Distance Estimation and Direction Finding Using I2C Protocol for an Auto-navigation Platform

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***Abstract*—This paper presents an auto navigation platform in Arduino which uses the i2c protocol to interface a digital compass and a rotation encoder to calculate distance travelled and direction with respect to the Earth's magnetic field. The digital compass IC used here is the HMC6352, while the rotation encoder is designed with the help of a MOC7811 coupler IC. The compass contains complete 2-axis sensors, analog, and digital electronics and also contains all the firmware for heading computation and calibration. The rotation encoder is an electromechanical device which obtains the angular position of the motor shaft it is connected to and then converts this position into some analog or digital value. This is mostly done using optoelectronic sensors which provide electric pulses in response to some stimulus. We use this property of the device to accurately guide our auto navigated device to pre-determined distances.**

Keywords- MOC7811, HMC6352, I2C protocol, Rotational encoder.

I. Introduction

Automobile navigation systems are a combination of diverse technologies used to guide a device to any location. Over the years a number of technologies have been introduced like GPS which help in auto-navigation, most of which works on the principle of position mapping. The first step is to identify the current location of the device and then correlate this data to navigate the device to any other location. But most of these technologies if not all have been concentrated on outdoor navigation of bigger automobiles while technological advancements in navigation platforms developed for indoor navigation which can be used for commercial applications has been few and far between. For instance in case of GPS, there is significant power loss in indoor systems due to signal attenuation, which leads to requirement of additional circuitry to setup the whole system. This is practically infeasible considering the cost to setup such a system for even the most basic of indoor navigation models. Alternatively other methods for positioning like Wi-Fi based positioning systems (WPS), Bluetooth, Magnetic positioning etc. have been on the rise. In this paper the method we use is Magnetic positioning. By using this method we can reduce the overall cost to implement such a system indoors. This is the most significant advantage of our system.

Here we use a digital compass IC HMC6352 to measure the orientation of the device with respect to the Earth´s magnetic field. HMC6352 is the integrated compass module developed by Honeywell which works on Anisotropic Magneto-resistive (AMR) technology. The compass senses Earth´s magnetic field (0.6 gauss) and provide the sensitivity for enhanced accuracy and performance. The compass has a Wheatstone bridge configuration that converts magnetic fields into a millivolt output and contains complete 2-axis sensors, analog and digital electronics and also other firmware for heading computation and calibration. This compass interfaced with the Arduino UNO is used to check the orientation of any device with respect to Earth's magnetic field. The communication between HMC6352 and Arduino uses the twin wire (TWI)or the I2C(Inter- integrated circuit) protocol in standard data rate mode of 100kbps, where the Arduino becomes the master and HMC6352 module becomes the slave.

The basic arrangement of an optical rotation encoder consists of a Light Emitting Diode (LED) and a light detector mounted exactly opposite each other. A patterned disc is placed between the LED and the light detector, while the disc itself is attached to the motor shaft. The disc contains alternate opaque and transparent sections. Once the disc starts rotating the opaque patterns block the light while the transparent sections lets it pass through. This results in a square wave pattern at the output of the detector. Now to calculate linear distance the formula used is

$$Distance = \frac{Wheel\ Circumference\ \times Counts}{Counts\ per\ Revolution} \quad (1)$$

In the following sections we discuss various aspects of the paper. In section II we discuss the basic motivation behind the development of such a platform and its real world applications. Section III lists the previous developments regarding the topic. In section IV, we explain the design and implementation of our hardware and software sections. Section V records the observations made during our experiments and finally we conclude our paper in section VI.

II. Motivation

The aim of this paper is to design a cost effective, compact auto navigation platform using a digital compass and rotation encoder to measure direction and guide the device to a predetermined location. Most navigation systems utilize systems like GPS to guide devices through any path. But such

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systems lose their credibility in indoor conditions, because of signal attenuation and other defects like reflection losses from obstacles in a confined space. Hence need for cheap navigation systems, especially for indoor conditions have been on the rise. Our system uses simple rotation encoders and magneticcompass to guide the devices which are not only cheap but also provide highly accurate values since they are not affected by internal reflection losses. Also since range of signal send and receive is not as wide as GPS systems, attenuation losses are also negligible. With further development this design can be used to guide small scale devices like automated wheelchairs without using satellite positioning or other similar procedures followed by bigger automobiles in outdoor condition. This also reduces the energy consumed by the system as a whole.

III. RELATED WORKS

Auto navigation gaining more importance in medical and space applications has led to considerable advancements in development of navigation systems based on distance and orientation calibrations. The Arduino platform helps to interface the digital compass for the purpose of orientation awareness so that the wheel chair motor can be controlled according to the distance which has already been calculated using the rotational encoder. The digital compass HMC6352 is interfaced with Arduino and follows I2C protocol to do so. Inter Integrated Circuit protocol [2] helps to establish communication between a numbers of devices with only two wires in common i.e. Serial Data Line and Serial Clock Line. The I2C protocol should be multi slave with single master or multi master multi slave or multi master single slave.

As compared to other types of compass, the 1490 compass sensor by Dinsmore gives heading information in eight directions such as North, South ,East and West ,which are the fundamental points and the intermediate points of North east, Northwest, South east and South west. The compass is simple, cheaper and easy to construct but it shows very less number of heading directions and has slower response times. A tilt of greater than 12 degrees causes errors in heading output.[1] The E Gizmo compass is better than 1490 compass which has resolution of 0.5 degrees gives the values from 0 to 359.5, but it needs to be positioned correctly so that objects which disrupt magnetic field cannot causes faulty readings. The digital compass with R1655 sensors has a wider range of temperature tolerance (-40 to +85 degree Celsius) but its in-efficiency and inaccuracy makes it unsuitable for applications requiring higher accuracies. The Honeywell's HMC6352 used here has 2 axis magneto resistive sensors and needs only 2.5 - 5.2 V supply for battery operations having a compass accuracy of 2.5 to 3 degrees. HMC 6352 has various applications in fields like Consumer electronics, Hand held devices like mobile phones, General Compassing Applications, Integration with GPS in case of outdoor navigation technologies, Vehicle direction and telematics and Satellite positioning systems.

Here HMC6352 and a rotational encoder are interfaced with Arduino Uno which has an embedded ATmega328 microcontroller chip. The Arduino has inbuilt Wire library which helps in the I2C protocol communication [2] with the compass. The compass has SDA and SCL lines which can be connected to Arduino. There are various types of auto-navigation based positioning systems such as Wi-Fi (WPS), Bluetooth based systems etc. In indoor conditions, positioning using Wi-Fi signals is easier to implement using Android smart phones with specialized applications for localization[3]. But this method is consumes more energy and installation charges are high. In WPS, the Wi-Fi signal strength of each location is calculated with reference to the pre-selected points and tabulated. This is known to be the fingerprint of that location. During the positioning the current fingerprint is compared with the previously obtained ones and the position is located[3].In Bluetooth positioning, Bluetooth hotspots are used to avail information about the device, for instance the hotspot zone in which it is present. These devices are more accurate than WPS, but requires expensive geometrical computations[3] and are much more expensive.

IV. DESIGNAND IMPLEMENTATION

Our design utilizes an Arduino UNO board which is interfaced with the HMC6352 compass and a rotation encoder. The basic block diagram of the arrangement is shown in Fig 1. The microcontroller in Arduino UNO is ATmega328, which controls the actions of the compass and motor driver according to information provided by the rotation encoder. The whole arrangement can be fitted into any indoor navigation device. In this case we use a wheelchair with two 320W, 24V motors with 4600RPM. These motors are driven by two Hercules 6-36V, 16A motor drivers with PWM control. An Encoder disc is connected to the motor shaft, which is placed between the LED and light detector sections of the MOC7811 encoder IC. The output from the rotation encoder is fed back to the microcontroller. Additionally the digital compass IC HMC6352 is directly interfaced to the Arduino board via I2C interface lines.

A. *ATMega Microcontroller*

The microcontroller embedded within the Arduino UNO board is ATmega328. It is an 8-bit microcontroller developed by Atmel which follows the RISC architecture and supports serial communication protocols like USART, SPI and TWI (otherwise known as I2C). Here we need to use the I2C communication protocol to interface the digital compass with the microcontroller. Microcontrollers provides overall control by performing functions like send and receive data from the HMC6352, control the distance travelled by the device by utilizing data from the rotation encoder, measure and control direction in which device needs to travel using inputs from compass IC and control speed of device via motor drivers.

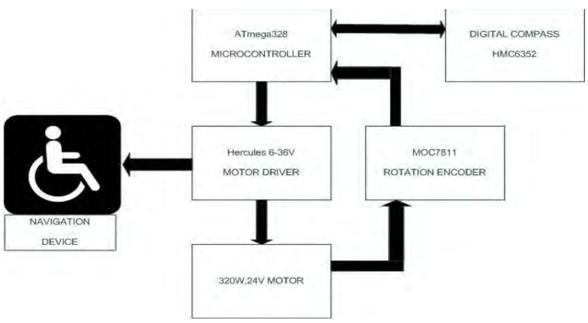

Fig. 1. Block diagram

B. Rotation Encoder

In our design we can program the ARDUINO UNO to use the rotation encoder output to move our device to set distances, by counting the number of pulses per time. The circuit arrangement is shown in Fig2. A patterned disc connected to the motor shaft is placed between the diode and detector sections as shown in Fig3. When the disc rotates a square pulse is generated according to the patterns on the disc. From this we obtain the number of pulses, which in turn can be used to calculate the linear distance as given below. Hence to move the device through a given distance, say 1m, we have to program the Arduino to stop moving once the required number of pulses is obtained from the rotation encoder.

C. HMC6352 Digital Compass

The compass as mentioned before follows the I2C protocol and is directly interfaced with the microcontroller via SDA and SCL lines as shown in Fig4. The supply voltage provided by the Arduino is a nominal voltage of 3.3V. In I2C protocol, there are only 2 wires for the communication between the devices i.e. SDA (Serial Data Line) and the SCL (Serial Clock Line). The master Arduino controls the communication by sending the clock pulses through SCL. The default value of the SCL and SDA line are logic high. When there is a transition of high to low occurs in SDA line during SCL with logic high shows the start condition which initiates the start of the communication. I2C communication is byte oriented, where the address of the compass module is send by the Arduino which will be the hexadecimal value 43 initiating the read from the compass module and hexadecimal value 42 for write operations as default. So the 8-bit data send through the SDA line following the start bit consist of a 7-bit address and a read or write bit. The logic high in 8th bit of transmission initiates the read operation which would give us heading values in return. The 9th bit on the SDA is the Acknowledgement bit if it is logic high otherwise if it is a logic low shows a not acknowledgement signal (NACK) which determines whether the master slave communication is achieved or not. The transition of low to high in SDA with SCL in logic high initiates the stop condition terminating the communication.

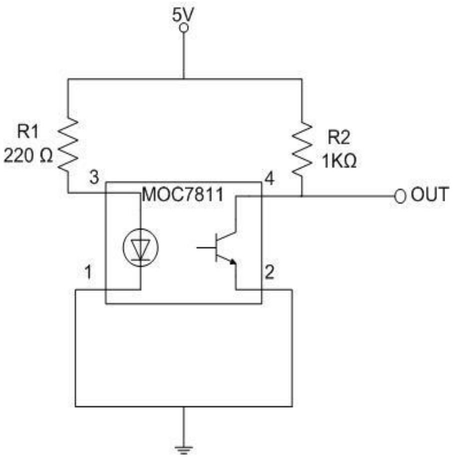

Fig. 2. Circuit diagram for detecting number of pulses using MOC7811 encoder IC

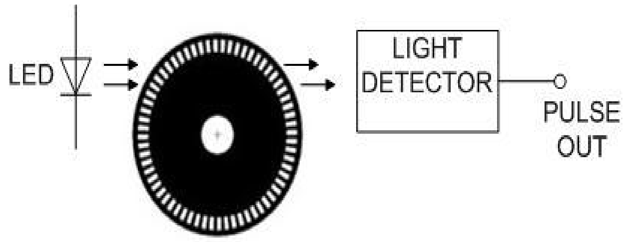

Fig. 3. Schematic of encoder disc placed between led and light detector section of MOC7811

D. Other Components

Test runs were conducted with 320W, 24V wheelchair motors which were driven by Hercules 6-36V, 16Amps motor drivers. The speed of the motors can be controlled by the drivers through a PWM input, maximum allowable frequency of which is 10 KHz. The speed required for our test device was 1.2km/hr. To control the motor we need three inputs to the motor from the driver. Two inputs to control the direction of rotation and one PWM input to control speed as shown in Fig5

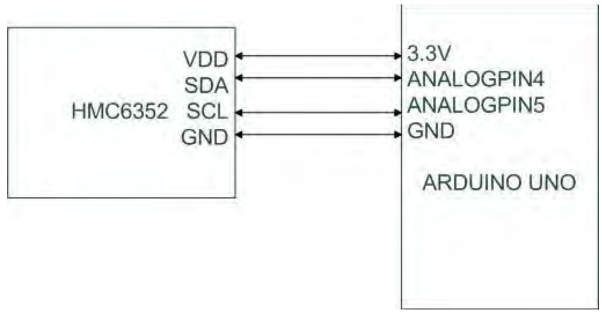

Fig. 4. Port diagram of HMC6352 and Arduino Uno

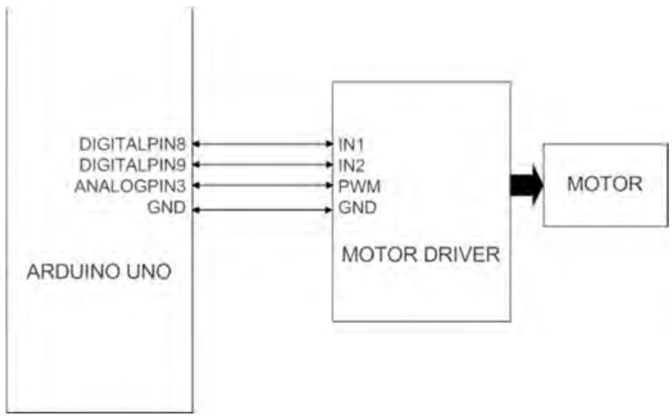

Fig. 5. Port diagram of Arduino Uno and Hercules motor driver

V. Experimental Results

A. Rotational Encoder with Arduino UNO

Test runs were conducted by using a wheelchair connected with two 320W, 24V motors driven by two Hercules 6-36V, 16A motor drivers. These motor drivers are controlled by the Arduino UNO board which in turn has a rotation encoder and digital compass interfaced to it. We designed a rotation encoder with diameter 6.5cms, with four leaves for initial testing. The accuracy of tests were high and were recorded as shown below.

The table 1 shows the readings obtained when Arduino Uno is interfaced with Hercules motor driver using the rotational encoder. We have discerned how to navigate any device to set distances via the rotation encoder. In Table 1, the expected distance to be travelled is compared with the obtained readings. From the table, it is found that the error percentage varies from a maximum of 1 to some negligible values(given in Table 1). Thus the accuracy obtained using the rotational encoder is higher than other navigation systems. The negligible amounts of error percentages can be ignored by careful calculations. Thus the rotational encoder based distance calculation is much more efficient.

TABLE I. Rotation Encoder Readings with Arduino UNO

No. of tries	Expected distance in cm	Distance travelled in cm	Error Percentage
1	100	101	1
2	150	149	-0.6667
3	100	99.5	-0.5
4	150	149.5	-0.333
5	160	161	0.625
6	130	129.5	-0.3846
7	200	201	0.5
8	180	179	-0.556
9	50	50.5	1
10	80	79	-1.25

TABLE II. Digital Compass Readings with Arduino UNO

No. of tries	Expected direction	Degrees obtained	Error percentage
1	NORTH	359.2	-0.133
2	NORTH	359.1	-0.25
3	NORTH	359.6	-0.111
4	NORTH	0.8	0.2999
5	NORTH	1.9	0.599
6	SOUTH	179.8	-0.3889
7	SOUTH	181.6	0.889
8	SOUTH	179.8	-0.3889
9	SOUTH	180.56	0.889
10	SOUTH	180.1	0.3111
11	EAST	89.5	0.05556
12	EAST	91.8	2
13	EAST	89.9	-0.111
14	EAST	90.81	0.9
15	EAST	89.69	-0.3444
16	WEST	271.2	0.444
17	WEST	270.8	0.2563
18	WEST	269.3	-0.259
19	WEST	270.3	0.111
20	WEST	269.79	-0.778

B. HMC6352 with Arduino UNO

The digital compass HMC6352 is interfaced with the Arduino Uno to set orientation in any navigation device. The heading values obtained from the digital compass is converted to degrees in Arduino. The readings are taken in accordance with the cardinal reference points, north as 0 or 360 degrees, South as 180 degrees, East as 90 degrees and West as 270 degrees. The turning of device in any of these directions has to show the exact readings as above. The maximum error percentage obtained is from 2 to some negligible values (given in Table 2) which can be ignored for further calculations. Thus the orientation calculation using HMC6352 is simpler, cheaper and more accurate.

VI. Conclusion

Experiment results show that by using rotation encoder MOC7811 magnetic compass and HMC6352 we can effectively design a navigation platform which is cost effective, consumes much less energy and is not considerably affected by noise as compared to existing technologies. The precision of compass and encoder readings are fairly high with very low error percentage. With further development, like adding features like location mapping and obstacle detection and avoidance, our system can be commercially used in indoor navigation and manufacture of fully automated devices like auto-navigated wheelchair would be possible, which would be affordable without any sacrifices in terms of accuracy.

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