Smart Automated Robot Changing Tires using Ultrasonic Sensors

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Abstract: 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 burst, or bends in rims of tires are actions or events surely lead to complete stop moving the car, and usually without earlier notification. The main idea of doing this study is to design a robot which acts as a mechanic to facilitate change tires and to avoid any issues with the removal or replacement problem of the tire. Plus, that many people don't have the required skills to change the tire easily and fast, which indeed may cause more problems and time-consuming. The Robot will be able to carry up the car exactly like the jack, 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 to solve this problem which considered as a real problem for many people.

Keywords: Autonomous robotic arm; Arduino; Microcontroller; Robotic changing wheel; DC motor; Tire puncture fixing system.

Received: April 15, 2022. Revised: May 19, 2023. Accepted: June 16, 2023. Published: July 21, 2023.

1. Introduction

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

The need of change burst tires and perform mechanic activities using other resources than human, is getting high 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].

Robotics concept became represents the future of the world 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 tire of any car on the road with safety and easy approach. The development approach of this system is to be applied in a prototype, which includes the required and proper hardware components fit to 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 human may face during change the tire of the vehicle for any reason.

2. Motivation and Goals

Robots is the main domain in the artificial intelligence science that focusing on the study to create and design a robot that act efficiently and intelligently. Computers and machines are created to solve many problems but at the end it is in limited terms. The main concept behind solving problems of using robots is simple, knowing that the execution and developing these approaches is complicated. Initially, AI machine or robot starting with gathering information and facts about specific situation by using sensors or through human input, then this machine starts comparing this gathered information with the saved or programmed data to do matching and make a decision.

The designed robot system supposed to reduce the direct contact to the tire burst or puncture which will reduce exposure of human to injuries. The paper reviews a variety of technologies and state-of-the-art technology of robot act as mechanic and change vehicle tires. The problem associated with this project is how to design a wheel changing robot, which can be controlled manually remotely or perform automatically. Hence, we were very careful to make the project easy as much as possible and that's why we decided not to use sensors, so we relied on the factors of distance and time to implement the desired idea.

3. Problem Statement

During performing this study and gathering the requirements of the project idea, it was observed that there are some critical issues handle may human 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 it will be very risky action. This matter makes the replacing this tire is very difficult task even the workers are well trained.

Also, the project considered as a real solution for elder people who suffers in changing the vehicle tire when burst or explosion, and this category of people is our target to be served, especially old women, who most of them are not able to change the tire when needed, or even doesn't has enough skills to do so.

Another concern is for the mechanic shops, which sometimes there are no 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 Robotics

Artificial intelligence (AI) has been found in 1950s when the standard for the concept of what determined the machine to act intelligently by Alan Turing. Then, AI started to be evolved in different industries. Currently, Artificial Intelligence algorithms and concept is being integrated and applied with different technologies in different ways such as IMB's Watson, and self-driving vehicles [7].

Robotics in general considered as a major domain in artificial intelligence that focusing on researches and studies of designing and implementing smart and efficient robot. Robots also considered as intelligent agents that acting the real environment [8].

So, robots aim to manipulating the objects by recognizing and 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 the vehicular tires changing systems, it seems that detect each part of the tire and conduct the required job is a new research field. However, many efforts have been done regarding the vehicle wheels changing within the domain of vehicles.

The overall aim of this project is to come up with a robot that is able 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 to switch between both tires. This section of the report looks at the relevance of robots in the modern-day world and the subsequent development of this field that has been greatly influenced by the advancement in technology.

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

The robot design is to use a robot to replace defective tires in vehicles. 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].

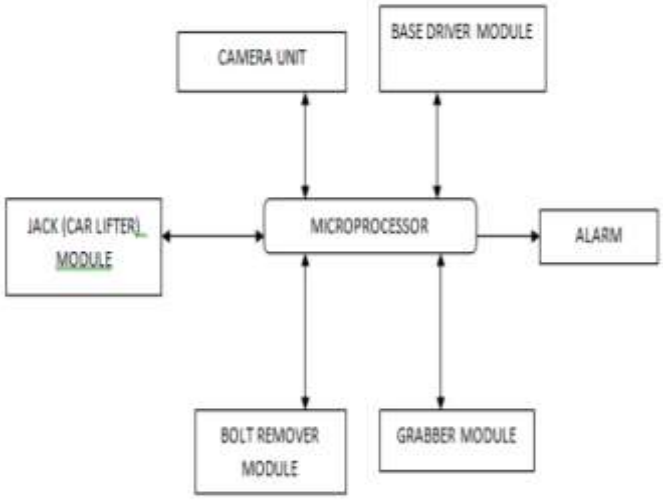

Fig. 1 Robot Block Diagram

Layer one is the foundation of the entire setup. Drive up to the steering wheel and lift. This is the first critical step; the replacement system will be synchronized to the car via the zigbee protocol and accessed via a digital display inside the car as a menu option alongside the other utilities; the driver will select the defective tire via the display. After selection, the system is activated; this is the base driver system; over it, other modules are installed; and this is navigated via a self-navigation system that is preprogrammed in the device around the vehicle's four tires [1].

When the device is activated, the punctured wheel, which is considered the back wheel of a car, is defected, and the robot from the deck descends through the slide path, which is set while constructing the car for this robot to climb up and down. The robot will then move to the selected wheel with a flaw and replace it. This is the robot's first action, which is accomplished by connecting four motors to four wheels, which are used to power the

entire setup. This entire section is the robot's lower body [1].

5.2 Dennis E. Farmer, 2001. Automatic jack and wheel change system

A jack and wheel change system that works automatically as shown in Figure5, having at least one inverted jack powered by an electric motor that is permanently attached to the vehicle. The system may use a jack positioned between the front and rear wheels on each side of the vehicle, or it may have a jack at each of the four wheels. The system also includes a novel wheel and hub-axle assembly with a split axle that can be adjusted by an electric motor. The hub has a number of arms extending from it in a star shape, each with a finger at its free end. When the axle is extended, the wheel has a plurality of slots defined in it for receiving the fingers to lock the wheel on the hub, and a plurality of holes defined in it for receiving the fingers to lock the wheel on the hub when the axle is retracted. Both the motor for raising the jack and the motor for adjusting the axle length can be controlled remotely [2].

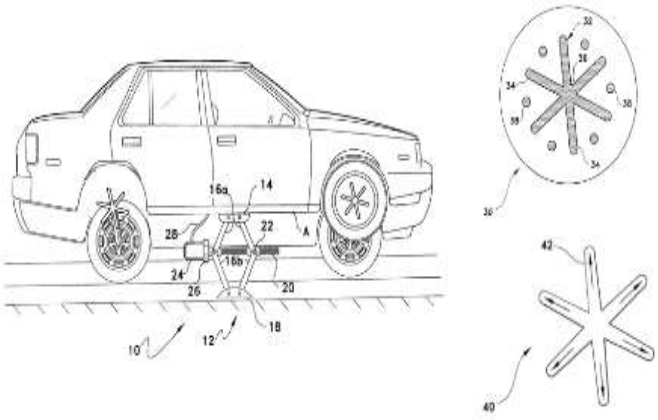

Fig. 2 Automatic jack and wheel change system

The present invention is an automatic jack and wheel change system, shown in Figure 4 as 10 in general. The system 10 consists of jacking means attached to the frame of a motor vehicle to raise the vehicle for wheel servicing. The jacking means may consist of a jack attached to the vehicle's frame on both sides, or four jacks positioned near the vehicle's wheels [2].

Figure4 shows a preferred embodiment of the invention, which includes a scissors jack 12 that is inverted and bolted to the chassis A of a motor vehicle B about halfway between the front and rear wheels of the vehicle, allowing a single jack to raise both wheels on the same side of the vehicle. The scissors jack 12 is bolted to the chassis A via a U-shaped base 14. The jack 12 has four lever arms 16, which form a parallelogram with two lower lever arms 16 a and two upper lever arms 16 b. The two lower lever arms 16 an are pivotally attached to the U-shaped bracket 14 at one end and pivotally attached to the upper lever arms 16 b at the other. A second end of the upper lever arms 16 b is pivotally attached to a ground engaging plate 18. A horizontal screw 20 is threaded through a nut 22 at one of the vertices of the parallelogram defined by the junction of the lower 16 a and upper 16 b lever arms. As it rotates through the nut 22, the horizontal screw 20 changes the length of the parallelogram's diagonal, raising and lowering the jack 12 [2].

The present invention's system 10 includes a novel wheel and hub-axle assembly that eliminates the need for lug nuts and studs to secure the wheel to the axle. According to the present invention, Figure 4 depicts a wheel 30 and a hub 40. The hub 40 is made up of six arms 42 that extend radially from a first section 50 of the axle 50, with generally cylindrical fingers 44 projecting from the free ends, as shown in Figure 4. The hub arms 42 are approximately 60° apart. The wheel 30 is defined by an aperture 32, which includes six slots 34 aligned radially about a center 36 and separated by about 60°. The wheel 30 also has six circular holes 38 defined in it, the holes 38 having a diameter slightly greater than the diameter of the fingers 44, the holes 38 being located on the circumference of a circle with a radius approximately equal to the length of the hub arms 42, the holes 38 being separated by about 60° and positioned midway between adjacent slots 34 [2].

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

This project's concept is to design and develop an automatic jack system using an Android app. An automotive jack is a device used to lift all or part of a vehicle into the air for repairs. A vehicle frame, also known as its chassis, is the supporting structure of a motor vehicle to which all of its components are attached, similar to an organism's skeleton. Where the jack is placed in the middle of the chassis and its movement is controlled by the app. A car jack operates on a 12V power supply obtained from the car battery. To change a tire, the operator only needs to press a button on the app rather than working in a bent or squatting position for an extended period of time [3].

Jack's movement is controlled by the android, which can be downloaded / found in the Google app, as shown in figure5. The SIGN IN procedure, where this procedure helps for user security, users will have a separate password where only the car owners can operate. And there are two steps to logging in: I) create my account II) Sign in, When the first two steps are completed, the system connected to the Arduino board appears. During the puncher time, the user has two options: front and back. By pressing the front button, the jack is placed between the front two tires, and similarly

with the back alignment. When the user presses the front and back buttons, an option called 'complete' appears; when the user presses complete, the jack is placed in the position where the user is required. The jack movement is controlled by the options OPEN and CLOSE. With the option OPEN, the jack lifts the vehicle, and with the option CLOSE, the jack is placed vertically. The IP address of the Wi-Fi module is carried away in the mobile app, which is mounted in the dashboard of the car [3].

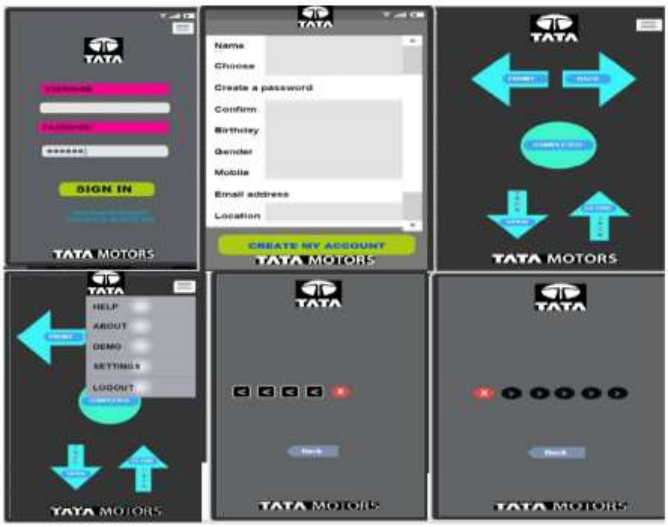

Fig. 2 Android App for Automatic Jack System for Vehicle

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

As shown in figure6, the remover is designed to be user-friendly, easy to maintain, easy to store, easy to handle, and capable of removing all nuts at once. The remover's design is based on a standard pitch circle diameter (PCD) of 100 mm and four numbers of nuts for the majority of cars on the market. Commercial computer aided design (CAD) software is used to create the vehicle all-wheel-nuts remover (VAWNR) tool [4].

Fig. 3 Removing all wheel nuts using VAWNR and impact wrench

Milling and fitting are the two processes used in the fabrication of a VAWNR tool. Custom designed gears require precision milling and fitting processes because they are not available on the market. Once the tool is complete, an experiment is carried out to determine the time required 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. On the driven gears, a standard shaft for a socket holder is cut and welded. 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 our project prototype, we have selected a set of hardware components that fit to our project requirements and suite the available functions in the system. These hardware components also have been automated and built the required functions through the software side represents the programming instructions added to perform the required functions. Most of hardware components have been ordered online and shipped to Kuwait, for example the Arduino microcontroller, and also another concern has been taken into consideration is the compatibility between the components, and especially with the selected microcontroller.

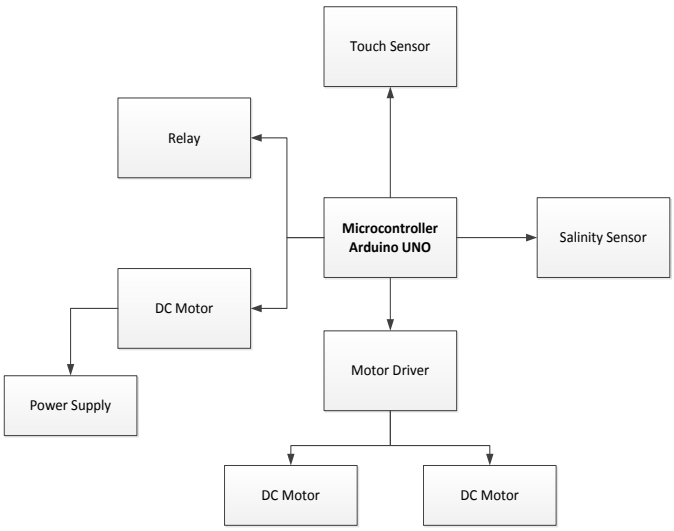

Fig. 4 System Block Diagram

The main component in the system is Arduino UNO that considered as control unit of the system used to connected all components and create the required circuit.

Figure7 clarifies that main components used in the system and do they integrate with each other. Motor driver is connected to the Arduino through positive, negative, and pin ports. From motor driver side, two DC motors are connected, which are responsible to control the movement of the small jack handler. The Arduino also connected to a relay that 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 to control the main arm to left the car up, and this DC motor is connected to external power supply (battery) with 3V because it needs higher Amp, which is not provided by Arduino board.

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

Touch sensor used to turn the system on/off by the user. The ultrasonic sensor added to the system to detect the distance between the car and the ground through sending ultrasonic signals and receive recoils when return back. Ultrasonic sensor installed under the car to detect the distance and decide the required action when distance reached to 9cm which means that car is on the ground, 10cm 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 is the system is working and how processes flow through the system components. As shown in figure8, system begins operating when the user clicks on the touch sensor (switch) to turn on the system.

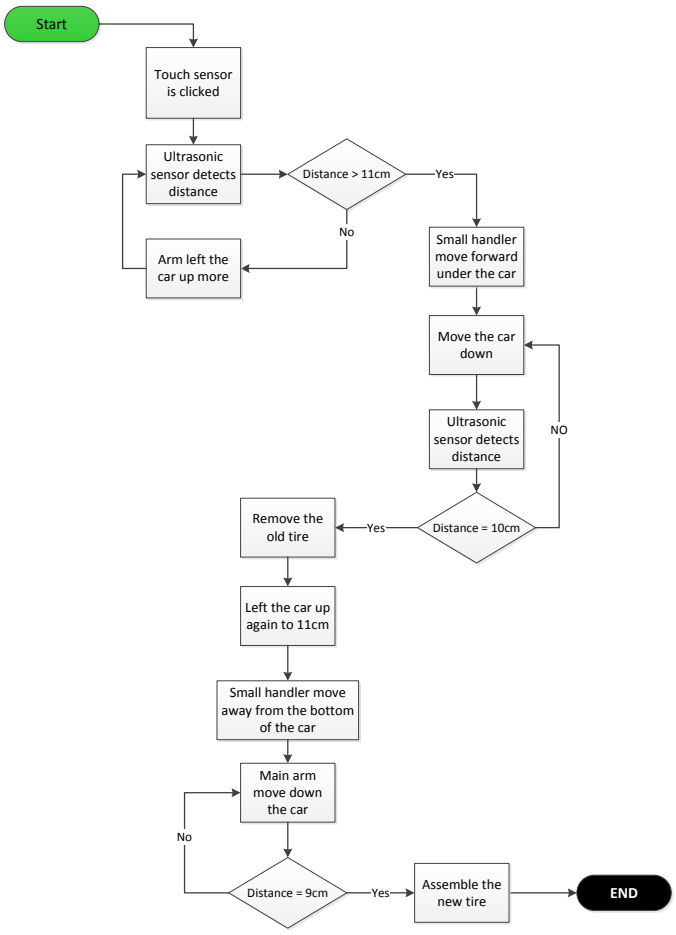

Fig. 5 System Software Flowchart

Once the switch (touch sensor) is clicked, sensor will detect the distance between the car and ground. If distance is 9cm, arm will hold the car up to more than 11cm to enable the small handler that responsible to remove and install the tire is to be able to go under the car. Then, system will send a command to move down until 10cm distance, so the arm is able to remove the tire. Then, and again will left up to more than 11cm, so the small handler that change the tire will move away from the bottom of the car, and the arm will move the car down until reach distance of 9cm, which means that 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 light type of wood with four wheels, in addition to a base where all components are connected and installed. In our project, not any type of sensor used, we tried as much as possible to make easy as possible. We have the car prototype that made from wood, small motor which operate changing wheels' process, and the handler that operate as jack with one arm which will carry up the car and drop it down on the ground.

Car prototype designed in a way to be over the handler (jack) that used in the system. Small motor as mentioned used to change the tire and aligned exactly to be fit with the tire location. In the system programming we add a delay between the jack operation in the system and the small motor that used to change the tire.

Initially, system will start operating with the handler that act as jack, which will carry up the car will, and will operate in 4 moves (quarter of the circle for each). So, will move the first double quarters to carry up the car, then the small car that perform changing 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 an enough space for the small car to change the wheel easily.

The small motor moves back again with the wheel, user will remove the wheel manually from the small motor and add a new one. In the meantime, we created a delay during this process to allow the handler that carries the car to keep waiting until small motor return back again to the car with the new tire.

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

Figure9 clarifies the hardware flowchart of the system, and how each step is performing during system workflow.

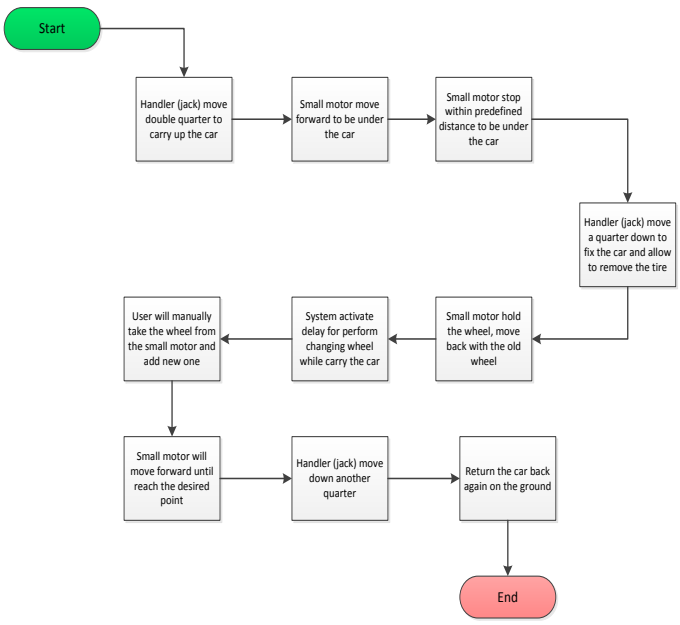

Fig. 6 System Flowchart

Figure 8 illustrates connecting hardware components together and with the main board microcontroller, plus the implementation steps until we reached the final developed prototype. Also, it shows the small motor used to move backward and forward to change the tire. The small motor (handler) connected to two DC motors, which will be responsible to control the forward and backward movement of the tire changer motor.

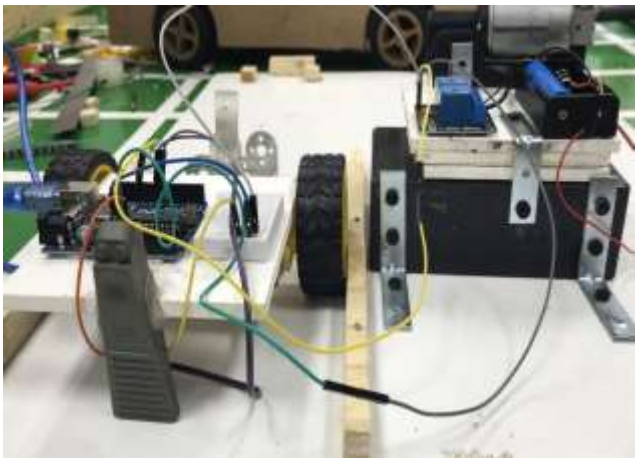

Fig. 7 Small Motor & Handler

Both small motors responsible of changing the tire, and the handler that responsible of carry up the car and drop it down again to the ground are connected to each other, to assure the balance between their operations, and keep monitoring the defined delay in the programming to prevent any conflict in time between their operations.

We also connected two sensors, touch and ultrasonic sensor. The touch sensor mainly used to switch on/off the system by the user, and the ultrasonic sensor which is usually used to detect the range distance between two points, in our project between the car and 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, robotic vehicle wheel changing project has been developed using the Arduino Integrated Development Environment (IDE), which is a text editor that enabled us to write the required code and functions as shown in figure15. 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 the text editor of Arduino IDE shown in figur15, where we write the required code to run the expected functions to be done by motors. After writing the code and instructions, we compile the code and generate the program, which named in the Arduino as “Sketches”, with file extension “ino”.

Testing phase has been divided testing phase into two levels:

First level including testing the microcontroller and other hardware components, to check and test if the Arduino UNO and each component and its main functions are working properly. Also testing the signals that coming from motors connected to the main board.

We have tested the main component, which is the microcontroller through plugging it into the computer through USB port, it supposed that green LED power indicator on the board to illuminate, to confirm that microcontroller board is working properly and nothing wrong with it. In case the green LED does not illuminate when the board is connected to the computer, it means probably not receiving power. Also, orang LED near the center of the board should flash on/off when the board is powered up.

The second level of testing, including testing all functionalities in the project after connecting all components and finalized writing the required programming code instructions. As discussed, one of the main function that has been tested in the project is move both small motor and the handler to operate the expected function, by staring moving the handler to carry up the car, then the small motor will move forward to take off the wheel and again backward for changing, and finally to 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 light type of wood to simplify the carrying operation on the handler, also the base which contains the electrical circuit connected through Arduino wires and relay to assure the balance in voltage between main microcontroller and other components.

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

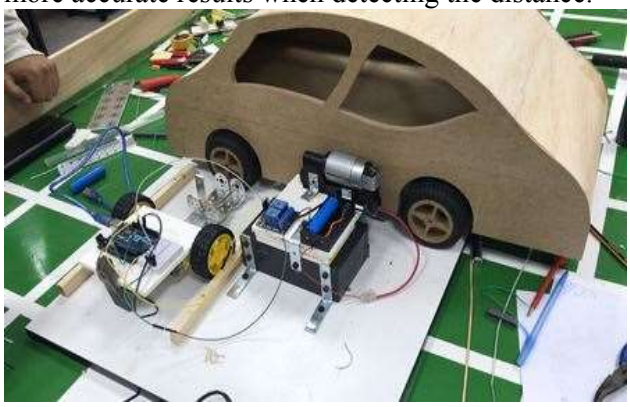

Fig. 8 Prototype Final View

9. Conclusion

In this paper, the design of lifting jack and changing wheels system is proposed. 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 task easily.

In our project, we tried hard to develop a useful prototype by using the proper devices and components and design a changing tire robot that can lift up cars and change the wheels with a new one safety through using ultrasonic sensor to detect the exact distance range and perform the required action. Project idea supposed to be more efficient than the use of humans as an alternative approach for the 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 we learned much things than we thought. New technologies and tools have been figured out by doing large research, which expanded our 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 fully integrated system.

10. Future Works

For future development and improvement, we are planning to add more features and components that would support our 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, define different sizes of wheels in the system to deal with, so system will change tires from different sizes and types. Also, we are thinking to read more researches of the ability to add more than one arms to handle more tasks in parallel, and reduce the error percentage, and increase safety and accuracy of the system.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.