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Original Article

Smart Automated Robot Changing Tires using Ultrasonic Sensors

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Abstract - *The drivers of cars always face issues and some difficulties during driving the car on the road with their car's tires. Puncture of tires, tube bursts, or bends in rims of tires are actions or events that surely lead to a complete stop moving the car, usually without earlier notification. The main idea of doing this study is to design a robot which acts as a mechanic to facilitate changing tires and to avoid any issues with the removal or replacement problem of the tire. Plus, many people don't have the required skills to change the tire easily and fast, which indeed may cause more problems and be time-consuming. The Robot will be able to carry up the car exactly like the jack, a small motor to remove the old tire and install the new tire. The robot will be developed to replace the mechanic in changing tires and solve this problem, which is considered a real problem for many people.*

Keywords - *Autonomous robotic arm, Arduino, Microcontroller, Robotic changing wheel, DC motor, Tire puncture fixing system.*

1. Introduction

The rapid developments in technology and major changes in the field of mechatronics and mechanics are substantially changing patterns according to the circumstances around them. So, fundamental changes both within mechanic shop services and beyond are improved over time. Also, the mechanic's role and function in changing burst tires or fixing perforated tires, how the mechanic operates, and how people deal with such situations are changing accordingly [9,10].

The need to change burst tires and perform mechanic activities using resources other than humans is getting great attention in different communities and attracted the attention of different countries as well because of its positive effects on the community and reducing exposure to risks during changing the tire or getting injured, which considered as dangerous missions and activities by some people [5].

The Robotics concept represents the world's future since, currently, the robotics count exceeds 9 million based on the latest edition of the world robotics, which is gown rapidly. Robots should possess new functions apart from the general ones. So, a powerful robot that will improve efficiency, effectiveness, and driver safety in a variety of ways will be programmed and loaded into a complete device and hit the market; it promises to change the tire of any car on the road with a safe and easy approach. The development approach of this system is to be applied in a prototype, which includes the required and proper hardware components to fit the project requirements [5, 6].

The proposed idea is to design and implement a prototype that can decrease the proportion of risks and dangers that normal humans may face while changing a vehicle tire for any reason.

The sections of this paper are set as follows: In section 2, the motivation and goals are presented, while in section 3, the problem of the project is highlighted. Section 4 presents the history of AI and Robotics, and section 5 discusses some related works. The system design and implementations are presented in sections 6 and 7. In section 8, the results are reported, while the conclusions and future works are presented in sections 9 and 10.

2. Motivation and Goals

Robots are the primary topic in artificial intelligence science, which focuses on the research and development of effective and intelligent robots. Although computers and other machines solve many problems, the solutions are ultimately constrained. Although the execution and development of these approaches are hard, the fundamental idea behind using robots to solve problems is straightforward.

Initially, an AI computer or robot gathers data and facts about a particular circumstance using sensors or human input. Then, it begins comparing this data with previously saved or programmed data to accomplish matching and come to a conclusion.

The implemented system as a robot was supposed to minimize direct contact with the tire burst or puncture, reducing human exposure to injuries. The paper reviews a variety of technologies and state-of-the-art technology of robots acting as mechanics and changing vehicle tires. The problem associated with this project is how to design a wheel-changing robot which can be controlled manually remotely or performed automatically. Hence, the project was designed in an easy way as much as possible, and that is why it decided not to use sensors, so it relied on the factors of distance and time to implement the desired idea.

3. Problem Statement

While performing this study and gathering the requirements of the project idea, it was observed that there are some critical issues that humans may face and need a solution to handle this part of the idea—mainly changing tires for those people who don't have enough skills to do this task. Replacing the tire of any vehicle due to pressures and heating will be a very risky action. This matter makes replacing this tire very difficult even though the workers are well-trained.
Also, the project is considered a real solution for elder people who suffer from changing their vehicle tires when they burst or explode. This category of people is the target to be served, especially old women; most of them cannot change the tire when needed or don't have enough skills to do so.

Another concern is for the mechanic shops, which sometimes there are not enough resources at the shop to do such a task, or even sometimes at rush hours, all staff are busy to handle any extra tasks, so the robot would be a good solution for shops to handle this task and serve as many customers as possible.

4. History of AI and Robotics

The term artificial intelligence (AI) was first used by Alan Turing in the 1950s to refer to the concept of what caused a machine to operate intelligently. Then, AI began to develop in several industries. Artificial intelligence algorithms and concepts are currently being used in many technologies in a variety of ways, such as IMB's Watson and self-driving cars [7].

In general, robotics is considered a major domain in artificial intelligence that focuses on research and studies of designing and implementing smart and efficient robots. Robots are also considered intelligent agents that act in the real environment [8].

So, robots aim to manipulate objects by recognizing, realizing, selecting, modifying, or even moving the object physically. Robots can also do repetitive functions without getting distracted, bored, or even exhausted [7,8].

5. Related works

When it comes to vehicle changing systems, it seems that detecting each part of the tire and conducting the required job is a new research field. However, many efforts have been made regarding the vehicle wheels changing within the domain of vehicles.

The main goal of this study was to come up with a robot to detect the place for screws in the tire, take them off from the base of the tire, remove the old tire that is already damaged, and finally replace it with a new one using another handle responsible for switching between both tires. This section of the report looks at the importance of robots in today's society and the following growth of this industry, which has been significantly influenced by technological improvement.

5.1. Vishal N.S, V.Prabhakaran, Dr.P.Shankar, 2015. Car Tire Replacement Robot Using AI

The robot design uses a robot to replace defective vehicle tires. This robot is part of the tire removal and replacement process. This robot is powered entirely by rechargeable batteries and uses artificial intelligence and image-processing techniques. The entire kit is controlled and works under a microprocessor, which is the brain of this device and reduces stress for car drivers or owners in the event of a tire problem. Figure 3 depicts the system's block diagram, which describes the system's main components and how they are linked to one another [1].

The base of the entire system is layer one. Drive up to the wheel and raise it. This is the first crucial stage. The replacement system will be connected to the vehicle via the zigbee protocol and made available to the driver through a menu option on a digital display inside the vehicle, along with other utilities. The base driver system is enabled after selection; other modules are added above it, and this is navigated using a self-navigation system that is preprogrammed in the device around the four tires of the car [1].

The robot from the deck descends through the slide path established while building the car for this robot to climb up and down when the gadget is engaged. The punctured wheel, which is called the back wheel of a car, is deemed to be defective. The chosen wheel with a fault will subsequently be replaced by the robot. The robot's first action is to move its four wheels, which is done with the help of four motors that power the entire apparatus. The lower body of the robot is this entire part[1].

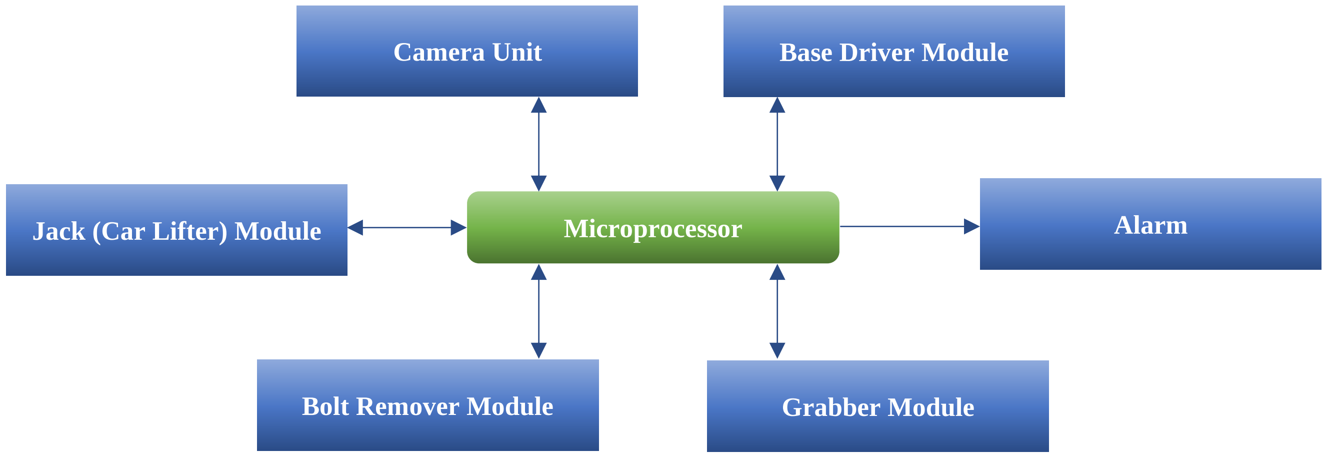

Fig. 1 Robot block diagram

5.2. Dennis E. Farmer, 2001. Automatic Jack and Wheel Change System

The robot from the deck descends through the slide path established while building the car for this robot to climb up and down when the gadget is engaged. The punctured wheel, which is called the back wheel of a car, is deemed to be defective. The chosen wheel with a fault will subsequently be replaced by the robot. The robot's first action is to move its four wheels, which is done with the help of four motors that power the entire apparatus. The lower body of the robot is this entire part. The center features a number of star-shaped arms that branch out from it, each of which has a finger at the free end. The wheel contains a number of defined slots for receiving the fingers to lock it on the hub when the axle is extended and a number of defined holes for receiving the fingers to lock it on the hub when the axle is retracted. Remote controls are available for both motors to raise the jack and change the axle length [2].

The automatic jack and the wheel replacement system of the current invention are represented generally as 10 in Figure 4. The car is raised using the jacking means in system 10 so that the wheels can be serviced. The jacking tools may be two jacks fastened to the vehicle's structure on either side or four jacks placed close to the wheels [2].

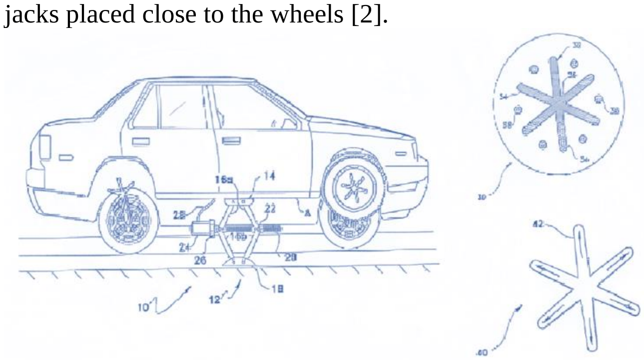

Fig. 2 Automatic jack and wheel change system

In the preferred form of the invention shown in Figure 4, a scissors jack 12 is inverted and fastened to the chassis A of a motor vehicle B about midway between the front and rear wheels of the vehicle, enabling the raising of both wheels on the same side of the vehicle with a single jack. Through a U-shaped base 14, the scissors jack 12 is fastened to chassis A. The jack 12 contains four lever arms 16, two of which are lower and two of which are upper, forming a parallelogram.

The U-shaped bracket 14 is pivotally attached to the two lower lever arms 16 and at one end and the higher lever arms 16 b at the other. A ground-engaging plate 18 is pivotally connected to the second end of the upper lever arms 16 b. At one of the vertices of the parallelogram formed by the intersection of the lower 16 a and upper 16 b lever arms, a horizontal screw 20 is threaded through a nut 22. The horizontal screw 20 raises and lowers the jack 12 as it turns through the nut 22 to alter the parallelogram's diagonal length[2].

The wheel and hub-axle assembly of system 10 of the present invention replaces the studs and lug nuts requirement to secure the wheel to the axle. The current invention is illustrated in Figure 4 by a wheel 30 and a hub 40. As seen in Figure 4, the hub 40 is composed of six arms 42 that radiate from the first portion of the axle 50, with usually cylindrical fingers 44 extending from the free ends. The hub arms 42 are separated by about 60 degrees.

The wheel 30 is enclosed by an aperture 32 with six slots 34 spaced around 60 degrees apart and radially oriented about a central 36. The wheel 30 also has six circular holes 38 defined in it, each hole 38 having a diameter slightly larger than the diameter of the fingers 44; hole 38 is situated on a circle whose radius is roughly equal to the length of the hub arms 42, the holes 38 being separated by roughly 60°, and the holes 38 being in the middle of adjacent slots 34 [2].

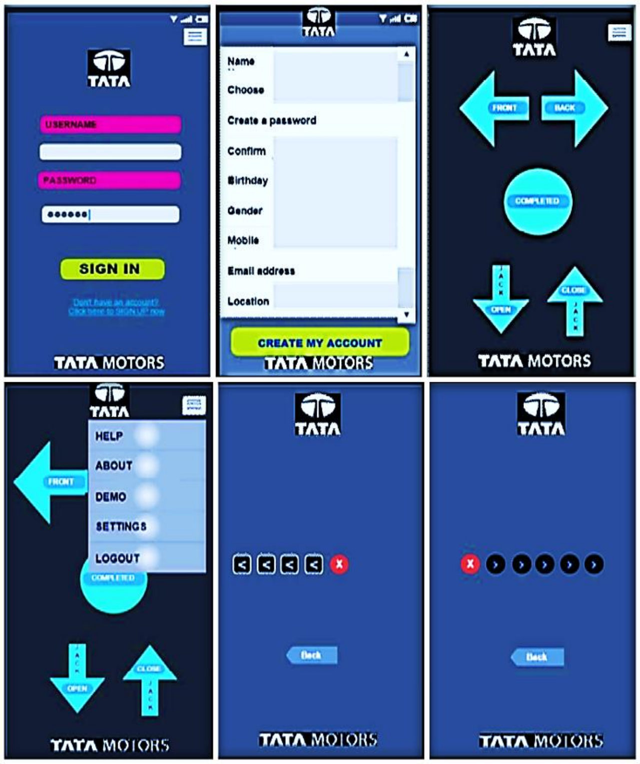

Fig. 3 Android app for automatic jack system for vehicle

Fig. 4 Removing all wheel nuts using VAWNR and impact wrench

5.3. Sourabh Savadatti, Amit Doddamani, Vijaylaxmi N Nadagouda, Sahana M Konnur, Chetan Patil. 2016. Android Controlled Automatic Jack System for Vehicle

This project aims to create and build an Android app-based automatic jack system. A vehicle's entire or portion can be raised into the air for repairs using an automotive jack. Similar to an organism's skeleton, a motor vehicle's frame, sometimes referred to as its chassis, is the supporting structure to which all of its parts are attached. Where the app regulates the movement of the jack, which is mounted in the center of the chassis. The automobile battery provides a 12V power source that a car jack needs to function. Instead of spending a lot of time bending over or squatting, the operator merely needs to push a button on the app to change a tire [3].

Jack's movement is controlled by the Android, which can be downloaded/found in the Google app, as shown in Figure 5. Users will have a unique password for the SIGN IN process, which aids in user security and can only be used by car owners. And logging in requires two steps: I) Register an account, II) Log in; the system connected to the Arduino board becomes visible after the first two steps have been finished. The user has two choices during puncher time: front and back. The jack is positioned between the front two tires by pressing the front button, and the back alignment is done in a similar manner.

The 'complete' option displays when the forward and back buttons are pressed, and when that option is selected, the jack is moved to the location where the user is needed. The choices OPEN and CLOSE manage how the jack moves. When the jack is set to OPEN, it raises the car, and when it is set to CLOSE, it is positioned vertically. The mobile software installed in the car's dashboard steals the Wi-Fi module's IP address [3].

5.4. Mohd Azman. Abdullah, Nurfarahin, 2013. Design and Fabrication of Vehicle All-Wheel-Nuts Remover

As shown in Figure 6, The nut remover is made to be simple to use, simple to maintain, simple to store, simple to handle, and able to remove all nuts at once. For the majority of cars on the market, the remover's design is based on a standard pitch circle diameter (PCD) of 100 mm and four numbers of nuts. The vehicle all-wheel-nuts remover (VAWNR) tool is made using commercial computer-aided design (CAD) software [4].

Milling and fitting are the two processes used to fabricate a VAWNR tool. Custom-designed gears require precision milling and fitting processes because they are unavailable on the market. Once the tool is complete, an experiment is conducted to determine the required time to remove the nuts. This result is then compared to the time needed with a standard L-shaped wrench. Experimentation with an impact wrench is also carried out [4].

The gears' shape after the milling process. The tool's housings are made of low-carbon steel. A standard shaft for a socket holder is cut and welded on the driven gears. Grease is used to reduce the wear, tear, and heat generated by mating gears. After assembling the tool, a layer of paint is applied to finish the surface and protect it from corrosion [4].

6. System Design

To build and design the project prototype, a set of hardware components was selected that fit this project's requirements and suite the available functions in the system. These hardware components have also been automated, and the required functions are built through the software side, representing the programming instructions added to perform the required functions. Most of the hardware components have been ordered online and shipped to Kuwait for example, the Arduino microcontroller. Also, another concern has been taken into consideration is the compatibility between the components, especially with the selected microcontroller.

The system's main component is Arduino UNO, considered the control unit of the system used to connect all components and create the required circuit.

Figure 7 clarifies the main components used in the system and do they integrate with each other. The motor driver is connected to the Arduino through positive, negative, and pin ports. From the motor driver side, two DC motors are connected, which are responsible for controlling the movement of the small jack handler. The Arduino is also connected to a relay that is used to turn on/off the electrical circuit, and also relay holds more power than the microcontroller. Also, a DC motor is connected and responsible for controlling the main arm to leave the car up. This DC motor is connected to the external power supply (battery) with 3V because it needs a higher Amp, which is not provided by the Arduino board.

As noticed also, the touch sensor for the push button is connected to the Arduino. This sensor is connected to a resistor with 100ohm, and finally connect, the ultrasonic sensor with four ports, positive, negative, and two pins.

The touch sensor is used to turn the system on/off by the user. The ultrasonic sensor was added to the system to detect the distance between the car and the ground by sending ultrasonic signals and receiving recoils when returning back. An ultrasonic sensor is installed under the car to detect the distance and decide the required action when the distance reaches 9cm, which means that the car is on the ground, 10cm is needed to assemble the tire, and above 11cm which means that car is fully lifted up.

The following flowchart diagram, Figure 6, clarifies exactly how the system works and how processes flow through the system components. As shown in figure8, the system begins operating when the user clicks on the touch sensor (switch) to turn on the system.

Once the switch (touch sensor) is clicked, the sensor will detect the distance between the car and the ground. If the distance is 9cm, the arm will hold the car up to more than 11cm to enable the small handler responsible for removing and installing the tire is to be able to go under the car. Then, the system will send a command to move down until 10cm distance so that the arm can remove the tire. Then, and again will leave up to more than 11cm, so the small handler that changes the tire will move away from the bottom of the car. The arm will move the car down until it reaches a distance of 9cm, which means the car is on the ground; now, the small handler will move forward to assemble the new tire and finish the process.

7. Implementation

The car prototype has been designed using a light type of wood with four wheels, in addition to a base where all components are connected and installed. In this project, not any type of sensor was used; it was tried as much as possible to make easy as possible. The car prototype was made from wood, the small motor which operated changing wheels process was used, and the handler operated as a jack with one arm which would carry up the car and drop it down on the ground.

The car prototype is designed in a way to be over the handler (jack) that is used in the system. A small motor, as mentioned used to change the tire and align it exactly to be fit the tire location. In the system programming, a delay between the jack operation in the system and the small motor was added to change the tire.

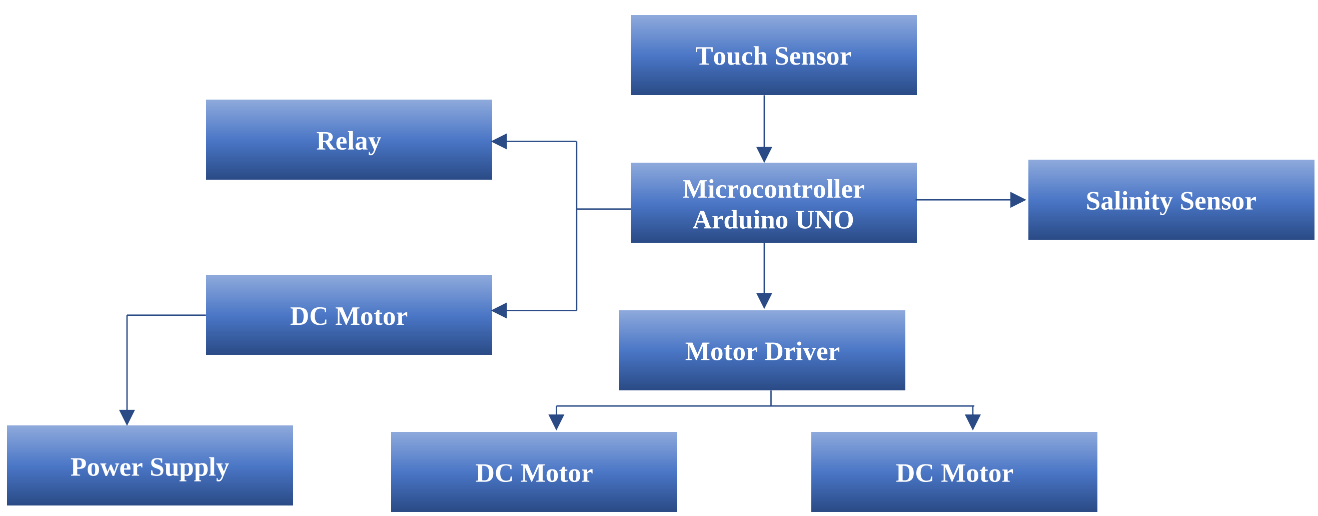

Fig. 5 System block diagram

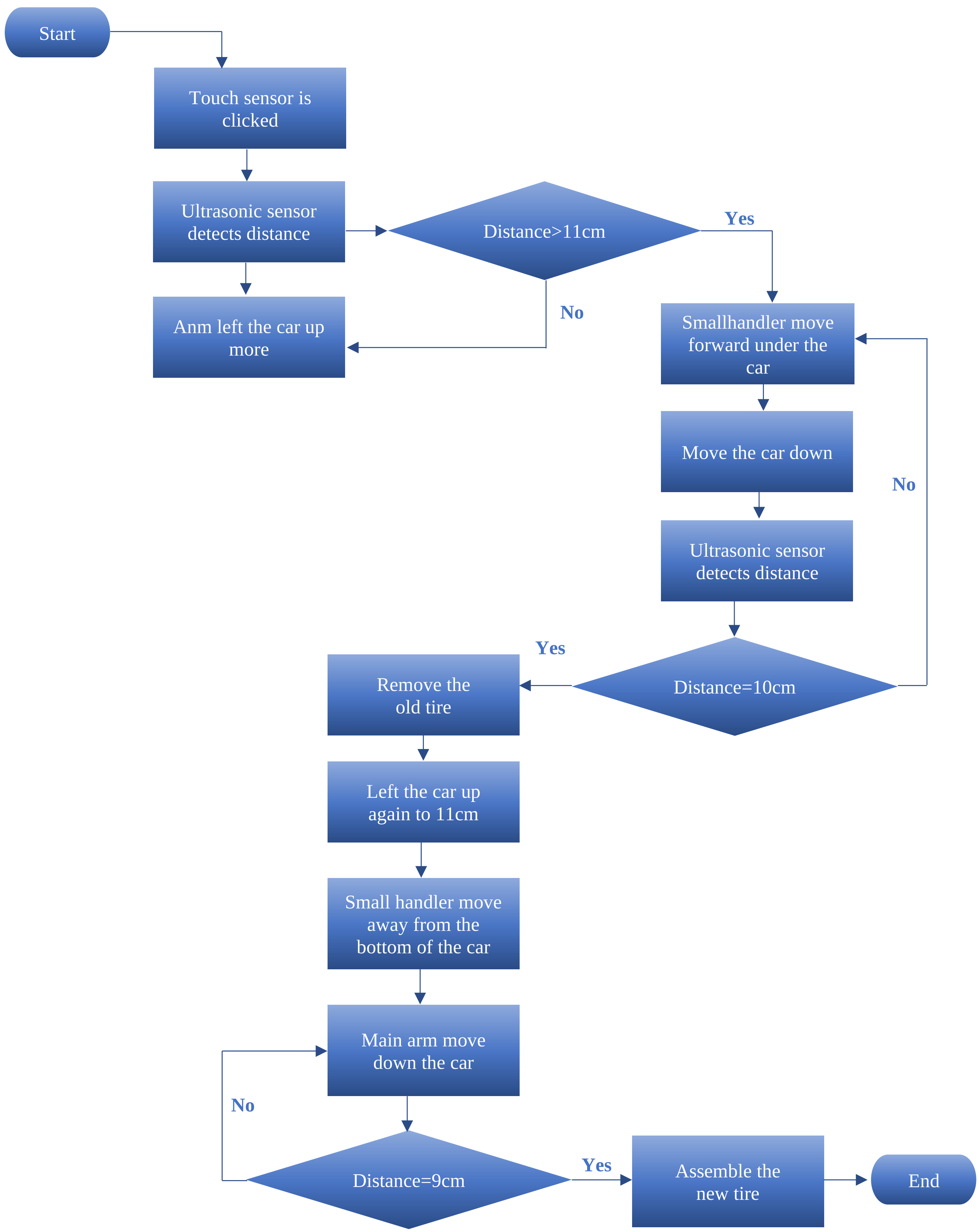

Fig. 6 System software flowchart

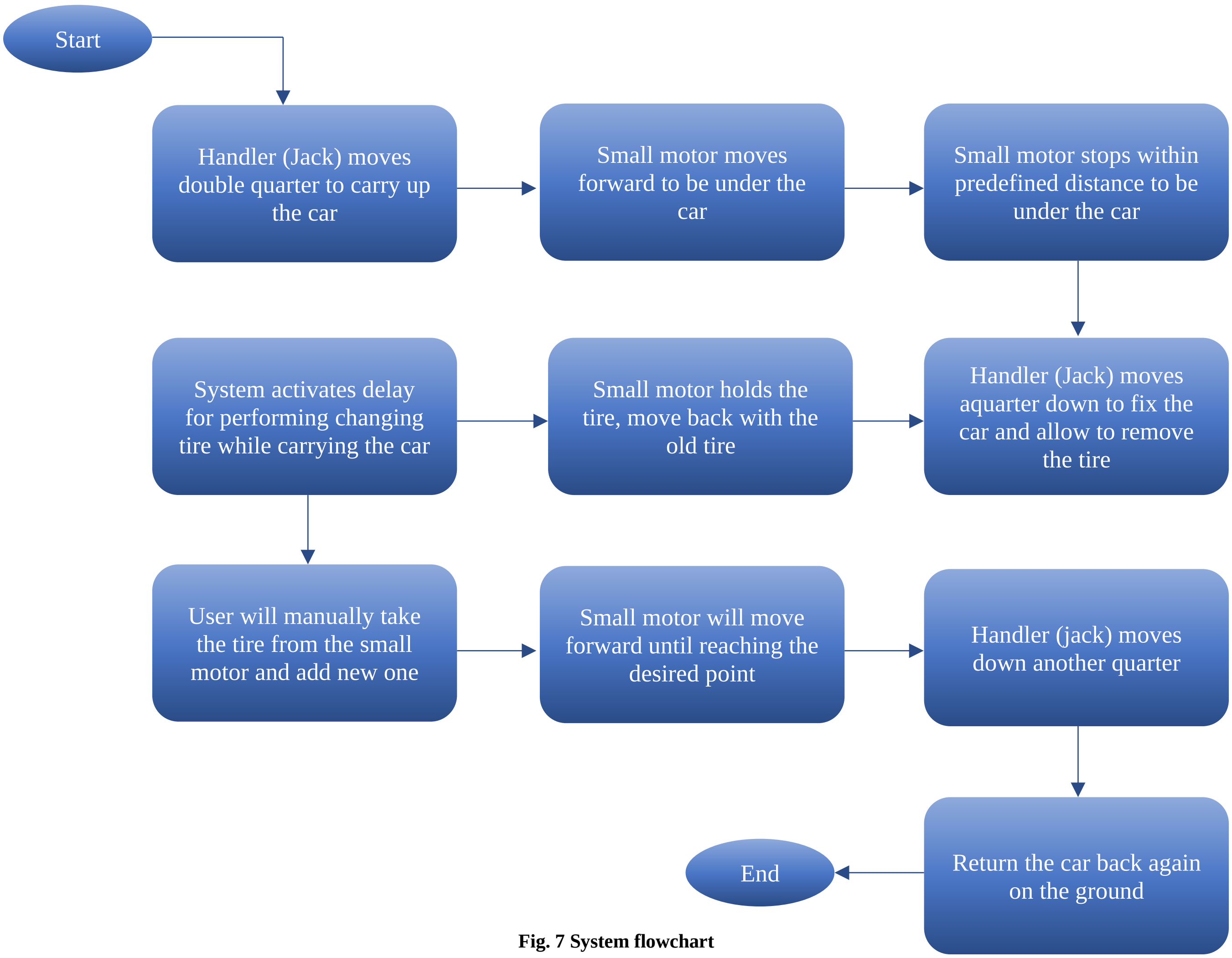

Fig. 7 System flowchart

Initially, the system will start operating with the handler that acts as a jack, which will carry up the car will and operate in 4 moves (a quarter of the circle for each). So, will move the first double quarters to carry up the car, then the small car that performs changing a tire will move forward to be under the tire and stop, then the handler (jack) will go down a quarter to fix the car while changing the wheel and leave enough space for the small car to change the wheel easily. The small motor moves back again with the wheel; the user will remove the wheel manually from the small motor and add a new one. In the meantime, a delay during this process was created to allow the handler that carries the car to keep waiting until the small motor returned back again to the car with the new tire.

After this waiting time, the small motor with the tire will move forward until it reaches the desired point, then the handler (jack) will move down another quarter to drop the car again to the ground, and in this way, the system changes the tire of the car.

Figure 9 clarifies the hardware flowchart of the system and how each step is performed during system workflow.

Figure 8 illustrates connecting hardware components together and with the main board microcontroller, plus the implementation steps until it reaches the final developed prototype. Also, it shows the small motor used to move backwards and forward to change the tire.

The small motor (handler) is connected to two DC motors, which will be responsible for controlling the forward and backward movement of the tire changer motor.

Both small motors are responsible for changing the tire, and the handler is responsible for carrying up the car and dropping it down again to the ground are connected to each other to ensure the balance between their operations and keep monitoring the defined delay in the programming to prevent any conflict in time between their operations.

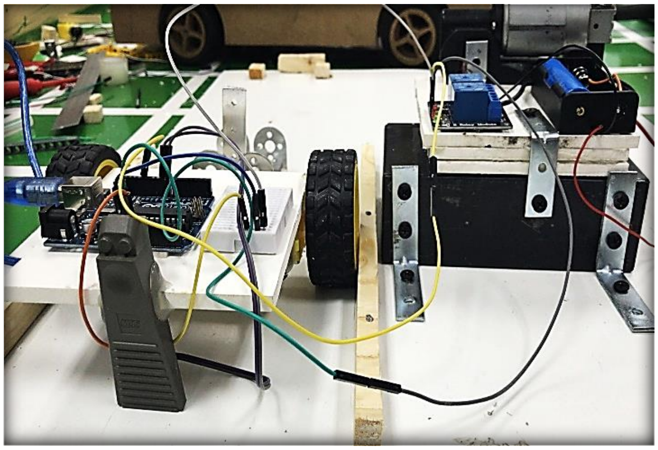

Fig. 8 Small motor & Handler

It is also connected to two sensors, a touch and an ultrasonic sensor. The touch sensor is mainly used to switch on/off the system by the user. The ultrasonic sensor is usually used to detect the range distance between two points, in this project, between the car and the ground, and display the distance value on the pc for the user to decide when to click on the touch sensor and activate the arm to push the car up or down.

For the development part, the robotic vehicle wheel changing project was developed using the Arduino Integrated Development Environment (IDE), a text editor that enabled us to write the required code and functions, as shown in Figure 15. The Arduino software IDE is an open source based on Java and runs on different OS platforms such as MS Windows, Mac OS, and Linux.

This is the text editor of Arduino IDE shown in Figur15, where to write the required code to run the expected functions by motors. After writing the code and instructions, the code is compiled and generated by the program, which is named in the Arduino as “Sketches”, with file extension “ino”.

Testing phase has been divided into 2 levels:

The microcontroller and other hardware components are tested at the first level to ensure that the Arduino UNO and all of its components and primary functionalities are functioning properly. Additionally, test the signals coming from the main board's attached motors.

The main component, which is the microcontroller, has been tested by plugging it into the computer through a USB port; it is supposed the green LED power indicator on the board illuminates to confirm that the microcontroller board is working properly and nothing is wrong with it. When the board is linked to the computer, if the green LED does not light up, it is likely because the board is not receiving power. Additionally, when the board is powered on, an orange LED in the center of the board should flicker on and off.

The second level of testing included testing all functionalities in the project after connecting all components and finalized writing the required programming code instructions. As discussed, one of the main functions that have been tested in the project is to move both the small motor and the handler to operate the expected function by starting to move the handler to carry up the car. The small motor will move forward to take off the wheel, again backward for changing, and finally drop the car down to the ground.

8. Results of the Project

Figure 9 shows the final result of the project prototype after assembling all hardware components together with the main microcontroller board and developing the required functionalities using Arduino IDE.

The car prototype, as mentioned previously made from a light type of wood to simplify the carrying operation on the handler; also, the base contains the electrical circuit connected through Arduino wires and relay to assure the balance in voltage between the main microcontroller and other components.

The project is distinguished from the rest of other projects by using both touch and ultrasonic sensors. The ultrasonic sensor provides a larger range than other sensors, such as the IR sensor, which gives the project the privilege of giving more accurate results when detecting the distance.

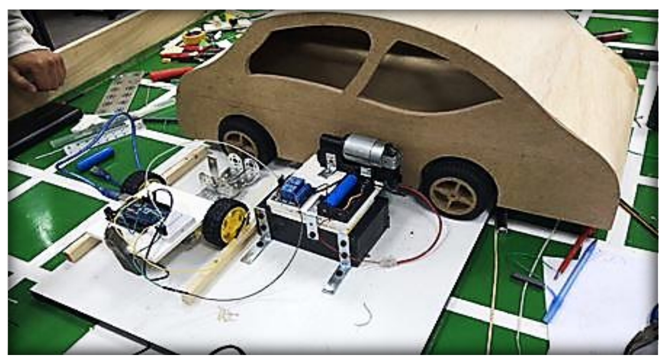

Fig. 9 Prototype final view

9. Conclusion

This paper proposes the design of a lifting jack and changing wheels system. The project area has the potential to use the available technologies that helped us to build and develop an initial prototype that will support mechanics and normal people to perform changing tire tasks easily.

In this project, a useful prototype was developed by using the proper devices and components and designing a changing tire robot that can lift up cars and change the wheels with a new one safely using an ultrasonic sensor to detect the exact distance range and perform the required action.

The project idea is supposed to be more efficient than using humans as an alternative approach for mechanics in the future, as there is a reduced risk of mistakes, and the devices used in the prototype can also be equipped with powerful protection tools. In this project, new technologies and tools have been figured out by doing large research, which expanded the knowledge in dealing with electrical hardware components, learned how to write the required programming instructions, and how to automate both hardware and software together to produce the fully integrated system. The project was implemented with basically less complexity compared to the state-of-the-art projects. However, the project can be improved in dealing with different tires size.

Future Works

For future development and improvement, it plans to add more features and components that would support the project to be more applicable in the real environment. More sensors and cameras may be added to the system to be fully automated and self-controlled, defining different sizes of wheels in the system to deal with, so the system will change tires of different sizes and types.

Also, it has to read more research on the ability to add more than one arm to handle more tasks in parallel, reduce the error percentage, and increase the safety and accuracy of the system.

References

[1] Vishal N.S, V.Prabhakaran, and Dr.P.Shankar, "Car Tyre Replacement Robot Using Artificial Intelligence," *International Journal of Scientific & Engineering Research*, vol. 6, no. 1, 2015.

[2] Dennis E. Farmer, Automatic Jack and Wheel Change System, 2001.

[3] Sourabh Savadattie et al., "Android Controlled Automatic Jack System for Vehicle," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 5, no. 7, pp. 13672-78, 2016. [Publisher Link]

[4] Mohd Azman Abdullah et al., "Design and Fabrication of Vehicle All-Wheel-Nuts Remover," *International Journal of Computer Science and Electronics Engineering*, vol. 1, no. 3, pp. 381-384, 2013. [Google Scholar] [Publisher Link]

[5] Enas A. Khalid et al., "Real-Time Control of Robotic Hand by Human Hand at Low Cost," *Journal of Mechanical Engineering Research and Developments*, vol. 43, no. 3, pp. 455-467, 2020. [Google Scholar] [Publisher Link]

[6] Maolin Jin et al., "Robust Control of Robot Manipulators Using Inclusive and Enhanced Time Delay Control," *IEEE/ASME Transactions on Mechatronics*, vol. 22, no. 5, pp. 2141-2152, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[7] Saeed B. Niku, *Introduction to Robotics: Analysis, Control, Applications.* John Wiley & Sons, 2020. [Google Scholar]

[8] Horigome, Noriyuki, Akira Terui, and Masahiko Mikawa, "A Design and an Implementation of an Inverse Kinematics Computation in Robotics Using Gröbner Bases," *International Congress on Mathematical Softwar*, 2020. [Google Scholar] [Publisher Link]

[9] Abdulrahman Alkandari et al., "Modeling an Automation Safety Massage System (ASMS) Based on Using Arduino and Mobile Applications for Safe Environment," *Journal of Green Engineering*, vol. 11, no. 1, pp. 366 – 378, 2021. [Google Scholar] [Publisher Link]

[10] Abdulrahman Alkandari et al., "Doctor-Patient Queue for Emergency Contact Appointment Registration," *International Journal of Engineering Trends and Technology*, vol. 71, no. 1, pp. 189-200, 2023. [CrossRef] [Publisher Link]

[11] Sivi Varghese et al., "Design and Fabrication of Fire Fighting Robotic Arm for Petrochemical Industries," *SSRG International Journal of Industrial Engineering*, vol. 5, no. 1, pp. 14-16, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[12] Sameer Grover et al., "Smart Blind Stick," *SSRG International Journal of Electronics and Communication Engineering*, vol. 7, no. 5, pp. 19-23, 2020. [CrossRef] [Publisher Link]

[13] Dr.S.Diwakaran et al., "Safe Home Smart Home," *SSRG International Journal of Electronics and Communication Engineering*, vol. 6, no. 3, pp. 15-17, 2019. [CrossRef] [Publisher Link]

[14] Priyadarshini. P et al., "Smart Backing Cane for Visually Impaired," *SSRG International Journal of Computer Science and Engineering*, vol. 7, no. 5, pp. 21-24, 2020. [CrossRef] [Publisher Link]

[15] Surin Subson, Dechrit Maneetham, and Myo Min Aung, "Kinematics Simulation and Experiment for Optimum Design of a New Prototype Parallel Robot," *International Journal of Engineering Trends and Technology*, vol. 70, no. 10, pp. 350-362, 2022. [CrossRef] [Publisher Link]