.2015].
[37] Pico Technology, *" Electronic Throttle Control [online]"*, https://www.picoauto.com/library/training/electronic-throttle-control-drive-by-wire-or-fly-by-wire, [Ziyaret tarihi: 21.10.2015].
[38] T.C. Milli Egitim Bakanligi, *"Motorlu Araclar Teknolojisi Motor işletim Sistemleri",* Ankara, 2013.
[39] Clemson Vehicular Electronics Laboratory, *"An Experimental Demonstration of Electronic Throttle Control [online]",* http://www.cvel.clemson.edu/auto/systems/throttle_control_demo.html, [Ziyaret tarihi: 15.11.2015].
[40] Clemson Vehicular Electronics Laboratory, *"Engine Control [online]",* http://www.cvel.clemson.edu/auto/systems/engine_control.html, [Ziyaret tarihi: 07.09.2015].

[41] Clemson Vehicular Electronics Laboratory, *“Navigation system [online]”*, http://www.cvel.clemson.edu/auto/systems/navigation.html, [Ziyaret tarihi: 10.09.2015].

[42] Elektrikport, *“GPS nedir? [online]”*, http://www.elektrikport.com/teknik-kutuphane/gps-nedir-yapisi-ve-uygulamalari/4276#ad-image-0, [Ziyaret tarihi: 05.12.2015].

[43] Clemson Vehicular Electronics Laboratory, *“Remote Keyless Entry Systems [online]”,* http://www.cvel.clemson.edu/auto/systems/remote_keyless_entry.html, [Ziyaret tarihi: 03.12.2015].

[44] Clemson Vehicular Electronics Laboratory, *“Security Systems [online]”*, http://www.cvel.clemson.edu/auto/systems/security_systems.html, [Ziyaret tarihi: 07.11.2015].

[45] Clemson Vehicular Electronics Laboratory, *“Transmission Control [online]”,* http://www.cvel.clemson.edu/auto/systems/transmission_control.html, [Ziyaret tarihi: 01.11.2015].

[46] Gilbert Ken, *“Automotic Transmission [online]”,* http://ken-gilbert.com/wrx/STi_Manual/08.%20MECHANISM%20AND%20FUNCTION/33.%20AUTOMATIC%20TRANSMISSION/13.%20Transmission%20Control%20Module%20(TCM).pdf, [Ziyaret tarihi: 11.08.2015].

[47] Clemson Vehicular Electronics Laboratory, *“Airbag Deployment Systems [online]”* http://www.cvel.clemson.edu/auto/systems/airbag_deployment.html, [Ziyaret tarihi: 03.07.2015].

[48] Gagnon Steve, *“The Element Sodium [online]”,* http://education.jlab.org/itselemental/ele011.html, [Ziyaret tarihi: 03.07.2015].

[49] T.C. Milli Egitim Bakanligi, *“Motorlu Araclar Teknolojisi Fren Sistemleri”,* Ankara, 2013.

[50] Audi, *“ESP [online]”*, http://www.volkspage.net/technik/ssp/ssp/SSP_204.pdf, [Ziyaret tarihi: 03.10.2015].

[51] Rai Amit, and Kumar Sundeep, and Sood Hitesh, and Tomer Prashant, and Malhotra Deepanshu, *"Major Project Report on Electromagnetic Braking System[online]"*, http://www.campusoxide.com/skyDocumentView/ELECTROMAGNETIC-BRAKING-SYSTEM/804, [Ziyaret Tarihi: 04.02.2015].

[52] P. Sevvel, and V. Nirmal Kannan, and S. Mars Mukesh, *"Innovative Electro Magnetic Braking System"*, "International Journal of Innovative Research in Science, Engineering and Technology", *Volume 3, Special Issue 2,46-53, April 2014.*

[53] Scanlon Michael, *"Magnetic Braking [online]"*, https://www.wpi.edu/Pubs/E-project/Available/E-project-042412-145451/unrestricted/MQP_Magnetic_Braking_Final_Report.pdf,[Ziyaret Tarihi: 11.02.2016].

[54] Jou Min, and Shiau Jaw-Kuen, and Sun Chi-Chian, *"Design of a magnetic braking system",* "Journal of Magnetism and Magnetic Materials", 234-236, September 2006.

[55] Littmarck Fanny, and "*Simulating Eddy Current Brakes [online]", https://www.comsol.com/blogs/simulating-eddy-current-brakes/,* [Ziyaret Tarihi: 09.02.2016].

[56] Computer Simulation Technology, *"Magnetostatic Simulation of a Magnetic Brake [online]",* https://www.cst.com/Applications/Article/Magnetostatic-Simulation-Of-A-Magnetic-Brake, [Ziyaret Tarihi: 09.01.2016]

[57] Clemson Vehicular Electronics Laboratory, *"Tire Pressure Monitoring Systems [online]"*, http://www.cvel.clemson.edu/auto/systems/tpms.html, [Ziyaret Tarihi: 06.09.2015].

[58] Sham Man-Lung, & Gao Ziyang, and Leung Lydia Lap-Wai, and Chen Yu-Chih, and Chung Tom, *"Advanced Packaging Technologies for Automotive Electronics"*, "Material and Packaging Technologies Hong Kong Applied Science& Technology Research Institute (ASTRI)", 2007.

[59] Pirelli, *"Lastik Basinci Goruntuleme SIistemi (TPMS) Hayat Kurtarir [online]",*http://www.pirelli.com/tyre/tr/tr/news/2014/09/19/lastik-basinci-goruntuleme-sistemitpms-hayat-kurtarir/, [Ziyaret Tarihi: 09.12.2015].

[60] Bhivate Part Bharat, *"Modelling & Development of Antilock Braking System"*, Thesis (Bachelor), National Institute Of Technology.

[61] Isermann, Rolf., *"Handbook of Agricultural Engineering*", International Commission of Agricultural Engineering, USA, 2006.

[62] Robotik Sistem., *"Sicaklik Sensorleri [online]",* http://www.robotiksistem.com/sensor_cesitleri_sicaklik_sensorleri.html, [Ziyaret Tarihi: 17.10.2015].

[63] Xu Huadong, "*Simulation on TPMS Based On Neural Network PID Control"*, International Conference on Mechatronic Science, 2011, Jilin, China, 205-208, 2011.

[64] Clemson Vehicular Electronics Laboratory, *"Antilock Braking System [online]"*, http://www.cvel.clemson.edu/auto/systems/braking.html, [Ziyaret Tarihi: 05.06.2015].

[65] Nice Kerim., *"How Antilock Brakes Work [online]",* http://auto.howstuffworks.com/auto-parts/brakes/brake-types/anti-lock-brake2.htm, [Ziyaret Tarihi: 18.09.2015].

[66] Hoseinnezhad Reza, and Hadiashar Alireza Bab, *"Efficient Antilock Braking by Direct Maximization of Tire–Road Frictions"*, "IEEE Transactions On Industrial Electronics", Vol: 58, No: 8, 3593-3600, AUGUST 2011.

[67] Park Jinhyun, and Wang Bin, and Jeon Jaewook, and Hwang Sung-Ho, "*Hardware In the Loop Simulation For ABS Using 32-Bit Embedded System",* International Conference on Control, Automation and Systems, Oct. 26-29, 2011, Gyeonggi, Korea, 575-580, 2011.

[68] Dousti Morteza, and Başlamışlı S.Çağlar, and Onder Teoman, and Solmaz Selim*, "ABS Fren Dinamiğine Yönelik Çoklu Model Geçişli Kontrol Algoritmalarının Tasarımı",* Otomatik Kontrol Ulusal Toplantısı, 2013, Antalya, 2013.

[69] Jiapeng Han, and Xiaofeng Tang, *"Research on ABS and TPMS Merging System Based on Sliding Mode Variable Structure Control System",* International Forum on Computer Science-Technology and Applications, 340-342, 2009.

[70] Wei Cai Jian, and Liang Chu, and Feng Cheng Wei, and Yan-bo WANG, "*Modeling and Simulation of ABS Hydraulic Control Unit,* International Conference on Electronic & Mechanical Engineering and Information Technology", 2012, Paris, France, Atlantis Press, 1820-1823, 2012.

[71] Clemson Vehicular Electronics Laboratory, “Traction System [online]”, http://www.cvel.clemson.edu/auto/systems/traction_control.html, [Ziyaret Tarihi: 23.07.2015].

[72] Hrovat Davor, and Fodor Michael, *“Automotive Engine Based Traction Control [online]”,* http://ieeecss.org/sites/ieeecss.org/files/CSSIoCT2Update/IoCT2-SS-Hrovat-1.pdf, [Ziyaret Tarihi: 22.06.2015].

[73] Koker Pieter M., and Gouws J., and Pretorius L., *“Fuzzy Control Algorithm for Automotive Traction Control Systems”*, “IEEE”, 226-229, 1996.

[74] Vaezi Masoud, and Shoori J. Hesam, and Anwar Sohel, *“IMC-PID Traction Control System for an Automobile via Engine Torque Control”*, “IEEE”, 296-302, 2015.

[75] Hongzhi LI., and Liang LI, and Jian SONG, and Kaihui WU, and Yanjuan QIAO, and Xingchun LIU, and Yongguang XIA, *“Algorithm for Calculating Torque Base in Vehicle Traction Control System”*, “Chinese Journal Of Mechanical Engineering”, Vol:25, No:6, 130-136, 2012.

[76] Demir Abdullah, *“ASR (Anti Slip Regulation – Çekiş Kontrol Sistemi) nedir ve nasıl çalışır?[online]”*, http://www.otoguncel.com/teknik-bilgiler/asr-anti-slip-regulation-cekis-kontrol-sistemi-nedir-ve-nasil-calisir/, [Ziyaret Tarihi: 28.11.2015].

[77] Junwei Li, and Jian Wang, “*Research on the Automotive EBD System Based on Fuzzy Control”*, 2nd International Conference on Computer Engineering and Technology, 2010, 505-508, 2010.

[78] Clemson Vehicular Electronics Laboratory, *“Electronic Stability Control [online]”, http://www.cvel.clemson.edu/auto/systems/stability_control.html, [*Ziyaret Tarihi: *17.05.2015].*

[79] Li Huiming., and Du Yuyuan, “*Research on the vehicle ESP System in FPGA,* Chinese Control and Decision Conference”, 2010, page: 294-298, 2010.

[80] Khurana Prateek, and Arora Rajat, and Khurana Manoj Kr., “*Microcontroller based implementation of Electronic Stability Control for automobiles”,* IEEE International Conference on Advances in Engineering & Technology Research, 2014, India, 2014.

[81] iihs., "*Crash avoidance Technologies [online]",* http://www.iihs.org/iihs/topics/t/crash-avoidance-technologies/qanda#electronic-stability-control, [Ziyaret Tarihi: 02.11.2015].

[82] Piancastelli Luca, and Frizziero Leonardo, and Marcoppido Simone, and Pezzuti Eugenio, "*A Fuzzy Control Algorithm for the Electronic Stability Program optimized for tyre burst control*" ,1-17.

[83] Feiqiang Li, and Jun Wang, and Zhaodu Liu., "*On the Vehicle Stability Control for Electric Vehicle Based on Control Allocatio",* IEEE Vehicle Power and Propulsion Conference, September 3-5, 2008, Harbin, China, 2008.

[84] Zhao Meiyuan, *"Advanced Driver Assistant System[online]"*, http://www.intel.com/content/dam/www/public/us/en/documents/white-papers/advanced-driver-assistant-system-paper.pdf, [Ziyaret Tarihi: 04.04.2015].

[85] Gietelink Olaf, *"Design and Validation of Advanced Driver Assistance Systems",* TRAIL Research School, Netherlands, 2007.

[86] Golias John, and Yannis George, and Antoniou Constantinos, *"Classification of driver-assistance systems according to their impact on road safety and traffic efficiency",* "TRANSPORT REVIEWS", VOL. 22, NO. 2, 179-196, 2002.

[87] Texas Instruments, *"Advanced Driver Assistance Systems (ADAS)[online]"*, http://www.ti.com/lit/sl/slyy044a/slyy044a.pdf, [Ziyaret Tarihi: 12.07.2015].

[88] Furukawa Yoshimi, and Takeda Hiroshi, and Yuhara Naohiro, and Chikamori Sunao, and Sawada Toichi, "*Development of Predicting Evaluation Platform of Advanced Driver Safety Assist Systems using Integrated Virtual Traffic Environments"*, IEEE International Conference on Systems, Man and Cybernetics, 2004, 4041-4046, 2004.

[89] Kannan Saravanan, and Thangavelu Arunkumar, and Kalivaradhan RameshBab., *"An Intelligent Driver Assistance System (I-DAS) for Vehicle Safety Modelling using Ontology Approach"*, International Journal Of UbiComp (IJU), Vol.1, No.3, 15-32, 2010.

[90] O. Gietelink, and J. Ploeg, and B. De Schutter, and M. Verhaegen, "Development of advanced driver assistance systems with vehicle hardware in the loop simula tions", Vehicle System Dynamics, vol. 44, no. 7, pp. 569–590, July 2006.

[91] Stevens A., and Krems J. Brusque, *“Drivers adaptation to information and assistance systems”,* IET published book, 2013.

[92] Dugarry Alexandre, *“Advanced Driver Assistance Systems Information Management and Presentation”,* Thesis (PhD), School of Engineering, 2004.

[93] Jenn David, *“Radar Fundamentals [online]”*, http://faculty.nps.edu/jenn/Seminars/RadarFundamentals.pdf, [Ziyaret Tarihi: 20.10.2015].

[94] Henriksson Tomas, *“Driver Assistance Systems with focus on Automatic Emergency Brake”,* Thesis (Ms.C.), Aeronautical and Vehicle Engineering, 2011.

[95] Portland State University, *“Light Detection and Ranging (LIDAR) [online]”*, http://web.pdx.edu/~jduh/courses/geog493f12/Week04.pdfhttp://web.pdx.edu/~jduh/courses/geog493f12/Week04.pdf, USA, [Ziyaret Tarihi:04.12.2015].

[96] National Geospatial Agency, *“Light Detection and Ranging (LIDAR) Sensor Model [online]”*, United States Of America, http://www.gwg.nga.mil/focus_groups/csmwg/LIDAR_Formulation_Paper_Version_1.1_110801.pdf, [Ziyaret Tarihi: 02.01.2016].

[97] Amadou Maranga A., and Pous N., and Gingras D., and Vigneron V., *“Short Paper: Inter-vehicular distance improvement using position information in a collaborative adaptive cruise control system”*, IEEE Vehicular Networking Conference, 2013, 210-213,2013.

[98] Tseng Stephen P, and Liao Yung-Sheng, and Yeh Chih-Hsie, and Huang, Li-Kung, *“A DSP-based Lane Recognition Method for the Lane Departure Warning System of Smart Vehicles”,* Proceedings of the IEEE International Conference on Networking, Sensing and Control, 2009, Okayama, Japan, IEEE, 823-828,2009.

[99] Mammeri Abdelhamid, and Lu Guangqian, and Boukerche Azzedine., *“Design of Lane Keeping Assist System for Autonomous Vehicles”, IEEE, 2015.*

[100] Habib Shabana, and Hannan Mahammad A., *“Lane Departure Detection and Transmisson using Hough Transform Method”,* Przegland Elektrotechniczny, 141-146, 2013.

[101] Taban Omer., *“Median Filtre [online]”,* Turkey, http://omertaban.com/tag/median-filtre/, [Ziyaret Tarihi: 09.12.2015].

[102] Delen Murat., *"Hough Transform [online]",* Turkey, http://muratdelen.com/hough-transform/, [Ziyaret Tarihi: 10.09.2015].

[103] Duda R.O., and Hart P.E., *"Use of the Hough Transformation to Detect Lines and Curves in Picture",* Communication of Association for Computing Machinery, 15(1), 11-15, 1972.

[104] Aung Thanda, and Zaw Myo Hein, *"Video Based Lane Departure Warning System using Hough Transform",* International Conference on Advances in Engineering and Technology, March 29-30, 2014 Singapore, http://dx.doi.org/10.15242/IIE.E0314058, 85-88,2014.

[105] Kumar Rajiv, and Arthanariee A. M., *"A Comparative Study of Image Segmentation Using Edge-Based Approach*", International Journal of Mathematical, Computational, Physical, Electrical and Computer Engineering Vol:7, No:3, 320-324, 2013.

[106] An Xiangjing, and Shang Erke, and Song Jinze, and Li Jian, and He Hangen, *"Real-time lane departure warning system based on a single FPGA"*, EURASIP Journal on Image and Video Processing, http://jivp.eurasipjournals.com/content/2013/1/38, [Ziyaret Tarihi: 2013].

[107] Hanwell David, and Mirmehdi Majid, *"Detection Of Lane Departure On High Speed Roads",* International Conference on Pattern Recognition Applications and Methods, 529-536, 2012.

[108] Orderud Fredrik., *"Comparison of Kalman Filter Estimation Approaches for State Space Models with Nonlinear Measurements [online]",* https://www.researchgate.net/publication/268325603_Comparison_of_Kalman_Filter_Estimation_Approaches_for_State_Space_Models_with_Nonlinear_Measurements, [Ziyaret Tarihi:2015].

[109] Ozcan Fatih, "*HC-SR04 Ultrasonic Sensör ile Cisim Algılama ve Mesafe Ölçümü*", Turkey, http://www.mcu-turkey.com/hc-sr04-ultrasonic-sensor-ile-cisim-algilama-ve-mesafe-olcumu/, [Ziyaret Tarihi: 11.12.2015].

[110] Jifei Hao, and Xiang Li, and Dashun Yan., *"A Multisensor Fusing System on Ultrasonic Sensors",* 0-7803-5396, 140-143. 1999.

[111] Lee ChoonYoung, and Choi Ho-Gun, and Park Jun-Sik, *"Collision Avoidance by the Fusion of Different Beam-width Ultrasonic Sensors"* , IEEE SENSORS 2007 Conference, 985-988, 2007.

[112] Bengtsson Johan., *"Adaptive Cruise Control and Driver Modeling"*, Lund University, Sweden, 2001.

[113] Liang Chi-Ying., & Peng Huei., *"Optimal Adaptive Cruise Control with Guaranteed String Stability"*, Vehicle System Dynamics, 31, 313–330, 1999.

[114] Lee John D, and McGehee Daniel V, & Brown Timothy L., and Reyes, Michelle L., *"Collision Warning Timing, Driver Distraction, and Driver Response to Imminent Rear-End Collisions in High Fidelity Driver Simulator",* Human Factors and Ergonomics Society, Vol. 44, No.2, 314-334, 2002.

[115] Lee K., and Peng, H., *"Evaluation of automotive forward collision warning and collision avoidance algorithms", Vehicle System Dynamics,* Vol. 43, No. 10, 735–751, 2005.

[116] Clemson Vehicular Electronics Laboratory, "Idle Stop-Start Systems [online]", http://www.cvel.clemson.edu/auto/systems/autostart-stop.html, [Ziyaret Tarihi: 07.08.2015].

[117] Aarathy M.S., and Abinaya S., *"Efficacious Idle Stop and System in Automobiles Using Intelligent Traffic Control Algorithm",* IEEE, 978-1-4799-6085, 2015.

[118] Weissler Paul, *"AGM battery takes primary role for idle stop-start in microhybrids [online]", United States Of America, http://articles.sae.org/10667/, [Ziyaret Tarihi: 12.01.2016].*

[119] Hollingsworth Noel, and Meyer, Jason, and McGee Ryan, and Doering Jeffrey, and Konidaris George, and Kaelbling Leslie, *"Optimizing a Start-Stop Controller using Policy Search"*, Association for the Advancement of Artificial Intelligence, 2014.

[120] Straughn Stacie M., and Gray Rob, and Tan Hong Z., *"To Go or Not to Go: Stimulus-Response Compatibility for Tactile and Auditory Pedestrian Collision Warnings"*, IEEE TRANSACTIONS ON HAPTICS, VOL. 2, NO. 2, 111-117, 2009.

[121] Suzuki Shigetaka, and Raksincharoensak Pongsathorn, and Shimizu Ikuko, and Nagai Masao, and Adomat Rolf, *“Sensor Fusion-Based Pedestrian Collision Warning System with Crosswalk Detection”,* IEEE Intelligent Vehicles Symposium, 2010, San Diego, IEEE, 355-360, 2010.

[122] Bonnin Sarah, and Weisswange Thomas H., and Kummert Franz, and Schmuedderich Jens, *“Pedestrian Crossing Prediction using Multiple Context-based Models”*, IEEE 17th International Conference on Intelligent Transportation Systems, 2014, Qingdao, IEEE, 378-385, 2014.

[123] Nicolao Giuseppe De., and Ferrara Antonella, and Giacomini Luisa, *“Onboard Sensor-Based Collision Risk Assessment to Improve Pedestrians’ Safety”*, IEEE Transactions On Vehicular Technology, VOL. 56, NO. 5, 2405-2413, 2007.

[124] Mohebbi Rayka, and Gray Rob, and Tan Hong Z., *“Driver Reaction Time to Tactile and Auditory Rear-End Collision Warnings While Talking on a Cell Phone”,* Human Factors and Ergonomics Society, Vol. 51, No. 1, 102-110, 2009.

[125] Kallakuri Sankalp, and Kondra Shripad, and S. Sridhar, and Bhat Sathyanarayan, and Singh Jitesh K., *“Accuracy Enhancement and False Acceptance Reduction in Multiple Pedestrian Detection and Tracking”, 5th International Conference-Confluence The Next Generation Information Technology Summit,* IEEE, 709-714, 2014.

[126] Phan Minh Tien, and Fremont Vincent, and Thouvenin Indira, and Sallak Mohamed, and Cherfaoui Véronique, *“Estimation of Driver Awareness of Pedestrian based on Hidden Markov Model”,* 5. IEEE Intelligent Vehicles Symposium, 2015, Seoul, IEEE, 970-975, 2015.

[127] Vlassenroot Sven, *“The Acceptability of In-vehicle Intelligent Speed Assistance (ISA) Systems: from Trial Support to Public Support*”, Thesis (PhD), Delft University of Technology, 2011.

[128] Goodwin Fraze, and Achterberg Franziska, and Beckmann Jörg, *“Intelligent Speed Assistance - Myths and Reality”,* Europen Transport Safety Council, ISBN-Number: 90-76024-23-5, 2006.

[129] Vlassenroot S., and Marchau V., and Mol J. De., and Brookhuis K., and Witlox F., *"Potential for in-car speed assistance systems: results of a large-scale survey in Belgium and the Netherlands",* The Institution of Engineering and Technology, Vol. 5, Iss. 1, 80–89, 2011.

[130] Vlassenroot Sven, and Molin Eric, and Kavadias Dimokritos, and Marchau Vincent, and Brookhuis Karel, and Witlox Frank, *"What drives the Acceptability of Intelligent Speed Assistance (ISA)?",* EJTIR 11(2), 256-273, 2011.

[131] Tradisauskas Nerius, and Juhl Jens, and Lahrmann Harry, and Jensen Christian S., *"Map Matching for Intelligent Speed Adaptation",* IET Intelligent Transport Systems , Volume:3 , Issue: 1, 57 – 66, 2009.

[132] Toyota Motor Corporation, *"Lane Keeping Assist [online]",* http://www.toyota-global.com/innovation/safety_technology/safety_technology/technology_file/active/lka.html, [Ziyaret Tarihi: 11.06.2015].

[133] Clemson Vehicular Electronics Laboratory, *"Lane Keeping Assist [online]",* http://www.cvel.clemson.edu/auto/systems/lane-keeping-assist.html, [Ziyaret Tarihi: 19.05.2015].

[134] Verband Der Automobilindustrie, *"Lane Keeping Assist Systems [online]"*, Germany, https://www.vda.de/en/topics/safety-and-standards/lkas/lane-keeping-assist-systems.html, [Ziyaret Tarihi: 11.05.2015].

[135] Liu Jing-Fu, and Wu Jui-Hung, and Su Yi-Feng, "Development *of an Interactive Lane Keeping Control System for Vehicle",* IEEE Vehicle Power and Propulsion Conference, 702 – 706, 2007.

[136] Howard Bill, "What is lane departure warning, and how does it work? [online]", http://www.extremetech.com/extreme/165320-what-is-lane-departure-warning-and-how-does-it-work, [Ziyaret Tarihi: 11.05.2015].

[137] Saboune Jamal, and Arezoomand Mehdi, and Martel Luc, and Laganiere Robert, *"A visual blindspot monitoring system for safe lane changes"* , ICIAP, 2011, Part II, 1-10, 2011.

[138] Lee Hong Guk, and Yoo Song Min, *"Evaluation Of The Vision Based Blind Spot Detection System Misjudgment Performance Based On Roadway Curvature [online]"* http://www-esv.nhtsa.dot.gov/Proceedings/23/files/23ESV-000331.PDF, [Ziyaret Tarihi: 13.09.2015].

[139] Wu Bing-Fei, and Kao Chih-Chung, and Li Ying-Feng, and Tsai Min-Yu, "A Real-Time Embedded Blind Spot Safety Assistance System", International Journal of Vehicular Technology, Volume 2012, Article ID 506235, 15 pages, 2012.

[140] Wu Bing-Fei, and Huang Hao-Yu, and Chen Chao-Jung, and Chen Ying-Han, and Chang Chia-Wei, and Chen Yen-Lin, *"The blind spot warning system for daytime and nighttime"*, IEEE International Conference, 2012, Athens, IEEE, 591 – 597, 2012.

[141] Lin Bin-Feng, and Chan Yi-Ming, and Fu Li-Chen, and Hsiao Pei-Yung, and Chuang Li-An, and Huang Shin-Shinh, and Lo Min-Fang, *"Integrating Appearance and Edge Features for Sedan Vehicle Detection in the Blind-Spot Area"* , IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, VOL. 13, NO. 2, 737-747, 2012.

[142] Clemson Vehicular Electronics Laboratory, "Blind Spot Detection [online]", http://www.cvel.clemson.edu/auto/systems/blind-spot-detection.html, [Ziyaret Tarihi: 19.07.2015].

[143] Baek Seunghwan, and Kim Heungseob, and Boo Kwangsuck, *"Robust Vehicle Detection and Tracking Method For Blind Spot Detection Sytem by using vision Sensors",* Second World Conference, 2014, Agadir, IEEE, 729 – 735, 2014.

[144] Clemson Vehicular Electronics Laboratory, "Night Vision System [online]", http://www.cvel.clemson.edu/auto/systems/night-vision.html, [Ziyaret Tarihi: 27.04.2015].

[145] Raghatate Rupesh P., and Rajurkar Swapnil S., and Waghmare Manisha P., and Ambatkar Pooja V., *"Night Vision Techniques and Their Applications",* International Journal of Modern Engineering Research, Vol.3, Issue.2, 816-820, 2013.

[146] Kallhammer Jan-Erik, *"Night Vision: Requirements and possible roadmap for FIR and NIR systems [online]",* https://www.autoliv.com/ProductsAndInnovations/Documents/Research%20Papers/5.%20Kallhammer.pdf, [Ziyaret Tarihi: 03.02.2015].

[147] Ahire Aniket S., *"Night Vision System in BMW",* International Review of Applied Engineering Research, Volume 4, Number 1, 1-10. 2014.

[148] Lee Sangyong, and Yu Yeonghun, *"Study of the Night Vision System in Vehicle",* IEEE Vehicle Power and Propulsion Conference, 2012, Seoul, 1312-1316, 2012.

[149] Elektrikport, *"Termal Kamera Nedir? [online]",* Turkey, http://www.elektrikport.com/teknik-kutuphane/termal-kamera-nedir-muhendislik-uygulamalari-ve-kullanim-alanlari/11460#ad-image-0, [Ziyaret Tarihi: 17.01.2016].

[150] Clemson Vehicular Electronics Laboratory, *"Adaptive Front Lighting [online]", http://www.cvel.clemson.edu/auto/systems/adaptive_front_lighting.html, [Ziyaret Tarihi: 12.06.2015].*

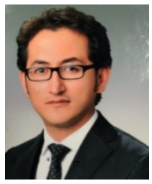
[151] Mueller Friedrich, *"Adaptive Lighting System Today and Tomorrow [online]",* http://www.smvic.com.cn/smvic/res_base/smvic_com_www/upload/article/file/2010_4/12_16/46ehghqzzcx7.pdf, [Ziyaret Tarihi: 08.12.2015].

[152] Mbouna Ralph Oyini, and Kong Seong G., and Chun Myung-Geun, *"Visual Analysis of Eye State and Head Pose for Driver Alertness Monitoring",* IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, VOL. 14, NO. 3, 1462-1469, 2013.

[153] Clemson Vehicular Electronics Laboratory, *"Driver Alertness Monitoring [online]",* http://www.cvel.clemson.edu/auto/systems/driver_alertness.html, [Ziyaret Tarihi: 17.10.2015].

[154] MathWorks, "Pedestrian detection and tracking [online]", https://www.mathworks.com/help/vision/examples/tracking-pedestrians-from-a-moving-car.html, [Ziyaret Tarihi: 19.07.2016].

RESUME



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PROJELER VE YAPILAN İŞLER:

1- Lisans döneminde Haberleşme laboratuvarı deneylerini ve föylerini hazırlayarak, lisans 4. Sınıfta haberleşme laboratuarı asistanlığı yaptım.
2- Lisans bitirme tezi olarak Rf haberleşme sistemi kullanılarak uzak bir yerdeki uzaklık ölçümlerinin kablosuz haberleşme ile lcd ekrana aktarılması projesi yapılmıştır.

3- Trafik kazaları için ilk yardım ve haberleşme sistemi projesi geliştirmiş olup, 2012 yılında Türkiye Patent Enstitüsüne başvurulmuş olup hali hazırda araştırılmalı patent olarak süreci devam etmektedir. Patent için TÜBİTAK'tan hibe alınmıştır.
4- EGO Genel Müdürlüğünde Ar-Ge Müdürlüğü olarak ASELSAN ile Milli Metro ve Sinyalizasyon projelerini başlattım ve EGO Genel Müdürlüğü adına projenin teknik yöneticisiyim.

BİLDİRİLER: 1-Cansev, Mustafa Emre., *"Kent İçi Raylı Toplu Taşıma Hizmetlerinde Dezavantajlı Gruplar için Erişebilirlik",* Sürdürülebilir Ulaşım İçin Yol ve Trafik Güvenliği Ulusal Kongre, Fuar ve Sergisi (ROTRASA), 07-08 Aralık, Ankara, 2015.

İLGİ ALANLARI: Elektronik Sistemler, Uydu Haberleşme Sistemi, Ulaşım araçları elektroniği ve haberleşme sistemleri, kablosuz haberleşme sistemleri, filtreler.

DİLLER: İngilizce

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