Smart Assistive Trolley for Elderly Care and Independence

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Abstract

As people get older their shopping experience gets harder, as they have to keep pushing a trolley that is made of steel, as well as they keep on adding items through their shopping journey the trolley gets heavier. As a result, this project aims to help these senior citizens by providing a robotic trolley that follows them during their journey (through face detection) without the need of any physical interreference, in addition to calculating the walking distance providing the property of showing how many meters they have walked. The trolley has been fabricated with the walking distance estimation feature that has been accomplished by the ultrasonic sensor after the camera detects the user and tracks him. This strategy is achieved by using an OpenCV library that is particularly could be used in Python programming language. The results have shown a great improvement in the elderly individuals' lives, as it supports them by giving more comfort and extra liberty to the shopping experience.

Keywords: Smart following trolley, OpenCV, Face detection, Walking distance estimation

1. Introduction

As we live in a time where technology is advancing daily, people occasionally come up with contemporary ideas to update or develop specific technologies as elaborated by Ng [1]. One of these technologies is the shopping trolleys which are available in all supermarkets to make it easier for customers to choose and store products. Customers need to drop the products they want to purchase and then proceed to checkout. Currently, when entering the shopping mall or a grocery store the customer has to choose a shopping cart (trolley), select the items they want to buy, and then put them in the shopping trolley which is very challenging this to do for senior citizens.

To get a robot to move and follow you, a brain of the prototype is in order, a brain will move everything in sequence and give orders to all the components chosen by the engineer (designer), and change this sequence if needed to and all of this is accomplished by the algorithm which is the software used to put everything in to place, the software means the language we people choose to communicate with device in this case an automated trolley we are creating as explained by Li [2].

The brain will keep reading the messages from the sensors the engineer chose to use as ultrasonic sensors which is very good when it comes to objects detection as demonstrated by Sanghavi [3], an infrared sensor is efficient to use for people detection even at night because it follows the temperature mapping technique as analyzed by Nagarajan [4], as well as the proximity sensor can be used for the reasons as the ultrasonic sensors used for however with better efficiency, on account of the proximity's higher efficiency it is used for accidents or collision prevention, which is why it's a perfectly suitable option as elaborated by Lee [5].

In order to get the trolley moving automatically, the presence of a motor is a must, as it will receive a signal from the brain (microcontroller) to move, however to get the motors to move in different directions forward, backward, right, and left motor controllers are needed, many motors can be used to get a robot to move it depends on the speed required, the place the robot will be used in, as DC motors or a servo motor.

Before the microcontroller sends a message to the motors to move in any direction first the microcontroller should locate the person who is supposed to follow and then send the message, and that is accomplished by adding a camera to the trolley that would track the person based on his/her features, or even the camera could follow something that the trolley user is holding on to, or even by using a transceiver

2. Methodology and Experimental Setup

In this chapter, the methodology applied for this project is described, as well as the mathematical approaches and correlations related to the smart follower trolley and the components selection shall be mentioned in Fig. 1.

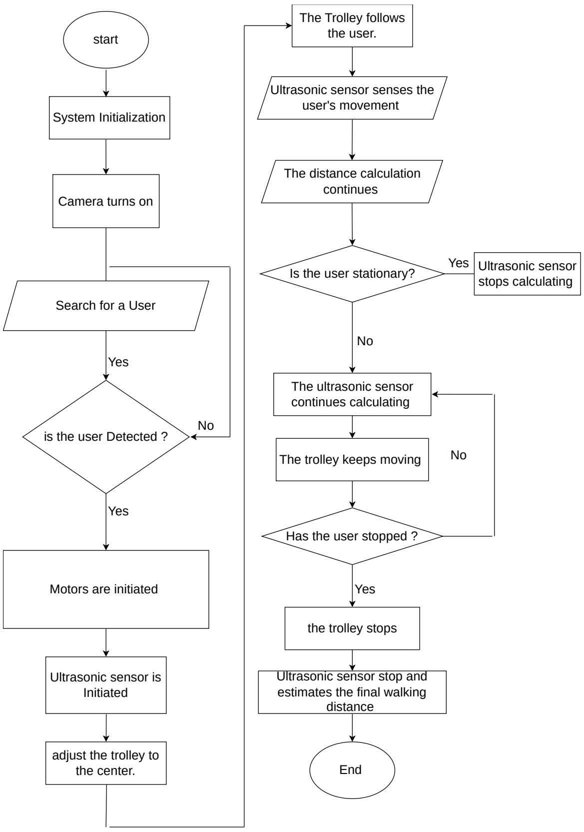

Fig. 1. Project flow chart

In this proposed project the methodology thesis will be implemented into three parts. To begin with, how will the detection and tracking of the user's movements will be implemented, following on from that, walking distance besides the user's directions estimation, finally the whole project's (the smart follower trolley) fabrication specification in terms of connecting all the components chosen due to their quality and cost.

The components used to bring this project's idea to life are a raspberry pi 4 model B as the main system core (brain of the system), a permanent magnet DC motor, an Arduino UNO is used to control these motors while being connected to the Raspberry pi 4 model B through an USB as a communication interface, the sensors chosen are the ultrasonic sensor used for obstacle detection and avoidance, as for the user's detection the infrared sensor is used along with a camera settled on the trolley.

2.1. *Hardware of the trolley*

Raspberry pi 4 Model B

The most recent model of the Raspberry Pi computer line is the Raspberry Pi 4 Model B. Comparing it to the Raspberry Pi 3 Model B+ of the previous generation, it provides revolutionary improvements in processing speed, multimedia performance, memory, and connection while maintaining backward compatibility and a similar level of power consumption. Performance on the desktop is comparable to that of entry-level x86 PC systems for the end-user on the Raspberry Pi 4 Model B as denoted by Raspberry Pi [6].

This fourth-generation raspberry pi model is chosen for in project as the main system core in other words the brain of the robot, due to its high-performance 64-bit quad-core processor, a dual display support at a resolution up to 4K (Kilo) through the micro-HDMI (High Definition Multimedia Interface) ports as modular compliance certification for Bluetooth and dual-band wireless LAN (Local Area Network) enables the board to be integrated into finalized devices with a great reduction in compliance testing, reducing cost and speeding up time to market, as well as the raspberry pi 4 model B contains a higher memory (2/4/8GB RAM option), its connectivity is better than the other raspberry pi computer types, as it has 2.4 GHz and 5.0 GHz, the data transfer is done at a very high rate as it contains 2 USB 3.0 ports 2 USB 2.0 ports. It has 40 GPIO pins.

Arduino UNO

An ATmega328P-based microcontroller board is the Arduino UNO. It contains 6 analogue inputs, a 16 MHz ceramic resonator, a USB port, a power jack, an ICSP(In Circuit Serial Programming) header, and a reset button. It also has 14 digital input/output pins, six of which can be used as PWM outputs. It comes with everything required to support the microcontroller; to get started, just use a USB cable to connect it to a computer, or an AC-to-DC adapter or battery to power it. You can experiment with your UNO without being very concerned about making a mistake as demonstrated by Arduino memory guide [7].

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Using an Arduino UNO to control the PMDC motors is very effective and why is that, due to its simplicity, the Arduino UNO is designed in a way to work efficiently with real-time projects, as well as the Arduino UNO can work easily with motor drivers as an L293D motor driver, L298N motor driver, in addition to it way to work effectively with components that consume low power, as well as changing the speed of a DC motor is fairly simple. The speed of a DC motor can change when PWM is applied to the analogue output pin of an Arduino. Therefore, it is a straightforward task. Unlike the raspberry pi 4 model B, it works efficiently with components that have high power consumption, it will work with the PMDC motor, but not as effectively as the Arduino UNO as explained by DC motor speed [8].

High precision ultrasonic sensor range finder

Three ultrasonic sensors will be used, each one of them will be directly connected to the raspberry pi 4 model B (brain), they will be used for obstacle avoidance, ultrasonic sensor ESP32 is chosen as its better than the ultrasonic sensor ESP8266 in terms of performance as well as it provides BLE.

PMDC motor

A PMDC motor is chosen for this project dues to its high torque and low power consumption, the kind of PMDC motor is chosen based on its torque speed, and this parameter is chosen after choosing the trolley itself and deciding which size is preferred to bring this idea to life.

43A H-Bridge driver

If any motor would work on its own it would work in only one direction (forward), however in order for us to control how the motor we are using, in this case, a PMDC motor needs a driver to make the motor move forward or backward, this driver will be receiving the orders from the main system core (raspberry pi 4) to tell what should be the motor's next move, in addition to what velocity should it move with, as well as the direction it should be headed to upon the logic added to this core.

LM2596 3A Buck module with display

A converter is in order as its very important when it comes to prototyping, as different components are chosen for this project and each work at a very specific level of voltage, so the converter's job is to step down the voltage in order not to ruin the components.

2.2. *Software*

The most important library used for this project is OpenCV python has the option of image processing that is chosen in this project to use in the software part for user's detection. Processing a video means executing operations frame-by-frame to the video. Frames are nothing more than a single discrete instance of the video at a given point in time. Even in one second, there could be several frames. It is possible to treat frames similarly to an image. Therefore, we can execute all actions on frames that we can on images precisely explained by [9].

3. Results and Discussion

In order for the brain to do its job which is to control all other components it needs to be connected to a power source which in this case is the laptop, after the connection is settled the set-up is made by VNC viewer which is a way to access and control the raspberry pi (any kind) desktop remotely from another computer, using a USB C-type cable to activate the brain itself, for this minicomputer to work it needs internet to function based on this the raspberry pi 4 model B has the feature to connect it to the internet without using an ethernet cable. In this project the raspberry pi has a wireless connection with internet.

The connection between the Raspberry Pi and the Arduino UNO is done using a USB B type cable, this is only done for energizing it and it's the way in which the Arduino UNO will take the orders from the raspberry pi, as for the connections between the Arduino UNO and the PMDC motor, first the motor works at a 250 watts, and it needs to be stepped down this is the main reason why a converter is used. The motors are designed in a way that when it works it works only in one direction to make this motor move in all directions a motor driver is used. The connections are made as follows starting with connecting the Arduino UNO to the motor driver ENA pins and IN1, afterward connecting the motor driver to the PMDC motor through positive and negative terminals, and the step-down converter as well in the same way. This converter will be connected to the power supply. And all of the components are connected to the same ground on the used breadboard.

For connecting the ultrasonic sensor with the raspberry pi to achieve the second objective, first the ultrasonic sensor is set at the front of the trolley to be able to detect the person and calculate his walked distance, there are four main wires for this connection, one from the VCC (ultrasonic sensor) to the positive railway, ground wire to the negative railway on breadboard. As for the raspberry pi the GPIO pin 5 volts which is pin number two connected to the positive railway of the breadboard, as well as pin number six is connected to the negative railway where I plugged in the ultrasonic sensor. Then connecting the trig connection of ultrasonic sensor to GPIO 23 which is pin number 16 through a blank rail on the breadboard, and finally connecting ECHO in the ultrasonic sensor with GPIO 24 which is pin number eighteen through blank rail on the breadboard. Fig. 2

shows the primary fabrication of the proposed smart trolley.

Fig. 2 Automated Trolley

3.1. *Software Results*

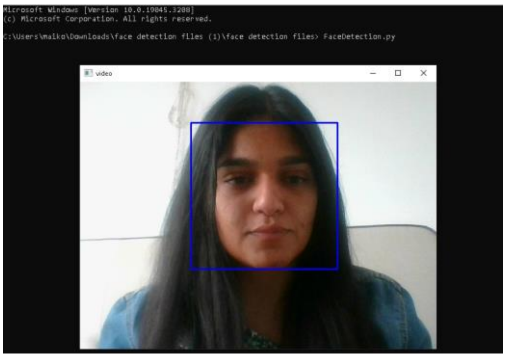

Fig. 3. Face Detection

The performance or real-time face detection is one of the goals of this project first the numpy and OpenCV libraries were added to the code, and then adding the XML file that contains all of the important knowledge for accomplishing the face detection for us to enable the camera to recognize the person in front of it, afterward a video of size 640 cm x 480 cm starts that its only functionality is to keep capturing images, then a while loop is created for the continuous photo capturing. Inside the while loop, the photos (frames) captured will be turned into a grayscale for a better quality formation. The next step for all the faces detected in each frame is a blue box will appear marking all of them that will keep appearing even if the people move around in the camera's region the system will wait for the person using the trolley to press the "ESC" button if they would like to end the shopping journey. If the person presses this button all data will be destroyed, and the system will be ready for the next customer. The result of face detection is illustrated in Fig. 3.

Supported Sustainable Development Goals

The Sustainable Development Goals ("SDGs") are intended to direct international development efforts during the ensuing fifteen years, from 2015 to 2030. They are planned to be endorsed by the United Nations General Assembly (UNGA) in 2015 as part of its development agenda. The Millennium Development Goals ("MDGs"), which were in effect from 2000 to 2015, have been replaced. The sustainable development means to make the world a better place without destroying the possibilities for the next generations keeping three life aspects in mind which are social progress, economic development and climate and environment. The smart follower trolley for elderly care project supports as explained by Pogge [10].

4. Conclusion

The fabrication of a smart assistive trolley specifically designed for elderly care has brought about a remarkable advancement in enhancing the shopping experience for senior citizens. The incorporation of face detection technology and walking distance estimation capabilities in this robotic trolley has resulted in increased comfort, convenience, and a greater sense of independence for the elderly. These improvements ultimately contribute to enhancing the overall quality of life for older individuals, making their shopping experiences more enjoyable and empowering.

References

1. Y. L. Ng, C. S. Lim, K. A. Danapalasingam, M. L. P. Tan, and C. W. Tan, 'Automatic human guided shopping trolley with smart shopping system', *J Teknol*, vol. 73, no. 3, pp. 49–56, 2015, doi: 10.11113/jt.v73.4246.
2. E. Li, L. Bi, and W. Chi, 'Brain-controlled leader-follower robot formation based on model predictive control', in *IEEE/ASME International Conference on Advanced Intelligent Mechatronics, AIM*, Institute of Electrical and Electronics Engineers Inc., Jul. 2020, pp. 290–295. doi: 10.1109/AIM43001.2020.9158815.
3. S. Sanghavi, P. Rathod, P. Shah, and N. Shekokar, 'Design and implementation of a human following smart cart', in *Proceedings of the 3rd International Conference on Smart Systems and Inventive Technology, ICSSIT 2020*, Institute

of Electrical and Electronics Engineers Inc., Aug. 2020, pp. 1142–1149. doi: 10.1109/ICSSIT48917.2020.9214217.

4. S. Nagarajan, P. Banerjee, W. Chen, and B. A. Chin, 'Control of the Welding Process Using Infrared Sensors', 1992.
5. H. K. Lee, S. Il Chang, and E. Yoon, 'Dual-Mode Capacitive Proximity Sensor for Robot Application: Implementation of Tactile and Proximity Sensing Capability on a Single Polymer Platform Using Shared Electrodes', *IEEE Sens J*, vol. 9, no. 12, pp. 1748–1755, 2009, doi: 10.1109/JSEN.2009.2030660.
6. Raspberry Pi Trading Ltd., 'Raspberry Pi 4 Computer Model B', 2019.
7. 'Arduino Memory Guide | Arduino Documentation'. Accessed: Jul. 28, 2023.
8. DC Motor speed control and measurement | Arduino Project Hub'.
9. 'Python - Process images of a video using OpenCV - GeeksforGeeks'.
10. T. Pogge and M. Sengupta, 'The Sustainable Development Goals (SDGs) as Drafted: Nice Idea, Poor Execution', Washington International Law Journal, vol. 24, 2015.

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