Journal of Scientific & Industrial Research
Vol. 76, April 2017, pp. 212-216

Investigation in Autonomous Line Follower Robot

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Received 20 October 2015; revised 16 September 2016; accepted 07 February 2017

The line follower robot is a mobile machine that can detect and follow a line drawn on the floor. In this paper, a predefined path is provided and the path is made up of a black line on a white surface with high contrast color. The mobile robot senses the path with two of its infrared sensors that installed under the robot and a third infrared sensor is used for obstacle avoidance. The left sensor controls the right wheel and the right sensor control the left wheel. The sensors detect the path and provide the information to the microprocessor. The microprocessor activates the motors depending on the path which may be straight or curved. The robot is allowed to follow a line of 4m length with varying wheel diameter and Castor position. The times taken for the travel under different arrangement were tabulated. Design of Experiments is used for finding optimal design parameters of the robot for time taken to complete the travel along the predefined path. The parameters considered are Wheel Diameter 'D' for three levels (70 mm, 80 mm, 90 mm), Centre to Centre (C-C Distance) between the Caster wheel centre and the Rear wheel centre for three levels (90 mm, 100 mm, 112 mm). Finally empirical model have been formulated by the application of Regression Modeling after evaluation of Test of hypothesis for above mentioned levels and factors for significant effects. The results obtained from the design of experiments are given fed in to the fuzzy logic controller. The results of the two methods were compared and obtained satisfactory results.

Keywords: Autonomous Line Follower Robot, Response Surface Modeling, Regression Modeling, Fuzzy Logic Control

Introduction

Mobile Robots are mechanical devices cable of moving in an environment with a degree of autonomy. Autonomous navigation is associated to the availability of external sensors that capture information of the environment through visual images or distance or proximity measurements[1]. A mobile robot is programmed to follow a dark line on the white background[2,8] and detect turns (or) deviations and modify the motors appropriately. The path was sensed by the IR (Infra-Red) sensors. Differential steering is used to turn the robot. Each back wheel has a dedicated motor while the front wheel is free to rotate. An Autonomous mobile robot for speed and position control on variable trajectory depending on trajectory curvature was designed. Road data image was captured by CCD camera[3,4] mounted on the vehicle and transferred to host computer and RF data link unit. Image processing was applied on trajectory. Reference speed was applied to fuzzy controller unit and output was send to vehicle by wireless transmitter unit. The robot has the capability to follow the line on the floor using visual feedback and maintaining its balance on two wheels. The visual servoing technique allowed the robot to follow the line on the floor captured by a camera as the desired trajectory[4]. A RCX LEGO robot is a robot for training undergraduate student which incorporates an on-board Hitachi H8 microprocessor. Two light sensors were used under the robot to sense a white line drawn on a black surface[5,7]. A fuzzy logic algorithm was used to move the robot to follow the line[5,8]. An educational mobile robot called Rug-Warrior Pro for robotics course was developed. It was the use of fuzzy logic[6,8] for controlling and could avoid obstacles. The robot was based on the Motorola MC68HC811E2 microcontroller with extended memory and real-time operating system.A line follower is made from a tankbot using twin line sensors. It follows white line drawn on the black surface[7]. A low cost educational microcontroller based robot called Robo-PICA and was equipped with a pair of infrared reflectors mounted at the bottom and at both corners of the robot. The fuzzy logic controller implemented inside PIC16F887 microcontroller using mikroC development environment kept the robot on track. The robots developed followed a black line follow on

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white surface[8]. A Line Follower robot that followed a specific path on the ground by following the black line while conveying the object placed on it by the ABB robot from one point to another. Their robot was controlled by a PIC 16f873 micro controller[9]. The Line following robots were very popular with technical university and vocational high-school students in Taiwan and those projects were quite helpful in motivating students to learn actively the implementation skills for intelligent mobile robots.

The line-following robot for educational purposes included not only accurate line detection algorithms with analog outputs of reflective optical sensors, but also home-made encoders, which helped record all information about the racing track[10.] A robot car follows a path which was black line on the white surface. It was an integrated design form the knowledge of Mechanical electrical and Computer Engineering. They presented a 700 gm weight of 9W LDR sensor based line follower. The dimension of the electromechanical robot was 7x5x3 cubic inches with a cost of BDT 1150. Their Robot could lift 500 gm without getting off the line[11].

Materials and methods

The work has its own hypothesis of tracking a dark line path marked on the surface. The dark line is created by pasting black tape on white surface. The environment considered is static. The robot is made to stop when it approaches an obstacle. Two DC geared motors are used in this work to power the wheels, the reason for using the DC motor are, it is easy to control, small and powerful. Gear-train reductions are typically needed to reduce the speed and increase the torque output of the motor. Wheels are used to move the robot from one place to another place. The wheels are connected with the motor and the motor are connected with robot. When the wheel rotates, the robot moves from its position. Wheeled robots are the robots that navigate around the ground using the motorized wheel. They are better controlled vehicle than the other types of Robots. In our work, two driven rear wheels and one idle wheel which is not driven by a motor which kept at front. The outer diameter of the wheel is 70 mm and the thickness is 20mm.Selection of chassis is very important task because the weight of the robot is withstand by the robot itself and also helps to hold the parts of the robot like processor, motor, sensors, battery and circuit board. The specification of the robot is that the length is 375 mm, breadth 285mm and Height 140mm. The infrared sensor is an electronic device that measures infrared light radiating from objects in its field of view. Wheeled mobile robot consists of three infrared sensors, two sensors are used to keep the robot in its path and the third infrared sensors is used to avoid obstacle in the desired path, the main purpose of the obstacle avoiding sensor is for safety consideration that is when an object or any human being comes in the robot path the obstacle avoiding sensors sense that and it will send a signal to the microprocessor to stop the motors and according to path it stops the specified motor which is used to turn the robot left or right and keeps the robot left or right and keeps the robot in its path. A potentiometer is an electronic device, a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. LM 358 comparator is used to compare two voltages or currents and switches its output to indicate which is larger. There are two inputs are required for comparator. One input is from photo-receiver, other is generated by us using potentiometer. The second voltage is also called as reference voltage for the sensor. Motor drive L 293 is used to control two DC geared motors fixed in the robot. From microcontroller we cannot connect a motor directly because microcontroller cannot give sufficient current to drive the DC motors. So for this purpose motor driver is used, motor drive is a current enhancing device, it can also be act as switching device. Thus we have to insert motor drive between motor and microcontroller. Motor drive takes the input signals from microcontroller and generates corresponding output for motor. The moving of the robot is achieved by using motor drivand it is used to power the motor by giving power to it. Processor AT89S52 is used. It uses simple algorithms and programming can be done without removing it from the system. The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer.A circuit board is a card made especially for attaching electronic components. The board is made of a fiber class. Parts are then attached to the base using a conductive

bonding material. The main advantage of the circuit board is for easy debugging, chances of loose connections get eliminated and it is reliable and durable due its compact nature.

Wheeled autonomous line follower Robot

When the robot is switched on, the IR sensor will ready to detect the surface color by sending IR rays and the rays getting deflected back from the surface which is observed by Photo diode and then to the comparator. The comparator compares the signal with the reference voltage and sends another signal to the processor whether it is high or low. The Processor receives the signal from the comparator and will command the motor as per the program programmed in the Processor. The working of the robot is tabulated in table 1. The line follower kit used in this work is shown in figure 1. Regression modling is a statistical tool used generate mathematical expression as function of input and output parameters by correlating the input and output. In this work Regression modeling is a function as

$$\text{Time (t)} = +280.81802 - 3.05177 * D - 1.82612 * x + 0.023213 * D * x \quad \ldots (1)$$

Where, D is Diameter and x is the castor distance. The figure 2 shows the 3D surface plot of the robot travel time against various levels of wheel diameter and the centre to centre distance between caster wheel and rear wheel axis. Time consumption to travel the given distance reduces with increase in wheel diameter and decrease in centre to centre distance. For minimum wheel diameter time decreases gradually with increase in C-C distance and for maximum wheel diameter it increases with increase in C-C distance. Finally minimized time consumption of travel can be obtained with maximum wheel diameter (90 mm) and min C-C distance (90 mm). Experimental values are shown in Table 2 and Analysis of variance is shown in Table.3.

Table 1–Operation of two wheeled mobile robot

Sensor input		Motors Output		
Left Sensor	Right Sensor	Left Motor	Right Motor	Movement
Low	High	Moves	Stops	Right turn
High	Low	Stops	Moves	Left turn
Low	Low	Stops	Stops	Stopped
High	High	Moves	Moves	Move Straight

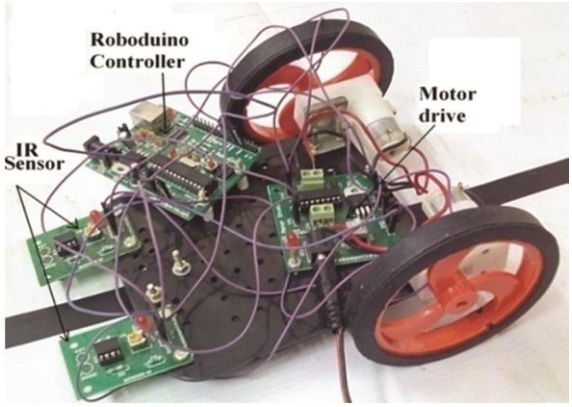

Fig.1–Line follower robot kit

Fuzzy logic control of design parameters of autonomous robot

In robotics design, it is often desirable to have a robot act more like a human being than a machine. Traditional logic is based on two values, one (true) and zero (false).This is inadequate for approximating the human decision making process. Fuzzy logic uses the entire interval between zero and one, and can therefore to be used to closely mimic the human Reasoning[12].The design process of a fuzzy logic system can generally be separated in two three stages: Fuzzification, Rule Evaluation, Defuzzification. In fuzzification stage, a quantified numerical control variable is converted into a qualitative value like

Table 2–Experimental Data Collection (L9 Orthogonal Array)

Exp. No	Wheel Dia. 'D' (mm)	Dist. b/n caster wheel and rear wheel centre 'x' (mm)	Time taken to travel 't' (sec)
1	70	112	44.69
2	70	100	44.81
3	70	90	50.47
4	80	112	41.66
5	80	100	40.81
6	80	90	38.59
7	90	112	34.72
8	90	100	32.25
9	90	90	30.1

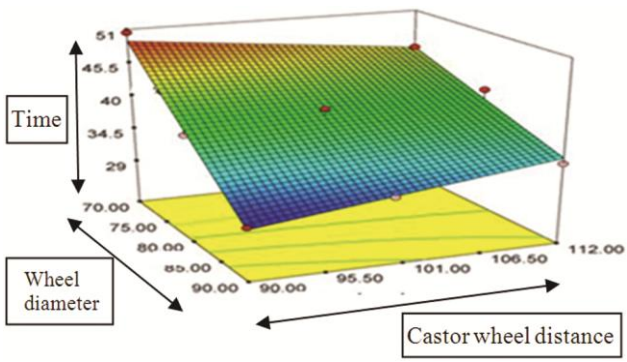

Fig.2–3D Surface plot of the Data collection

Table 3–Analysis of variance

Source	Sum of squares	DOF	Mean Square	F value	P-value prob > f	RESPONSE
Model	333.58	3	111.19	45.87	0.0005	Significant
D – Wheel Dia	299.72	1	299.72	123.64	0.0001	
X – C-C distance	0.70	1	0.7	0.29	0.6151	
D *X	26.15	1	26.15	10.79	0.0218	
Residual	12.12	5	2.42	--	--	
Cor Total	345.70	8	--	--	--	

small, medium or large known as linguistic variables. These linguistic variables are described by membership functions are triangular and trapezoidal. Once the inputs are fuzzified, they are fed into fuzzy interface. This engine consists of two sub-block namely fuzzy rule base and fuzzy implication. The fuzzy rule base is a set of if-then statements known as linguistic rules which describes the behavior of the robot for a particular set of inputs. Fuzzy implication evaluates the set of rules to compute a qualitative output result for the controller. The commonly used implication method is Mamdani implication. This stage plays a key role on the fuzzy controller operation as its rules model the Whole behavior of the robot. Finally, the qualitative value is converted into numerical value is defuzzification stage. Among them center of gravity (COG) method is easy to implement and has a fast execution time. The first input 'wheel diameter' is divided into small, medium, and big; the universe of discourse being ranges from 70 to 90 mm and The second input the distance or the castor position is divided into short, medium and long; the universe of discourse ranges from 90 to 110 mm. The output of the FLC i.e., time is divided into minimum, medium and maximum; the universe of discourse ranges from 30 to 45 seconds. Nine rules are used. Typical rule is "If wheel diameter is big and Distance CC is short then time is minimum. The 3D plot for the values of Wheel diameter, centre to centre distance and time is shown in figure2.The rule view which is shown in figure 3. The design parameters of the mobile robot considered in our work are Wheel diameter of the robot, Centre to centre distance between the caster wheel and Rear wheel centre of the robot. The experiment was conducted on a four meter trajectory path by varying the design parameters. The size of the wheel diameter and the distance between centers are the input of the fuzzy logic controller and time is the output.

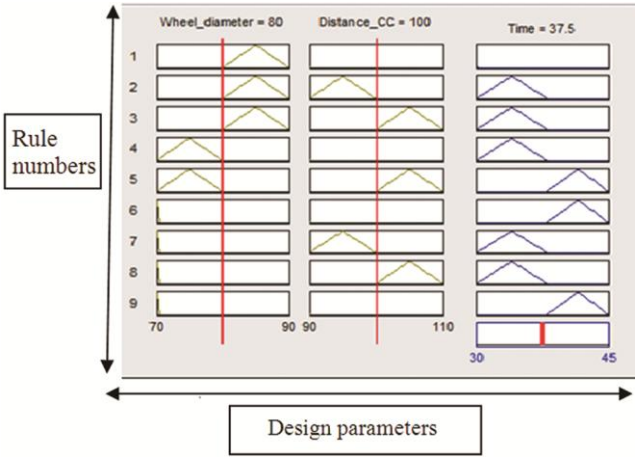

Fig.3–Rule view

Results and Discussion

The time obtained from design of experiments (DOE) method for the trajectory tracking of 4m path of An autonomous line follower robot is 32.5 seconds when the wheel diameter value is bigger and the distance between castor wheel and real wheel centre is medium whereas the value obtain from DOE embedded fuzzy logic is 37.5 seconds. It was found that when the wheel diameter is small and the distance between the castor wheel and the rear wheel is small the time taken value is maximum. Hence the time value is minimum only when wheel diameter is bigger and the distance between castor wheel and the rear wheel from medium to small.

Conclusion

In this work, trajectory tracking of an Autonomous line follower was analyzed using Design of Experiments and (DOE) and DOE embedded Fuzzy logic system. The Experiments indicated that time taken for 4m of trajectory path is minimum in DOE based approach as compared to DOE embedded Fuzzy logic system. It is also evident that, if wheel diameter is bigger and the distance between caster wheel & rear wheel is

medium then the robot takes minimum time to reach the designation. In future work, the membership function of fuzzy logic control system can be fine tuned by using various nontraditional optimization techniques like Genetic algorithm, particle swarm optimization etc., to obtain optimal time .

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