DESIGN AND FABRICATION OF HUMAN FOLLOWING SMART TROLLEY USING KINECT SENSOR FOR DIVERSE APPLICATIONS

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Abstract

In the recent years both the researchers in the industry and academia have invested a lot of their time and hard work in the region of automation, smart living. As a part of automation and smart living, smart shopping also plays a key role in enhancing the life of people in the modern life.

In this work the word "smart trolley" depicts an auto bill generating, obstacle avoiding, theft preventing and auto parking trolley which will follow the footsteps of the consumer. The scope of this work is beyond the barriers of trade and commerce. Furthermore it will be largely helpful in Medicare sector, childcare, luggage handling and also in the area of material handling in industries. Especially in industries, when Industry 4.0 just started to roll its dice.

Navigation of the vehicle is done using the Kinect sensor which is used by Microsoft in the X box applications. It is the hardest part among the features since, former examples are comparatively less. The parking facility of the trolley is supported by the line following mechanism of the vehicle which ensures the safe parking of the same in the specified region. For preventing the theft of the trolley, an alarm sound will be generated after the defined perimeter of usage. For auto bill generation, RFID tag is attached to every single product in the supermarket and RFID reader is merged to every single trolley. So that the billing will be decentralized, long queues at the bill counter could be avoided and substantial time of customer is saved. The hardware part consists of Mecanum wheel which simplifies the programming required for the vehicle. The usage of Mecanum wheels also helps in proper and more efficient navigation by avoiding the obstacles. The main concern of the work is that, how the device will perform during rush hours inside a supermarket. During the further development of the product an exclusive application cum wallet could be developed for the completion of the smart shopping experience. Payment could be done exclusively using that application. The mechanical and design aspects of the vehicle is studied, mentioned wherever required.

Keywords: Automation, Kinect sensor, Mecanum wheel, RFID, Smart living, Smart trolley

I. INTRODUCTION

As the name itself indicates Human following smart trolley is a trolley having some special features and has the capability to follow its leader that is, the customer. Even though this work is

dealing with the aspects of the trolley, with minor alternations it can be used in various sections of the day to day life. This includes sections of Medicare, Childcare and material handling.

Automation in day to day life with IoT technologies are the latest trend embracing the world and global markets. Human following smart trolley, which is mentioned in this work will be another stepping stone in to the fully automated life of human beings. After the implementation of the above mentioned product the growth to fully automated stores will be more vibrant. As of now Amazon has started a fully automated store in the United States of America. With implementation of our work and integrating the same with automatic stores it will be changing the whole world scenario of shopping.

In this work further applications are not detailed. Rather it is focused on navigation and other facilities of the trolley. As stated in the earlier paragraphs the applications of the work is not confined only to a single sector. It has got wide range of applications. Especially in manufacturing sector during the complete swing of Industry 4.0. Recent studies regarding the navigation of a robot or a device following a human being gives extra motivation to our work.

II. LITERATURE REVIEW

Human following smart trolley is a non-traditional trolley which has the capability to follow the human footsteps rather than being taken on by the consumer. To name it as smart it has some special features like, auto bill generation, automatic parking, theft prevention feature and tracing of the same in place. On the further development of the product an application is developed to control the navigation system of the trolley. In the application it has two different operating modes such as shopping mode and parking mode. After the purchase of items by activating parking mode the trolley will automatically parked in the specified area for parking. At that situation it is acting as a line following robot. On the other hand during shopping mode it is an obstacle avoiding human following robot. In future if the finance sources allows the application can be further developed into an exclusive app cum wallet feature, which will permanently eradicate the billing counters in the stores.

Academicians and researches are always interested in the optimum method to follow a human being by avoiding collisions and other navigation issues. Even though there are several methods available like the usage of Ultrasonic senor, Laser beams or gyroscope each of the methods has its own difficulties. The latest method used by several researchers are the method of Kinect sensor. Kinect sensor is actually a complicated sensor made for Xbox games by Microsoft. But the same is widely used these days in robotic applications. The same method will be tried to use in optimum manner in this work. Other facilities such as auto bill generation, automatic parking and theft prevention are comparatively easy tasks to implement since, it has some former examples to follow.

Recent trends in the industry and academics clearly establishes the fact that automation will be the future of humankind. Hence, the work like this will provide an extra boost to the same.

III. ANALYSIS OF FORMER EXAMPLES AND POSSIBLE METHODS OF NAVIGATION

Navigation of human following of a robot is an issue which should be addressed in depth in order to find an optimum method for doing so. In the current scenario there are lots of methods used to follow a target. This includes usage of ultrasonic senor, different tags or other kinds of technologies such as accelerometer or gyroscope. But during the analysis of these examples we came across to the knowledge that none of the above technologies is completely accurate and cannot serve our needs efficiently.

Bluesmart is one product which we found very efficient and interesting, depending on our need. It is actually a smart connected suitcase which has the ability to connect to the phone using Bluetooth and it has also a GPS tracker. But since, our application was confined to only a single building the usage of GPS tracker was not possible in case of tracking. It was actually a guided suitcase rather than a following one. The most difficult task in our work was to make our

product human following. Because, it didn't have much former examples and complex coding also contributed to the difficulty. Many research papers have proposed different theories for the human following navigation. Some of the most important ones are mentioned here.

(A) Infrared sensor
(B) Ultrasonic sensor
(C) Laser range finders (LRF)
(D) Kinect sensor

A. Infrared camera

Most common method which is used conventionally for human following is the usage of Infrared sensors. An infrared sensor measures the Infrared light that is transmitted in to the environment which tracked by infrared LED. This type of sensor is commonly used in navigation for object avoidance or line following applications. The sensor is very sensitive to Infrared lights and sunlight, So that the Infrared sensor could be used with very high precision in the areas of low light. It has further advantages like can operate in wide areas and is real time functioning one. But our work was not able to take up the same because, the following of single person using the same was not easy in crowded space.

B. Ultrasonic sensor

These sensors are designed to generate high frequency sound waves and receive the echo reflected by the target. These sensors are used in a wide range of applications and are very useful when it is not important the detection of colors, surface texture, or transparency. As stated earlier the detection of more than one person becomes an issue in crowded area. So usage of many vehicles such as trolley incorporated with ultrasonic sensor was not feasible.

C. Laser range finders

In the case of laser range finders the leg detection algorithm is used to follow the leader which is the consumer in this scenario. The algorithm provides contrasting of which is the relative velocity of the target person with respect to the robot. The information will be passed to fuzzy controller which will set the speed needed by robot to follow the target person's leg. Fuzzy inference system is being used to deal with humanistic and complex situation where it is not possible with mathematical models.

D. Kinect sensor

The system is using Kinect high speed sensor to detect and tracking movement or target person. The target person needs to raise their hands in front of the robot in order for it to calculate using human skeleton method. The input then passed to software. It then being passed to basic stamp for Kinect. After that, it being passed basic stamp for ultrasonic, and lastly to basic stamp for motor to generate movement of the robot.

IV. DESIGN AND FABRICATION OF HARDWARE

The hardware part of the work mainly consists of an ordinary trolley which is used in supermarkets and groceries for the purchase of items. After seeking the various options for the fabrication of trolley, Stainless steel was selected as the material for frame work. Main reason for the same was it had less weight with adequate strength. Moreover, it was a trolley and it should carry lot of weight of purchased items hence, the weight of the trolley should be as small as possible for efficient movement so, stainless steel was chosen.

Another important part of the hardware is the Mecanum wheel. It is actually an alternative design for the wheel which has the capability to move the vehicle in any possible direction. It means that, using a Mecanum wheel it is possible to move the vehicle in complete parallel direction to the plane. In order to have a 45º inclined movement to the plane two wheels which are horizontally placed should be operated as per the requirement of the movement. All these movements are made possible by the rollers fixed on the circumference of the wheel. With the usage of Mecanum wheel the programming part becomes very easy and navigation will also become proper and effective when compared to other wheels used for the robotic applications.

V. DESIGN AND FABRICATION OF ELECTRONIC PLATFORM

The electronic platform is the core part of this work. It is fabricated using aluminum composites panel (ACP) sheet. It gives high strength with low

weight. The main objective of the electronic platform is to achieve portability. The ordinary trolley can be converted in to a human following smart trolley, which is mentioned in this work, by installing the platform into the ordinary one. So effectively, existing trolleys itself can be easily converted. Different components required for the navigation and data communication were integrated into the platform. The main components are listed below.

1. Arduino board Mega
2. Mecanum wheel
3. Geared motor
4. Motor driver
5. Node MCU
6. HC-05 Bluetooth Module

1. Arduino board Mega

Arduino was the electronic platform used for controlling whole process of navigation and other features. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. Arduino read these signals and send commands to driver circuit to drive the motor. In this work Arduino Mega 2560 microcontroller is used as a main microcontroller to interface with all hardware and components. 2. Mecanum wheel

Mecanum wheel was chosen over other ordinary wheels in order to increase the mobility and to decrease the complications in the programming. Mecanum wheels, also known as Omni wheels or ilon wheels, consist of a hub with rollers oriented 45° to the axis of rotation. Mecanum wheels are prefect for the tight spaces such as shopping spaces in the supermarkets. With the rollers fixed to the circumference of the wheel they enable conventional forward and backward movement. Along with that side to side movement with even rotation is possible. To accomplish the same, each wheel turns independently. To move side to side, pairs of wheels oppose one another, acting like a worm gear.

3. D C geared motor

Motor coupled with a gearbox or transmission. A gear motor is added to mechanical gears to alter the speed or torque of the motor for an application. Usually such an addition is to reduce speed and increase torque. By using the geared motor we were able to provide the required torque for the trolley.

4. Motor driver

A motor driver is a little current amplifier. The function of motor driver is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor. However the need for motor driver arises because your micro-controller is not powerful enough. The direction of the gear motor can be reversed by reversing the polarity of the battery connection. The speed of the motor can be controlled by changing the voltage level across it. A motor driver IC named L293D is used here for interfacing the gear motor with Arduino. L293D consist of two H-bridge designed using 4transistor circuit that helps us to reverse the direction of rotation and to control the speed of the DC motor.

5. Node MCU (ESP 8266)

Wi-Fi module is a complete Wi-Fi network where you can easily connect as a serving Wi-Fi adapter, wireless internet access interface to any microcontroller based design on its simple connectivity through Serial Communication or UART interface. ESP8266 will serve as Access Point (AP Mode), meaning it will provide access to Wi-Fi network to other devices (stations) and connects them further to a wired network 6. HC-05 Bluetooth Module

It is a Bluetooth device used for wireless communication with Bluetooth enabled devices (like smartphone). It communicates with microcontrollers using serial communication (USART). It can be configured as either Master or slave. As HC-05 Bluetooth module has 3.3 V level for RX/TX and microcontroller can detect 3.3 V level, so, there is no need to shift TX voltage level of HC-05 module. But we need to shift the transmit voltage level from microcontroller to RX of HC05 module for the efficient working.

VI. FEATURES OF THE TROLLEY

The ‘smart’ features of the trolley is the one thing making this work attractive. As explained earlier

in this document the various features are listed as follows.

(a) Human following
(b) Auto parking
(c) Anti-theft
(d) Auto bill generation

(a) Human following

In order to develop the human following trolley, choosing a suitable following method is very important. As the supermarket is a very dynamic environment, the navigation method chosen must be able to detect the presence and position of the human. The tracking method must be able to distinguish the human with any other object.

The Kinect is an input device that can sense the motion, it track human skeletons and to identify people from the depth image .The Kinect sensor has human tracking capabilities from a static position that can provide full-body motion capture The system selects a person who raises his two hands as the target to follow at the beginning. The system then identifies the target to follow from the person's location and RGB color characteristics of clothes. The threshold distance between trolley & human could be set through coding. If objects appear to be there in between that value the robot classifies it as an obstacle. Then the robot initiates the collision avoidance process. Kinect sensor captures the movement of the human arm in real time. Then, the skeleton joint data is communicated to computer via USB for processing. Computer processes the information from the Kinect sensor and converts it into a skeletal image then calculates angle between joints and sending it Arduino microcontroller via USB. Depending on the receiving data, which are the angles, the Arduino generates PWM signals designed to move a Servo-Motor to a specific angle. Received data from Arduino (PWM) the servo motor turn their axles to the angles which are received. The above mentioned mechanism explains the nonlinear movement of the trolley.

(b) Auto parking

One of the main issues faced by supermarkets with the usage of the trolley is the abandoning of the same. In India usually the customer tend to abandon the trolley after usage or they do the same during the purchase, if they decides to abandon the shopping for the time being. Also the inability of customers to take the trolley to the parking lot is also a major concern. Above mentioned issues are solved using this auto parking facility.

Line following technique is used for autonomous parking of the trolley. The trolley have the capability to detect a black or dark line on a lighter surface depending on the contrast. They estimate whether the line underneath them is shifting toward their left or right as they move over them. Based on that estimation, they give respective signals to the motors to turn left or right so as to maintain a steady center with respect to the line. An array of IR (infrared) sensors are used in order to calculate the reflectance of the surface beneath them. The basic criteria is that the black line has a lesser reflectance value (since, black absorbs light) than the lighter surface around it. This low value of reflectance is the parameter used to detect the position of the line by the robot. The higher value of reflectance will be for the surface around the line. So in this linear array of IR sensors, if the leftmost or rightmost IR sensor presents the low value for reflectance, then the black line is toward the left or right of the robot correspondingly. The controller then compensates for this by signaling the IR light emitted by the LED strikes the surface and is reflected back to the IR photodiode. The photodiode then gives an output voltage proportional to the reflectance of the surface. Arduino UNO detects this change and sends signal to motor driver accordingly. Arduino UNO continuously monitors the data from both the sensors and turns the robot as per the line detected by them The IR sensor will sense the dark line and travels along its way, At the end where the trolley need to parked there is dark line perpendicular to the path which leads to the termination of the movement of the trolley at the parking area. The parking mode can be activated using the application developed for shopping.

(c) Anti-theft

A theft prevention system is needed to avoid unauthorized usage of trolley outside the defined perimeter. Anti-theft system will generate an alarm sound when the trolley is taken outside the defined perimeter. The main component in the mechanism is a Node MCU. There is a central

Wi-Fi assessment point, having a "SSID" and password used in Node MCU program. Node MCU is used as a client in the trolley which will be connected to the central Node MCU access point. Node MCU will be continuously analyzing WiFi strength. If the trolley is moving outwards the Wi-Fi strength will be gradually declining. If the Wi-Fi strength is reduced below the threshold value, alarm sound will be initiated. The threshold value was set by different trial and error experiments. (d) Auto bill generation

Long queues are nothing but very familiar things in the supermarkets of India. Normally the technology used in India is a centralized barcode scanning of materials at the billing counter. It takes substantial amount of time, especially in the rush hours.

To avoid this time lag, a RFID reader should be blended to the trolley. When consumer deposits their purchased item to the trolley it will scan its tag. It is almost equivalent to the barcode scanning in the counter. But, the major difference is, here the scanning is distributed or decentralized. When compared to the barcode readers multiple tags can be scanned simultaneously using RFID reader. Other packed items like Grains or pulses can be tagged if necessary. All these data will be transferred to the centralized server computer. The storage of the data will be based on the unique identification number of every RFID reader. Every RFID reader is connected to the same as wireless nodes. Therefore, separate bills for each id or customer could be generated. Hence, the customer will obtain a pre calculated bill from the counter and could make the payment without delay. With the usage of and RFID reader at the exit door the theft of items could be prevented.

VII. CONCLUSION

Human following smart trolley is a good alternative when compared to the conventional shopping trolleys which are being used currently in the supermarkets. Huge amount of work, time and money could be saved by the implementation of the concept. The technologies similar to the ones implemented in the work could be used in other sectors such as in Medicare field as a nurse following robot, in childcare or in material handling in manufacturing industries. Further application of the same along with an exclusive app cum wallet feature will be the biggest stepping stone to the full automated stores or fully automated shopping. Furthermore, if possible, the tracing facilities of the trolley should also be developed for the efficient tracking of the trolley inside the market. But as of now the extrapolation of coordinates is difficult and is a tougher ask to deliver.

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