UGC Approved Journal

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 4, Issue 9, September 2017

Hardware Implementation of Auto Guided Vehicle using Advanced Controller

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Abstract: The conventional transport vehicle should not look like a self steering Vehicle on its own. Rather, it should be conceived as an inherent part of the work under research. Researchers therefore introduce the concept of Auto Guided Vehicle a user-interface prototype, derived from a theoretical frame of reference, called act orientation to working model, in which all controlled tasks are interpreted as steps performed by the actual embedded system. Our implication continues the design, development and implementation of proposed prototype, reaching radically deeper than usual in related approaches. In this paper a method to eliminate the need of physically operated driving assistance system, has been put forward. Authors expect that our idea will, when applied, improve the control, productivity and quality of the outcome of work, assessed from the researcher's point of view.

Keywords: AGV, DC Motor, Echo, Microcontroller, Trigger, Ultrasonic.

I. INTRODUCTION

Road Traffic Transportation concern is growing day by day for human being. Recent years, transportation system has been witnessing an increasing amount of traffic on the roads, leading to increased risks for road traffic accidents to occur. Accident usually defined as an unplanned, unexpected event which occurs suddenly and causes injury or loss that leads to decrease in value of the resources, or an increase in liabilities[1]. The degradation of Road surfaces has large impact on accidents which are very sensitive to health consequences and household economy.

Road traffic accidents also been identified as an important public health problem requiring urgent attention in the context of developing countries such as India, which has the highest proportion of deaths due to road traffic accidents. Evidence from developed and especially developing countries indicates that road traffic accidents are on the rise and are found to be the fifth important cause of deaths globally leading to a significant proportion of injuries, deaths and disabilities in the population[2]. Poor street lighting, bad road surface, open manholes in the cities and large objects lying around on road, some of the road related factors noted to be responsible for crashes. The automobile industry has geared up for increasing speed making changes in the design and fabrication. This speed needs to be taken care by studying the vehicle dynamics for various parameters like weight of the vehicle, braking system, driving condition and driver's security etc. In the present work the DC motor control mechanism has been studied and efficiently used in the designed system. DC motor can provide high starting torque with possibility of fine speed control [3] over wind range. *Akons and Alexadrovitz* developed a mathematical model for brushless DC motor and studied the dynamic behavior under changing condition [4]. Almost all materials reflect sound waves, so ultrasonic sensors are a fine choice for many tasks in the present activity. Excellence in detection and measurement of solids, transparent objects and liquids separate these sensors from their photoelectric counterparts [5]. These distance sensors are non contact distance measurement and consist of transceiver which is able to transmit and receive ultrasonic sound. Main idea is to measure time to fly of ultrasonic wave from sensor to detected object. The objective of this work is building the prototype model of Auto Guided Vehicle.

II. ULTRASOUND

Sound frequencies below and greater the human threshold have been used for engineering and medical purposes worldwide for more than 50 years. Since the frequency is above (ultra) the sound humans can hear, this frequency is called as ultrasound frequency. Ultrasonic technique has been widely employed in distance measuring field [6] with advantages of non destructive, non-contact, not affected by electromagnetic interference, convenience and low cost [7]. In a continuous medium, the performance of ultrasonic waves is closely associated with a relation between the moment of inertia and of elastic deformation [8]. The linear relationship between stress σ and particle velocity *is*:

$$\sigma = zv \qquad (2.1)$$

The proportional factor z is called the Specific Acoustic Impedance of an ultrasonic wave [9][10]. Specific acoustic impedance is the characteristic that determines the amount of reflection and it is the product of the density and velocity.

IARJSET
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ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 9, September 2017

$$Z = \sigma / v = \rho c \tag{2.2}$$

Where, ρ is the density, and *c* is the velocity of wave.

Some Phenomena such as Reflection, Refraction, Diffraction and Absorption can influence the propagation of ultrasonic waves. When an ultrasonic wave normally incident on boundary connecting two media as shown in Fig.1, a part of the wave is reflected back with phase change [11] and the remaining part is transmitted in the medium 2. The ratio of the magnitude of the reflected wave A_R to that of the incident wave A_I is called Reflection Coefficient R, and the ratio of the magnitude of the transmitted wave A_T to that of the A_I is called Transmission coefficient T

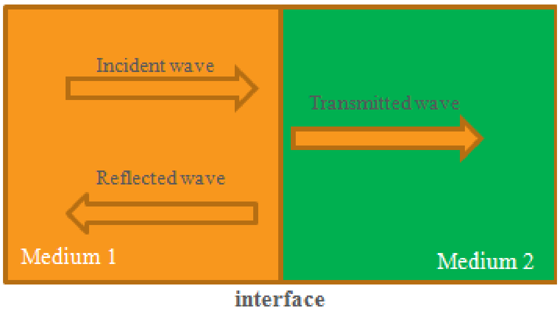

Fig.1 Normal reflection and transmission at an interface

The reflection and transmission coefficient are given as fallows

$$R = \frac{A_R}{A_I} = \frac{Z_1 - Z_2}{Z_1 + Z_2} \tag{2.3}$$

$$T = \frac{A_T}{A_I} = 2.\frac{Z_1}{Z_1 + Z_2} \tag{2.4}$$

The amplitude of the reflected wave is given as:

$$A_R = \frac{Z_1 - Z_2}{Z_1 + Z_2} \tag{2.5}$$

where $Z_1 = \rho_1 C_1$ and $Z_2 = \rho_2 C_2$

Subscripts 1 and 2 refer to the medium 1 and 2, respectively, and Z is the specific acoustic impedance defined as Eq. (1). It can be seen from these equations that the maximum Reflection of ultrasonic wave occurs when the impedances of the two media are very different. The ultrasonic signal can be propagated through homogeneous medium with velocity (speed) of sound. The sound velocity is defined by the rate of change of particle displacement with respect to time. Different characteristics of different medium will influence the velocity of the sound differently. The general expression [12] of the speed of all mechanical waves in a given medium is expressed as

$$v = \sqrt{\frac{elastic\_properties}{inertial\_properties}} \tag{2.6}$$

Ultrasound is widely researched as an effective triggering for obstacle prevention from echogenic pulse reflection. These waves can be generated at different frequencies, intensities and duty cycles, etc [13]. Hence ultrasonic sensor is used for obstacle detection in our current work. As stated in [14], use of sensor for detecting obstacles has performed very well for automobiles to enable collision avoidance and assisted driving. The another important reasons for the usage of this type of sensors are that they are quite compact and light weight, give high accuracy and sensitivity detecting objects compared to other sensors like IR sensors which fail in case of certain surfaces, light changes etc. as stated in[15].

An ultrasonic sensor measure the *time* that ultrasonic signal take to propagate, return and arrive to the sensor. Knowing the transit time and the signal velocity (speed) in the (Water, air, dielectrics, etc.), the device computes the travelled distance. Since the velocity of sound signal varies with temperature. Any variation in temperature will modify the velocity of the ultrasonic wave. Measured ambient temperature, T converted Farehnite (°F) to Celsius (°C) using the following equation:

$$T(in\ °C) = (T(in\ °F) - 32) \times 5/9 \tag{2.7}$$

As the speed of sound changes according to the surrounding temperature. The speed of sound in atmosphere reaches 331.45 m/s at 0^0C [16].The speed of sound in terms of temperature can be determined with following equation

DOI10.17148/IARJSET.2017.4923

IARJSET
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International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 4, Issue 9, September 2017

$$C = C_0 + KT \quad (2.8)$$

where C is the speed of the sound.
C_0=331.45 m/s at 0^0C
T is the temperature in degree Celsius.
K is the rate at which the speed changes with respect to the temperature, which is approximately 0.607 m/s at every change of 1^0C in temperature. Based on the round trip transit (flight) time and the speeds of sound in the medium, we can compute the distance that the sound traveled.

$$Distance = Speed \times time \quad (2.9)$$

$$s = C \times t \quad (2.10)$$

The theory of ultrasonic distance measurement based on the fact that the speed of ultrasonic wave C spread stays constant in a certain situation[17], if the flight time t is known, then the distance between the transducer and object can be figure out through equation given as.

$$D = \left(C * {}^{t}/_{2}\right) \quad (2.11)$$

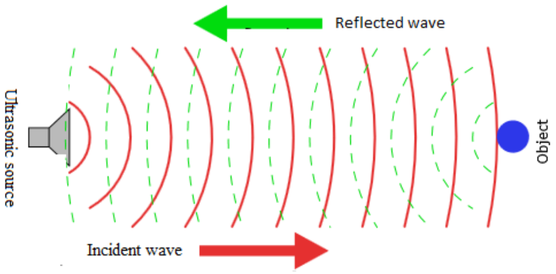

Fig. 2. Working principle of US Sensor

The literature survey has highlighted some issues which should be discussed about ultrasonic distance detection in relation to its accuracy particularly in dynamic environment. The important issues in dynamic environments such as Slosh, Temperature variation and Contamination i.e. obstacles and dust. As stated earlier, the variation in ambient temperature influences the speed of sound. , if the variation in ambient temperature is continuous, the speed of ultrasonic wave should not be considered constant. To improve reliability of ultrasonic sensing systems, generally a temperature sensor could be included in the system design to adjust the speed of ultrasonic waves used in the distance calculation by using Eq. (2.6), which describes the relation between the speed of the ultrasonic wave and ambient temperature. Also problem may arise while travelling through medium that need to discuss here, false parasitic pulses originating from reflecting wall surfaces and other obstacles in the vicinity of the test vehicle. The parasitic pulses may be confused with main echo pulse and can results in an erroneous reading [18]

A low noise ultrasonic sensor should be equipped with high accuracy, long term stability, and robustness by taking account significant effect such as, chemical, geometric and acoustic properties of the medium that leads to reduction of signal amplitude or signal to noise ratio (SNR). The contamination density is obtained from the reflection coefficient and transit time of ultrasound between the sensor and obstacle. *Borenstein et al*. [19] categorized different types of noise and discussed methods for eliminating effects of each types of noise. As a result a vehicle under development could be able to traverse an obstacle course of densely spaced sample object at speed of up to 1 m/s.

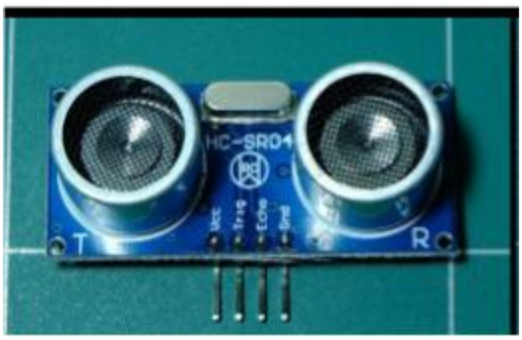

Fig. 3. Ultrasonic Sensor HC-SR04 module

The HC-SR04 ultrasonic sensor is used in the present work, which emits sound chirps at 40 000 Hz frequencies and can measure the distance of an object located up to 255 cm ± 3cm away.

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ISSN (Print) 2394-1588
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ISO 3297:2007 Certified
Vol. 4, Issue 9, September 2017

III. DC MOTOR

The equivalent circuit of a DC motor is depicted in Fig.2. including the armature resistance Ra and winding leakage inductance La.

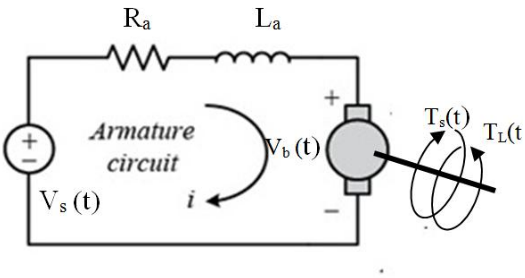

Fig. 4. Electrical equivalent of DC Motor

According to the Kirchhoff's voltage law in armature loop, the electrical equation of the DC motor [4][20][21] is described as

$$R_a I_a(t) + L_a \frac{di_a(t)}{dt} + v_b(t) = v_s(t) \tag{3.1}$$

where $I_a(t)$ the armature is current, $v_b(t)$ is the back emf voltage and $v_s(t)$ is the voltage source. The back emf voltage $v_b(t)$ is proportional to the angular velocity ω(t) of the rotor in the motor, expressed as

$$v_b(t) = k_b \omega(t) \tag{3.2}$$

where k_b is the back emf constant. In addition, the motor generates a torque T_M proportional to the armature current, given as

$$T_M(t) = k_T i_a(t) \tag{3.3}$$

where k_T is the torque constant.
If the input voltage $v_s(t) = V_s$ is a constant, the resulted armature current $i_a(t) = I_a$ angular velocity $\omega(t) = \Omega$ and torque $T_M(t) = T$ are also constant in the steady state.
From (3.1) and (3.3), we have

$$R_a I_a + K_b \Omega = V_s \tag{3.4}$$
$$T = K_T I_a \tag{3.5}$$

From the conservation of power, we know that the input power $I_a V_s$ is equal to the external power $T\Omega$ and the power $R_a I_a^2$ consumed in the resistance, i.e.,

$$V_s I_a = T\omega + R_a I_a^2 \tag{3.6}$$

Substituting v_s in (3.4) into (3.6) yields

$$T = k_a I_a \tag{3.7}$$

From (3.5) and (3.7), we know that k_T and k_b both are the same. From (3.2), we can write (3.1) and (3.3) as

$$R_a I_a(t) + L_a \frac{di_a}{dt} + k\omega(t) = v_s(t) \tag{3.8}$$
$$T_M(t) = k i_a(t) \tag{3.9}$$

Where $k = k_T = k_b$ Besides, if the DC motor is used to drive an external torque $T_L(t)$ of payload then its mechanical behavior is described as

$$J_M \frac{d\omega(t)}{dt}(t) + B_M \omega(t) = T_M(t) - T_L(t) \tag{3.10}$$

where J_M is the rotor moment of inertia and B_M is the frictional coefficient. Based on (3.8), (3.9) and (3.10), the dynamic equation of the DC motor can be expressed as

$$L_a \frac{di_a(t)}{dt} + R_a I_a(t) + k\omega(t) = v_s(t) \tag{3.11}$$
$$J_M \frac{d\omega(t)}{dt}(t) + B_M \omega(t) - k i_a(t) = -T_M(t) \tag{3.12}$$

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Note that the electrical time constant $\boldsymbol{L_a/R_a}$ is often neglected since it is at least unity magnitude smaller than the mechanical time constant J_M/B_M. In other words, by neglecting the term, $\frac{di_a(t)}{dt}$ becomes

$$i_a = \frac{1}{R_a}v_s(t) - \frac{k}{R_a}\omega(t) \qquad (3.13)$$

Substituting it into (3.12), finally we have

$$\frac{d\omega(t)}{dt}(t) + \left[\frac{B_M}{J_M} + \frac{k^2}{J_M R_a}\right]\omega(t) = -\frac{1}{J_M}T_L(t) + \frac{k}{J_M R_a}v_s(t)$$

Clearly, the motor will encounter two external sources, the input voltage $v_s(t)$ *to* drive the motor and the torque $T_L(t)$ reacted from the payload [22].

IV. MODEL DEVELOPMENT

From the individual components, the complete dynamic model of the AGV can now be assembled. The following assumptions are contained in the model
1) The drive wheels of the AGV do not slip.
2) The centre of gravity of the AGV is at the center of the wheelbase.
3) All damping is viscous in nature, no Coulomb friction is included.
4) No backlash in the gears (DC motor) of the model, even though the AGV gear system described significant backlash (10^0 at the wheels).

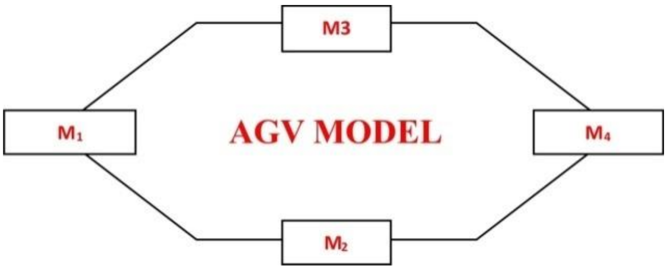

Fig. 5. Proposed Model of AGV

A. *Flow of Development*

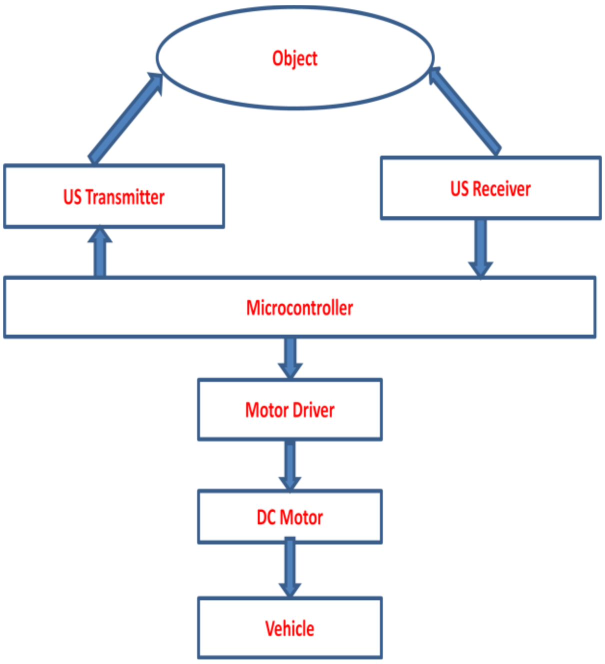

Fig. 6. Working Flow of proposed model

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ISSN (Print) 2394-1588
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Fig. 7. Test vehicle of AGV and ultrasonic Instrumentation configuration

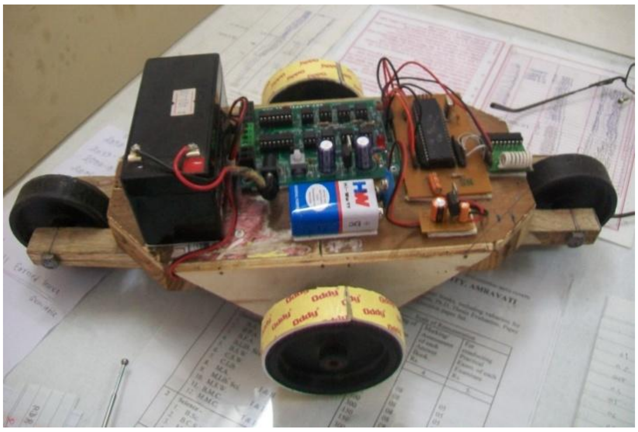

Fig. 8. Working model (a) AGV

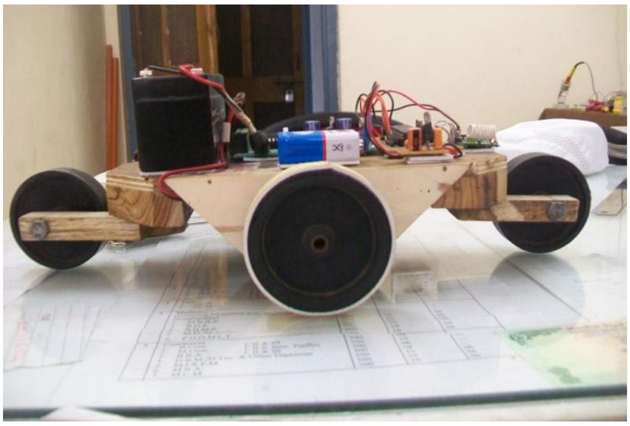

Fig. 5. Working model (b) AGV

B. Hardware

The system hardware was designed using Atmel's 89C52 microcontroller as an MCU, which initializes the system, reads the outputs of Ultrasonic receiver, move the values on controller strategy and take action according to the algorithm. The HC-SR04 ultrasonic distance sensor was used whose output is well conditioned to suitable digital pulse. The digital pulse of 40 KHz waveform is generated and transmitted towards the obstacle object. An interfering object would let the waves to bounce back to the source. If the pulse is collected by the receiver after emitting it, we can assume that there is an obstacle nearby in the way. A TW101 motor driver card module was used to control the current and voltage of the DC motor. This module has eight inputs and eight corresponding output for each direction. The reason behind selection of this module was to have better interactivity between the dc actuators and the hardware so that direction could be easily controlled using software algorithm, which could be controlled by the user. The port P3 pins of 89C52 MCU were used for specifying the Txd and Rxd signals i.e. Trigger and Echo signals of the HC-SR04 ultrasonic distance sensor. Pin 3.1 is set as an output pin for sending the trigger signal to the ultrasonic module for starting transmission and port pin 3.0 is set as an input pin for receiving the echo.

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Vol. 4, Issue 9, September 2017

The port P0 pins P0.0 through P0.3, these lines were connected to the motor driver card through optocoupler IC. The outputs of the optical isolators were connected to buffers so that digital output can be boosted to suitable strength which is required for the DC motor.

C. Software

The software was developed using 8051 MCU based assembly language. The concept of modular programming was used so that system could be easily upgraded. The major software modules developed as fallows.

i. Initialization Module
ii. Trigger Pulse transmitter module
iii. Echo Pulse receiver module
iv. Distance Measurement module
v. Decision making module
vi. Motor speed control module

After reset, the initialization module loads the preprocessor directives, stack, and other necessary registers to their default values set by the programmer, initialize the Ports P3, P0 and start them. The ultrasonic sensor module generate High level (logic "1") Trigger pulse, propagates through the air medium to obstacle object. An interfering object would let the Trigger pulse to bounce back to the source. If the pulse is collected by the receiver after emitting it, we can assume that there is an obstacle near in the way. Timer Mode control (TMOD) register of the microcontroller 89C52 is loaded in such a way that the Timer 1 operates in (8 bit auto-reload mode) mode 2. In the main part of the program (main loop), the predefined initial values are loaded in TH1 and TL1 registers of microcontroller.TH1 is used to store reload value whereas TL1 is loaded with initial value to start counting. When Timer Run (TR1) bit of the Timer Control register (TCON) is set to 1, the TL1 start incrementing itself from the initial value loaded into it through TH1 and keeps counting until roll over (i.e. 255D). When TL1 attains the maximum count (FFH) value, Timer interrupt T0 is generated when TF1 flag is set and TL1 is loaded automatically with the reload value which was stored in TH1. The sequence is continuously repeated until Timer Run Bit (TR1) is made low by the program. The Timer Flag (TF1) goes high initially before at the first roll over. Hence it is necessary to make it low (logic "0") using the main program after each cycle. In order to generate $10\mu s$ trigger pulse P3.0 is set high for $10\mu s$ and then cleared it using the main program loop. The ultrasonic module receives the trigger pulse from the microcontroller and issues a 40 KHz pulse in the forward direction in which vehicle is travelling. The microcontroller program executes a continuous (wait) loop for suitable echo at P3.1 pin. Once valid echo pulse is obtained, width of the echo pulse is calculated. The calculated pulse width of the echo signal is equals to the distance to the obstacle. Whenever there is a valid echo pulse at at pin P3.0, the Timer1 starts counting from the initial value to FFH. Then the counter restarts and ACC register is incremented by one for every restart. This sequence is repeated until the echo signal at P3.0 vanishes (i.e. P3.0 goes low). Now the content in accumulator will be equal to the number of Timer1 reloads which is in fact proportional to the distance. If measured distance is 30.48 cm (1 feet), AGV will moves in safe direction where there is no obstacle. The Decision making module allows the user to set the directions, motion settings and make the output bits P0.0-P0.3 ON and OFF so that the DC motor will moves in corresponding directions. The digital outputs were generated for rotating and steering the motor system in specific direction using port P0 of 89C52.

V. CONCLUSION

The objectives mentioned in the paper have been achieved through design, implementation and experimental results of HC-SR04 Ultrasonic sensor and AT89C52 Microcontroller based AGV. The whole work attempted to develop an AGV simulation system integrated with designed software. Because of the great enhancement in device performance, improvement of hardware interfaces, and reinforcement of software functions has become very efficient and turned into reality. After several experiments, we believe that using microcontroller combined with software program to operate the constructed vehicle has the sustainability.

The robot developed in this activity was lightweight and in some cases, slow speed. For future works the performance of the AGV system may be improved by incorporating high performance sensors, transducers and advanced controller.

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UGC Approved Journal

IARJSET

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ISSN (Print) 2394-1588

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Vol. 4, Issue 9, September 2017

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