RESEARCHARTICLE OPENACCESS

Autonomous Bicycle: Obstacle Detection and Real time positioning

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ABSTRACT
Industrial revolution and rapid urban growth have led to increased rates of carbon dioxide emission. A simple approach to reducing these increasing pollution rates is the use of eco-friendly transportation such as a bicycle. Considering an area like a campus or an institution, bicycle sharing system is a promising solution. This paper proposes an autonomous bicycle which provides on demand mobility to the user. The user can call a bicycle from a particular hub and the bicycle will autonomously arrive to the user's location and after that it can be used as a regular bicycle. It incorporates smart features like Obstacle detection using ultrasonic sensors, real time location of the bicycle through web interface, automatic steering control, self-balancing etc. thus making it an efficient and reliable mode of transportation.
Key words: Autonomous Bicycle, Obstacle detection, Steering mechanism, web interface, bicycle-sharing

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Date of Submission: 04-08-2022 Date of Acceptance: 17-08-2022

I. INTRODUCTION

Industrial revolution and associated rapid urban development have increased the pollution rate and carbon emission. In order to reduce the increasing carbon emission, it is indeed to promote the bicycle and bicycle sharing system which is relevant now days. By implementing an autonomous bicycle sharing system which can act like an on-demand mobility solution will help in eliminating the walking distance of the user. The development of an autonomous bicycle is hence here being concentrated on a smaller scale like a campus or an institution which later with the help of a more reliable technology can be developed for implementation in large platforms.

Autonomous bicycle sharing takes place in a way that when user request a ride the bicycle can autonomously reach the user thereafter it can be used as a regular bicycle. The main challenge in such an operation is the lateral stability required for the bicycle. This is made possible with the help if balancing wheels. On the way to destination, it encounters with obstacles. So, proper obstacle detection and real time positioning is necessary for the working [1]. Autonomous bicycle completely depends on the sensors to determine the quality of the road and make the decisions, and their safety rests on the reliability of these components. For the purpose of obstacle detection, Ultrasonic sensors are highly preferred as they sense the presence of an obstacle by transmitting ultrasounds and analyzing their reflection. [2]. Calculation of front and rear wheel torque helps to provide stability for the vehicle using electronic systems. This helped to determine the motor torque required to drive the entire bicycle and move stably in autonomous mode of operation [3]. Gyroscopic control for self-balancing and tracking control using Compass, GPScan be implemented. It focuses on autonomous behaviour of the bicycle which includes balancing and tracking to the desire destination. Wheel and steering are run by DC motors [4]. LIDAR or Light Detection and Ranging based system and segmentation of surrounding environment into various obstacle clusters along the path of the bicycle [5].Obstacle avoidance using a laser ranger sensor and road quality detection system created for an autonomous bicycle is proposed in [6]. Obstacle detection using Ultrasonic sensors has been addressed in [7]-[9] It can be done with the help of sensors, microcontrollers. Alarms or buzzers indication can be provided when an obstacle is detected in the path. This can be integrated using a smartphone. Ultrasonic sensors are preferred due to the cost effectiveness. Ultrasonic sensors which can sense a range up to

400cm is used here. Ultrasound-based Obstacle Detection System for Vehicles under Interference Environment is also considered. The system demonstrates good detection for different obstacle materials (e.g., wood, plastic, mirror, plywood and concretes) and colours. The minimum size of an obstacle that the system can detect is 5 cm x 5 cm [10]. Web page interface for real time positioning has been derived. The data related to the path and hub position from controller is interfaced with a web page where user can locate the position and motion of the bicycle [11]. Ultrasonic System Approach to Obstacle Detection and Edge Detection in [12]. Application of RFID technology in navigation of mobile robot is studied and the movement of bicycle in a predefined route is enabled using RFID based system. RFID tags are placed in the cycle hubs, whenever the cycle reaches the hub the RFID reader which is placed in the bicycle will read the unique code in the tag and stop and move operation takes place [13]-[15].

The main constraints while designing an autonomous bicycle are self-balancing during autonomous motion, obstacle detection, steering control and autonomous navigation. In autonomous bicycles, self-balancing is the most tedious task and sophisticated design methods are used for this. For obstacle detection, normally LIDAR based system is used which is not economical. In a bicycle, rather than integrating an expensive system for obstacle detection and navigation, it is recommended to use a more cost-effective method. Hence, in this paper an autonomous bicycle is designed which uses Ultrasonic sensors for obstacle detection and RFID based navigation system for autonomous motion from one hub to another. Self-balancing of the bicycle is incorporated by using a set of balancing wheels.

II. METHODOLOGY

In this autonomous bicycle, there are two modes: user driven mode and autonomous mode. The bicycles are parked in specified hubs and each hub has got an RFID tag. This RFID tag is an address of the particular hub. The bicycles are provided with RFID reader. When a bicycle comes in contact with a particular hub the current position of the bicycle is sent to the node MCU from the RFID based navigation system. An RF remote is used to give the signal which consists of push button switches representing the hubs. An RF remote is used to give the signal which consists of push button switches representing the four hubs. When the user calls the bicycle through the RF remote the current position of the bicycle from the RF transmitter is sent to the web page through the node MCU and will be displayed in the web page. The user will thus get to know the current position of the bicycle and thus can call the nearest available bicycle which will later arrive autonomously to the user. A stepper motor is used to actuate the steering control system in the bicycle. A chain and sprocket mechanism are used for steering mechanism and the autonomous control of balancing wheels is achieved by using pressure sensor and dc motors. The movement of the steering will be based on the control from the obstacle detection module and the motion of the bicycle from one hub to another.

2.1 Obstacle Detection

When the bicycle is moving autonomously, it is essential that it accurately detects the obstacles that the bicycle encounters along its path. The bicycle should be able to detect the obstacle before a certain distance and immediately should take the action i.e., either stop or change the course of the bicycle accordingly.

Obstacle detection will be done using two ultrasonic sensors which has a range of 2-400cm. If either the left or right ultrasonic sensor is encountering an obstacle then the bicycle will steer to the opposite direction and will continue its path. When the obstacle is removed it will come back to the preset position. When both the ultrasonic sensors are encountering obstacle, the stepper motor will disconnect from the supply and the bicycle will come to stop. It will only continue its motion when the obstacle is removed. In this way, obstacle detection with a considerable field of view was achieved. The block diagram of the basic working is shown in the figure below.

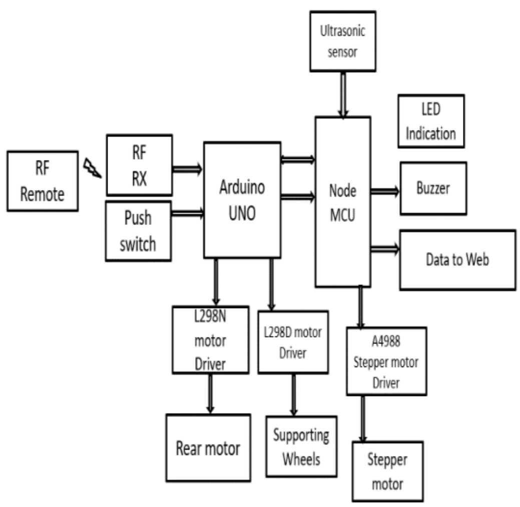

Fig 1. Basic Working

Node MCU is the main microcontroller used here. An ultrasonic sensor is connected to the Node MCU so that when the sensor senses any object, the signal from the sensor is sent to the Node MCU. So, when an object is detected, LED and buzzer will get enabled and sent an alert message. An RFID based navigation system is get connected which includes an RF remote and receiver. When the user calls the bicycle through RF remote the current position of the bicycle from RF transmitter is received by RF receiver and then this signal is sent to the Arduino UNO. These data are then sent to the webpage through node MCU and the route from one hub to another hub is also coded so the stepper motor will steer according to the angle and it will finally reach the destination.

2.2 Steering Mechanism

The steering mechanism is essential in determining the positioning of the bicycle. In this bicycle, the steering mechanism will be based on a predefined route if it is moving from one hub to another and the former can be coded in the Node MCU module. But when it encounters an obstacle, it will have to move by a certain angle, here 1.8° step angle and maintains that angle until the encountered obstacle is removed from the path and then comes back to its default position after the ultrasonic sensor stops detecting the obstacle. To control the steering of the bicycle the motor should overcome torque on the stem of the bicycle which can occur due to the momentum of the bicycle, gravity etc.

For autonomous control according to the route that the bicycle takes, a stepper motor is used for achieving the required steering angle and a chain and sprocket mechanism is used for the power transmission. A chain and sprocket mechanism performs the same task as a belt and pulley system, i.e. they transfer motion and force from one shaft to another. Using a belt can slip on the pulley but the teeth on the sprocket will prevent the chain from slipping. The movement of the steering will be based on the control from the obstacle detection module and the motion of the bicycle from one hub to another.

The microcontroller receives the data from the RFID based system which determines the route of the bicycle, and the steering of the bicycle is controlled accordingly as per code in the RFID based module and obstacle detection module. For moving from one hub to another the motion of the steering will be as per the code of the RFID based system. On encountering an obstacle, the obstacle avoidance module is activated instantly and its data is overridden on the steering control and the vehicle will move away from the obstacle and then continue on its path towards the destination. The bicycle will have a predefined route when it moves from one hub to another. While moving in the autonomous mode if it encounters any obstacle then the stepper motor will have to steer by a certain angle and the action will be transmitted through the chain and sprocket mechanism.

Fig 2. Stepper Motor

Fig 3. Chain and sprocket mechanism

2.1 Obstacle Detection

When designing an autonomous bicycle, the current position of the bicycle is to be determined. Only when the current position of the bicycle is known, one can know on which bicycle hub the nearest bicycle will be available. A web page is designed to keep the user informed about the current location of the bicycle. A data communications link enables a remote operator to issue commands to the Autonomous bicycle from a web interface. These can include signals to switch between various hubs; hub numbers will be specified in the web page and start command to initiate the motion of dcmotor. The link also allows the server to be kept up-to-date on the cycle's current position and state, information which can be relayed to the human operator. The steering will move by a certain angle depending upon the input from obstacle avoidance module and RFID based navigation system.

The web page is made available to the user through an internet link. The link directs the user to the web page where the user will enter the pre-set username and password for the security of the web page considering the future prospects. After that, the user will be directed straight to the dashboard whose interface consists of no. of hubs and will display the current cycle position. The web page can be further customized to add control and information displays to aid remote navigation and start stop operation off the bicycle. A message console can also be provided which will send the data as status messages to the human operator. The web page is interfaced withNodeMCUESP8266 is a microcontroller with an integrated Wi-Fi module. It integrates a Wi-Fi transceiver which allows it to connect to existing networks or to set up its own network. To communicate on the network, a special protocol is used. This protocol is integrated in all the libraries relating to Wi-Fi communication. The Wi-Fi module is first connected to the network, then the server and the client is defined. The current positionof the bicycle is sent to the Node MCU from the RFID based navigation system whose transmitter and receiver are connected to the Node MCU. An RF remote is used to give the signal which consists of push button switches representing the four hubs. When the user calls the bicycle through the RF remote the current position of the bicycle from the RF transmitter is sent to the web page through the node MCU and will be displayed in the web page. The user will thus get to know the current position of the bicycle andcan call the nearest availablebicyclewhich will later arrive autonomously to the user. Fig 3 shows the web page interface consisting of the current position of the bicycle and the specified hub numbers.

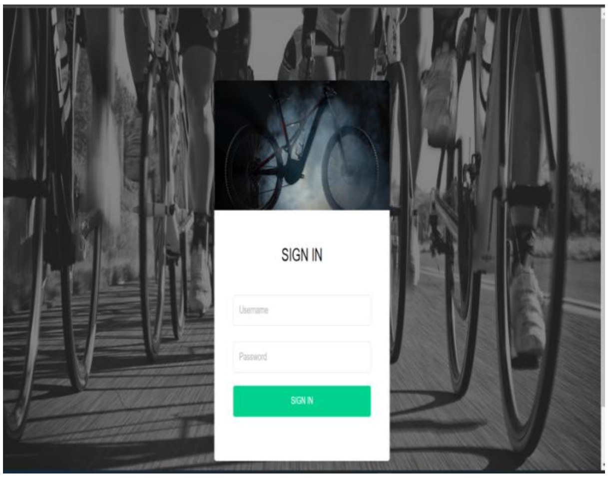

Fig 4. Web page layout

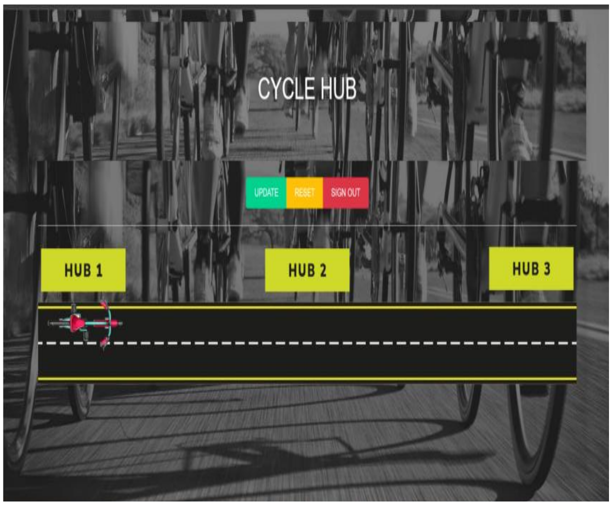

Fig 5. Web page interface

III. SIMULATION

Figure6shows proteus simulation of Obstacle detection. It shows a Node MCU module which is connected to two ultrasonic sensors, named object sensor 1 and object sensor 2, the interrupt pin is connected to buzzer. Node MCU is connected to stepper motor driver which is in turn connected to the stepper motor. A power supply of 12 V is also provided. If object sensor 1 detects an obstacle, then the control is passed to the stepper motor driver and the stepper motor moves with a certain step angle. Similarly, if object sensor 2 detects an obstacle, the stepper motor will rotate in the opposite direction. If both object sensor 1 and 2 are detecting an obstacle then the supply will be cut off from the motor and the vehicle will thus come to a stop and the signal will be sent to the buzzer and it will beep. This continues until the obstacle is removed from the path. Once the obstacle sensors stop detecting the obstacle, then the bicycle will continue its Each time the bicycle stops in a particular hub, the data from the node MCU will be pushed to the web and the current position of the bicycle will be made available to the user.

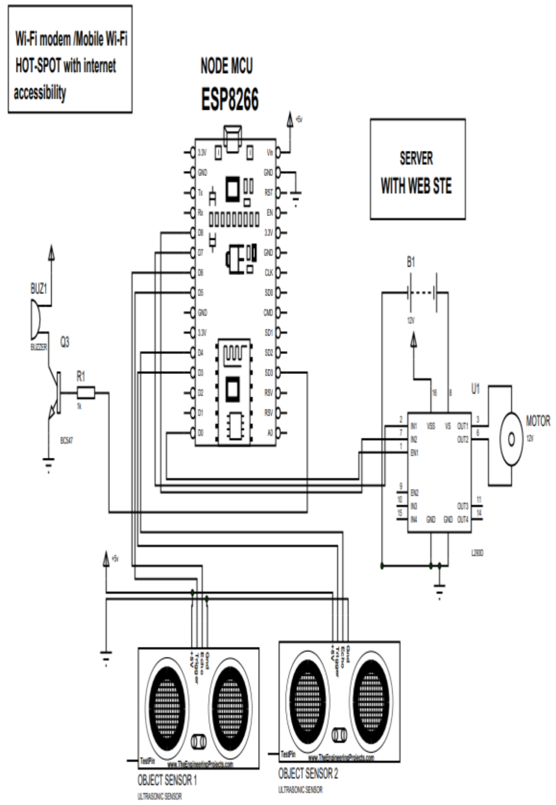

Fig 6. Handle Control

IV. HARDWARE IMPLEMENTATION

Hardware Selection and configuration of the bicycle are crucial for the functionality and performance of the bicycle. A stepper motor of rating 12 V, 350 mA is used for the steering mechanism and it is mounted parallel to the head tube of the bicycle. A chain and sprocket mechanism are incorporated for power transmission. This arrangement is connected to the stepper motor thus controlling the stem of the bicycle and connecting the position as per the motion from one hub to another and the Obstacle detection module. The motor is connected to the cycle using a clamp. Designs were made in Solid works for calculating the strain before fabricating the bicycle. Fig 7, Fig 8, Fig 9 shows the CAD design for bicycle, steering mechanism and battery slots respectively. Ultrasonic sensors of range nearly 2 – 400 cm are selected. They require an operating voltage of 5-10V. The Ultrasonic sensors are connected beneath the stem of the bicycle which are in turn connected to the microcontroller (here Node MCU) unit. A dc motor is attached to the rear wheel which provides the motion in Autonomous mode and it is controlled by the microcontroller (Arduino UNO) unit. A pair of balancing wheels are also connected to the to operate in autonomous mode. An RFID reader is connected near the rear wheel of the bicycle such that when it comes in contact with the RFID tag placed in each hub stops the bicycle. The ratings of the motors and other components were considered after the proper calculations. The power requirements of the system are met by a 12V,10Ah battery which is placed in a slot near the control unit. The components were selected in a way such that it doesn't interfere with the user's ability to control the bicycle in the user driven mode. The components are properly welded to the bicycle using lathe work. The movement of the steering will be based on the control from the obstacle detection module and the motion of the bicycle from one hub to another.

Fig 7. Bicycle design

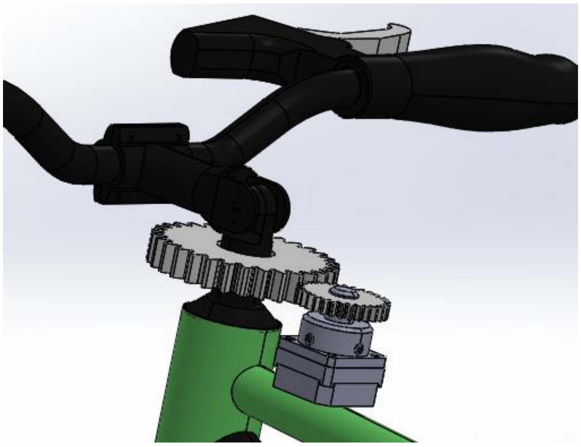

Fig 8. Steering Mechanism

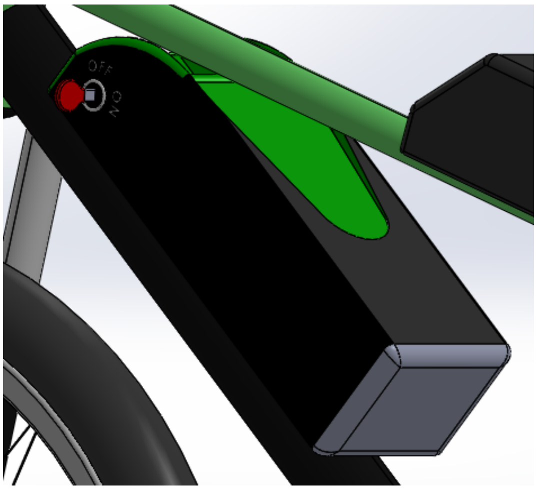
Fig 9. Battery Slot

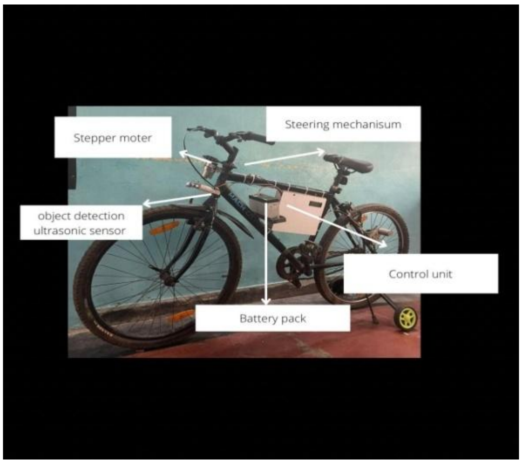

Fig 10. Bicycle Hardware


Fig 11. Hardware Connection


Fig 11. Obstacle Detection

V. CONCLUSION

An autonomous vehicle is capable of sensing its environment real-time through a detector management system interfaced to the vehicle. By the implementation of autonomous-driving technology we present a new approach to bicycle-sharing system. An autonomous bicycle not only makes the transportation over small distances convenient but also enhances safety and provides on- demand mobility. The proposed system could also solve some of the challenges found in current systems such as the rebalancing problem or the over quantification of fleets. For users, to have a door-to-door service without having to deal with the problem of finding available bicycles or docks would greatly improve the bike-sharing experience. Reduced travel times and increased convenience would incentivize more people to use shared-bicycles for commuting, supporting this way a transition towards more comfortable and sustainable cities.

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