Wi-Fi Indoor Navigation System Controlled Automated Wheelchair

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***Abstract*—Wi-Fi Indoor Navigation System Controlled Automated Wheelchair aims to give a motorized wheelchair the capability to self-navigate in an indoor environment. With the use of two (2) cameras attached on the sides of the wheelchair, the wheelchair will be able to know its current location by scanning the QR codes attached to an adjacent wall. The wheelchair can enable a person to go to the desired location through the controller or make a manual maneuvering with the use of joystick. The wheelchair performs obstacle detection and avoidance using ultrasonic sensors, manual control whilst capable of autonomous operation.**

***Index Terms*—Automated Wheelchair; Indoor Navigation; Obstacle Avoidance; QR Code.**

I. INTRODUCTION

Wheelchairs are medical equipment that helps people with disabilities and the elderly to go from one place to another. Wheelchairs improve the mobility of the user and it makes them feel more comfortable as they move around. With the advancement of technology, wheelchairs evolved from being manually pushed to automatically controlled.

The work done by [1] made an implementation of robotics to a wheelchair. The objective of the study is to combine three approaches to motion control to evaluate the usefulness and efficacy of three paradigms, namely, deliberative plans, local reactive behaviors, and human inputs. The wheelchair is autonomous meaning that it moves on its own when given the destination, the navigation is based on lasers where it pinpoints landmarks on where to go. IR proximity sensors are used to detect obstacles which the wheelchair will then avoid using reactive controllers. There is also an override system where the user can command the wheelchair on where to go using a joystick. Another feature is the Omnidirectional Camera wherein the user can have 360 degrees vision around the wheelchair. The study stated that on autonomous driving, there is obviously less effort, however, causes a level of frustration for the user because of lack of control and most users felt more control in semi-autonomous driving. The testing was done on a similar environment and limited only to one floor, then calculate each driving method with the same placement of obstacles then the succeeding tests having different obstacles. During the testing stage, the ability of the system for vehicle avoidance was proven. The wheelchair reached its destination without hitting any obstacles that were placed along its way.

Power Wheelchairs are very much helpful nowadays as explained by Kim, et all [2]. Most Power Wheelchairs comes with a joystick which serves as the wheelchair controller. Though joystick controlled wheelchairs are already a big convenience, users are still sometimes burdened with controlling the wheelchair as well as navigating their way to their destination. The prototype built in this study automatically detects and avoids the obstacles that are detected by the Infrared Sensor connected to the robot while driving the wheelchair. Aside from the Obstacle Detection and Avoidance, different Human Bio-Sensors are connected in the Wheelchairs System. These Bio-Sensors monitors and detect the electrical activity of the users heart (ECG), the heart rate (PPG), and the skin temperature of the user. Once one of these bio-sensors detects any abnormal signals from the user, the system will send an alarm signal to the family or the doctor. Most of the wheelchairs today are controlled by a joystick but it can’t reach its destination on its own. This project focuses on automatically moving the wheelchair to reach its destination by just letting the patient indicate a room number and it will automatically stop once it reaches its destination.

The work done by [3] is to develop a cost effective control unit for the wheelchair which will be used by a person with Tetraplegia. Quadriplegia or Tetraplegia is partial or total loss of use of all four limbs and torso, which is caused by an illness or injury. The system is embedded in an Arduino board, and the movement control will be detected by two accelerometers. Since the accelerometer measures the acceleration forces and the sensing of inclination, the accelerometers in this study is place in the neck or head of the user. This accelerometer will help the user control the wheelchair through the movement of the direction and magnitude of the neck or head. There are five control functions which are: Bend head Forward for Forward Motion, tilt head right for Right Turn, tilt head left for Left Turn, lift head upwards for Reverse motion and Rest for default. This Automotive Control is cost effective because it does not use many sensors, or expensive sensors to control the robot, the system only utilizes two accelerometers to control the robot.

The work done by [4] is to develop a prototype for an electric wheelchair with a dual control access for both the users in the wheelchair and their caregivers. A prototype has been built to prove the design concept; and further, the method of control switching between people in and behind the wheelchair has been optimized with the established prototype.

Prior studies regarding wheelchairs include controlling it with the use of a joystick and using sensors to detect obstacles and with more studies focusing on the improvement of the wheelchair. The project is made to help patients to go from one room to another, by making a wheelchair capable of self-navigation. This type of wheelchair is capable of letting the user to reach their destination by indicating their desired location and the wheelchair will automatically move to the indicated location.

II. WHEELCHAIR IMPLEMENTATION

Medical Technology is one area where technological advancements have helped people with different illnesses live easier and more comfortable given the health condition that they have. Examples of these medical technologies are Magnetic Resonance Imaging Machines or MRI machines, the stethoscope, and the wheelchair. For example, stethoscopes were invented for the Doctors to hear the heart and lungs easier, MRI machines capture detailed images of the organs and tissues within a body without literally opening the body. A simple wheelchair helps the elderly and people with disabilities go where they need to go. The innovation being presented by this project shows that the development and completion of it will lead to the advancement of technology and it can help bring more convenience to people with disabilities. Using the NI myRIO in detecting QR codes as a means of navigation, the wheelchair would be able to move with its initial position being recorded.

This project specifically aims to help people with disability or the elderly through improvement of currently available hospital/mobility equipment. It gives the patient more convenience and freedom as they will be able to move about and go to their destination without being dependent on other people. And since the system is self-navigating, the patient can be assured he reaches his destination without being burdened of navigating his/her way. The obstacle avoidance feature would also ensure safety to both the patient as well as other people in the hospital.

The automated wheelchair was made from a standard steel wheelchair with NI myRIO serving as the controller of the wheelchair which enables it to move according to the user's command. Drivers, Voltage Regulators, and Converters were used to make the myRIO compatible with the two motors. The system block diagram is shown in figure 1.

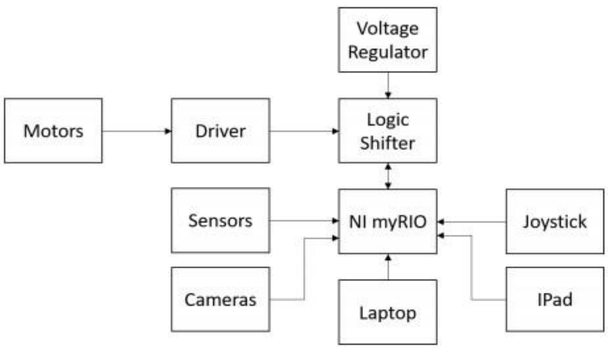

Figure 1: System Block Diagram

A. *Wheelchair*

The standard steel wheelchair was modified by adding motors and batteries as well as other components necessary to control the system. These are installed at the back and bottom of the seat to avoid hindrance for the user of the wheelchair and at the same time maintain a good center of gravity; this is shown in Figure 2. Two cameras are installed to the left and the right of the wheelchair. Two ultrasonic sensors are placed in the left and right front side of the wheelchair to detect obstacles. Additional metal slabs are attached to the sides so that if ever the wheelchair would come in contact with other people in emergency cases, they would not be hurt as much as when they would be bumped with the wheel [5].

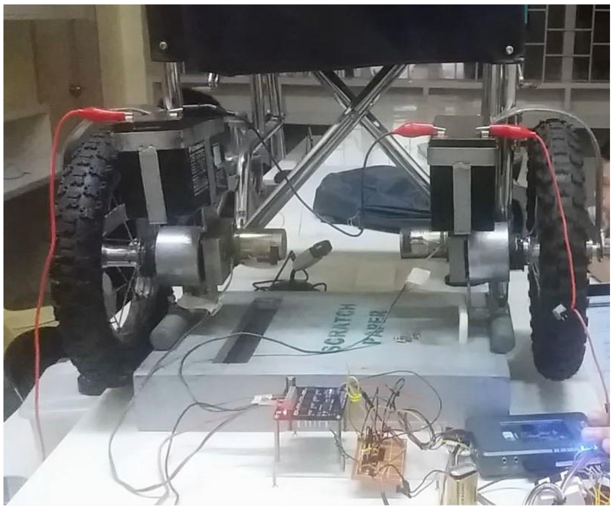

Figure 2: Modified Wheelchair

The motor used is a GSD BMG-4032NT Engine which has a maximum input voltage of 24 VDC. The motor rotates at a maximum of 28 rotations per minute (rpm) which is enough for a wheelchair speed.

The battery used are two 12-volt Panasonic Sealed Lead Acid battery with a maximum output current of 7 amperes are connected in series to supply 24V to the motor.

As shown in Figure 1, the motor is driven by a motor driver with the following specifications: input voltage ranging from 4.8V to 35V with maximum output current of 15A, and Four digital IO to control the movement. Shown in Table 1 is the logic operation of the motor driver.

Table 1
Logic Operation of the Motor Driver

M2_EN	M2_PWN	M1_EN	M1_PWM	Direction
1	1	1	1	Forward
1	0	1	0	Backward
1	1	0	0	Left
0	0	1	1	Right

A logic converter, TXB0108, is used between the motor driver and the digital IO of the myRIO since the myRIO has 3.3V general purpose DIO lines while the motor driver has 5V DIO lines. Similar to [6], the speed and direction of the motor are controlled using PWM.

The voltage regulator used to supply 3.3 Volts to the VCCB pin of the Logic Converter is a simple LM3940 which has an input voltage of 5 Volts which will be supplied by the 5-Volt pin of the DIO output pin of the NI myRIO. The voltage regulator was used for the logic shifter because the logic shifter used has two different input voltages.

B. *Wheelchair controller and Sensor*

The NI myRIO served as the controller of the wheelchair. Connected to the controller are two cameras for automatic navigation, motors, sensors to detect obstruction, and joystick for manual operation. It indicates whether the wheelchair will move automatically or manually, determining its exact location and information, avoiding obstacle along its way, and determine whether it reach its destination or not.

Two A4 Tech PK - 635G cameras is used to detect QR codes. It is a 16 megapixels camera, which has an anti-glare to coating to avoid disturbing reflections. It can also capture great quality images even in low-light conditions, and also has an intelligent multisampling delivers fluent video transmission with no aliasing. The cameras are used to scan and process images that will read the QR code. The QR code detection and reading will determine the location of the wheelchair to be transmitted to the database system. One camera will be placed in the left side while the other camera will be placed on the right side so that both sides can be seen by the user.The camera on the left is used if it moving in one direction and the other camera is used if it is moving in the opposite direction. The QR codes contain information about the location in the hallway. Once the QR is detected, it will be transmitted to the database system. This enables the remote tracking of the current location of the wheelchair and monitors the status of the wheelchair.

To detect and avoid obstacles, ultrasonic sensors were installed on both sides of the wheelchair. Two sensors are placed on both sides of the wheelchair such that when a wheelchair detects an obstacle on the left, the wheelchair will turn right for 5 seconds and then left for another 5 seconds. When the right sensor detects an obstacle, the wheelchair will turn left for 5 seconds and then right for 5 seconds. However, when both sensors detects obstacles up to 9 inches, the wheelchair will stop.

The controller of the wheelchair in manual mode is a joystick. The joystick will be from Digilent like most of the components are because they are compatible with the NI myRIO, besides controlling the wheelchair moving forward or turning left or right, the toggle button also acts as a switch for the user to choose whether to be in manual mode or automatic mode.

C. Software Implementation

Indoor navigation and localization are fundamental issues to mobile robotics. QR codes can be used as landmarks to provide location information [7-9]. The implementation of self-navigation of the wheelchair to different locations on the building floor is based on a QR code that are placed on the wall of the hallway. These QR codes essentially contains the location information which will be detected by the wheelchair as it moves from one location to another. Shown in Figure 3 is the QR Code detection block diagram

Figure 3: QR Code Detection

The data obtained from QR code detection are transmitted to the server of the monitoring system. To communicate with the database, the Labview database connectivity toolkit was used. There are two separate VIs for the integration of the database and the QR Code Detection. The VI for the database is placed under the My Computer while the QR Code Detection is placed under the myRIO. The group used shared variables so that the data can be transferred from myRIO to My Computer and vice versa. Shared variables are used to publish data over a network with the use of Shared Variable Engine (SVE). Shared variables are created by creating a new variable. Shared variables should be made under myRIO if the data will come from myRIO but if the data will come from the laptop, shared variables should be made under My Computer. In the integration of the Database VI and QR Code Detection VI, a date and time function is used to indicate the current date and time when the VI is used. This function is helpful in getting the real-time date and time when the program is running. It converts a timestamp value to a date string and a time string. To be able to get the correct time zone, myRIO should be configured so that the time will match on the time in the laptop. In order to get the seconds, a true control should be placed in order to display time in hours, minutes, and seconds.

For the monitoring system, another VI is implemented to display the current location of the wheelchair. The monitoring system is used to enable the user to identify the current location and the desired location of the wheelchair. It displays the images captured by the two camera at its side. It also displays the velocity and acceleration of the wheelchair to be able to see the distance it can covered. The main purpose of the monitoring system is to help the user monitor the wheelchair's location and to help whether it reached its desired location or not.

III. WHEELCHAIR TESTING

For the prototype testing, it was tested in St. Joseph Walk and STRC hallway. The manual control and automated control of the wheelchair was tested.

To measure the speed of the wheelchair, a tachometer was used to measure the rotational speed of the motor. The rotational speed of the motor is around 26-28 rpm. Given the wheel diameter, this translates to a speed of 0.5 meters per second. The wheelchair can cover approximately 30 meters per minute at a voltage of 24V or when the battery is fully charged.

Through a series of testing, it was determined that a maximum distance of 90 centimeters, between the camera and the QR codes, must be maintained for accurate QR code detection. QR codes were placed along the hallway, 3.0 to 3.5 meters apart, 9 codes to represent the 9 rooms used during testing, and both cameras were able to show 100% accuracy in detection for all 10 runs. The testing covers a distance of around 30 meters.

From that testing, it was observed that the camera easily detects the QR code when it is far from it. A total of 20 tests are performed for the QR Detection. 10 tests for camera 1 which reads the QR code in ascending order, and 10 tests for camera 2 which reads the QR codes in descending order.

Based on testing done, the system detects obstacles within 9 inches from the wheelchair. For testing purposes, obstacles were placed randomly along the path of the wheelchair. The system behaved and reacted as expected once an obstacle is detected. Once the left sensor came across an obstruction, the system turned right to avoid the object then left again to get back on course. The same test was done with the other sensor. When both sensors detect an obstacle the motors will stop. As expected the wheelchair detects obstacles up to 9 inches and performs obstacle avoidance. The obstacle detection test results can be seen in Table 2.

Table 2
Obstacle Detection Test

Left Sensor	Status	Right Sensor	Status	Both Sensors	Status
3	Detected	3	Detected	3	Detected
6	Detected	6	Detected	6	Detected
9	Detected	9	Detected	9	Detected
12	No	12	No	12	No

The U-Turn capability of the wheelchair was also tested both manually and automatically. A total of ten trials were made for both set-ups. For the manual set-up, the wheelchair needs to move left, right, or forward depending on the user. The group calibrated the U-turn through trial and error. The wheelchair needs to have the same distance as its original position from the post, to have a 100 percent assurance of scanning the QR codes correctly. The wheelchair performs 270 degrees to the left, then 90 degrees to the right, to achieve the 90 centimeters distance of the wheelchair from the post. After series of calibration testing, the ideal U-turn operation was achieved. To test the automatic set-up, the group indicated the desired location and let the wheelchair proceed to the specified location. After scanning the QR code, the wheelchair performed the necessary U-turn operation.

For the database and website, the transmission delay of the data in the database and website are tested. The program is created that will automatically store the data scanned by the QR code to the database, the priority of this testing is the delay of the sending of the data. The testing resulted to a delay of 0 to 3 seconds.

IV. CONCLUSION

The main objective of the project is to retrofit a standard wheelchair by adding a motorized controlled system for manual and auto operation, and equipped with NI myRIO for obstacle detection and avoidance. In autonomous operation, navigation is performed via two cameras that are attached to the sides of the wheelchair to detect the QR codes corresponding to the current location of the wheelchair.

Lastly, a monitoring system was also developed to track location of the wheelchair and monitor the status of the wheelchair such as acceleration, speed, and displacement. The online system can also display the images the camera captures as the wheelchair moves.

This project specifically aims to help people with disability or the elderly by introducing improvement to current hospital/mobility equipment. Patients can move about independently using the joystick for manual control. This is taken a step further with the autonomous mode, as this allows the patient to reach his destination without the need for the patient to do the navigation. Safety is ensured with the obstacle detection and avoidance feature.

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