Design of an Autonomous Electric Vehicle for Assistance in the Movement of People with Visual Disabilities using Vision Algorithms and Artificial Intelligence

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Abstract

Currently autonomous vehicles are equipped with a variety of sensors, controls and actuators, depending on the objectives and requirements of the vehicle. One of the biggest challenges in the development of the autonomous vehicle system for the assistance in the movement of people with visual disabilities is the high cost. Therefore, researchers with a limited budget carry out their experiments and research in simulation environments, while other researchers use small vehicles that in many cases do not accurately represent a real parametric dynamic system. This article describes the design of a low-cost prototype of an autonomous electric vehicle that includes its control systems, microcontrollers, encoders, motor controllers, sensors and cameras. Therefore, the designed vehicle has the ability to move autonomously through the use of vision and artificial intelligence algorithms to assist in the movement of the visually impaired person. The document details the first steps of the design taking into account the parameters of a real environment and artificial intelligence algorithms.

Keywords (12 font)
Design, Autonomous Vehicle, Visual Disabilities, Vision Algorithms and Artificial Intelligence.

1. Introduction

Recently, the field of autonomous systems research has grown very fast. Most companies and organizations spend a great deal of time and money developing autonomous vehicles for numerous applications. This article describes the design of a low-cost prototype of an autonomous electric vehicle for the assistance in the movement of people with visual disabilities using vision algorithms and artificial intelligence that includes its control systems, microcontrollers, encoders, motor controllers, sensors and cameras These vehicles generally combine a variety of sensors to identify appropriate navigation routes to avoid obstacles efficiently.

There are five levels of autonomous driving that describe how a car is driven through tasks and responsibilities, and how the car and driver interact. This project proposes the design of an automation car between levels three and four. The third level is highly automated driving. It states that the driver can allow the car to be driven only for long periods of time in certain situations. The fourth level is fully automated driving. It consists of a vehicle that drives completely independently.

The main application is to navigate a preprogrammed route, avoiding any obstacle that the vehicle may encounter on its way. The vehicle can complete this task using sensors to recognize its surroundings. The most common sensors are LIDAR 3D scanning and global positioning systems. In addition, it uses a control system that integrates all these components to apply the algorithm that processes images and classifies, and an algorithm based on artificial intelligence.

The technological or general situation of the person with visual impairment depends in the majority of a cane or guide dog (traditional or classical method) due to the lack of technology, but they are not sufficient since they are currently in Peru, as in many places in the world, there are many dangers that people with visual disabilities have to face when they move to the streets, these dangers are obstacles such as unevenness, steps, and other people with whom the individual can get hurt and even have a high risk of being run over. The canes that exist today have the limitation that they can only indicate to the person with visual impairment what is in front and on the floor, instead with a mobile robot they improve the results.

The literature on the development of low-cost autonomous vehicles shows that several engineers and researchers, as well as in the automotive industry, are exploring the field of autonomous vehicles. Researchers at the University of Idaho [1] built a low-budget autonomous vehicle using a modified radio-controlled car chassis equipped with GPS and ultrasonic sensors. In the DARPA Urban Challenge 2007, MIT researchers manage to convert a regular passenger vehicle into an autonomous vehicle with perception of local information and a variety of low-cost sensors [2]. In 2014, researchers from the Southern Polytechnic State University designed an autonomous land vehicle using a base platform with easily available parts of a functional kart of approximately $ 400 [3]. In the control system, use Arduino and Raspberry Pi. These components allow them to reduce the cost. The project under development is still very close to the last perspective. The autonomous vehicle system was designed from scratch.

2. Mechanical and electrical design of the project

This section corresponds to the design and selection of autonomous vehicle components.

2.1. Mechanical Design

In the mechanical domain, it includes the design of the structure, the suspension system and the power train. Then, the optimal design will be present in CAD format, to generate the necessary plans for its implementation. The simulation tests of the structure were carried out according to the forces applied during the movement using ANSYS.

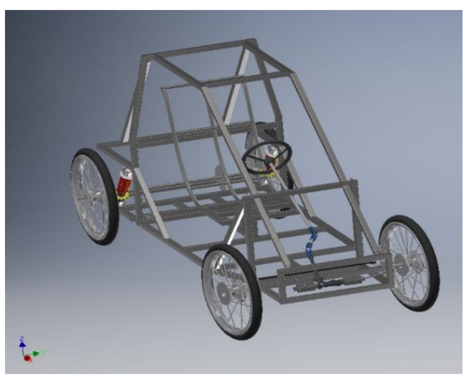

Fig. 1: Perspective view of the CAD design of the chassis and mechanical components.

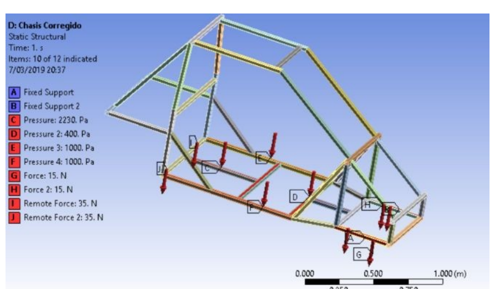

Fig. 2: Simulation of the frame and powertrain in front of the calculated loads.

To start the development of the autonomous vehicle, we need to find the necessary power. We start by taking as a reference the approximate speed of the vehicles on the roads in Lima-Peru, that speed is equivalent to 60 km / h. To begin with the calculation, we need the value of the resistive motion force for our autonomous vehicle. This force is composed of rolling resistance (Rr) and aerodynamic resistance (Ra) [4].

A1) Rolling resistance (Rr)
The engine of a vehicle develops a torque that, after being transmitted by the organs of the transmission system, reaches the driving wheels. Consequently, the driving wheels create a tangential force, which is transmitted tangentially by the tire at the point of contact with the ground. This force must be less than the adhesion force between the driving wheels and the ground to achieve the driving condition of the driving wheel, making the vehicle move correctly in its march. This condition is expressed by rolling resistance (Rr), which is calculated by the following expression.

$$Rr = \mu r \cdot MT \quad (1)$$

MT: is the total weight of the vehicle,
μr: is a dimensionless coefficient, called the rolling coefficient.

During the development of the proposal, estimated sea a total weight equivalent to 3000 N, which consists of the sum of the specific weight of a person, the weight of the batteries, the engine, the structure and all the components detailed below.
The equilibrium coefficient takes the value of 0.0030. It has been chosen by common values according to the condition of the pavement and for the normal conditions of circulation and condition of the autonomous vehicle. In this case, the autonomous vehicle will circulate on a paved road.

Finalmente, la resistencia a la rodadura (Rr) según los valores elegidos es equivalente a 76 N.

A2) Resistencia aerodinámica (Ra)
El aire ejerce una fuerza de acción sobre una superficie frontal efectiva efectiva a la proyección del vehículo en un plano perpendicular a su eje longitudinal. La resistencia aerodinámica (Ra) se calcula de la siguiente manera.

$$Ra = (1/2)\cdot\rho\cdot Cd\cdot A\cdot v2 \quad (2)$$

ρ : is the density of air;
Cd : is the drag coefficient
A : is the frontal area of the car
v2 : is the value of the square of the velocity

During the development of the mechanical design, it was discovered that the frontal area is equivalent to twenty percent of an area of 1.6 mx 1 m. With what it takes to take a value of 0.32m.The drag coefficient is a number that aerodynamics use to model all complex drag dependencies on shape, inclination and some flow conditions [5]. Take the value of 0.7. It has been chosen through the common values of tubular vehicle designs.
The air density under normal conditions is equal to 1.2754 kg / m^3 and the approximate speed requirement in road vehicles is equivalent to 60 km / h.

Finally, the aerodynamic drag (Ra) according to the chosen values is approximately equivalent to 39.70 N.

A3) Power (Pf)
He made the calculation of the previous forces. The resistive force of the movement is equal to the sum of both forces. In this sense, to calculate the power needed to overcome the total resistance force to the movement, multiply this value by the estimated speed [4].

$$Pf = (Ra + Rr)\cdot v \quad (3)$$

Ra : Aerodynamic Resistance; Rr : Rolling Resistance
v : is the value of the velocity

Finally, the power takes the approximate value of 1911 W. Assuming, a mechanical efficiency of 96%. An effective power of approximately 2 kW is required.

2.1. Electric Design

According to the development approach and impulse of an electric vehicle which has been chosen to use an electric motor of about 2.5 HP of power (2kW DC motor). This power has been calculated by the aerodynamic drag and the force required to maintain a speed of approximately 60 km /h. In the other hand, we use another motor that permits us to control the car's direction with 500W of power (Motor DC).

We chose three kinds of wires according to the rated current and Peruvian technical standards. The cross sections are 2.5, 8 and 16 (all in square millimeters). Likewise, we designed a system to protect our circuits in case of overloads and short circuits with thermomagnetic switches and protection fuses. These components let us to open the circuits in case of failures and in this way, they protect our circuits.
About the DC source, we have a group of six lead batteries (12 VDC each one) connected in series that power the motor's driver and the converter. The converter changes the dc voltage from 72V to 24V; this voltage, is necessary to power correctly our motor driver-direction.

The following table shows all the electric components

Quantity	Type
6 units	lead battery 12VDC
1 unit	Driver of 2kW DC motor
1 unit	500 W DC motor
1 unit	Driver of DC motor
1 unit each one	thermomagnetic switches 40A and 16 A
1 unit each one	fuses 40A and 16 A
1 unit	converter 72VDC to 24VDC
6 units	lead battery 12VDC

Table 1: Power components

3. Results and discussion

This section corresponds to the design and selection of the algorithms in their respective domains.

3.1. Computer Vision

This domain is responsible for the implementation, selection and development of algorithms that can process the images obtained by sensors, such as LIDAR. Subsequently, classify the lines and obstacles that allow to be the dynamic variables that influence the driving autonomy of the vehicle.
Currently, there are many ways to classify and object, such as using Gradient Oriented Histograms (HOG) or using Tensorflow, which includes a red neural to learn to recognize an object. In this case we use YOLO and OpenCV to use and train how to recognize each object of interest that we find on a path.

In order to classify all the different objects, we divided the algorithm in two separate models of object detection.

A1) Road Line Detection
This algorithm processes every frame than the camera and the LIDAR detection, make then predict the fine of best fit, due to the marks of a line are not always on the best state and this issue could create a bug in our algorithm.

Fig. 3: Processing of images using algorithms that detect lanes

A2) Pedestrian and Sign Recognition

For this process, we used a model of object detection called YOLO, than it's based on a single neural network which help us to predict the class of an object than the camera detect. For every class of object presente in the COCO (common object in context) dataset the algorithm classified by itself such cars and pedestrian. But, for classes than are not in this list, we have to train this neural network to learn how to recognize this new class, like a red traffic light, yellow traffic light and green traffic light.

Fig. 4: Processing of images using algorithms that detect vehicles

4. Conclusion

It is concluded that simulations can represent an almost real environment with obstacles. And also neural networks and computer vision can predict and solve a real road driving problem.

It can be concluded that the mechanical and electrical design takes into account the requirements of a full-size vehicle, which demonstrates that using mathematical formulas and deformation simulations we can predict and approximate almost exact behavior in a real environment. Finally, the interaction between mechanical design and electrical design has allowed us to explore the capabilities acquired to find the most appropriate solution taking into account time, price and manufacturing.

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Biographies

Juan José Encinas C. He was born in Lima, Peru on 09-12-1997. He graduated in mechatronics engineering. He was awarded a certificate for attendance and delivery of a presentation in 2018. The 2nd International Conference on Intelligent Manufacturing and Automation Engineering (ICIMA 2018) in Penang, Malaysia, from December 18 to 20, 2018, has indexed paper. I participate in the 10th International Symposium on Innovation and Technology - ISIT 2019, held from July 22 to 24, 2019 in the city of Cusco, Peru, participated as part of the Peru Section of the IEEE of the event called the XXVI International Congress of Electronics, Electricidad Ingeniería y Computación - INTERCON 2019, held from August 12 to 14, 2019 in the city of Lima, Peru.

Mario Chauca was born in Ica, Peru. He was a past director in AOTS-Kenshu Kiokay del, Peru. He is a steering committee member of MWSCAS, and technical committee member of MWSCAS. He is a reviewer of the Journal named IRJPEH, and a chair session in ICIMA 2018. He obtained a scholarship AOTS-Japan, NIPA-Korea. He is a consultant in information and communication technologies in the government sector of Peru and in the United Nations Project-Inter-American Development Bank-Congress of the Republic of Peru and the Ministry of the Interior of Peru and in the private sector.