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Realization and control of an electric vehicle

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Dedication

First of all, I want to thank ﷲ

For giving me the strength and courage to lead

To this modest work.

I would like to dedicate this humble work to:

To my dear mother and my dearest father

To my precious sister: Mayssem

To my brother: Zino

To my best friends: Amel, Rami, Nessrine, Loubna.

To all my childhood friends and long school and university career.

To all my family

Everyone who loves me and whom I love

Rihab Aouichet

Dedication

First of all, I want to thank ﷲ

For giving me the strength and courage to lead
To this modest work.

I would like to dedicate this humble work to:
To my dear mother and my dearest father (ربي يرحموا)

To All my friends
To all my family
Everyone who loves me and whom I love

Abdrraouf Hansali

ABSTRACT

Development of projects in the field of electric vehicles can be explained by the environmental objectives such as climate change by minimizing CO2 emissions. This work relates to the development a self-driving car based on artificial intelligence. In this work an NVidia Jetson Nano card is used as main controller. Also a front camera sensor that monitors the path, obstacles and sends data to the control unit has been considered. By application of artificial intelligence many experiment tests have been performed.

Résumé

Le développement de projets dans le domaine des véhicules électriques s'explique par des objectifs environnementaux tels que le changement climatique en minimisant les émissions de CO2. Ce travail porte sur le développement d'une voiture autonome basée sur l'intelligence artificielle. Dans ce travail, une carte NVidia Jetson Nano est utilisée comme contrôleur principal. Un capteur de caméra frontale qui surveille le chemin, les obstacles et envoie des données à l'unité de contrôle a également été envisagé. Grâce à l'application de l'intelligence artificielle, de nombreux tests expérimentaux ont été effectués.

تلخيص

يمكن تفسير تطوير المشاريع في مجال السيارات الكهربائية بالأهداف البيئية مثل تغير المناخ من خلال تقليل انبعاثات ثاني أكسيد الكربون. يتعلق هذا العمل بتطوير سيارة ذاتية القيادة تعتمد على الذكاء الاصطناعي. في هذا العمل، يتم استخدام بطاقة نانو "نيفيدا جيتسن نانو" كوحدة تحكم رئيسية. كما تم الأخذ بعين الاعتبار مستشعر الكاميرا الأمامية الذي يراقب المسار والعقبات ويرسل البيانات إلى وحدة التحكم. من خلال تطبيق الذكاء الاصطناعي تم إجراء العديد من الاختبارات

Summary

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Symbols

Ψ : Heading angle.

CG: Center of gravity.

r: The speed of the acet.

VX: The longitudinal velocity.

Vy: Lateral velocity.

Fyf, Fyr: The tire-road contact forces applied to the front and rear wheel respectively.

Jv: Vehicle inertia.

Mv: The mass of the vehicle.

FX: The longitudinal force.

Fy: Lateral force.

Vs: DC source voltage.

I: the armature current.

Te: the electric torque.

Kf: the friction constant.

J: rotor inertia.

wm : angular velocity.

TL: assumed mechanical load.

ke: the back emf constant.

kt: torque constant.

U(t): the supply voltage.

i(t): the current flowing through the winding.

w: the angular speed of the motor.

e(t): the back electromotive force.

Kw: the "against electromotive" constant expressed in V / RPM

Acronyms

EV: electric vehicle.

AI: Artificial intelligent.

BLDC: Brushless DC motor.

NN: neural network.

SSD: The signal shot detector.

CNN: Convolution neural network.

General introduction

General introduction

The automotive industry has been one of the most developed sectors in recent years and has been characterized by continuous renewal and its ability to absorb the technological development that has included all components of the vehicle. If today's car is equipped with the same technology as the aircraft 10 years ago, tomorrow's car will be more technically advanced, will become a smart, self-driving machine connected to the Internet of Things and can communicate with others and not polluting the environment.

The main function of the car as a mobility tool is no longer the only concern for car manufacturers today, but in the context of using technology to develop a modern, luxurious lifestyle, make it a smart mobility machine focused on performance, comfort and security and able to reduce the stress of daily transportation. Future cars will provide maximum comfort, well-being and safety, reducing road use risks while reducing environmental pollution. One of the most important techniques in this area is to connect cars to each other on the Internet of Things and road information systems, enabling the vehicle's computer to receive information on busy road points and propose alternative routes to avoid them. Many car manufacturers have already tested self-driving systems such as the Traffic Assistance system, in which the vehicle is responsible for controlling brakes, steering the steering wheel during traffic jams, navigational control systems, self-parking and keeping track on the road [1].

Self-driving systems, as well as intelligence, will avoid a significant proportion of accidents on the road thanks to the exclusion of the human element behind a significant proportion of them due to fatigue, inattention or drowsiness. Automated driving will also help reduce energy consumption and reduce consumption by up to 15%. [1]

This work consists of three chapters. The first one presents a general history of electric cars. The second chapter describes the basic elements of the electric car, especially the elements used for the car development. In addition, the artificial intelligence theory and methods of electric cars control are given. The last chapter describes the designed model of the self-driving car. The designed model of the car integrates artificial intelligence. So, an artificial neural network model is used for driving autonomously the car on a track. The electronic card used for electric car control is NVidia jetson Nano. This card allows to managing automatically the car. Experiment tests, analysis and interpretation of the results are presented in this chapter. Finally a conclusion and perspectives are mentioned.

Chapter I : stat of art about electric vehicle

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1 Introduction :

Electric vehicles have only recently begun to challenge the internal combustion engine for the future of roads. Electric vehicles (EVs) have been around for over a century. The long history of EVs has been one of many twists and turns. Many people do not know that at the turn of the century there were actually more vehicles on the road than gas-powered ICE vehicles. This prevalence wa challenged empowered by the knowledge that gasoline was more widely available than electricity, built a transport system based on gasoline that would last over a hundred years. The history of EVs is an interesting tale filled with many twists that gave rise to this nascent technology.

This introduction gives an overview of the history of electric vehicles, the current state of electric mobility, and what the future is predicted to hold for the EV revolution.

2 History of Electric Vehicle:

2.1 Early electrical cars:

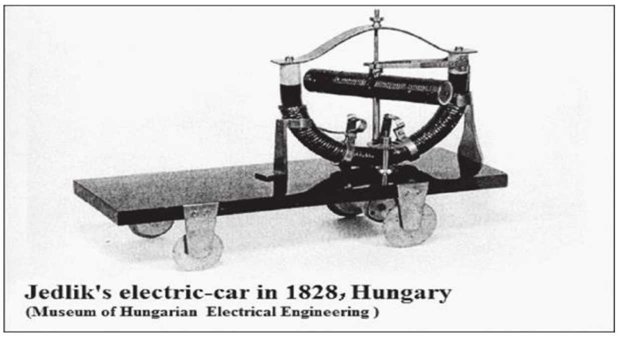

Figure (I.1): Redelk’s toy electric car, 1828.

Disposable batteries, like all other electric vehicles of that time, powered this four-wheeled vehicle.

American electrical experimenter Charles Grafton Page (1812–1868), when in 1851 he made a locomotive powered by his reciprocating electrical engine adopted the same solution. Conducting rails opened the possibility to place the batteries apart from the car: the use of rails as conductors was patented in 1840 in the UK and in 1847 in the United States. [2]

Figure (I.2): Starling's small electric car, 1835.

Figure (I.3): Electric car by Thomas Parker, 1884

2.1.1 French-Belgian electrics :

The early electric car producers raced in a sees of competitions, mainly in France, which promoted major technical improvements. On 18 December 1898 an electric JeantaudDuc driven at 63.13 km/h by French car racer Gaston de Chasseloup-Laubat (1867–1903) set the first official land speed record. A series of records were then broken within a few months by Gaston and his rival Belgian Camille Janay (1868–1913), who on 29 April 1899 drove his missile-shaped electric JamaisContente (Never Satisfied) at 105.88 km/h presented in Figure (I.4).

That was the first time ever a land vehicle broke the 100 km/h barrier. The final aim of those races was to galvanize and conquer the rising market of individual self-propelled cars.

In the age of positivism those devices powered by electricity, the dominant high-tech of the time, and capable to run much faster than horses and even steam locomotive, allured the wealthy class of the Belle Era. France soon became the largest automobile maker in the world, and was surpassed by the US only in 1904. [2]

2.2 A new beginning for electric cars :

While all the starts and stops of the electric vehicle industry in the second half of the 20th century helped show the world the promise of the technology, the true revival of the electric vehicle did not happen until around the start of the 21st century. Depending on whom you ask, it was one of two events that sparked the interest we see today in electric vehicles.

The first turning point many have suggested was the introduction of the Toyota Prius. Released in Japan in 1997(fig.4), the Prius became the world's first mass-produced hybrid electric vehicle. In 2000, the Prius was released worldwide, and it became an instant success with celebrities, helping to raise the profile of the car. To make the Prius a reality, Toyota used a nickel metal hybrid battery technology that was supported by the Energy Department's research. Since then, rising gasoline prices and growing concern about carbon pollution have helped make the Prius the best-selling hybrid worldwide during the past decade.(Historical footnote: Before the Prius could be introduced in the U.S., Honda released the Insight hybrid in 1999, making it the first hybrid sold in the U.S. since the early 1900s). [3]

Figure (I.4) : Road test: 1997 Toyota Prius.

The news in 2006 that a small Silicon Valley startup, Tesla Motors, would begin building a luxury electric sports car that could travel more than 200 miles on a single charge was another event that helped change electric vehicles. Tesla got a $465 million loan from the

Department of Energy's Loan Programs Office in 2010 to develop a manufacturing facility in California, which Tesla returned nine years early. Tesla's automobiles have received widespread acclaim in the short time since they were introduced, and the company has grown to become California's largest employment in the auto business. [3]

Tesla’s announcement and subsequent success spurred many big automakers to accelerate work on their own electric vehicles. In late 2010, the Chevy Volt Figure (I.5) and the Nissan LEAF Figure (I.6) were released in the U.S. market. The first commercially available.

Plug-in hybrid, the Volt has a gasoline engine that supplements its electric drive once the battery is depleted, allowing consumers to drive on electric for most trips and gasoline to extend the vehicle’s range. In comparison, the LEAF is an all-electric vehicle (often called a battery-electric vehicle, an electric vehicle or just an EV for short), meaning it is only powered by an electric motor. [3]

Figure (I.5) : tesla electric sport car2006.

Figure (I.6) : The Chevy Volt 2010.

At the same time, the Energy Department’s Vehicle Technologies Office supports new battery technology. Began hitting the market, helping to improve a plug-in electric vehicle’s range. In addition to the battery technology in nearly all of the first generation hybrids, the Department’s research also developed the lithium-ion battery technology used in the Volt. More recently, the Department’s investment in battery research and development has helped cut electric vehicle battery costs by 50 percent in the last four years, while simultaneously improving the vehicle batteries’ performance (meaning their power, energy and durability).

This in turn has helped lower the costs of electric vehicles, making them more affordable for consumers. [3]

Consumers now have more choices than ever when it comes to buying an electric vehicle. Today, there are 23 plug-in electric and 36 hybrid models available in a variety of sizes – from the two-passenger Smart ED (Figure (I.7)) to the midsize Ford C-Max Energy (Figure (I.8)) tothe BMW i3 luxury SUV figure(I.9). As gasoline prices continue to rise and the prices on electric vehicles continue to drop, electric vehicles are gaining in popularity – with more than 234,000 plug-in electric vehicles and 3.3 million hybrids on the road in the U.S. today.

Figure (I.7) : Nissan LEAF 2010.

Figure (I.8): Smart electric drive 2014.

Every day there is news of a new Electric vehicle being introduced, or a new battery, or a new technology in a related area like autonomous vehicle technology that is because the cars become automated.

Autonomous vehicles have software systems that drive the vehicle, meaning that updates through reprogramming or editing the software can enhance the benefits of the owner (e.g. Update in better distinguishing blind person vs. non-blind person so that the vehicle will take extra caution when approaching a blind person). A characteristic of this re-programmable part of autonomous vehicles is that the updates need not only to come

After Tesla, electric vehicles exploded in both popularity and innovation. They cultivated interest, as every almost every major car company hopped on board. The 2009 Chevy Volt brought the first ‘plug-in’ electric vehicle and, the 2010 Nissan Leaf further popularized the idea. The prevalence of both shaped the future of how public and private [3]

EV charging points. That said, the last five years have brought a near 600 per-cent global increase in electric vehicles on the road.

Figure (I.10) : Ford C-Max Energy 2014

Figure (I.11) : 2021 BMW I3

2.1 The future of electric cars:

Never has there been a better time to make the switch to electric. With fuel stations up and down the country running dry, its EV drivers who are having the last laugh.

Automotive groups and car manufacturers are pumping a huge amount of investment to establish a new generation of electric vehicles. In fact, many manufacturers have pledged to go green by producing electric-only vehicles in the future. There are 11 new brands working on electric car including Abarth, Alfa Romeo, Fiat, Jeep, Hyundai, Nissan,Nismo, Peugeot, MG, Renault and Dacia.

It is a big move for the automotive industry as the UK transforms its approach to a greener future, by banning the sale of new petrol and diesel vehicles by 2030 in the end, only time will tell what road electric vehicles will take in the future.

3 Advantages and disadvantages of the electric cars:

3.1 Advantages:

- No air pollutants and no CO_2 emissions during use.
- Reduction in the use of fossil fuels for transportation.
- Economical in use.
- Low maintenance.

3.2 Disadvantage:

- The impact of its batteries (its use increases the pressure on the rare Lithium metal).
- The capacity of the batteries decreases with time.
- Recharging time and availability of charging stations.
- The high cost of the cars and the high cost of the batteries.

4 Safety of electric car:

Electric cars represent a new technology introducing electrical components in the vehicle ; the various risks associated must be rigorously identified. [4]

When dealing with safety related to electric cars, several aspects need to be taken in consideration :

- Safety of the electrical system.
- Safety of the operational part.
- Safety of battery charging operations.

Maintenance, operation and level of training the regulatory framework is also lagging behind the technological evolution of electric cars.

In this article, only electrical, chemical and explosion hazards will be addressed.

4.1 Safety of the vehicle's electrical system:

- Protection against electric shock.
- Protection against direct contact :

Protection of people against direct contact with the active electrical parts of the traction system must be ensured by adequate insulation and by an inaccessible positioning of said parts. [4]

- Protection against indirect contact

The issue of indirect contact is often related to structural problems. Contact between the traction circuit and the structure can lead to dangerous situations such as :

- Short circuits
- Electrocution.
- Unplanned and / or uncontrolled vehicle behavior.

4.1.1 Battery safety

For an electric car, the battery is the most important component. It is the origin of several dangerous phenomena such as electrical, mechanical and chemical hazards, not to mention the risk of explosion.

4.1.2 Electrical hazard

Protection against electric shock : The battery cases must be reinforced as needed.

Short-circuit protection : Traction batteries have considerably high short-circuited currents, and safety devices such as fuses must be installed, in particular at the electrical center of the battery. The arrangement of the battery must be designed to avoid any risk of unmanageable contact or short-circuit. To minimize leakage currents, especially in ventilated batteries, a creep age calculation is required. [4]

4.2 Safety of battery charging operation:

During the charging of the battery, the car is connected to the main power grid, preventive measures must thus be taken in order to avoid the risk of electric shock. These preventive measures depend mainly on the type of charger:

- External charger.
- On-board charger.

4.3 Maintenance

For electric cars, there are three maintenance levels to consider:

- First level maintenance: by the user Examples: vehicle cleaning.
- Second level maintenance: in a workshop, by qualified people.

Examples : routine mechanical maintenance, replacement of controllers. • Third level maintenance : in the manufacturer’s workshop. Examples : major electrical repairs, to be performed by qualified persons only. [4]

5 CONCLUSION

In this chapter state of art of electric vehicles are presented. Different categories of electric vehicles of many companies are given.This chapter focuses on the presentation of some main generations of electric cars. The next chapter will present the basic components of the EV and meth control.

Chapter II : Sizing and control of electric vehicles.

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1 Introduction

As is well known, EVs use the electricity saved in the battery to cycle the motor and generate the power necessary for driving this is the biggest difference to internal combustion vehicles, in which the engine exhausts fossil fuel to generate that power. As such, EVs have no need for the engine and transmission, the two of the most crucial components for internal combustion vehicles. Instead, EVs carry several components for electric power: the motor, the battery, the on-board charger, and the Electric Power Control Unit (EPCU). All are essential components to achieve the conversion of the battery's electricity into the kinetic force that drives the EV forward.

Classical control laws of the PID type give good results for linear systems with constant parameters. For non-linear systems or systems with non-constant parameters, these classical control laws can be insufficient because they are not robust, especially when the requirements on accuracy and other dynamic characteristics of the system are strict. We must use control laws that are insensitive to parameter variations, disturbances and non-linearity.

2 Electric vehicle Components

2.1 Motors

Electric car motors work by mounting one set of magnets or electromagnets to a shaft and another set to a housing surrounding that shaft. By periodically reversing the polarity (swapping the north and south poles) of one set of electromagnets, the EV motor leveragesthese attracting and repelling forces to rotate the shaft, thereby converting electricityinto torque and ultimately turning the wheels. Conversely—as in the case of regenerative braking—these magnetic/electromagnetic forces can transform motion back into electricity.

2.1.1 Brush-less DC Motor (BLDC) :

The brushes and their maintenance are eliminated by moving the permanent magnets to the rotor, placing the electromagnets on the stator (housing), and using an external motor controller to alternately switch the various field windings from plus to minus, thereby generating the rotating magnetic field. [5]

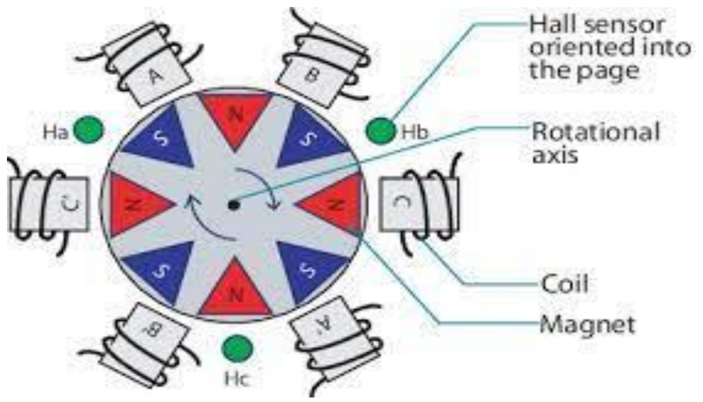

Figure (II.1): Brushless DC Motor (BLD

The BLDC hub motor used in this experiment utilizes 27 electro-magnetic stator coils and 30 permanent magnets (also referred to as 15 pole pairs) (Figure (II.2)). Many diagrams show the Hall Effect sensors labeled as U, V, and W spaced equidistant (120 degrees) around the stator coils. Sensors are located equidistant from each other, but most are located on one side of the stator (figure (II.3), this type of motor is selected for our project because its advantages. [5]

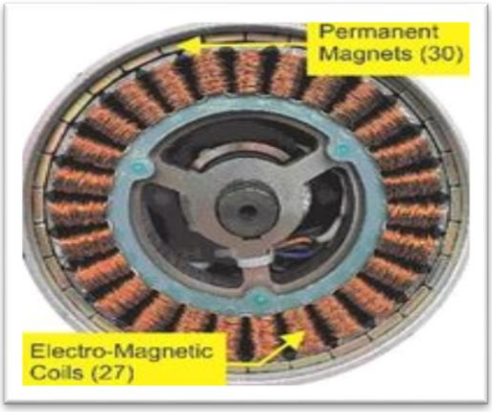

Figure (II.2) : electro-magnetic stator coils

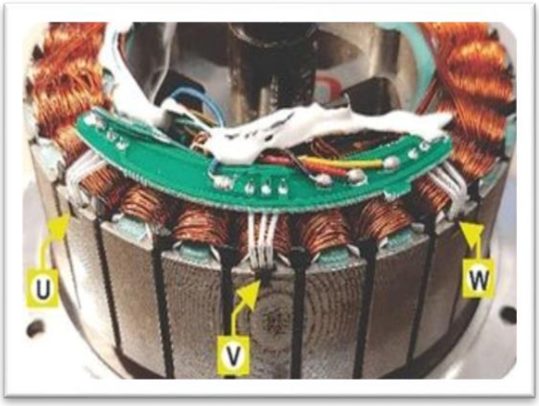

Figure (II.3) : The sensor labels (U, V, W).

2.1.2 Advantages of BLDC :

BLDC motors have many advantages over brushed DC moto and induction motors. A few of them are better speed versus torque response, high dynamic response, high efficiency,

Long lifetime and work in silent mode. In addition, the ratio between delivered torque and motor size is higher, which is in applications where space and weight are ideally, BLDC motors have trapezoidal waveform EMFs and are fed with rectangular stator currents, which give a theoretically constant torque.

2.1.3 Commutation principle of brushless motors with hall sensors:

In this type of brushless motor, Hall Effect sensors are used to know the position of the rotor at any time, and adapt the power supply to the coils and the magnetic field accordingly. The magnetic sensor detects the passage of a magnetic pole, from this information the electronic control circuit the switching of the coils.

The use of a Hall Effect sensor in the motor allows excellent adjustment ; however, the addition of these components, the fact that they must be located very close to the motor, leads to additional costs and additional risks of failure. This solution is the most used in industry applications. [5]

2.1.4 Mathematical model of a brushless motor:

Generally, the mathematical model of a brushless DC motor is not entirely different conventional DC motor.

This difference mainly affects the mechanical and electrical constants these are very important elements of the parameters of the mechanical constant:

The mechanical constant and electric constant are giving respectively by the following mathematical equations :

$$\tau_m = \sum \frac{Rj}{kekt} = \frac{j\sum R}{kekt} \qquad (II.1)$$

$$\tau_e = \sum = \frac{L}{R} = \frac{L}{\sum R} \qquad (II.2)$$

In the BLDC motor, there are three phases. The mechanical and electrical constants described in the following form :

$$\tau_m = \frac{j3R}{k_e k_t} \qquad (II.3)$$

$$\tau_e = \frac{L}{3R} \qquad (II.4)$$

Therefore, the BLDC motor equation can now be obtained as the equation following :

$$G(s) = \frac{\frac{1}{k_e}}{\tau_m . \tau_e . s^2 + \tau_m . s + 1} \qquad (II.5)$$

2.2 Battery :

An electric vehicle battery (EVB, also known as a traction battery) is a rechargeable electric used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV). Typically lithium-ion batteries, they are specifically designed for high electric charge (or energy) capacity. Many types of battery can be using for EVs. The dimensioning of the battery bank for an EV is depends on different parameters. Among these parameters : vehicle size (weight, consumption) and cost.

2.2.1 Lithium-ion :

Lithium-ion batteries have an immensely high power-to-weight ratio, making the cars highly energy efficient. The battery performs quite better than others at high temperatures do as well. This is mainly using due to its energy per weight ratio, which is an important consideration in electric car batteries.

In other words, the smaller the weight of the battery Figure (II.4), the further the car can drive on a single charge. The battery also has a low self-discharge level, meaning it is better able to maintain its charge when compared to the other alternatives. In addition to that, most components of the Li-ion batteries can get recycled. This is a bonus for electric cars since they are made with the main motive of saving the environment. These are mainly used in PHEV and BEV cars. [6]

Figure (II.4): Lithium-ion battery 36v

This type of battery is selected for our project because its advantages.

2.2.1.1 Lithium Battery Advantages

Lithium iron phosphate batteries offer significant advantages, including improved discharge and charge efficiency, longer life span and the ability to deep cycle while maintaining power. LiFePO4 batteries often come with a higher price tag, but a much better cost over the life of the product. No maintenance and super long life make them a worthwhile investment and a smart long-term solution.

- Safety.
- Drop-in Replacement.
- Lightweight.
- Longest Life.
- More Usable Capacity.
- Constant Power.
- Temperature Tolerant.
- Charging - Fast & Safe.
- PSOC Tolerant.
- Long Shelf Life.
- Maintenance Free.
- Non-Hazardous.

3 Modeling of Electric Vehicles:

The purpose of the modeling is to describe the motion of the vehicle in the spatial reference frame three-dimensional spatial reference (two-dimensional displacement in the plane of the road and rotation of the vertical direction). [7]

For the modeling of the vehicle considering a displacement along the x, y, and a rotation around the vertical axis z.

The generalized forces FXFY and the total moment of rotation MZ in the inertial reference frame(X, Y) are given by the following [7]

$$M_X \ddot{X} = F_X$$

$$M_V \ddot{Y} = F_Y \qquad \textbf{(II.6)}$$

$$J_V \ \ddot{\Psi} = M_Z$$

Using a simple rotation of an angle around the axis o-z, we can evaluate the velocity vector associated with the center of gravity CG of the vehicle.

$$\begin{pmatrix} \dot{x} \\ \dot{y} \\ \dot{\Psi} \end{pmatrix} = \begin{pmatrix} \cos(\Psi) & -\sin(\Psi) & 0 \\ \sin(\Psi) & \cos(\Psi) & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad (\mathbf{II.7})$$

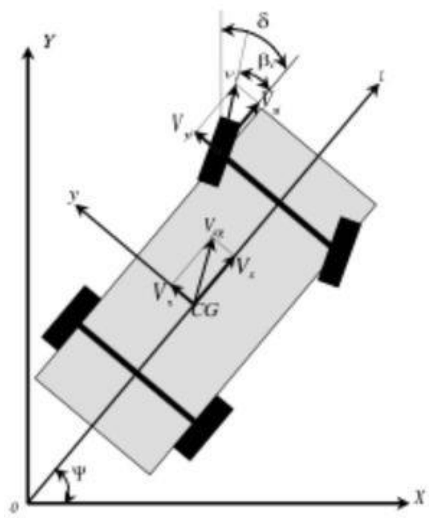

Figure (II.5): Vehicle movement in the axis system (X, Y).

Deriving $(\mathbf{II.7})$ with respect to time, we obtain the accelerations :

$$\frac{d}{dt}(\dot{x}) = v_x \cos(\Psi) - v_x\dot{\Psi} \sin(\Psi) - \dot{v}_y \sin(\dot{\Psi}) - v_y\dot{\Psi} \cos(\Psi)$$

$$\frac{d}{dt}(\dot{y}) = \dot{v}_x \sin(\Psi) + v_x\dot{\Psi} \cos(\Psi) + v_y \cos(\Psi) - v_y\dot{\Psi} \sin(\Psi) \qquad \textbf{(II.8)}$$

$$\frac{d}{dt}(\dot{\Psi}) = \dot{r}$$

Taking into account (II.6) in equations (II.8), we obtain:

$$\frac{f_x}{M_v} = (\dot{v}_x - \dot{\Psi} v_y)\cos(\Psi) - (\dot{v}_y - \dot{\Psi} v_x)\sin(\Psi)$$

$$\frac{f_y}{M_v} = (\dot{v}_x - \dot{\Psi} v_y)\sin(\Psi) + (\dot{v}_y - \dot{\Psi} v_x)\cos(\Psi) \qquad \textbf{(II.9)}$$

To establish the forces acting on the vehicle, we consider the reference frame (x, y) with a one angle steering of the front wheels. The forces acting at the wheel-ground interface are shown in Figure (II.6)

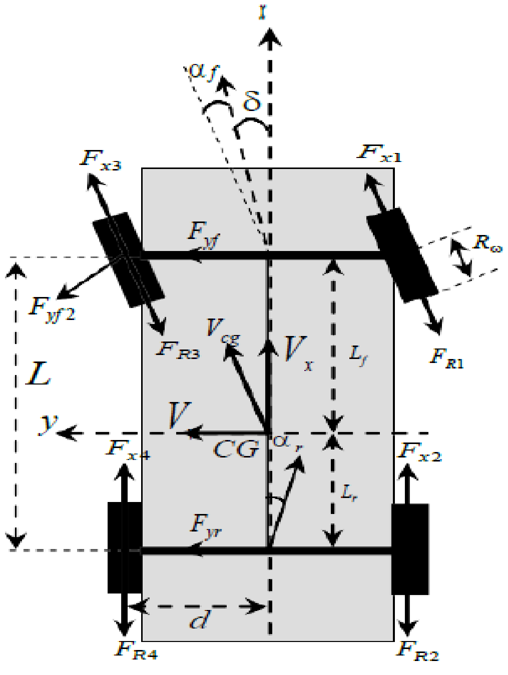

Figure (II.6): Forces at the wheels of the vehicle, in the (x, y) plane.

Substituting equation (II.7) into (II.9), we obtain the expressions for the accelerations at the center of gravity (CG) of the vehicle as shown in (II.10) :

$$\frac{f_x}{M_v} = (\dot{v}_x - rv_y)$$

$$\frac{f_y}{M_v} = (\dot{v}_x - rv_y) \quad (II.10)$$

$$\frac{M_z}{J_v} = r$$

Replacing the various longitudinal and lateral forces in equation (II.10) gives the final expressions for the equations of mot :

$$M_v(\dot{v}_x - v_y r) = F_{xf}\cos(\delta_f) + F_{xr} - F_{yf}.\sin(\delta_f) - k_x.v_x|v_x|$$

(II.11)

$$M_v(\dot{v}_y + v_x r) = F_{xf}\sin(\delta_f) + F_{yr} + F_{yf}.\cos(\delta_f) - K_y.v_y|v_y| + F_w$$

$$J_v r = L_f(F_{xf}.\sin(\delta_f) + F_{yf}.\cos(\delta_f)) - L_r F_{yr} + \frac{D}{2}(\Delta F_x - \Delta F_y.\sin(\delta_f)) + L_w F_w \quad \textbf{(II.12)}$$

4 Control methods of electric vehicle:

Generally, different methods of control are used for controlling EVs. There are classical methods and advanced methods. In this project, an advanced method is used.

4.1 Artificial Intelligence:

Artificial intelligence (AI) is a branch of computer science. It involves developing computer programs to complete tasks which would otherwise require human intelligence. AI algorithms can tackle learning, perception, problem-solving, language-understanding and/or logical reasoning. [8]

AI is used in many ways within the modern world, from personal assistants to self-driving car. Artificial intelligence (AI) is evolving rapidly. While science fiction every so often portraits AI as robots closely as possible to humans. [8]

However, Robotics is a branch of technology which deals with robots. Robots are programmable machines which are usually able to carry out a series of actions autonomously, or semi-autonomously.

There are three main important factors which constitute a robot :

Robots interact with the physical world via sensors and actuators. Robots are programmable. Robots are usually autonomous or semi-autonomous. [8]

Robots are "usually" autonomous because some robots aren't. Telerobots, for example, are entirely controlled by a human operator but telerobotics is still classed as a branch of robotics.

Eventually, artificially intelligent robots are the bridge between robotics and AI. These are robots which are controlled by AI programs.

Many robots are not artificially intelligent. Up until quite recently, all industrial robots could only be programmed to carry out a repetitive series of movements. As we have discussed, repetitive movements do not require artificial intelligence. Non-intelligent robots are quite limited in their functionality. AI algorithms are often necessary to allow the robot to perform more tasks that are complex. [8]

4.1.1 Traits of an AI:

Capable of predicting and adapting, AI uses algorithms that discover patterns from huge amounts of information. [8]

1. Makes decisions on its own, AI is capable to augment human intelligence, deliver insights and improve productivity.
2. Continuous learning, AI uses algorithms to construct analytical models.
   From those algorithms, AI technology will find out how to perform tasks
   through innumerable rounds of trial and error.

3. AI is forward-looking, AI is a tool that allows people to reconsider how we analyze data and integrate information, and then use these insights to make better decisions.
4. AI is capable of motion and perception.

4.1.2 Natural Language Processing (NLP) :

Natural language processing helps computers communicate with people in their very own language and scales other language-related tasks. For example, NLP makes it possible for computers to read text, hear speech, interpret it, measure thoughts and emotions, and determine which parts are important. Today's machines can analyze more language-based information than humans without exhaustion and in a continuous, unbiased way. [9]

4.1.3 Ai and Autonomous Vehicles:

Autonomous cars generate data from their surroundings and feeds it into the intelligent agent, which in turn takes decisions and allow an autonomous vehicle to conduct specific activities in almost the same environment, a repetitive loop is established called a perception activity cycle. [9]

The figure below shows the autonomous vehicle data flow:

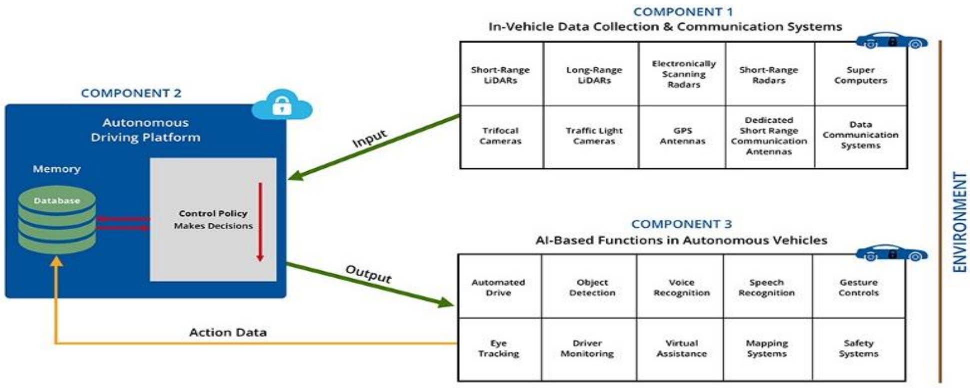

Figure (II.7) : AI Perception Action Cycle in Autonomous Cars [9]

4.2 Evs command:

Multiple control methodologies combined with perception techniques have made it possible to achieve innovations in terms of active safety and assistance. A state of the art is carried out in the context of lateral control, the technical solutions adopted.

Are based on automatic methods namely :

4.2.1 Classical commands such as PD, PID:

The aim is to compensate for the phase delay induced at high longitudinal speeds. The action integral action has the function of cancelling the lateral displacement for a constant curvature. [10]

4.2.2 Robust controls:

LQG, FSLQ (Frequency Shaped Linear Quadratic). They guarantee the robustness of the control laws and take into account the performance and driving quality specifications quality specifications by introducing frequency weightings on different representative quantities. [10]

4.2.3 Sliding mode commands:

The sliding surfaces combine the lateral displacement, the heading angle and the yaw rate. [10]

4.2.4 The fuzzy command

Two strategies are presented : one is based on the Madman type description and tries to the behavior of a driver by exploiting information expressed in terms of "fast", "slow", "big", "small". "Fast", "slow", "big", "small". The other one corresponds to the Tagaki-Sugeno formalism. These approaches allow building robust control laws, which are similar to gain sequencing strategies. [10]

4.2.5 The Neural Command:

Neural networks are small and can be distinguished by their direct, radial, or recurrent. The sensors provide the incoming information. It should also be noted that the two main variables available for variables available for looping are the lateral displacement and the error on the error on the heading angle. In addition, the road curvature information can be used to make the lane tracking more track more accurate. In order to implement the different lateral control strategies, the vehicle requires control strategies; the vehicle requires a powerful instrumentation of sensors and actuators. [10]

5 Conclusions:

This chapter deals with the main components of an electric car, with the identification of the components used in our topic, such as the BLDC motor and battery, and the reasons that led to their choice. Finally, the artificial intelligence has been discussed.

Chapter III
Electric Vehicle Realization

Chapter III Electric Vehicle Realization

1 INTRODUCTION:

Self-driving car uses artificial intelligence (AI) to drive autonomously on a track. This intelligence is programmed in electronic cards. In this work, NVidia Jetson Nano is used as a main onboard computer for implementing an algorithm of control based on AI. The goal of our project is to realize a vehicle car to handle three tasks: self-driving on the track, stop sign detection, and front collision avoidance.

The obtained results, the experiment tests of the electric car are presented in this chapter.

2 Methods and materials:

The realization of the project is based on the use of a multitude of elements mainly free of access at low costs and easily found on the market. The robot is based on some all software and libraries used in the project are open access. This chapter details the electronic, mechanical and software components of the robot. All the components used allow the autonomous control of the vehicle in real time without the support of an external computing effort (cloud computing).

2.1 Operating conditions:

In order to perform experiment tests of the car it is necessary to respect the following conditions.

- Light for clear road line.
- Clean road lines for easy detection.
- The color of the line varies with the color of the road such as black and white, red and gray, yellow and black....
- The camera well placed as the detection would be well.

2.2 Materials:

Several components are necessary to achieve the autonomous driving of a vehicle.

The next section will describe exhaustively the electronic components selected for the design.

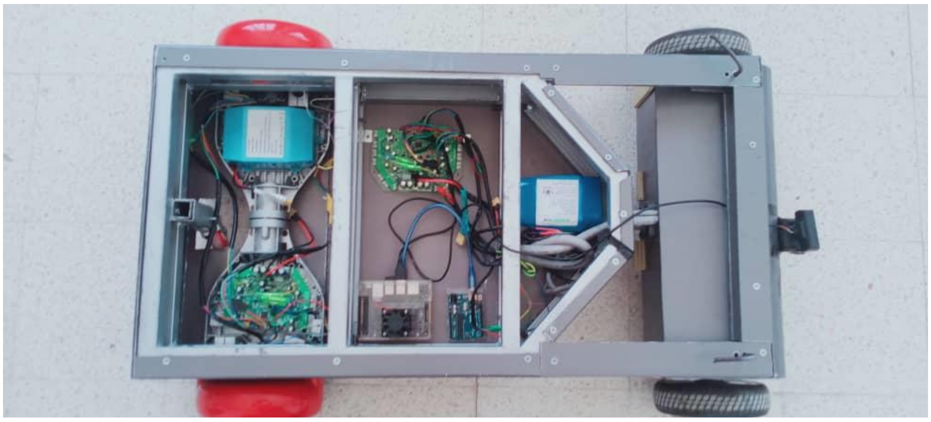

Figure (III.1) the electronic components for the design.

2.2.1 The Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contain

Everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

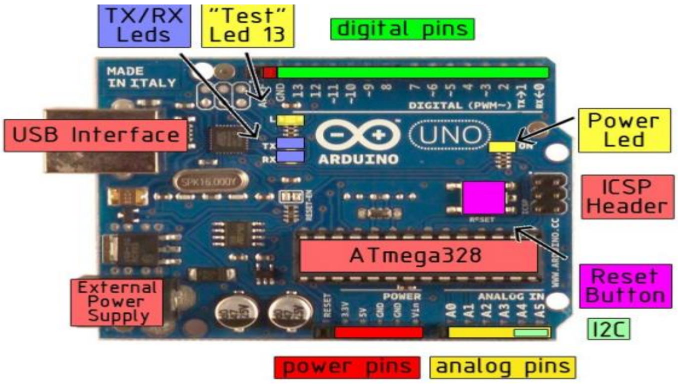

Figure (III.2) The Arduino Uno board.

2.2.2 **Jetson Nano cart of command**:

Jetson Nano is a small AI computer made for beginners, learners, and developers. If you want to enter into AI world, this board will be the best start for you. Jetson Nano is built with 64 quad-cores ARM Cortex-A57 CPU. Its running speed is 1.43 GHz and has a maxwell GPU with 128 CUDA cores capable of 472 GFLOPs (FP16). Talking about processing memory, it has 4GB of 64-bit LPDDR4 RAM on-board and 16GB of eMMC storage and runs Linux for Tegra.

We will divide the application/benefits of this board into two sections such as :

- **Educational:**

  Free NVIDIA courses

  Free Certification from NVIDIA

  you can use it for model training in less price

- **Robotics:**

  Py Bullet

  ROS

  Real sense (Depth camera)

  Made for AI

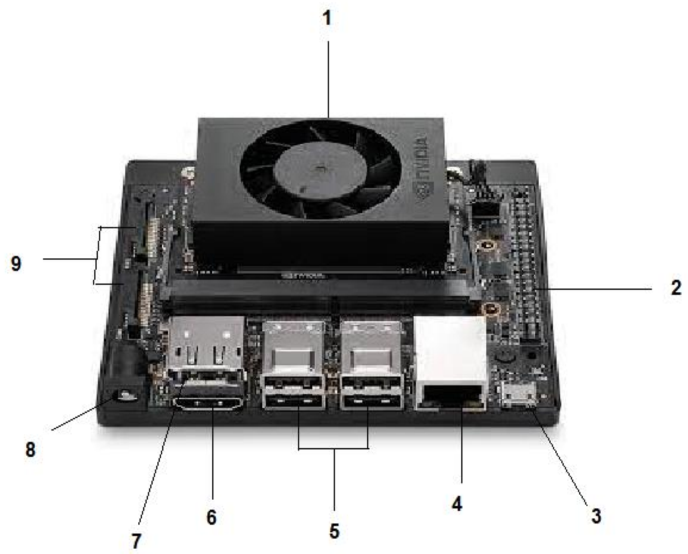

Figure (III.3) : jetson nano nx

Table (III.1) Jetson Nano’s technico spécifications

1	MicroSD card slot for main storage
2	40-pin expansion header
3	Micro-USB port for 5V power input, or Device Mode
4	Gigabit Ethernet port
5	USB 3.0 ports (x4)
6	HDMI output port
7	DisplayPort connector
8	DC Barrel jack for 5V power input
9	MIPI CSI-2 camera connectors

2.2.2.1 Advantage *:*

Talking in terms of advantages, the board comes with several advantages

- It comes in a compact size and is powerful enough for advanced AI applications with low power consumption.
- It enables development of AI applications using NVIDIA Jetpacks SDK.
- This board also supports Entire GPU-accelerated NVIDIA Software Stack for application development and optimization.
- Good numbers of I/O Peripherals to further expand AI projects.
- Large community support with a wide collection for tutorials of beginners.
- Large heat sink for better heat dissipation.
- Easy to create, deploy, and maintain AI at the edge.
- Flexible and scalable platform to get to market with fewer development costs
- Low power consumption,

2.2.2.2 Disadvantages :

It has very few disadvantages while considering the price

- It does not come with the Wi-Fi module inside.
- Also, they haven't added Bluetooth to the board, while the raspberry pi comes with 10 xs less price and the Bluetooth and Wi-Fi module inside it.
- Only two PWM pins have been provided on the board.

2.2.3 Carte driver of brushless:

The control boards for DC motor and DC brushless motors perfectly manage the speed control of the associated motor, acceleration, and deceleration as well as braking.

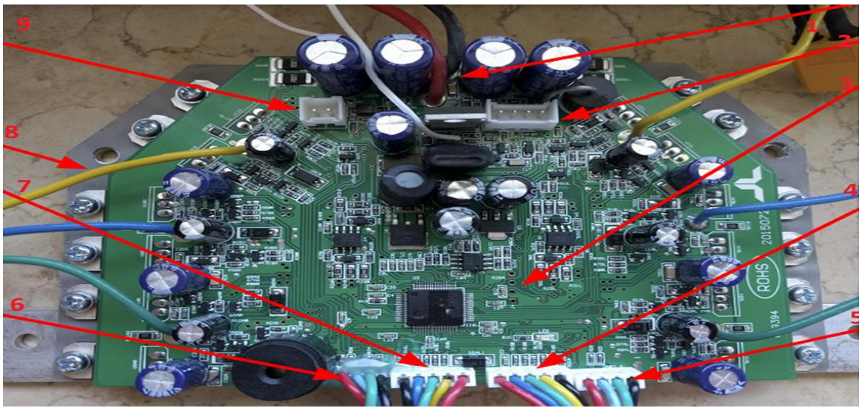

Figure (III.4) Carte driver of brushless.

Table (III.2) Carte driver of brushless specification.

1.	XT60 Main Power.
2.	Charging Connector.
3.	SWD Programing: 3.3V / 50mA max, PA14 / SWCLK, GND, PA13 / SWDIO.
4.	Right Hall Cable: 5v / 10 mA max, HALL A, HALL B, HALL C, GND.
5.	Right Sensor: 15v / 200mA max, PB10 / TX / SCL, PB11 / RX / SDA, GND.
6.	Left Sensor: 15v / 200mA max, PA2 / TX / ADC1, PA2 / RX / ADC2 / PPM, GND.
7.	Left Hall Cable: GND, HALL A, HALL B, HALL C, 5v 100 Ma max.
8.	Main Motor Wire.
9.	Power Button: Latch circuit, STM32GPIO.

2.2.4 Camera:

The resolution is not the most important detail when considering what camera to use. Having a larger field of view is more beneficial, as more information can be captured from the surroundings in a single image and as such a wide-angle camera lens is preferred.

2.3 Block scheme:

To simplify the study of the electric car a block scheme is given. Information flows through the node sequentially without threads, as shown in Figure III.4. Communication protocols are identified and represented by dashed lines. The robot performs its tasks by first reading the camera input and generating an output value through a controller. Values are then transferred to the Jetson Nano module by the USB protocol, which then outputs the signals to the driver and to the steering servomotor, thus inducing trajectory modifications on the vehicle.

The loop is repeated as long as needed, but can be stopped at any time by the evaluator or if the algorithm raises any safety concerns.

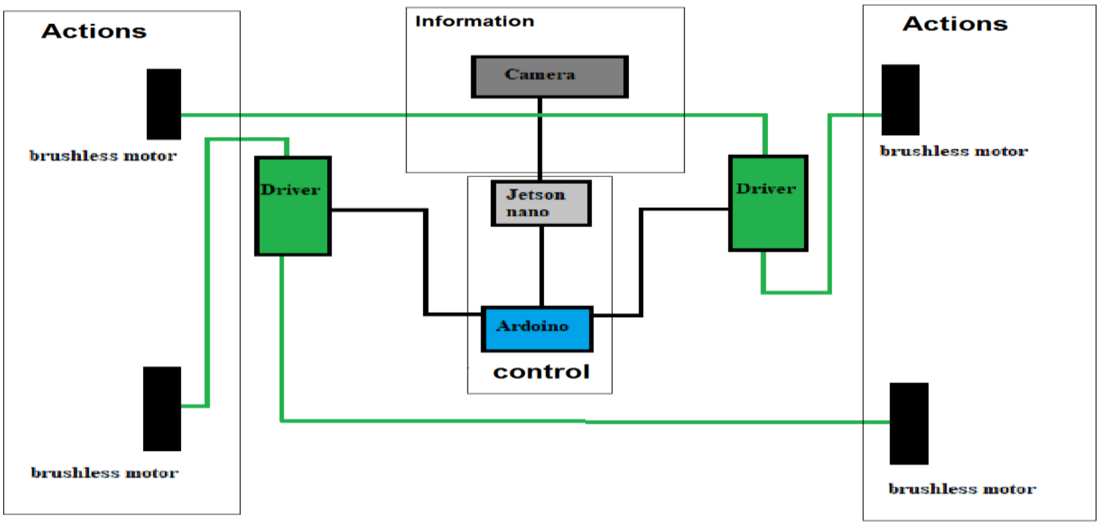

Figure (III.5) : schema bloc.

2.4 Organizational chart

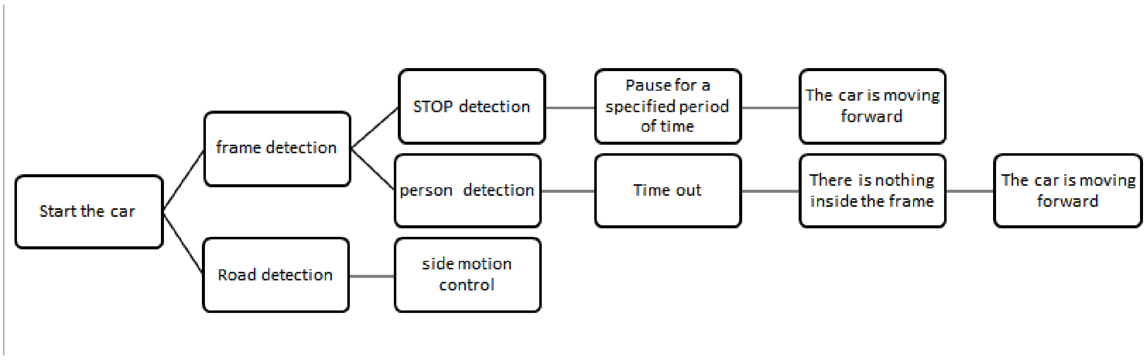

Figure (III.6) : Organizational chart

2.4.1 Line Camera Program:

The program initially generates a bridge using a library to capture the CSI (Camera Serial Interface) signal from the camera used. The captured image is then subjected to different digital treatments in order to generate a projection of the trajectory ideal mathematics to be followed by the vehicle (mid-lateral position in relation to the lines followed).

2.4.2 Steering control:

Similar to speed control, vehicle direction control, the heart of autonomous driving is-reserved for an independent object jetson nano card. This tracker uses the robot's ideal trajectory planning, which comes from a request made to the line reader program, evaluates its position now and calculates a physical response in the form of wheel angulation allowing the correction of the trajectory of the vehicle.

2.5 Methods:

The Autonomous Vehicle Lateral Control System provides a lateral control system implemented in an open source autonomous vehicle simulator called jetson nano that allows for total lateral autonomy when keeping and changing lanes.

The project a cost-effective solution for lateral control in simulation, system takes camera data; it uses the data to run a variety of algorithms tell the vehicle to make a lane change if it's sure to do so and if an object is encroaching the vehicle's path or keeping a way. Provided the autonomous vehicle is functioning properly, moves it at a safe speed in a lane once an object is detected on the vehicle trajectory, the vehicle decides if the lane next to it is available and if it is allowed to perform a safe and smooth lane.

On a successful lane change, the vehicle controls operation as before. The outcome of the autonomous lateral control system provided would impact the autonomous vehicle market reducing the cost of autonomy for size vehicles while increasing the level of reliability and autonomy for large vehicles.

2.5.1 Software and libraries:

In order to achieve the autonomous driving objective, a range of modules, libraries and software had to be taken advantage of. The next section identifies and describes the critical elements needed to achieve autonomy.

2.5.2 Python:

Python is the programming language selected for this project, more specifically Python 3.7.4. Python is an interpreted and cross-platform typed object-oriented programming language.

There are many interpreters such as C Python (C++) and Python (Java) allowing the link between Python and other languages. (9)

2.5.3 **NumPy**:

NumPy is a library for performing various numerical calculations in Python. It includes matrix and vector matrix and vector calculations, as well as complex numbers. NumPy is also the tool prioritized by Python programmers for the treatment of lists and arrays for its flexibility. The library is available under an open source license. The version used in the final version of the control program is 1.18.4. (9)

Algorithm for import Numpy: import numpy as np

Algorithm work of Numpy:

IB=np.array ([0,0,0])

Ub= $np.array$([179,255,109])

Mask= $cv2.inrange(hsv, Ib, ub)$

2.5.4 **OpenCV**:

OpenCV is an open source library used for Computer Vision (CV) and Machine Learning (ML). Interfaces of the library are available in Python, Java, C++ and MATLAB. It is supported on Windows, Linux, Android and Mac OS. In the context of the project, version 4.1.0.25 was used. It is not the latest version available, but this one had the best compatibility with the different elements of the present. (9)

Algorithm how to open a camera :

Cap= $cv2.videocapture(0)$

Algorithm displays the result of camera:

Success, frame = $cap.read()$

Cv2. Imshow ("CAM", frame)

2.5.5 **Pyserial**:

PySerial is a library, which provides support for serial connections ("RS-232") over a variety of different devices : old-style serial ports, Bluetooth dongles, infra-red ports, and so on. It also supports remote serial ports via RFC 2217 (since V2. 5). (9)

Algorithm import serial :

Import serial

2.5.6 Serial :

The Software Serial library allows serial communication on other digital pins of an arduino board, using software to replicate the functionality (hence the name "Software Serial"). It is possible to have multiple software serial ports with speeds up to 115200 bps. (9)

2.6 Artificial neural networks:

Inspired by the way biological neural networks in the human brain process Information, artificial neural networks are a computational approach for problems in which the solution of the problem, or finding a proper representation, it is difficult for traditional computer programs. Such systems can be trained from examples, rather than explicitly programmed. (10)

Artificial neural network consists of a set of nodes similar to a human neuron.

Each inputs Xi, has its correspondent weight wi, bias B0 and outputs y0. The node applies a non-linear activation function, to the weighted sum of product to produce the node output y0 the activation function introduces non-linearity to the output because most of real data are non-linear, so the network can learn from this non-linear representation :

$$y_0 = \varphi(\sum w_i . x_i + B_0) \quad \text{(III.1)}$$

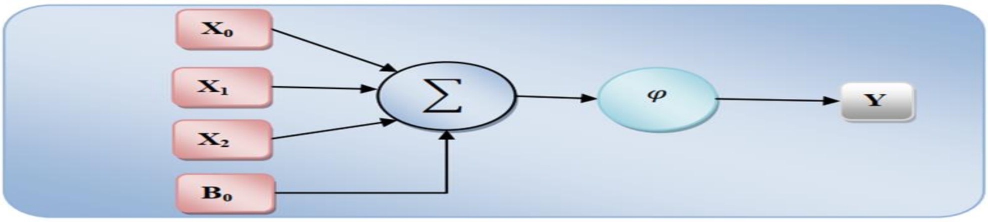

Figure (III.7): One node consists from three inputs, bias and one output Activation Function.

There are many activation functions each one for a specific purpose each one has its

Advantage and disadvantage here a list of the most important activation functions :

Sigmoid : They have nice interpretation as a saturating “firing rate” of a neuron

There are two problems of this function, the first is saturated neurons “kill” the

Gradients, the second come from the fact that Exp () is a bit compute expensive.

$$Ϭ(X) = \frac{1}{(1-e^{-X})} \qquad (III.2)$$

Tanh : This activation function is very useful in the recurrent network this is because of squashes numbers to range [-1, 1] and zero centered (nice).the problem of this function is that it kills gradients when saturated :

$$\mathrm{H(x) = tanh(x)} \qquad (III.3)$$

ReLU : This activation function is very useful in the convolution neural network in computer vision. This function does not saturate converge much faster than sigmoid/tanh in practice :

$$F(x) = \max(0,1) \qquad (III.4)$$

2.7 Neural network architecture:

In applied cases, a large group of the nodes are linked in form of layers, input layer, output layer, and the hidden layer, each layer is connected to the next with weights, which are multiplied to the output of the nodes in the previous layer. (10)

Additionally each node has a bias. The output of the network Y can be obtained by flowing in the network from the input layer through the hidden layer (Feeding-forward in the network), the output of output layer:

$$\mathrm{y} = 6\left(\sum_{\mathrm{J}=1}^{\mathrm{M}} \mathrm{W_j h}\left(\sum_{\mathrm{j}}^{\mathrm{d}} \mathrm{i\,W_i . X_i + B_0}\right) + \mathrm{B_1}\right) \qquad (III.5)$$

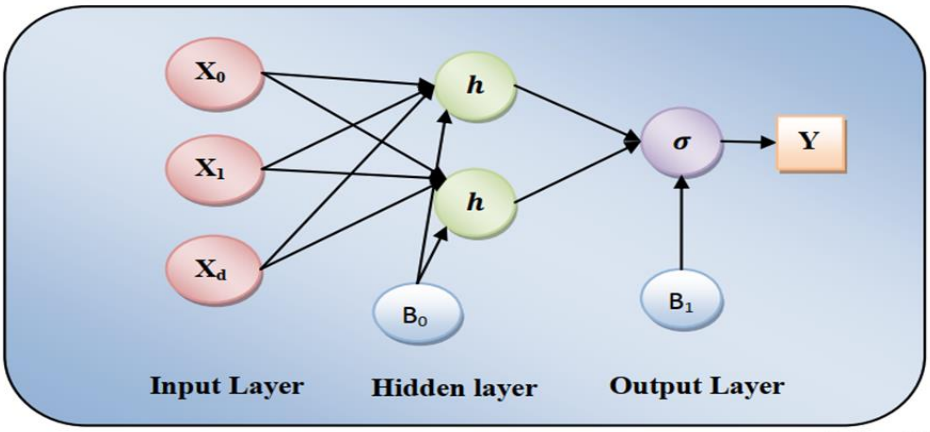

Figure (III. 8): Network diagram for neural network. The input, hidden, and output Variables are represented by nodes and the weight parameters are represented by links between the nodes

- **The loss function**:

Neural Network is a supervised learning, means that each input data has its correspondent label called the target value TN that the output should be taken for a deferent sample of the same class, the data samples form a certain distribution, so for the same class the output Y of the Neural Network takes various values according to the data distribution. The loss function is the function that is used to calculate the Error between the target value T and the output distribution values Y. there are three main loss functions:

•**Cross-entropy**:

It is used for binary classification ; means that the output layer contains one output takes a binary target value, the loss function in this case dealing well with logistic sigmoid output activation function. (11)

•**Multiclass cross-entropy**:

It is used for multiclass classification, means that the output layer contains multi-output nodes, the loss function in this case dealing well with soft-max activation function output activation function. (11)

•**Mean square error**:

It is used for regression purpose the output activation function should be linear activation function, and mean square error is used in the output layer. (11)

.C. Training :

So far, we have viewed neural networks as nonlinear functions those transform from a vector X of input variables to a vector Y of output variables. A simple approach to the problem is to determining the network weights. If there are two deferent dataset each of them has N samples, then the aim of training is to get the proper boundaries between them by varying the weight such that the Loss function will be as minimum as possible.

The first step in training is to choose random initial values of the weights. The value of

Y is calculated using feed forward method ; calculate the gradient using Back propagation. Multiply the gradient by a negative real number called learning rate. The new values of the weights are calculating by adding all the previous parameter together :

$$W^{i+1} = W^{i} - \alpha * \Delta E(W) \qquad (III.6)$$

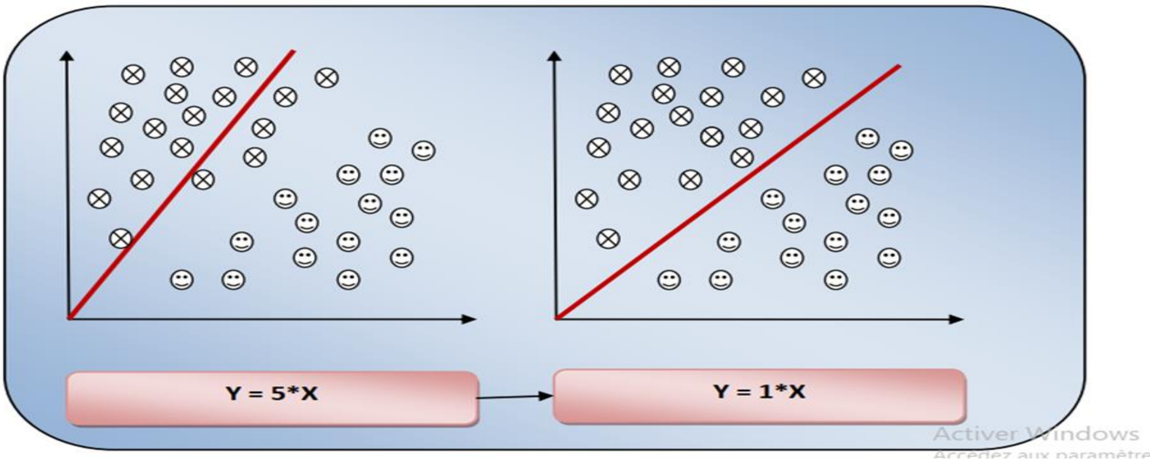

Figure (III.9): An example of how the weights adjust the boundary between two classes

Check the value of the gradient if it is null. Repeating the previous steps until the loss will be minimum (the number of repetition is known by the number of epoch.

2.7.1 Optimization algorithm:

To get the minimum error the derivative of the error function is calculated with respect to the weights. In multiple dimensions, the gradient is the vector of (partial derivatives) along each dimension. This method is called Stochastic Gradient Descent SGD. Because the high nonlinearity of the network there are many positions where the gradient will be zero and the loss will not be the minimum (local minimum), the actual minimum position of the loss is called global minimum. For this reason there are many methods to find the global minimum. The most useful optimum methods in recent year is Adam optimum method , The Adam optimization algorithm is an extension to stochastic gradient descent that has recently seen broader adoption for deep learning applications in computer vision and natural language processing. (12)

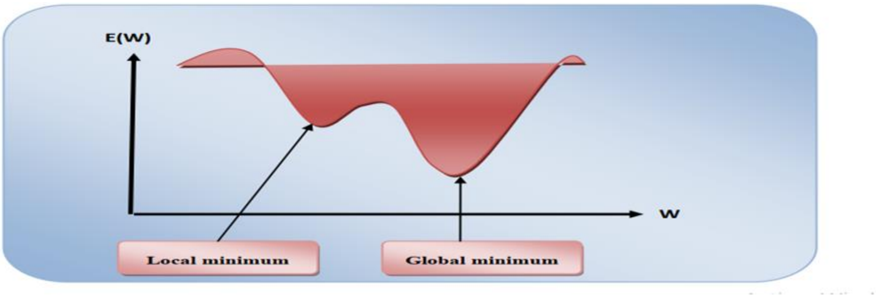

Figure (III. 10): Local and global minimum.

2.7.2 Error Back propagation

So far we have seen that for best training the gradient of the loss function with respect to the network weights should be calculated in order to minimize the loss, unfortunately in a very complex neural network, It is very to calculate the gradient using the analytical way; instead a partial derivative of the loss function is calculated with respect to network weight, after feed forward parameter aj, and Yk are calculated

$\delta_k , \delta_j and\ \frac{dE_N}{dw_{ij}}$

The back-propagation parameter for each node in the network Figure (III.5) where n is the nth pattern. The total error E can then be obtained by repeating the above steps for each pattern in the training set and then summing overall patterns. (11)

$$\frac{\partial E}{\partial wji} = \sum_n \frac{\partial E_n}{\partial wji} \qquad \text{(III.7)}$$

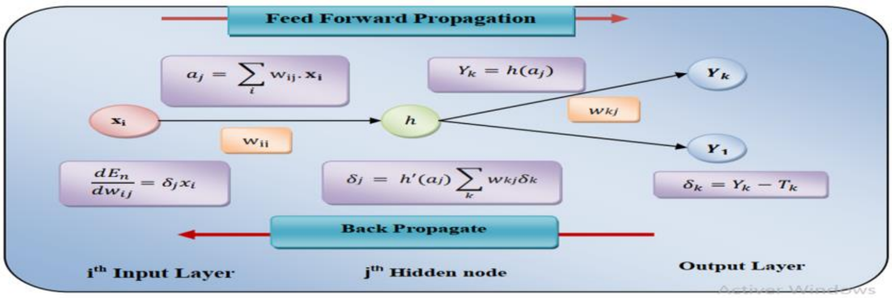

Figure (III.11): Illustration of forward propagation and back propagate steps in the Back propagation algorithm.

2.8 Object Detection :

The object detection is a computer vision technique that detects the localization coordinate of the object in the image and classifies it, thus the network of such technique is composed from two networks, classification network and localization network.

Classification network Firstly the classification network extracts the features from the input image using Convolution neural network CNN, actually CNN is composed from 3 layers (2D Convolution, ReLu activation function, Maxpooling function) respectively, we will explain each one later, the output of Maxpooling is 2D dimension data so as a second stage of classification network a flatten layer is used to convert the 2D output data to 1D data, finally a simple neural network is used to classify the image. The whole process of classification network is shown in Figure (III.12)

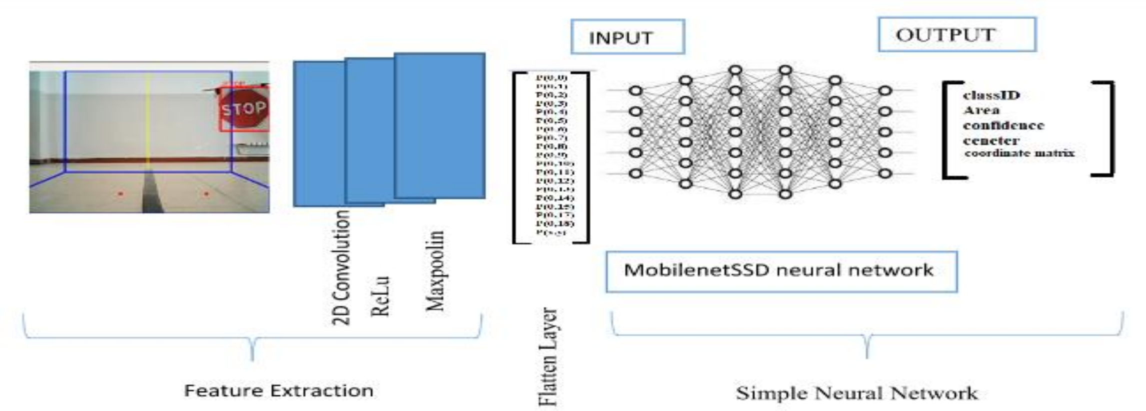

Figure (III.12) Object Detection

2D Convolution :

Convolution is a mathematical operation defined as:

$$y=f \otimes g = \sum f(x-u) * g(u) \qquad (III.8)$$

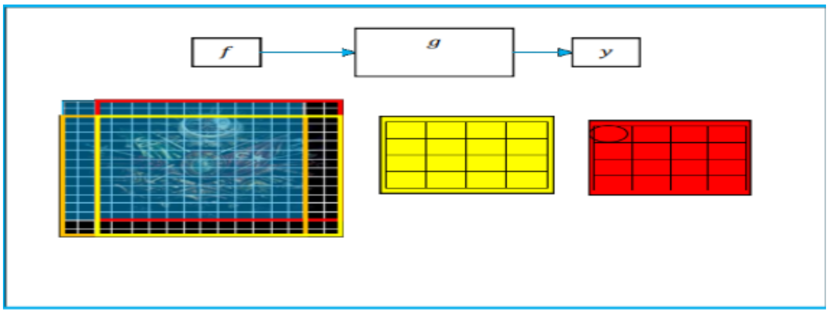

Figure (III.13) : 2D Convolution operation

ReLU :

This activation function is very useful in the convolution neural network in computer vision. This function does not saturate converges much faster than sigmoid/tan in practice:

Maxpooling Layer :

The output of the ReLu function is divided to 16 X 16 array then from each 4X4 array the maximum value is token as showed if Figure (III.13):

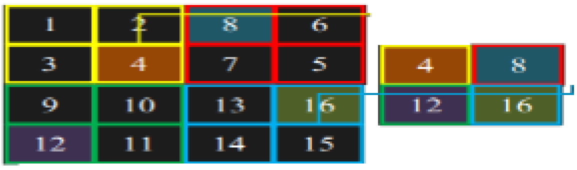

Figure (III.14) : Maxpooling Layer

2.9 MobilenetSSD method :

We present a method for detecting objects in figure (III.15) using a single deep neural network. Our approach, named SSD, discretizes the output space of bounding boxes into a set of default boxes over different aspect ratios and scales per feature map location. At prediction time, the network generates scores for the presence of each object category in each default box and produces adjustments to the box to better match the object shape. Additionally, the network combines predictions from multiple feature maps with different resolutions to naturally handle objects of various sizes. Our SSD model is simple relative to methods that require object proposals because it completely eliminates proposal generation and subsequent pixel or feature resampling stage and encapsulates all computation in a single network.

2.9.1 The output

Is a set of bounding boxes that closely match each of the detected objects, as well as a class output for each detected object. The image below shows what a typical "stop" outputs.

2.9.2 Confidence :

This measures how confident the network is of the objectless of the computed bounding box. Categorical cross-entropy is used to compute this loss.

2.9.3 Area

Area of bounding box coordinates.

2.9.4 Class ID :

Class index of the detected object:

Table (III.3) Class ID of name object.

1	unlabeled	2	person	3	bicycle	4	car
4	motorcycle	5	airplane	6	bus	7	train
8	truck	9	boat	10	traffic light	11	fire hydrant
12	street sign	13	stop sign	14	parking meter	15	bench
16	bird	17	cat	18	dog	19	horse
20	sheep	21	cow	22	elephant	23	bear
24	zebra	25	giraffe	26	hat	27	backpack
28	umbrella	29	shoe	30	eye glasses	31	handbag
32	tie	33	suitcase	34	Frisbee	35	skis
36	snowboard	37	sports ball	38	kite	39	baseball bat
40	baseball glove	41	skateboard	42	surfboard	43	tennis racket
44	bottle	45	plate	46	wine glass	47	cup
48	fork	49	knife	50	spoon	51	bowl
52	banana	53	apple	54	sandwich	55	orange
56	broccoli	57	carrot	58	hot dog	59	pizza
60	donut	61	cake	62	chair	63	couch
64	potted plant	65	bed	66	mirror	67	dining table
68	window	69	desk	70	toilet	71	door
72	TV	73	laptop	74	mouse	75	remote
76	keyboard	77	cell phone	78	microwave	79	oven
80	toaster	81	sink	82	refrigerator	83	blender
84	book	85	clock	86	vase	87	scissors
88	teddy bear	89	hair drier	90	toothbrush		

- ✓ If class ID = 13 (stop detect): The result shows that the implementation is working perfectly. When the “stop” sign is near; the car stops 1 meter away for a minute, and if there is not object; it continues at the end of the time.

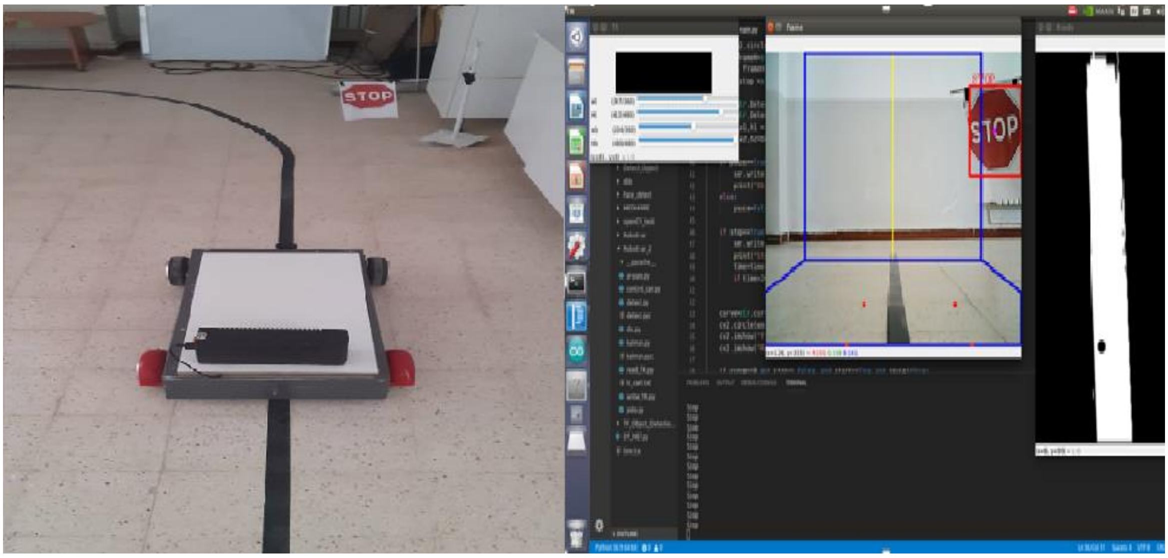

Figure (III.15) stop detection

- ✓ If class IID ≠ 13 (person detect): The result shows that the implementation works well .when the car sees the object through the camera; it stops and waits until the roads are clear to continue driving.

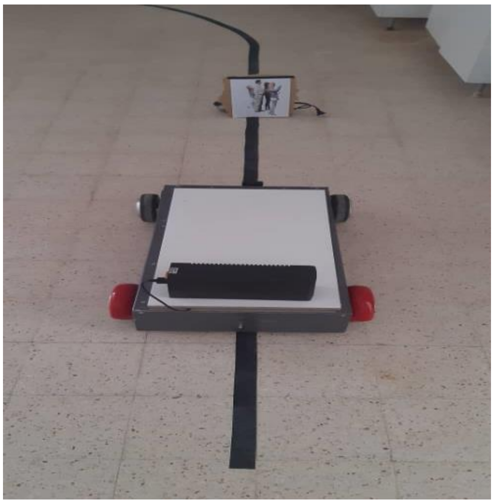

Figure (III.16) object detection.

- **Detection of road**

The programmer converts the box selected in the frame to binary pixel (black and white). The image is extracted from the side not from the top.

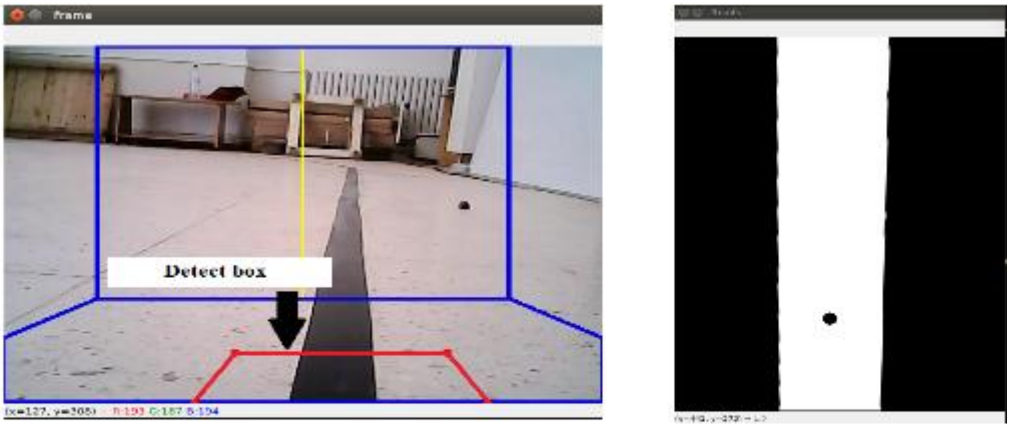

Figure (III.17). Detection of the Road.

The programmer count the number of pixel whit To the right of the center of the frame and to its left, if the number of pixels on the right is greater than the number of pixels on the left, the car will turn to the right, but if the number of pixels on the left is greater than the number of pixel on the right, the car will turn to the left, but if the number of pixels is equal The car takes a straight path.

3 Results and discussion:

Trials were conducted through different testing which include a 4 m. All tests were carried out on an indoor track, as described in the results.

3.1 Results:

To present the results, we conducted several experiments on the vehicle to test its response to detecting the road and the object.

3.1.1 Test (1):

When the rotational speed is step (1) and the linear speed is variable :

1.8 cm/s, 3.3 cm/s, 6.1 cm/s, 12 cm/s.

Figure (III.18) : When the rotational speed is step (1) the on the straight line.

Figure (III.19) : When the rotational speed is step (1) at the turn.

We saw that the vehicle was following a road line and when they came to a curve it slowed down and turned evenly. So when the linear speed a big then the ramping time is short, the response is quick.

3.1.2 Test (2)

When the rotational speed is step (2) and the linear speed is variable : 1.8 cm/s, 3.3 cm/s, 6.1 cm/s, 12 cm/s.

Figure (III.19) : When the rotational speed is step (2) the car

Figure (III.20) : when the rotational speed is step (2), the car

We saw that the vehicle did not follow the line and got out there. So when the rotational speed is more than step (1) ; the car is out of control.

4 Conclusion:

In the first part of this chapter, we presented the experimental bench made in this work. Indeed, we have given the role of each component of the bench and the implementation of the control algorithm. In the second part, some experiment results have been presented. Finally, the obtained results demonstrate the stability of the car.

General conclusion

General conclusion

The goal of this master's thesis is to implement an autonomous electric car. The developed car is able to follow automatically a track based on artificial intelligence. The proposed implementation focuses on a Jetson Nanao card. The electric car is equipped by a camera to control.

Regarding the procedures for testing the output results ; three different scenarios are proposed a straight line, a turn line or an obstacle. The experiment tests show that the proposed implementation works perfectly.

Concerning the performance of accuracy without obstacle, the self-driving vehicle can follow along the mid-line smoothly or add the GPS to save the way to be followed. However, when the lighting changes, such as daylight in the daytime and indoor lights, a situation of instability presents itself. Moreover, the self-driving car will start to pause in different lighting conditions. Due to the relationship between the materials of the floor track, the reflection phenomenon under the sunlight has been observed. As a result, the center line is difficult to locate correctly during interpretation, resulting in pause. In future experiments, one suggestion would be to take into account the change of light intensity and the material of the ground.

Overall, the experiment was successful. Three models were able to provide a good feedback response with significant degree of accuracy pertaining to obstacle collision or the tracking road.

Regarding parameter adjustments of future experiments, it is recommended that more emphasis should be placed on the areas discussed above. As perspectives for the future works, the use of Global Positioning System (GPS) technology for localization and control is suggested. So, the electric car will be connected to internet for collecting data and improving communication in real time. The use of this car for different services will become more save and secure.

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