Neurocontrol Car Driving by Assistance Of Radar Networks System

Safa A. Najim Alsalahi[1]* and Hayder Q. Mashri[2]**

[1]Computer Science Dept., Science College,
[2] Materials Engineering Dept., Engineering College,
Basrah University, Basrah, Iraq
** safanajim@yahoo.com*
***hqm3@ymail.com*
ISSN -1817 -2695
((Received 17/5/2010, Accepted 11/4/2011))

Abstract

In this paper we are concerned with the construction of an artificial intelligence program as a neurocontroller for safely driving a car in the road with different probable situations. This research mainly interested in the use of neural network (*NN*) and its work with radars. The proposed approach deals with decision-making mechanisms depending on the target position. The main novelty in this paper lies in the *NN* controlling depending on the front and back radars readings. This neurocontroller decides car status to increase or decrease acceleration, and turning direction with steering angle to the left or the right while accelerating. Results showed the good capability of this controller with emphasis on skills learning behavior.

Keywords: Controller, Neural Networks, Radar.

Introduction:

Roadways and highways accidents may occur mainly because of the driver errors or a bad weather, such as the headlights of oncoming ***cars*** frequently make it difficult for the driver of a car to see the road and safely operate the car. This is a significant cause of accidents and much discomfort [1]. The problem is especially severe during bad weather where the rain can cause multiple reflections. Opaque visors are now used to partially solve this problem but they do so by completely blocking the view through a large portion of the window and therefore cannot be used to cover the entire windshield [2]. Similar problems are happen when the sun is setting or rising and the driver is operating the car in the direction of the sun. The car monitoring system disclosed herein can contribute to the solution of this problem by determining the position of the driver's eyes.

Particular mention should be made for the use of the ***radar***, which it is the use of the electromagnetic waves and a voltage-controlled oscillator (VCO). In this embodiment, the frequency of the oscillator is controlled via the use of a phase detector which adjusts the oscillator frequency so that exactly one half wave occupies the distance from the transmitter to the receiver via reflection off of the occupant. The adjusted frequency is thus inversely proportional to the distance from the transmitter to the occupant. These systems could be used in any direction [3].

Control systems for cars typically utilize an architecture in which a central processor carries out many instructions at a time. These controllers utilize a so-called ***Neural Network (NN)*** which analyzes data coming from radar and passing the control result to the driver [4, 5]. These controllers are generally dedicated to specific functions such as distance, angle turn, etc. After training with several examples, the network begins to organize itself and refines its own architecture to fit the data, much like a human brain learns from examples.

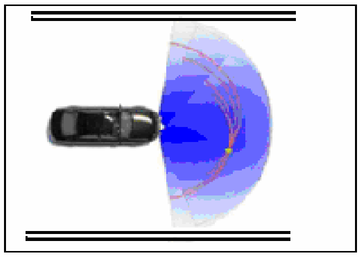
Radar System:

Radar was continued to develop and new powerful and compact radars where produced, conventional radar uses beamed and reflected microwave energy to detect, locate, and track objects over distances of many miles. Almost all types of radar were developed for defense applications, and they continue to be used by the military and a few civilian organizations [6, 7, 8].

There is a wide interest in the application of millimeter wave (*MMW*) technology to automotive use as *MMW* radar for Automotive Longitudinal Control. The most promising short-term applications in this area is the headway monitoring radar, which provides a contactless measurement of range and closing velocity to a car in front for maintaining a safe following distance and uses this information as input to semiautomatic and automatic longitudinal control, collision warning and avoidance, and automotive telecommunications systems, with the goal of maintaining a minimum safe following distance and improving safety of travel. The radar operates by transmitting a signal with a center frequency f linearly swept over a bandwidth B during a time T. The received signal is used as an input to an intelligent adaptive speed control system which will adapt the speed of the car, whenever traffic induced changes in speed require keeping the car at a safe distance from the car in front of it [9].

Table (1): Requirements for a single sensor in radar network system

Parameter	Value
Observation area	120^o in azimuth
Maximum range	40m
Range resolution	0.4m
Range accuracy (required by multilateration)	0.02m
Velocity resolution	1m/s
Velocity accuracy	0.3m/s
Target acquisition time	20-100ms



Figure(1): Neurocontroller car driving with front radars network

Automotive radar systems need to have the capability to measure range, velocity and azimuth angle simultaneously for all points and ex-tended targets inside the observation area. Short time measurement even in dense target situations, high range accuracy, and resolution, are required in all automotive applications. Thus instead of a single radar sensor radars network system used, as in figure (1). The relevant system parameters for a short-range radar network are given in Table (1). Requirements for a single sensor in a radar network system in azimuth angle and a maximum range of up to 200m. If, in contrast, large azimuth angle coverage and a short maximum range are required, radar network systems with e.g. four individual sensors mounted behind the front bumper are used instead of a single radar sensor. Typical automotive applications for radar networks with a large azimuth angle coverage but limited range are, for example, Collision Avoidance and Pre Crash Warning. The figure below illustrates the observation area in consideration.

The developed near distance single radar sensor provides target range and radial velocity simultaneously with high accuracy and for all objects inside the observation area. It is characteristic of radar networks signal processing that the angular position of each target is calculated by means of multilateration techniques based on the sensor specific measured target ranges inside the network. This is to derive the desired target position by calculating the intersection point of all range measurements from different radar sensor positions [8, 10, 11]

Neural Networks (*NNs*):

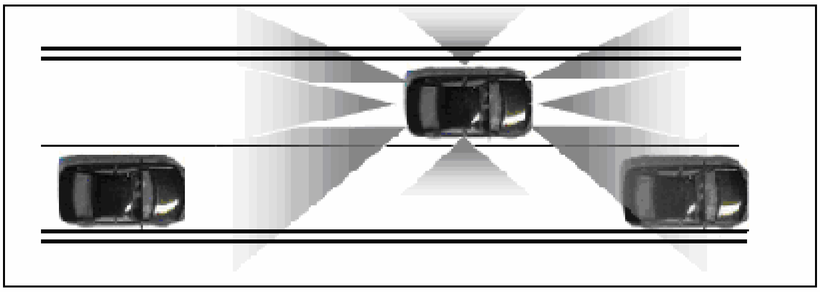
Neural network is a software model of certain poorly understood neurophysiologic process through to exit in brain, for that its composed of large number of neurons (or processing units) which implemented as a nonlinear (or activation) functions to explicit its output. The key feature of *NNs* is asynchronous parallel and distributed processing, and higher speed computation capability. These allow it to be used increasingly in control and recognition. There are many kinds of *NN* models that have been proposed, but backpropagation neural network (*BpNN*) is a most and general type [4, 12]

Bp network is composed of three types of layers (input, hidden, and output). These layers are composed of a number of neurons. Each neuron has a number of inputs and outputs connect it with other neurons in the other layers. These connections are represented by connection weights.

There are several applications used *NNs* as controller, using radars with car in driving control [13, 14, 15, 16], and these applications try to build strong controller for allowing car in a safe side. This paper takes this goal, where it adds radars networks to achieve strong neurocontrol system.

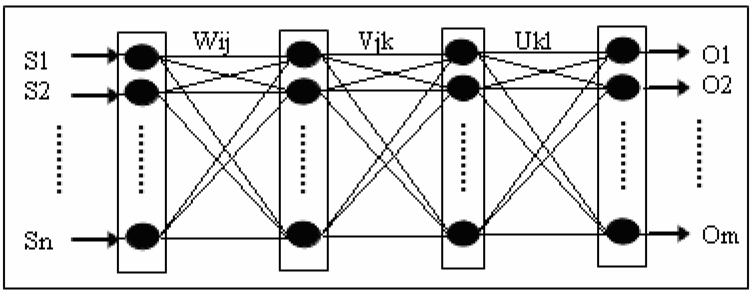
Neurocontrol System:

In order to build a good controller car system, the radar may be moving. The radar system can identify multiple targets; determine their speeds, range, shape, altitude, angle of travel direction…etc. While Radar is small size, low cost, and high reliability, we used two groups (or networks) of radars. One network put on the front of a car, and another one put on the back of it, as in figure (2). Each radars network has four radars, to get a full radar vision around the car and scan objects in four sides of the car. The front radars are responsible to determine the status of front cars. The back radars network is responsible to check the status of the other cars in the back.



Figure(2): Car with front and back radars networks

This control system is for driving a car in auto-moving using neural network method. This network (as in figure (3)) consists of four layers back-propagation network with input layer nodes, two hidden layers nodes, and output layer nodes.



Figure(3): NN with 4- layres

We have built the neurocontrol car driving system by using *NN* with radars that protect and guide car. The radars scan the ambient and detect the other cars and obstacles; their results are entering to *NN* as inputs. *NN* is training to take decisions. After that, the neurocontrol system is able to encounter anything in the street environment when car run through it.

This system is run by high level and very fast hardware and software. They also have the characteristic of small size, they analyzed delivered data from sensors and process it within relatively very short time and response to prevent accidents and guide car safely. The architecture of this control system is depending on the task decomposition method. We build subcontrol networks, where each one has a specific role. These sub-nets are connected to the master gate network, which distributes the control signals through them. In order to explain this neurocontrol system, we must study two running car states:

1- Car is straight running.

2- Car turn to a direction (to right, or to left).

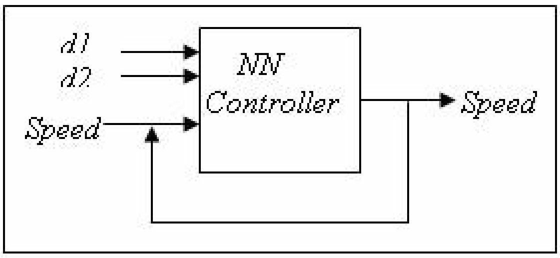
1- *Car is Straight Running*:

Here radars network unit sends out a beam on the road in front and back of car, a portion of this beam will reflect off the road and returns to the unit, which determines the distance between it and the cars in front and back of it. The distance is computed through the following relation [10]:

$$D = M(Constant \quad Value) + \left(\frac{S_{eq}^2}{2\beta_{eq}} - \frac{S_t^2}{2\beta_{eq}} + S_{eq}.T_{eq.r} + 2 \right) \text{----------------} (1)$$

Where:
D=measured distance by radar
M= standard distance
S_{eq}= speed of equipped car
β_{eq}= breaking coefficient of equipped car
S_t= speed of targeted car
β_t= breaking coefficient of targeted car
$T_{eq.r}$=reaction time of equipped car

There are two distance values which were computed d_1 & d_2, d_1 is a distance value from the front cars, while d_2 is a distance value to the cars found in the back of the current car. When radars detect these targets and their distances, they send these values to the *NN* as inputs for controlling the speed of the cars, as in figure (4).



Figure(4): NN controller for straight running

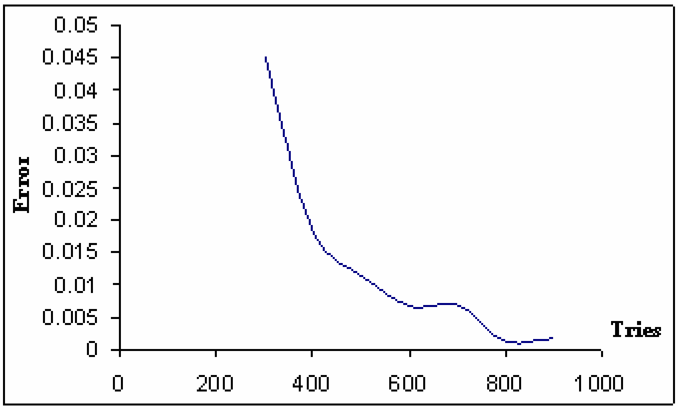
Neurocontrol system for this status is depending on the current car speed, front distance, and back distance. The car speed is fedback as input, this is very important because the speed of the car may change smoothly. The speed could be increased or decreased. The Neurocontrol system increased the speed when:

1- (*d1* & *d2*) > Normal Cars Distance. or
2- *d1* > Normal Cars Distance, and *d2* = Normal Cars Distance.

While speed decreasing might occur in the following state:

d1 ≤ Normal Cars Distance.

Figure (5) shows the error of this controller in this state. The error reaches to the (0.0018) when the training cycles for neural network are 900. Through training cycles, we show the error is decreased reaching to the minimum value. The control style in the state is very well, because it depends on the little parameters (three parameters).



Figure(5): The neurocontroller error style in the straight running

***2- Car Turns to a Direction (to Right, or to Left)*:**

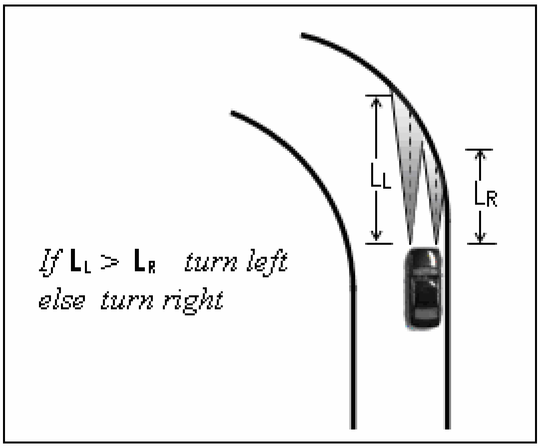
The neurocontrol system can decide to turn right (or left) direction depending on the status of front and back cars, where:

1- Car may turn to the left side and increase speed if the current speed is not high (less than 80 Km/hr), d_1 is equal to the car safe distance and there are no cars on the left side from the back.

2- Car turns to the right side and decrease speed if the current speed is high (greater than 80 Km/hr), and d_2 is equal to Car safe Distance, and there are no cars on the right side from the back.

The relation (2) is used when car turns to any direction, where the reading of the two radars (L_L and L_R) are only required. These two radars are put at the end front radars network

If $L_L > L_R$ the car is turn to left direction
Else the car is turn to right direction. } ------------------------ (2)



Figure(6): Nerocontroller system turn car to left depending on the L_L and R_R distances

Figure (6) shows how car turns to left or right depending on the reading of front radars network. When the turn direction is determined, the angle of turning (or stern angle) is evaluated through the relation (3) [7]. This relation depending on the steering angle cannot exceed ±60o.

$x = A(x(t), u(t))$ -------(3)

More explains:

$$\begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \\ x_4(t) \end{bmatrix} = \begin{bmatrix} \cos(x_3(t)) \\ \sin(x_3(t)) \\ \frac{\tan(x_4(t))}{l} \\ 0 \end{bmatrix} u_1 + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} u_2(t)$$

$$where: \quad -\frac{\pi}{3} \le x_4 \le \frac{\pi}{3}$$

and x1*(t)* is the x value of the center of the rear axle of the car

x2(t) is the y value of the center of the rear axle of the car

x3(t) is the heading of the car

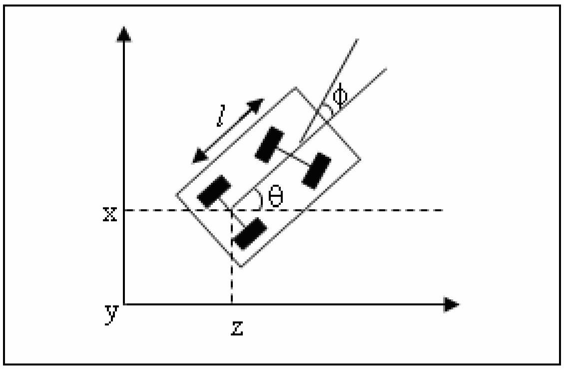
x4(t) is the steering angle for the car

l is the length between the axles

u1 is the car velocity

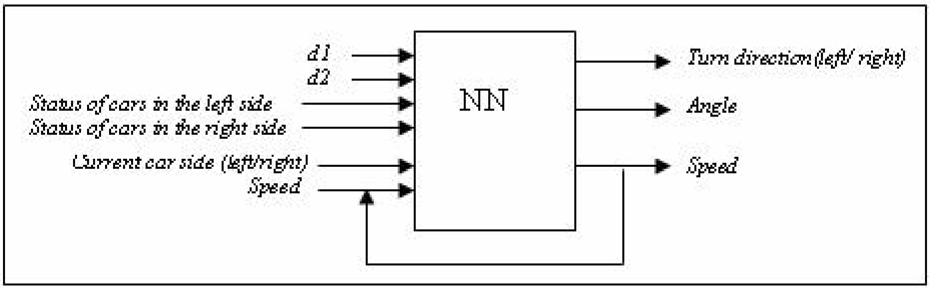
u2(t) is the steering angle velocity

The relation (3) required the steering angle cannot exceed ±60^o, and the figure (7) showed that.



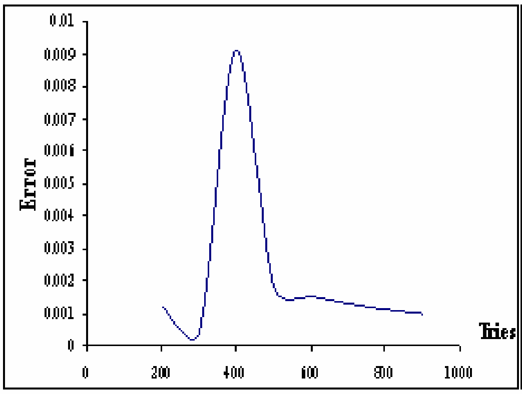
Figure(7): The stern angle is ranged between ±60°

Figure (8) shows that the Neurocontrol system has six inputs and three outputs. The speed parameter is fedback, because it smoothly changes depending on the street environment states. The moving strain angle changes each time, while car is turning to any direction.

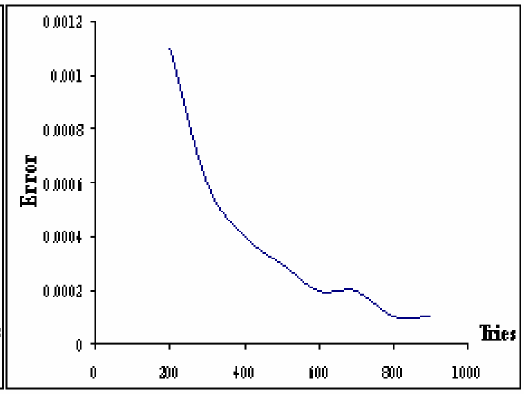


Figure(8): Neurocontroller car moving when car is turn to any direction

The qualification of this system when it turns to the left and right were shown in figure (9) and figure (10), respectively. When turning to the left, we show unstable state in the start training. This is because the increasing value is in the car speed parameter, and this required more driving control. The error after that will be smoothly decreasing, while car speed is near to be stable, where control system succeeds to decrease error to (0.001) when training cycle is 900 epochs.



Figure(9): The style of Neurocontroller when car is turning to the left direction.



Figure(10): The style of Neurocontroller when car is turning to the right direction.

The driving control when car turning to the right required little control compared with left turning. The control, in this state, decreasing error to (0.0001) when training cycle is 900 epochs. This strong qualification is because the speed is decreasing and the car driving in a low speed may be easy.

The performance of the neurocontrol car system is depending on the data that are used to train the network. The amount and the distribution of data upon possibilities are known to have a large effect on the ability of the network to control and to generalize. The network was trained using the all above-states. A general and optimum result was found after 900 training cycles where error reaches the 0.0032. Figure (11) shows the performance of the general neurocontrol driving car by radars support.

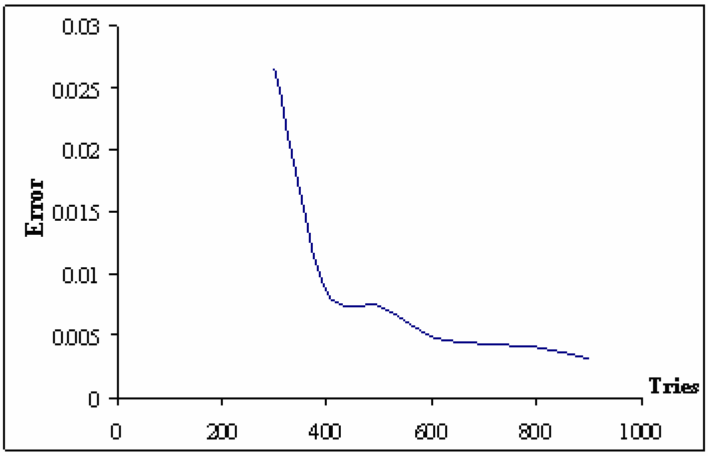


Figure (11): The performance of the general neurocontroller driving

Conclusion:

Two successful types of neurocontroller software were used for the car driving, they are accurately determined with the assist of virtually produced data of the radar networks and *NN* process. First type uses the fundamental of task decomposition, and the second type is general form. This paper showed how is the *NN* takes its decisions depending on the front, back and side radar signals. The control decisions are car acceleration and steering direction with an angle. The experimental results showed that the control system would be high accurate, where the mean error from standard value of measurement reached 0.0018 when car run in straight direction which is a very good estimation. The error reached 0.001 and 0.0001 when car turns to left and right, respectively, again, it’s a very good estimation too. Finally, the experiment showed that the general error value of the controller system was 0.0032. These results with such errors, fulfill that the control system has high optimization with the proposed events of the road when car running.

References:

[1] Honda Company, "*The Honda Intelligent Driver Support (Hids) Syste*m", Tokyo, September 19, Honda Motor Co., Ltd, 1997.

[2] J. Lindamood, "*Bad-Weather Driving Tips*", Rodale, Inc, ISSN: 0028-6974. , 1997.

[3]M. I. Skolnik, "*Radar Handbook*", McGraw-Hill Professional, ISBN 007057913X, 9780070579132, 1990.

[4]C. Lin, "*Application Of Neural Network In Control Problem*", International Conference on Machine Learning and Cybernetics, Hong Kong, Vol: 6, pp: 3465-3471, ISBN: 978-1-4244-0973-0. , 2007

[5]S. A. Alsalahi, 2004, "*Neurocontroller For Roads Junction*", Basrah Journal of Science, Iraq, Basrah, Vol.22 (1), pp: 158-164.

[6] S. A. Hovanessian, 1973, "*Radar Detection & Tracking Systems*", Artech Hou, ISBN: 0890060185.

[7]W. K. Grefe, 2005, "*Integral Collision Avoidance, Lane Keeping, And Cruise Control With Optimal Controller And Fuzzy Controller*", MSc thesis, faculty of the Virginia Polytechnic Institute, USA.

[8]H. Rohling, 2006, "*Radar Topics: Waveform Design, Range Cfar And Target Recognition*", Springer Netherlands, Vol.2, ISBN 978-1-4020-4284-3. pp: 293-322.

[9]W. David, 1997, "*FMCW MMW Radar For Automation Longitudinal Control*",

[10]L.Sakkila, P.Deloof, & X. Elhillali, 2007, "*A Real Time Signal Processing For Anti-Collision Road Radar System*", proceeding of the IEEE vehicular technology conference 2006 fall.

ISSN 1055-1425, California Path.

[11] J. Shahram, N. Mohammad-Ali, and M.A., 2007, "*Adaptive Car Safety Syst*em", Engineering and technology, Vol.21.

[12]S. A. Alsalahi, and A. El-Sheribini, 2003, "*Enhancement Neural Networks Architecture By Use General Genetic Algorithm (GGA)*", Basrah J. Science, Iraq, Basrah, A, Vol.21, No.1, pp:46-54.

[13] Breed, David S., 2008, "*Neural Network Systems For Cars*", United States Patent Application 20080144944, Kind Code: A1.

[14]Nishio Tomoyuki, 1996, " *Vehicle Crash Predictive And Evasive Operation System By Neural Networks*", United States Patent Application 5541590,

[15]Roy Rini, 2004, "*Vehicle Control System Having An Adaptive Controller*", United States Patent Application 20040243292, Kind Code: A1.

[16]David S., Wilbur E., & Wendell C., 2001, "*Vehicular Occupant Motion Detection System Using Radar*", United States Patent Application 20010042977, Kind Code: A1.

السيطرة بواسطة الشبكات العصبية لقيادة السيارة بمساندة نظام شبكة رادارات

صفاء عامر نجم الصالحي [1] حيدر قاسم مشري [2]

1 قسم علوم الحاسبات، كلية العلوم

2 قسم هندسة المواد، كلية الهندسة، جامعة البصرة

البصرة، العراق

الخلاصة

هذا البحث يركز على استخدام مسيطرذكاء صناعي لقيادة السيارة بأمان في الشارع، تم التركيز على استخدام الشبكات العصبية و الرادارات. الطريقة المقترحة هي إلية اتخاذ القرارات بالاعتماد على مواقع الأجسام قرب السيارة وحالة الطريق، الشيء المتميز في هذا البحث هو السيطرة بواسطة الشبكات العصبية بمساندة الرادارات من خلال استخدام قراءات شبكات الرادارات الموجودة أمام و خلف السيارة. يمكن لهذا المسيطر تغيير تعجيل السيارة وبالتالي زيادة أو تقليل سرعتها، الاستدارة باتجاه اليمين أو اليسار مع تحديد زاوية دوران مقود السيارة. نتائج الاختبارات أثبتت كفاءة سلوك هذا المسيطر من خلال القيم الواطئة للخطأ.