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Automated Mobile Robots – A Survey on Controls

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ABSTRACT
This research mainly focuses on optimizing the transportation system in King Abdulaziz University (KAU) girls' campus by designing an autonomous robotic golf cart. The quality of any research would be promoted by conducting in-depth literature review in the domain. Hence, this research begins with a review to investigate similar artifacts (robotic cart and the ways of displaying the arrival time for the cart) that are relevant to the work. It is divided into six parts which are: autonomous mobile robots, the types of microcontrollers boards that are used in the robotic field, the types of alerts, the types of sensors that are used in autonomous mobile robot to move on track and avoid the object, the ways of displaying the arrival time schedule and the connection ways. The detailed survey on the above mentioned six areas are conducted and the results are discussed in terms of the techniques and the resources used, the methodology followed, the merits and de-merits of the work, and the implementation details with the problems faced. Thus, the widely-used approaches suitable for the automated transportation system are studied and analyzed thoroughly in this literature, in order to provide directions for academicians and researchers for further work

General Terms
Autonomous, Robotics

Keywords
Microcontrollers, Robotic, golf cart, sensors.

1. INTRODUCTION
There are big goals in everyone's lives that might seem impossible until they are dissected into small goals. The big goal of this work is to make a difference in this world and not leave it the same way it was found; The first small goal is to play the role of the designer by collaboratively working in a team and extracting every bit of knowledge and experience. The team intends intend to give its best effort in every step taken to successfully achieve great progress in the research. This work aims to optimize the transportation system in King Abdulaziz University (KAU) girls' campus by designing an autonomous golf cart (self-driving golf cart, driverless golf cart, robotic golf cart), and displaying its estimated arrival time. To ensure high quality work, first of all, this work will focus on an in-depth literature review for a deep understanding of various concepts.

2. LITERATURE REVIEW
A literature review is an essential and important part of the project, because it covers and investigates all strengths and weaknesses in previous researches that done in the same field. It helps in preventing from repeating any errors that have been identified in previous work. So, this literature review will be carried in order to investigate similar artifacts (robotic cart and the ways of displaying the arrival time for the cart) that are relevant to the work. The literature review carried out and reported in this paper will be divided into six parts which are: autonomous mobile robots, the types of microcontrollers boards that are used in the robotic field, the types of alerts, the types of sensors that are used in autonomous mobile robot to move on track and avoid the object, the ways of displaying the arrival time schedule and the connection ways. These six areas are chosen for the survey since they would be the most suitable ones for an automated golf cart.

2.1 Autonomous Mobile Robots
A robot is an intelligent machine designed to perform specific tasks to serve the humanity needs. It can be controlled by human instructions. Human instructions will be in the form of codes. So, a computer program will be used to write the codes and program the robot. To sum up, by programming, the robot will be able to apply human instructions easily.

Sensors are a big part of autonomous navigation. Sensors control the robot by sending information to the controller in the form of electronic signals and the output provides motor control commands (e.g. turn left or right). Robots use a variety of different electromechanical sensors to explore and understand their environment and themselves. Thus, using sensors, the robot can detect its surroundings, know its exact position, see in the dark, smell, taste and touch.

There are many kinds of robots; one of them is a mobile robot. A mobile robot has the ability to move freely from one location to another in an environment to perform its tasks. The autonomous mobile robot assesses its environment by using various sensors. The sensors are employed to control the robot's motion without continuous human interference.

2.1.1 Moving a mobile robot on a specific track
The aim of this part in this literature review is to investigate the previous researches made by others in moving a mobile robot on a specific track (move the mobile robot from one point to another without human interference).

Moving a mobile robot on a specific track can be done by making one of these robots which are: line follower robot, environment recognition robot, time delay robot and autonomous mobile robot with GPS navigation. Investigating of the previous researches on these different robots will help to realize them and determine the suitable one for the project.

Line follower robot is an autonomous robot that detects and follows a line. The path may be visible like a black line on a white surface or it can be invisible like a magnetic field. A closed loop control system (feedback system) is used in the line follower robot. It continuously monitors the performance of the robot (location and speed) and changes the commands as necessary to keep the robot on a specific track.

Design autonomous robot use IR sensor under it, to detect the black path on the white surfaces [1]. The circuit sends the received signal from the IR sensor (in analog form) to the processor directly (to convert it to the digital form). Finally, the processor sends a signal (required voltage) to the DC motors to move the robot on the path (e.g. move forward). This IR (IR photodiode) sensor is found to be very sensitive to IR lights and sunlight and also has a weakness to darker colors such as black. So, the performance of their IR sensor was dependent on shielding and on the path width.

Another project was created based on environment recognition robot, by using double ultrasonic sensors and a charge coupled device (CCD) camera to recognize a rectangular-shaped environment [2]. Environment recognition robot is an autonomous robot that takes observation from various sensors to provide information of the path (very useful for the self-localization) and reach the target without collision. In their robot, double ultrasonic sensors and a CCD camera were combined to measure the distance within the environment, detect the object and a vision system for object boundaries detection. The CCD camera takes a photo for the environment and sends it to a special program for processing the image and analyzing the environment which sends data to the microcontroller to provide a signal that control the motors.

In the implementation phase, they found that using only double ultrasonic sensors to detect the environment, it will be difficult to determine the ends of an object or a flat wall. To improve this, the CCD camera was added to determine the position of the boundaries of the object and flat wall. Also, camera was installed on the ceiling of the test environment to localize the robot and know its initial position.

Time plays an important role in the dynamics of robotic systems. A time delay robot is designed in which the robot is programmed to go in specific direction for a certain period of time. But this robot is not efficient in the real life because accurate tracking might be challenging if any obstacle cross the robot path. Hence, the range of potential applications on time delay robot is limited.

Moreover, an autonomous mobile robot with GPS navigation was created, the robot moves on its route by using a GPS receiver data. Global Positioning System (GPS) is widely use in navigation and localization. The combination of GPS and ultrasonic sensors in their robot will determine the position and avoid the obstacles. The fuzzy controller receives input data from the sensors and GPS receiver determines the steering angle and velocity of the robot (the controller is implemented with an embedded system). All the waypoints have to be preset to the GPS module before robot can navigate. The GPS provides the current position, direction, velocity of the robot. Along the navigation from the first waypoint to the final waypoint the three ultrasonic sensors which are in the left, front and right side of the robot will detect the obstacles within the path.

The microcontroller (used to implement the Fuzzy logic controller) of the robot is responsible to collect all the data from the GPS module and the ultrasonic sensors. From this data, the decision making provides pulse width modulation (PWM) signals to control the DC motor (to move left or right). Along the navigation, if there were any obstacles the robot avoids the obstacle and returns to the preset path.

The drawback make the robot needed longer power for localization and navigation and the accuracy of the GPS module can up to 9 meter. So, they concluded that, to make the system more effective using the GPS accuracy, the preset waypoint should not be far from each other more than 6 meter.

Finally, this part in this literature review helped to understand how to move a robotic car on a specific track. Also, it showed the problems that faced in implementing wheeled mobile robot in order to help to avoid these problems in future.

2.2 Controlling the Robot

In robotics, microcontrollers are commonly referred as the brain of the robot. since it mimics the same logic as the human brain "input/ decision / output" sequence, it helps the robot to interact and communicate with outside environment, by taking the inputted data from its pins and then make a decision based on its programming instructions and then perform some output action. [4]

One of the basic chip microcontrollers is PIC-family microcontrollers, they are equipped with memory, timers, and parallel I/O pins, an autonomous robot was created based on PIC18 microcontroller to control the robot. The robot moves autonomously using obstacle avoidance algorithm to sense the leakage of gases by using three different types of sensors. Whenever it detects a leakage it stops and sends alert message using GSM (Global System for Mobile Communications) modem. The developers concluded that they used PIC18F458 mainly because of its low cost, and simple coding instructions, the simplicity of the coding led to use small amount of program memory without any need of external memory, which make it much faster than other microcontrollers. Also, the PIC provides simple interfacing instructions, which was a primary issue since the robot use different external component [5].

Even though the chip microcontrollers seem to operate perfectly alone, Some modern microcontroller has it own development board that contains extra features such as, Analogue - to - digital converters, voltage regulator, and serial communication protocols [6], these features will make implementing the project much easier and will provides protection to the microcontroller chip, one of the famous microcontroller development board is Arduino board.

Arduino was used as the main microcontroller of self-balancing robot, along with DC motors, gyroscope, accelerometer, and wheel-angle encoders. To control such robot, Arduino Mega board with ATmega2560 processor has been selected. The selection was based on four considerations, which are; high speed Performance, high number of I/O Pins,

Open Source programming feature, low price and expansions. The robot needed a lot I/O pins, to interface with the robot's sensors and motors, the board has 54 general-purpose digital I/O pins, 15 pin provides PWM output, while the other support serial communication as well as handling interrupt. Also, the Arduino are low-cost and expandable boards with shielding that can be used in various applications, such as Wi-Fi, GSM, and a lot more. Not to mention, the Arduino has its own user-friendly (integrated development environment) IDE that use programming language similar to C language, and it has a large amount of available function libraries [7].

However, even though the microcontrollers chips and boards seems to do much, they cannot operate and execute complex algorithms and large programs, for such purpose microprocessors are used, Unlike the microcontroller, the microprocessor is CPU (Central Processing Unit) that cannot be operated alone it requires peripherals such as external storage and output device to operate, the most commonly used microprocessor board is Raspberry pi. It is a microprocessor that can be described as single-board computer. It is based on Broadcom BCM2835 SoC, which includes an ARM1176JZF-S 700 MHz processor, VideoCore IV GPU, and 512 Megabytes of RAM. However, it does not contain storage devise, instead it use an SD cards as ROM. The board programmed by python, based on Linux kernel operating systems. Raspberry pi provides an open-source website that will help the beginners to understand and to code their board.

A robot was created using Raspberry Pi board as processor. The function of the robot is to detect and measure the size of the object the robot face using ultrasonic sensors and camera, since it needs a camera to capture images. They used Raspbery Pi to perform image processing, however one of the pit fall of Raspberry Pi board that it has no real-time clock. For this, the researcher introduced several solutions such as, using network time server, asking the user to enter the time as he operate the robot, or adding real time clock to the robot and communicate with raspberry pi with serial communication protocol [8].

Moreover, to prevent such pitfalls of raspberry pi a solution is made by integrating the Arduino and Raspberry Pi side-by-side. The purpose of this paper is to demonstrate real-time feedback control system by implementing a line follower robot. It uses Arduino Uno board to control the real-time execution of the control law, to provide movement of the robot and to collect the sensors data. While the Raspberry Pi provides Wi-Fi connection and web interface, which will send the data easily, using wireless data streaming, this will help debugging and control tuning. Such combination competed the downfalls of each board and created a complete system [9].

Thus, this part in this literature review shows the pros and cons of each microcontroller as well as the problems the others faced, which will help preventing them, and provides a guide to choose the best microcontroller that fits the purpose of the robot design.

2.3 Obstacle Avoidance Sensors

The obstacles avoidance sensor is very important in a fully autonomous mobile robot to avoid accident and to be safety for passenger, it classified into two categories, sensor detect obstacle based on range and based appearance.

The obstacle avoidance sensor based on range is sensor detect obstacle based on distance between the obstacle and sensor. The obstacle avoidance sensor based on appearance is a sensor that detect obstacle based on physical appearance of the obstacle such as shape. But this type not useful in autonomous mobile robot.

Autonomous mobile robot implemented in indoor environment with fuzzy logic based control [10]. The autonomous mobile robot uses nine Infrared (IR) sensors to detect obstacle and avoid accident. The nine Infrared (IR) sensors are distributed as six in front and three behind the robot.

The robot programed to move randomly with help of infrared (IR) sensors to detect obstacle and avoid it for example if any sensors detect obstacle the robot will move to side that has not detected any obstacle. The disadvantage of this methodology is that the infrared (IR) sensor works in short range and can face interference by other light like sunlight. So, cannot use infrared (IR) sensor alone to obstacle avoidance.

However, in another project created fully automated robot by using Ultrasonic and Infrared (IR) sensor in obstacle avoidance in way to make prototype model of fully automated car [11]. This robot uses an ultrasonic sensor in front of robots, two Infrared (IR) sensors one in right side and the other in left side of robot. Infrared (IR) sensors detect obstacle in short range in right side and in left side of robot. If there is no obstacle on the sides the robot will move to right and same to the left side. Ultrasonic sensor will detect obstacle in long distance and measure the distance between obstacle and robot. Based on the distance, the speed of robot will be controlled. This methodology of combination of Ultrasonic and Infrared (IR) sensor helps to detect obstacle in different range with low cost.

On the other hand, an autonomous mobile robot with five Ultrasonic sensors is created to implement obstacle avoidance, each sensor in different angle to avoid interference between sound wave (ultrasound) of each sensor, the beam angle is about 30 to 60 degrees so the distance between sensors should be more than this angle to avoid interference. The five Ultrasonic sensors placed in robot in this order sensor one in front, sensor two and three in left and sensor four and five in right of robot. The robot detects obstacle in range less than 60 cm. If ultrasonic sensor detects an obstacle in right and there is no obstacle in left, then the robot will move to right and same to the left side. If all ultrasonic sensors detect obstacle than the robot will move back [12].

Hence, this part in this literature review helped to understand different type of obstacle avoidance sensors, how they work, the different implementation to them in mobile robot and the problems that faced in implementing them.

2.4 Display

Since this project needs a way to display the arrival time schedule of golf cart to customer. There are many ways to display data such as LCD, application on smartphone, webpage and so on.

Autonomous mobile robot implemented using four Infrared (IR) sensors, three to detect objects and one to detect height [13]. The robot always goes forward. If sensor detect object, the robot will rotate and the LCD will display the number of rotation. The disadvantage of this way in displaying data is

the user cannot see the data from anyplace and anytime because the LCD is fixed in one place.

However, in another project tried to solve problem elderly people staying on home alone in daytime by implementing auto following mobile robot System for the elderly with Ultrasonic sensor to obstacle avoidance [14]. Wi-Fi network connects the robot with data base and application on smartphone and webpage. This system has three modes, which are auto following mobile robot, manual following mobile robot and data mode. Auto following mobile robot mode is the way to move robot automatically to user by determining user and robot location by Received Signal Strength Indication (RSSI). Manual following mobile robot mode is way to move robot manually by user command from application or webpage.

Last mode is data mode which has the data history of mobile robot movement sin manual and auto following mobile robot which has been saved in data base. The advantage of this way of display data is the user can see the data from anyplace and at any time if the user has internet connection.

Thus, this part in this literature review helped to understand different way to display data to user and the implementation of them in mobile robot.

Alerts

Alert is a way to notify people about actions depending on the project goal. There are many ways or instruments to apply the alerts on the project such as Buzzer, timer, LED and LCD. The Buzzer and timer ways will present below.

An alerts system was developed to warn the person using the microwave about the leaking of RF signal [15]. The system stats when the microwave is operated. It has two different parts one for receiving the RF signal and the other for detect any leaking of the RF signal. The leaking of RF signal will make the buzzer's sound to alerts the microwave user.

Another system used the buzzer as an alert system. An intelligent traffic system was developed [16]. The system detects the vehicles passing through the zebra lane. When the red light is on, there are two cases; first, if the vehicle is an emergency, there will no reaction occur. If not, then system will turn on the buzzer to alert the traffic police.

Moreover, another type of alert was used in similar system developed an intelligent traffic light system that also may increasing the number of cars passing through the road and reducing the waiting time on each road. This system contains controller and sensors to detect the cars present on the intersection lane and the countdown timer which would display he time [17].

2.5 Connecting

Connections between two or more devices would occur either by wires or by wireless communication. The sections below discussed some types of the wireless communication for mobile.

2.6.1 Bluetooth

Honeybee robot is an example of robots using the Bluetooth communication. It was a multi-robot system designed to do the tasks of bee. The system had two discrete robots connected together by Bluetooth communication. One of these robots works as a guidance robot where it is looking to discover a target on the environment; Then, driving the second robot to it through their communication.

Applied the brainstem Palm Pilot Robot Kits (PPRKs), interfaced with Compaq iPAQ to use it as a primary control of the both robots where the iPAQ has an ability to use Bluetooth wireless technology to link the two discrete robots.

Moreover, in another project applied the same concept of the honeybee robot to detect the fire by using TIR sensor and fighting the fire by sending its location coordinate to another robot to help in fighting fire [18].

Using Bluetooth is an easier way in connecting between devices where most of devices has a Bluetooth technology in it so connecting the system to one of that device is easy. On the other hand, Bluetooth communication had some disadvantages compared to others wireless communication ways where the range of Bluetooth modules approximately equal to 30 feet, which is a small range when wide spaces are needed.

2.6.2 WI-FI

A smart robot has developed to sense the environment states and send it to the cloud by using Wi-Fi connection. The robot consists of a humidity sensor connecting to cloud by using raspberry pi board.

The Raspberry Pi used in this work instead of computer to connect the robot to the cloud using a Wi-Fi, where the raspberry is cheaper than using a computer and more power saver when compared to computer. But the using of Raspberry Pi demand another device for wireless communication.

This system could work as team of robots to be an efficient and remotely in collecting data. In the future, the system may be more efficient in using instruction detection [19].

2.6.3 Radio Frequency

A monitoring device was created, the system consists of server, coordinate unit and solar street lamp unit. The server had connection to lamp via coordination unit by sending to it a data through GPRS. Also, the ZigBee module was used to transmit the data from street lamp to the server.

This system helps to detect lamp street damage in addition to set them. Also, it is safer and more intelligent system in saving energy and using a wireless communication to connect more coordination unit together.

The paper discussed the disadvantages of the ZigBee module, which the small range. On another project used multiple coordination units for sending and receiving data from the server to target the exact coordination to overcome this disadvantage [20].

Similarly, a system for measuring the blood pressure of patients consists of two XBee module one of them work as a transmitter and the other as receiver. The transmitter consists of Arduino board, XBee module and blood pressure measurements. The second parts consist of XBee module connecting to the computer to receive the data from the first part [21].

3. RESULTS AND DISCUSSION

This work mainly focuses on optimizing the transportation system in KAU girls' campus by designing an autonomous robotic golf cart. To promote the quality of the work, first an in-depth literature review is carried out for a deep

understanding of various concepts. The review would investigate similar artifacts (robotic cart and the ways of displaying the arrival time for the cart) that are relevant to the work. It is divided into six parts which are: autonomous mobile robots, the types of microcontrollers boards that are used in the robotic field, the types of alerts, the types of sensors that are used in autonomous mobile robot to move on track and avoid the object, the ways of displaying the arrival time schedule and the connection ways. The detailed survey on the above mentioned six areas are conducted and the results are discussed in terms of the techniques and the resources used, the methodology followed, the merits and de-merits of the work, and the implementation details with the problems faced.

4. CONCLUSION

Six key areas for an automated golf cart are chosen for a detailed survey and the results are discussed in terms of the techniques and the resources used, the methodology followed, the merits and de-merits of the work, and the implementation details. The widely-used approaches for the automated transportation system have been studied and analyzed thoroughly in this literature, in order to provide directions for academicians and researchers for further work.

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