Study and Analysis of Embedded System based Indoor Navigation on Multiple Platforms

Jeeba M. Varghese and Rajesh Kannan Megalingam

***Abstract*—A Navigation Platform assists individuals whose degree of disability is high. In this paper a low cost auto-navigated wheelchair is designed for patients suffering from paraplegia or quadriplegia (paralysis caused by illness or injury), which uses cheaper components that assists navigation. Here a comparative study on fixed path navigation is done in embedded platforms such as Arduino and Raspberry Pi. The design works on the principle of Distance Estimation. The distance estimation is done with the help of rotation encoder with MOC 7811 IC with the pulse counting circuit placed at one of the wheelchair motors. The comparative study shows that in terms of controlling extra hardware the better performer is the Arduino platform as compared to the Raspberry Pi platform, whereas for compiling bigger algorithms Raspberry Pi is better. Various test runs were conducted by navigating through different rooms in a building and the results were plotted by using both the platforms.**

***Index Terms*—Arduino, Raspberry Pi, Rotation Encoder, Distance Estimation, MOC7811, Fixed Path Navigation.**

I. Introduction

Navigation helps us to travel from one location to another. Huge advancements have been made in this field. But individuals with higher degrees of disability who suffer from restricted movement should be helped by the developments in electronic industry as it is still lacking. There are various types of auto-navigation methods available in indoor as well as outdoor environments nowadays, but most of them are of high setup costs making the entire navigating system more expensive and out of reach for the weaker economic community. Among the various outdoor navigation methods, Global Positioning System (GPS) method is commonly employed. Even so this is only effective in outdoor environments where the current position of the device is mapped with the help of satellite preloaded map and information obtained by the help of GPS receivers, it leads to huge setup costs, also it is inefficient to use this in indoor environments due to large signal attenuation. As the paper mainly focuses on the aspect of navigation for medical aid, the accuracy of the system should be high. So we can't rely upon methods like GPS.

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Other types of navigation system include Radio-Frequency Identification or RFID tags. RFID transmitters and receivers use radio waves to identify the location of device. Even if the RFID tags by themselves are cheap, it has a very less range of operation which means a lot of tags are to be placed throughout the expected path of navigation making the entire system expensive and inconvenient to use. Other methods we can use for indoor positioning are Wi-Fi and Bluetooth methods. In both of these, the place to be navigated to should be access point rich. The indoor environment should be surrounded by hotspots making the system not feasible to use when there is power failure and also it has high installation charges and may be subject to interferences. Other methods such as magnetic positioning which locate the device in accordance with the earth's magnetic fields are prone to interference if there are any magnetic materials near the device.

In this paper a cost effective solution for indoor navigation is discussed and compared in Arduino and Raspberry Pi platforms. Arduino is a microcontroller which we can program for specific applications but lacks an operating system and has very less memory in kilobytes range. Whereas, Raspberry Pi is a microprocessor which works like a mini computer, we can connect peripherals such as a keyboard, display, mouse, printer, speaker, etc. Raspberry Pi has large amount of memory compared to Arduino in the range of hundreds of megabytes. As a brain, Pi can support complex tasks or algorithm which is forty times faster than Arduino. In this paper fixed path navigation is programmed in both the platforms where the distance estimation is done through rotation encoder with the pulse counting circuit using MOC 7811 circuit. The performance of both platforms are compared and tabulated.

In the following sections we discuss the design in detail. Section II discusses the basic motivation behind the design and its applicability to the real world. Section III lists the related developments regarding the mentioned design. In section IV, we explain the implementation of hardware and software sections of our design. Section V records the observations made during our experiments. Section VI deals with observations. Finally we conclude our paper in section VII.

II. Motivation

The needs of a cost effective, efficient, smart wheelchair with auto navigation led to the idea of this paper. There are various methods by which indoor navigation is implemented nowadays. These includes Image processing, RFID, Wi-Fi, Bluetooth, magnetic positioning etc. But these systems are out of reach for economically poor communities as these have high setup costs along with huge calibrations and calculations in navigation. As

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the system discussed in this paper is for medical purposes, mass production of these wheelchairs even reduces the cost and can cause a revolution in the market.

The paper does a comparison of fixed path navigation in Arduino and Raspberry Pi platforms. This shows how a microcontroller and microprocessor varies in functionality and support in navigation. The system uses rotational encoder with pulse counting circuit attached to the wheel which is cheaper than any other navigation methods that helps in fixed path calculations. Thus the entire system is modeled in such a way that the overall expenditure is considerably reduced.

III. RELATED WORKS

In earlier technologies, Raspberry Pi was used to control electric wheelchairs by eye movements through image processing [1]. A large data base is stored in Pi and the current position of eye pupil is compared with the collected samples. According to the pupil position of one of the eyes of the patient the motors of wheelchair is controlled with motor drivers. Wheelchair stops when obstacle is detected. This system cannot be used in dark and unclear environments and takes some processing time when it works. Also the system needs a lot of database, calculations and suitable environment to work perfectly. Smart wheelchair is designed in focus with the patients affected with quadriplegia is discussed in [2]. The wheelchair prototype is designed in Raspberry Pi platform which can be controlled with joystick, chin movements, voice method, head movements, by calls from mobiles and through internet. The device is incorporated with obstacle detection, elevation and depression detection system. Various indicators are provided along with alarm, reminder, email, video chat, web browsing etc. This system needs large amount of data processing along with large amount of power to drive all the activities together. A low cost indoor positioning system which uses ADNS-2610 optical sensor attached to the wheel in Arduino platform is discussed in [3]. The optical sensor works by continuously taking images as in the same principle of the optical mouse. By comparing the subsequent frames, the distance moved is calculated. A smart phone is used with the Bluetooth module connected with Arduino is used to find the orientation. Even though the system is low cost, when the speed of wheel increases the error percentage increases.

Paper [4] describes an indoor and outdoor positioning system in Arduino platform. The outdoor positioning is done with the help of GPS module which receives the data from satellite. The two ultra sound sensors attached at X and Y direction and four LEDs calculates the position inside the room. The position information can be transmitted through GSM which will be obtained globally via individual smartphones. As the system gives only the location information with the help of GPS, it can't be used for indoor navigation as the GPS signals are weak inside the buildings.

The indoor navigation system described in this paper uses only rotational encoder attached to the wheel, counting the number of pulses according to the distance travelled. Using the Raspberry Pi and Arduino platforms the comparison based on the performance is done.

IV. DESIGN AND IMPLEMENTATION

In our design Arduino and Raspberry Pi is used as platforms for navigation. The navigation device or the wheelchair is fitted with two motors each of 320W, 24 V with 4600 RPM maximum speed. The rotational encoder disc along with the pulse counting circuit using MOC 7811 level detector IC is fixed at the top of any one of the wheels. The Arduino or the Raspberry Pi is programmed in such a way that the distance to be traversed will be calculated according to the number of pulses predetermined through the formula.

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

The wheelchair motors are controlled via Hercules motor driver with a voltage range of 6-36 V and 16Amp current. The control signals from the Arduino or the Raspberry Pi reaches the motor driver and thereby controls the wheelchair motion according to the program. The functional block diagram is shown in Fig. 1. A comparison of the Arduino and Raspberry Pi platforms is shown in Table I.

TABLE I
COMPARISON OF ARDUINO AND RASPBERRY PI FEATURES

Feature	Arduino Uno	Raspberry Pi
Model	R3	Model B+
Processor	ATMega 328P	Broadcom BCM2835 SoC
Clock speed	16 MHz	700 MHz
Register Width	8 bit	32 bit
Flash	32KB	External SD Card
RAM	2 KB	512MB
Input Voltage	7-12 Volt	5 Volt
Multitasking	No	Yes
Digital	14 digital pins	26 GPIO
Dev IDE	Arduino Tool	Linux, Squeak, IDLE, Scratch
Graphical processing	No	Yes
Operating System	None	Yes
Power Consumption	175mW	700mW
I/O Current Max	20mA-40 mA	5-10 mA

A. *Arduino UNO*

The Arduino UNO is a reprogrammable board which uses ATMega 328P micro-controller shown in Fig. 2. The program remains within the board even after the power is removed. So the Arduino Board can be made application specific as it works only according to the program we upload in to the board. The operating voltage is 5V which has an input voltage range of 7-12V. The flash memory for the Arduino UNO is only 32 KB which is much less compared to the Raspberry Pi. It has 14 digital I/O pins, 6 PWM pins and 6 analog pins. The Arduino UNO supports UART, I2C and SPI protocols. Arduino has no operating system, no firmware and non-interpreter, which supports 8 bit operations mainly written C code. The Arduino has strong I/O capability which can drive extra hardware directly. Arduino can easily interface sensors, motors, LCD displays etc. The pulses from rotational encoder are counted by Arduino and in accordance with that the control signals are given to Hercules motor driver to control the wheelchair motors.

B. *Raspberry Pi B+*

Raspberry Pi is a micro-processor or Single Board Computer (SPC) which can support Ethernet, HDMI, SD Card, Video, Audio and USB (host) shown in Fig. 3. It has GPIO headers works alike I/O pins in Arduino. Raspberry Pi has an operating system mainly supports Linux. Pi supports 32 bit operations which are 40 times faster than Arduino with a clock frequency of 700 MHz. Pi has weak I/O capability which needs transistors to drive extra hardware. Pi is mainly used for video processing, graphic interfaces and for complex mathematics. It has current output range of 5-10mA and a memory of 512 MB. Pi has input voltage of 5V and can multitask. The flash memory varies according to the size of SD card used. A Wi-Fi adapter is used with Pi to make the whole system wireless so that the system can be navigated freely over a Wi-Fi connection. The Pi counts the number of pulses from encoder so that the control signals to motor driver are generated in accordance with the count.

C. *Rotation Encoder*

In Fig. 4 the rotational encoder disc with pulse counting circuit fabricated on the ASIC board attached to one of the wheels on the wheelchair is shown. The rotational encoder disc we made has four leaves. As the number of the leaves increases the accuracy also increases. The pulse counting circuit uses the MOC 7811 IC which has two lobes with a slot at the center, infrared emitter diode is on one side and IR detector on the other. If one of the encoder disc leaves passes through the slot, a pulse waveform is generated and these pulses are counted by the Arduino or the Raspberry Pi. According to the predetermined pulse count the navigation is carried out. Fig. 5 shows the working principle of rotational encoder block. The internal circuit diagram of the MOC 7811 IC is shown in Fig. 6.

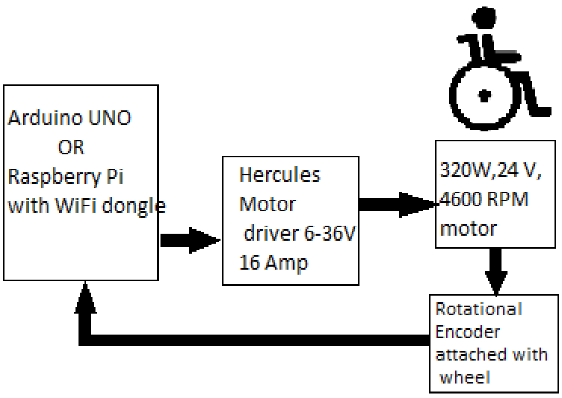

Fig. 1. Block diagram

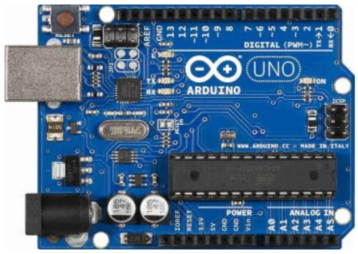

Fig. 2. Arduino UNO

Fig. 3. Raspberry Pi B+ model

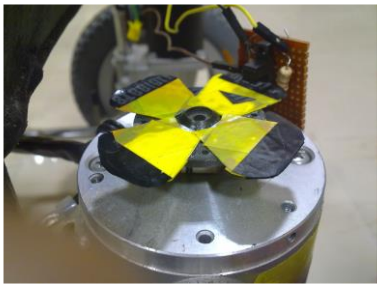

Fig. 4. Rotational encoder disc with pulse counting circuit

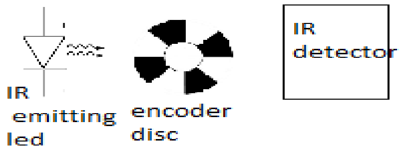

Fig. 5. Working principle of Rotation Encoder

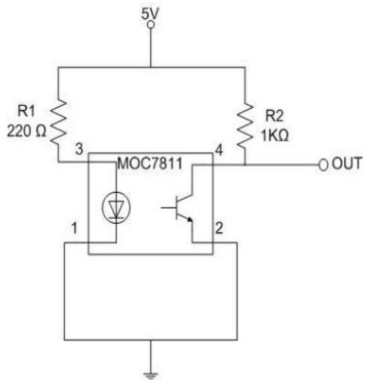

Fig. 6. Circuit Diagram of Rotation Encoder

D. Supply and Wheelchair motor

The system uses two 12 V batteries which produce 28 Amp current for the continuous operation. The wheelchair motors used has of 320W power, driven by 24 V which has a maximum speed of 4600 RPM. The wheelchair motors has two leads which is connected to motor driver to set the direction of motion. The power supply is also connected to the motor driver via a switch.

E. Motor Drivers

The wheelchair motors are connected to the back wheels of the wheel chair. In order to control the motion of the wheels, we use two Hercules motor drivers. The Hercules motor driver can be used with a voltage range of 6-36 V that provides a 15 Amp continuous output current which can take up to a maximum of 30 Amp peak current load. This motor driver can be operated with up to 10 Khz PWM waves and can be interfaced with 3.3V and 5V logic levels. The motor driver is compatible with both the Arduino and Raspberry Pi platforms. The motor driver has built-in protection from temperature overshoot and voltage inconsistencies. In Fig. 7 the connection diagram of motor driver with Arduino or Raspberry Pi, supply and wheelchair motor is shown

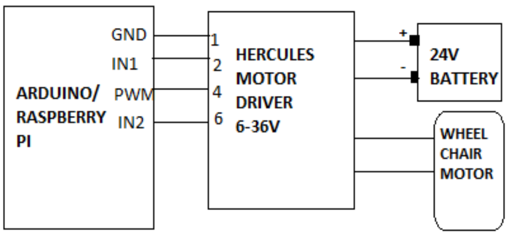

Fig. 7. Port Connections between Arduino or Raspberry Pi, Motor Driver and Motor

V. Experiment Result

Various test runs has been conducted between different rooms in a building. Rooms are divided into various grids with a size of 0.6m x 0.6m. Paths to be traversed are selected with the help of switches. The rotation encoder we use contains four leaves with a diameter of 6.5cm, along with pulse counting circuit using MOC 7811 IC fabricated in ASIC board, shown in Fig. 4.The motors used were 24V, 320W wheelchair motors, which were driven by 6-36V, 16 Amp Hercules motor drivers. The platforms were Arduino UNO and Raspberry Pi B+ model attached with Wi-Fi dongle. The experimental setup is shown in Fig. 7 and Fig. 8.

Table II shows the difference between actual distances to be travelled and expected distances travelled in Arduino and Pi platforms. From the table, it is concluded that the error percentage of Arduino controlled wheelchair is less than the Pi controlled wheelchair. The plots showing some of the trials using the Arduino while traversing through the rooms are shown in Fig. 10a and using Raspberry Pi platform is shown in Fig. 10b.

Fig. 7. Experimental Setup of the design in Raspberry Pi platform

TABLE II
DISTANCE ESTIMATION WITH ROTATION ENCODER

No of Tries	Expected Distance in cms	Obtained Distance in cms with Arduino	Error percentage	Obtained Distance in cms with Pi	Error percentage
1	100	98	2	102	2
2	100	101	1	105	5
3	150	148	1.3	147	2
4	150	149	0.6	145	3.3
7	250	248	.8	247	1.2
8	250	249	.4	255	2
9	300	308	3	306	2
10	300	303	2.6	308	2.6
11	350	351	.28	348	.5

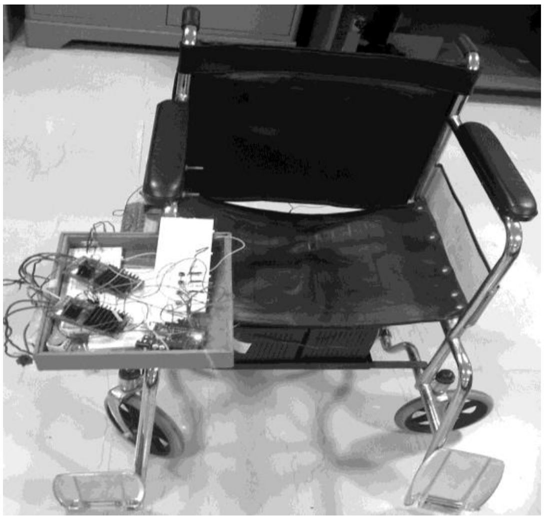

Fig. 8. Experimental Setup of the design in Arduino platform

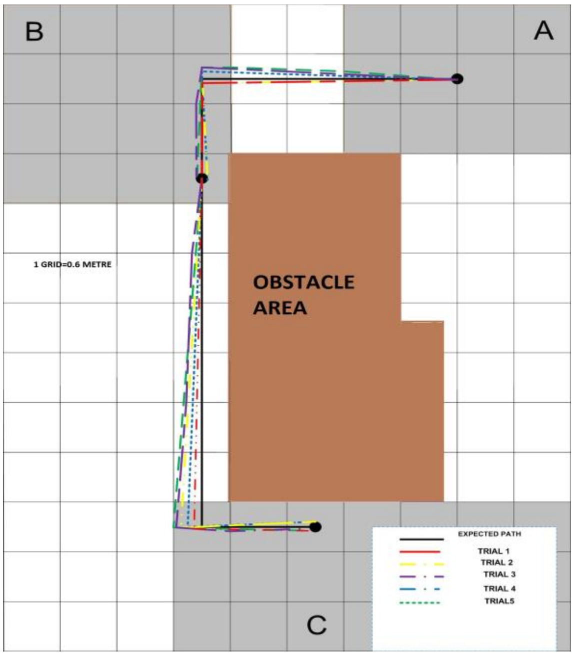

Fig. 9a. Plots showing expected path and different paths obtained for some of the trials using Arduino UNO

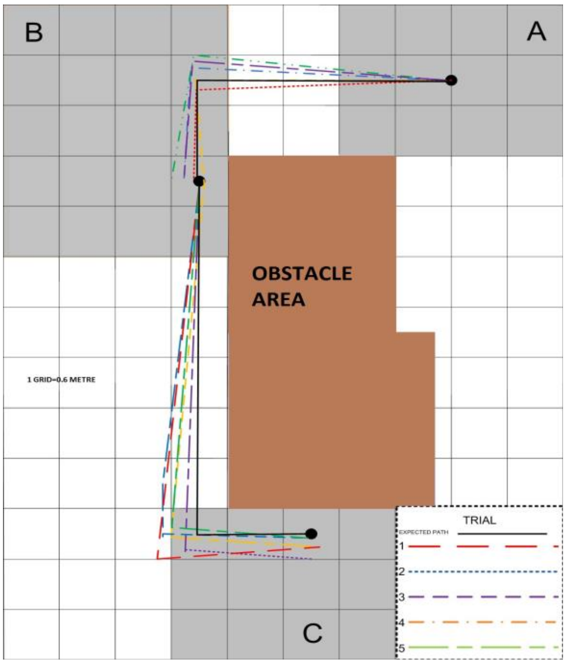

Fig. 9b. Plots showing expected path and different paths obtained for some of the trials using Raspberry Pi

VI. Observation

The test runs were conducted in various paths inside a building. The plots in Fig. 9a and 9b shows the paths traced by Arduino and Raspberry Pi between three rooms. The grid size taken is 0.6 meter. From the plots it is clear that the deviation from the expected path is more for Raspberry Pi than Arduino. Arduino can control external hardware more efficiently than Raspberry Pi due to better voltage and current rating of its digital pins. Arduino digital I/O pins can supply a maximum of 5 V and 20 mA current whereas Raspberry Pi GPIO pins can supply a maximum of 3.3 V and 5- 10 mA. Because of these specifications, Arduino can control the wheelchair motor powerfully than Pi getting accuracy in traversing paths. But when we compile bigger algorithms and integrate more components, Pi can process the code easily due to its better processing speed.

VII. Conclusion

Fixed path navigation in Arduino and Raspberry Pi platform has been designed. The design uses rotational encoder for the calculation of distances in navigation. Test runs have been conducted in various paths and it was found that the Arduino platform is better in controlling the wheelchair than Raspberry Pi. There is a maximum 5 percent error, if the platform is Raspberry Pi controlling the wheelchair whereas the Arduino has only 3 percent maximum error. Due to the high processing speed and efficient operating system, Raspberry Pi can be used for compiling large algorithms but the GPIO pin efficiency is less in terms of controlling the extra hardware. From the results it is concluded that the Arduino is efficient in controlling the extra hardware than Pi. Raspberry Pi can be integrated with Arduino for controlling the system if the project is mainly in focus to mathematical calculations. The project can be further extended to variable path navigation.

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