Conceptual Design of a Wi-Fi and GPS Based Robotic Library Using an Intelligent System

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Abstract—In this paper, an attempt has been made for the design of a robotic library using an intelligent system. The robot works on the ARM microprocessor, motor driver circuit with 5 degrees of freedom with Wi-Fi and GPS based communication protocol. The authenticity of the library books is controlled by RFID. The proposed robotic library system is facilitated with embedded system and ARM. In this library issuance system, the previous potential readers' authentic review reports have been taken into consideration for recommending suitable books to the deserving new users and the issuance of books or periodicals is based on the users' decision. We have conjectured that the Wi-Fi based robotic library management system would allow fast transaction of books issuance and it also produces quality readers.

Keywords—GPS based based robotic library, library management system, robotic library, Wi-Fi library.

I. Introduction

THE public and the research libraries are often facing unexpected challenges for meeting the quick tracing and lending of high-rated books to the potential readers due to large collection of bound volumes. Despite digitization, the bound collections continue to grow. Admittedly, in the present scenario it takes too much time for finding out the required book from the library. The available automatic library robot systems are having the limitations and most of the times consumers are in queue and significant time lag is reported for the issuance of books. Therefore, a solution is desirable rather inevitable for meeting the quick needs of the potential users. The main aim of the Library Management Robot using RFID tag is to take books from a library and return it with the help of a robot. Therefore, we can collect and return the book from library very easily. The users' random requests, the retrieval of books, and the delivery and return of the books are the four sequences of events, which need more attention for reducing the task time. In most of the existing automatic library management systems when a library user requests a book through the online card catalog, the catalog shares the request with the *dematic system*, which pulls up a book's bin and

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compartment information along with the bin's current location on the racks. Therefore, the design and development of Wi-Fi based robotic library is the need of the day.

II. Literature Review

Literature review reveals that many leading libraries all books can be requested online, then pulled up to the surface by an automated retrieval system that keeps track of every volume through barcodes [1]-[5]. The radio frequency identification (RFID) is a new generation of auto identification and data collection technology which helps to automate business processes and allows identification of large number of tagged objects like books, using radio waves. RFID based Library Management system (LMS) would allow fast transaction flow for the library and will prove immediate and long term benefits to library in traceability and security. The existing system is based on RFID readers, supported with antennas at gate and transaction sections, and library cards containing RFID-transponders which are able to electronically store information that can be read or written even without the physical contact with the help of radio medium [6]-[9].

In the existing system, manual methods are generally used where the lists of library books are made and whenever the books are taken it is registered in the record. This method is not fast and large number of staff is also required for that. Note that in certain sophisticated libraries barcodes are also implemented. In this model, we are replacing it with RFID tags. The RFID offers advantages over manual systems or use of bar codes. The tag can be read if passed near a reader, even if it is covered by the object or not visible. The tag can be read inside a case, carton, box, or other container, and unlike barcodes, RFID tags can be read hundreds at a time. Note that barcodes are able to read one item at a time.

One should appreciate the fact that the RFID tag can be affixed to an object and used to track and manage inventory, assets, people, etc. For example, it can be affixed to cars, computer equipment, books, mobile phones, etc. The RFID technology is being implemented in a number of libraries lucratively for the large volume of transactions. Further, another non-library agency could potentially record the RFID tags of every person leaving the library without the library administrator's knowledge or consent. One simple option is to let the book transmit a code that has meaning only in conjunction with the library's database. Another specialty of the existing system is that PIC microcontroller is used for controlling the whole operations. It requires more supply voltage and the operating speed is low. Therefore, through this paper we are replacing it with most advanced ARM

microprocessor. The Robot is used for finding the books as well as for recommendations for the users. Note that the robot moves according to the GPS.

III. LIBRARY MANAGEMENT ROBOT

The system mainly consists of ARM (Advanced RISC Machine) microprocessor (LPC2148), motor driver circuit with 5 degree of freedom, RFID reader, Wi-Fi Router, and user interface. The interfacing makes possible by the Wi-Fi technology. The book rack design plays a major role in time management in tracing and delivering books to the customer. The proposed block diagram of the library management robot is shown in Fig. 1. In this model, a small rectangular shaped book shelf has been selected for books storage and effective customer-specific algorithms have been built-in for quick automatic delivery of the books [5]. The typical window of a user interface system is shown in Fig. 2.
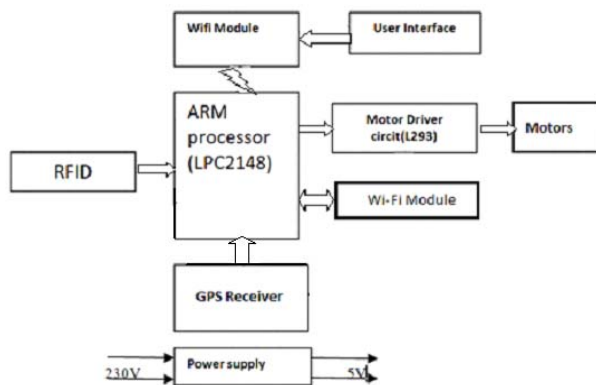

Fig. 1 Block Diagram of Library Management Robot

If a user wants to take a book from the library, the user will enter the username and password in the *touch screen* at the library entrance. For each book, a RFID code is stored in the system. After the credentials details it will show a screen which will have the details of the books which one has already been taken. The user can select the return tab which will be there with each book. If the user wants to renew the same book then it can be done with a corresponding option. The system will have an option '*New*' in which one can see a huge collection of books. The user can select the category first and subsequently the name of the book for transaction. The corresponding RFID number will be passed to the robot which is placed in the particular category through Wi-Fi.

Note that an option of '*Recommend books*' will be invoked once the user entered the specific topic title and/or unknown about the book titles. Here the system sends a particular signal to every robot which is placed in each category to send the top rated books name. The robots have an intelligence mechanism such that it will send the books name according to the other user's ratings and also filter out read and un-read books. The algorithm for this sort out is done already in each robot. The user will get the books name in every category. When the user

identifies the name of the book the corresponding robot will get the signal and the robot will pick the book.
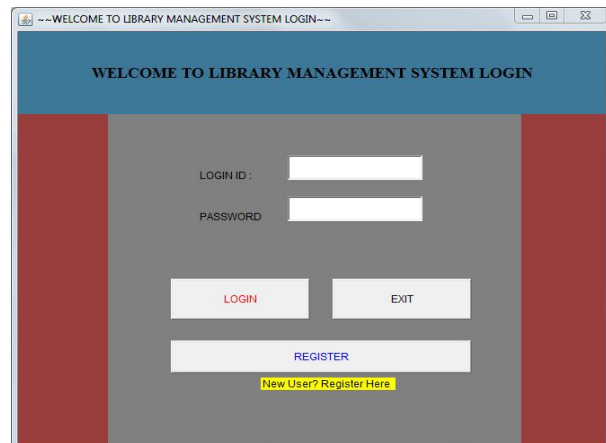

Fig. 2 The initial window of a user interface system

The each rack is in a rectangular type, which can accommodate one book. Note that the robots are assigned to pick up any book within its specified range at one book at a time. The robot will place the book in a cart within itself. This will be useful if the same user requests more books within the range. Also, note that the robot will not be carried out simultaneous operations of multiple users at the same time. In this proposed design the robot with a motor driver circuit will facilitate it to reach the coordinate where it can pick the identified book(s) from the rectangular shelves. The robot will confirm the book by reading the RFID tag placed on the book. This is to confirm that the books are not misplaced. In case of any misplace of books happened then the robot will give a false alarm, which will send false signal to the user interface system through Wi-Fi. This ensures the robot to work error freely. Then the robot will walk to the user's side. Note that the GPS is controlling the route of the robot by sending the signal through Wi-Fi. The robots are having a processor equipped with GPS module. The GPS module will control the path. The obstacle avoidance mechanism also provided in this robot. It will help the robots to walk without much delay. If the two robots are walking in the same path then the robot having high priority task will walk first, which are programmed accordingly. If the return book is within the same category, the same robot will pick the book from the user. The book is confirmed by reading the RFID tag. Then robot will return the same section and place that book in the specified shelf.

A. RFID Module

The radio-frequency identification is the use of a wire-less non-contact radio system to transfer data from a tag attached to an object, for the purposes of automatic identification and tracking. Note that a certain class of tags requires no battery and it is powered by the radio waves. Other classes use a local power source. The tag contains electronically stored information which can be read up to several meters away.

Unlike the barcode, the tag does not need to be within the line of sight. The use of RFID reduces the amount of time required to perform circulation operations. The most significant time savings are attributable to the facts that information can be read from RFID tags much faster than from barcodes and that several items in a stack can be read at the same time. A radio-frequency identification system uses tags, also known as labels, which are attached to the objects to be identified. The two-way radio transmitter-receivers readers send out a signal to the tag and read its response. The tag's information is stored electronically in a non-volatile memory. The RFID tag includes a small RF transmitter and receiver. An RFID reader transmits an encoded radio signal to interrogate the tag. The tag receives the message and responds with its identification information. This may be only a unique tag serial number, or may be product-related information such as a stock number, lot or batch number, production date, or other specific information.

When an RFID tag passes through the field of the scanning antenna, it detects the activation signal from the antenna. That wakes up the RFID chip, and it transmits the information on its microchip to be picked up by the scanning antenna. In addition, the RFID tag may be of one of two types. Active RFID tags have their own power source; the advantage of these tags is that the reader can be much farther away and still get the signal. Even though some of these devices are built to have up to a 10 year life span, they have limited life spans. Passive RFID tags, however, do not require batteries, and can be much smaller and have a virtually unlimited life span. RFID tags can be read in a wide variety of circumstances, where barcodes or other optically read technologies are useless. Note that the books on the rack are recognized by an RFID reader. Here a database is made in the system relating the name of the books, the shelf number, and RFID tag number. This is send via Wi-Fi module to the ARM processor and the robot moves forward towards the shelf which is provided by the stored information in the user interface system. Then RFID number of the book is compared with the send tag number and if a match occurs the robot picks up the book, then returns back to librarian.

B. ARM Microprocessor (LPC2148)

ARM means Advanced RISC Machine. It is the most widely used microprocessor. It has various series like ARM5, ARM7, ARM9, ARM11 etc.:-.Here we are using ARM 7 versions. It has three stage pipelining and Von Neumann architecture. ARM7 is a generation of ARM processor designs. It controls the motor movement of arm and the wheels and also the opening and closing of the arm. Here the information transferred from the PC via Wi-Fi is collected using serial communication pins and then comparison is done. It requires only 3.3 v for its operation.

1. Features of LPC 2148

- Flash Program Memory: 512 kbytes
- SRAM Data Memory: 32 kbytes
- I/O Pins: 45
- Timers: Two 32-bit
- A/D Converter: 10-bit Fourteen Channels
- DAC: 10-bit
- Real-Time Clock (RTC): Independent Power and Dedicated 32kHz Input
- I²C: Two Modules with Master or Slave Operation
- SPI: Full Duplex Serial Operation
- 64-pin High-Performance ARM Microcontroller
- UART: Two Modules
- USB: 2.0B Fully Compliant Controller with RAM
- External Oscillator: up to 25MHz with integrated PLL for 60MHz Operation

C. Wi-Fi Module

Wireless Fidelity, more known by its short form Wi-Fi, is a digital communications protocol, through which gadgets can communicate with each other in a unicast or a broadcasting manner without using any wires. The idea of fast speed wireless LAN originated when the United States Federal Communications Council, a communication agency of the US government, decided in the year 1985 to utilize a few bands of wireless spectrum without subjecting them to a license fee. Following this, the IEEE committee for 802 standards which manages networking protocols among electronic devices, formed an extension 802.11 which would work on the wireless mode. Being a wireless protocol, Wi-Fi standard uses the ISM (Industrial, Scientific, and Medical) band of frequency which are free to use and require no licensing. Launched in 2.4GHz with transmission rates of 1-2mbps, Wi-Fi now works at 5GHz frequency also with astounding data transmission rates reaching up to 54mbps at both frequencies. In this system Wi-Fi plays an important role of sending the RFID information as well as guiding the robot with correct path with the help of GPS.

D. Global Positioning System

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses satellite ranging to triangulate your position. In other words, the GPS unit simply measures the travel time of the signals transmitted from the satellites, then multiplies them by the speed of light to determine exactly how far the unit is from every satellite it's sampling. GPS uses a constellation of 24 satellites in precise orbits approximately 11,000 miles above the earth. The satellites transmit data via high frequency radio waves back to Earth and, by locking onto these signals; a GPS receiver can process this data to triangulate its precise location on the globe. In this system, the whole robot movement is controlled by the GPS with the help of Wi-Fi. Each robot placed in different categories will have a separate IP address. Commands and data can be sent through this technology.

E. Power Supply

The 5 volt power supply is provided for all motors. Power should also be provided to ARM microprocessor, ZIGBEE module, RFID antenna, and Wi-Fi Router.

F. Motor Driver Section

Whenever a robotics hobbyist talks about making a robot, the first thing comes to his mind is making the robot move on the ground. And there are always two options in front of the designer whether to use a DC motor or a stepper motor. When it comes to speed, weight, size, cost, DC motors are always preferred over stepper motors. There are many things which one can do with the DC motor when interfaced with a microcontroller. For example, one can control the speed of motor and the direction of rotation. Usually H bridge is preferred way of interfacing a DC motor. These days many IC manufacturers have H bridge motor driver available in the market like L293D is most used H Bridge driver IC. H bridge can also be made with the help of transistors and MOSFETs etc. rather of being cheap; they only increase the size of the design board, which is sometimes not required so using a small 16 pin IC is preferred for this purpose. By using two motors, we can move our robot in any direction. This steering mechanism of robotics called as differential drive. L293D is a dual H Bridge motor driver, so with one IC we can interface two DC motors. Note that such system can be controlled in both clockwise and counter clockwise direction using a motor with fix direction of motion. You can make use of all the four I/Os to connect up to four DC motors. L293D has output current of 600mA and peak output current of 1.2A per channel. Moreover, for protection of circuit from back EMF output diodes are included within the IC. The output supply (VCC2) has a wide range from 4.5V to 36V, which has made L293D a best choice for DC motor driver. Here we use 5 degrees of freedom for the robot. So that the robot can move much fast compared to usual forward to backward movement.

G. Design

The robotic automatic library needs a special type of design compared to other libraries. The primary requirement is the book shelf design. The shelf will accommodate one book in each portion. The gap of each shelf will be in such a way that two robots can move and cross each other at the same time. Note that the proposed robot will be having a height that of the book shelves on the order of 5 feet. This will enable the robot to pick any book within its range. Since the path of the robot is depend on the signal from GPS, the signal strength should be strong in the entire region of the library. To ensure the required signal strength the Wi-Fi router is placed in every robot. Note that suitable algorithm can be invoked for the design of the robotic path with collision avoidance.

Fig. 3 shows the different movements of the robotic arm. Note that the current system also uses these types of movements for the robotic arm. It consists of three rotations at the shoulder, one at the elbow, and three rotations at the wrist. Since the shelf of the proposed system is in rectangular shape the high rate of accuracy in the mechanical design of robotic arm is expected. A suitable size cart is provided with the robot for keeping the books already picked up from the shelves. This will allow the robot to move freely after picking the books. Note that at the user end again the specially designed robotic arm will pick the book of any size and shape and give to the user ergonomically.
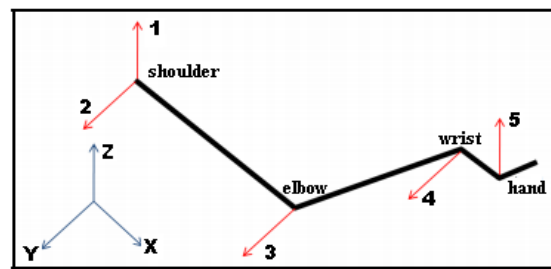

Fig. 3 Library Robotic arm's degree of freedom

IV. Summary

In this paper, we introduced a user interface system having login id and password for the robotic library users. This system introduces the robot having an intelligence capability that can suggest books as well as pick up the books according to user's preference. At the user interface system, there are three main options viz., *the return, the renewal, the issuance*. The Wi-Fi enabled robot will be there in every category of the books. The books are arranged in a separate shelf having rectangle shape. For each book, the separate shelf will be allocated and the database is stored in robot systems. The user will select the book from the touch screen and the same information is passed to the corresponding robot by the Wi-Fi enabled technology. If the users are not particular about the books, which need to be taken by them, then the robot will recommend a book according to other potential readers' feedback rating. Accordingly, the logic of solution has been generated and an attempt has been made, however not reported in this paper, for developing an algorithm for invoking the robot intelligence to recommending a particular book or periodical to the users who are in need of such assistance. Note that after getting the confirmation from the users, the robot will pick the books and issue the same to the intended user. Also note that the issuance, the renewal and the return of the books are done by robots with the help of RFID for saving time. The advantage of this system is that lender need not be checked each book manually when the user placed a request. Instead, the robot will take book from the corresponding shelf using RFID so that we can save the time of checking each book separately. Since the Wi-Fi has better range compared to Zigbee and other communication protocol one can cover a wide range of libraries for clustering it by implementing this method. Note that the GPS is helping the robot to control the path.

V. Concluding Remarks

In this paper, a new model for the library management robot system has been proposed for meeting the conflicting needs of the customers. In this library, the robot is picking up the books according to the user's requirements and recommending the best available books to the deserving users. This option is invoked based on the authentic review reports of the previous

potential readers. The robot will be picked up the books after getting the required information from the user. The algorithm is generated by the developer such that robot will use the ratings from potential readers only. The ratings are given by the users at the time of returning the books. The user interface will ask the ratings from the user at the time of pressing the return button. Further, an attempt has been made, however not reported in this paper, for developing an algorithm for an efficient automatic robotic library operation such that the average time taken by the user is reduced. This reduction in time is apparent because it involves no physical presence of the user to pick up the book from the shelves. The library managers are interested in finding the most economical way of getting book issue list, which minimizes the costs involved in terms of travel distance or travel time of the robot arm. In this model, the user will be selecting the book from the *touch screen* and the same information will be passing to the corresponding robot by Wi-Fi technology. Additionally, the robot uses its intelligence to recommending the books to the deserving users based on the potential readers' previous rating; and after getting the confirmation from the users the robot will pick the books and deliver to the user using RFID. We concluded that our proposed model reduces the business operating costs and the user's operating time. Note that this study is a pointer towards for developing a fully automated user-friendly library for creating win-win situations to the library managers and the users for getting more profitable and intellectual output for meeting the global challenges.

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