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ARTICLE

Unmanned Drug Delivery Vehicle for COVID-19 Wards in Hospitals

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ABSTRACT

The prime reason for proposing the work is designing and developing a low-cost guided wireless Unmanned Ground Vehicle (UGV) for use in hospitals for assistance in contactless drug delivery in COVID-19 wards. The Robot is designed as per the requirements and technical specifications required for the healthcare facility. After a detailed survey and tests of various mechanisms for steering and structure of UGV, the best mechanism preferred for steering articulated and for body structure is hexagonal as this approach provides decent performance and stability required to achieve the objective. The UGV has multiple sensors onboard, such as a Camera, GPS module, Hydrogen, and Carbon Gas sensor, Raindrop sensor, and an ultrasonic range finder on UGV for the end-user to understand the circumferential environment and status of UGV. The data and control options are displayed on any phone or computer present in the Wi-Fi zones only if the user login is validated. ESP-32 microcontroller is the prime component utilized to establish reliable wireless communication between the user and UGV.

These days, the demand for robot vehicles in hospitals has increased rapidly due to pandemic outbreaks as using this makes a contactless delivery of the medicinal drug. These systems are designed specifically to assist humans in the current situation where life can be at risk for healthcare facilities. In addition, the robot vehicle is suitable for many other applications like supervision, sanitization, carrying medicines and medical equipment for delivery, delivery of food and used dishes, laundry, garbage, laboratory samples, and additional supply.

1. Introduction

A guided Unmanned Ground Vehicle (UGV) is a type of Robotic assistance vehicle. The accurate guidance from system or human makes the operating vehicle easy over a wide variety of terrains and capacity to perform a wide variety of tasks in place of humans but with human or system supervision. Unmanned robotics are effectively created for regular citizens and military use to serve dull, grimy, and hazardous tasks. Unmanned Ground Vehicle' is classified into two types:

1) Tele-operated: A Tele-operated UGV is a vehicle that a human administrator constraint at a distant area

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employing communication links. The administrator gives every psychological procedure, dependent on sensor feedback from either viewing visual perception or input from the sensor, such as camcorders [7].

2) Self-governing: A self-governing UGV is an autonomous robot that is entirely self-ruling and self-correcting in most cases.

The Robotic vehicle (UGV) that we made tests the feasibility and efficacy of surveillance and environmental study. The robot assists guidance program made by us relays the ecological parameters and stores a set of data for suggestions in a similar scenario in the future. The data include the convergence of gases in the environment, like hydrogen and Carbon monoxide. Detection of humidity and temperature is also recorded. This gives humidity and temperature to the surrounding air. Nowadays, the interest in robots and their utilization in clinics have expanded because of segment patterns and clinical cost control changes. The most important current contagious pandemic can risk one's life. These robotized frameworks are structured explicitly to deal with mass material, drug medications, and transportation of food, grimy dishes, bedding, garbage, and biomedical instruments for medical management provisions. A processor is used with a few sensors, including a RF transmitter for communication over Wi-Fi using ESP-32 to study and act in the environment.

2. Literature Review

The following passages show the survey done by our group on the vast literature relating to the UGV's. The literature includes work carried out by various researchers. The survey may also include information from different authentic internet websites. To keep the literature survey simple, we have briefly summarised the work carried out by researchers. The following passages show the survey done by our group on the vast literature relating to the UGV's. The literature includes work carried out by various researchers. The survey may also include information from different authentic internet websites. To keep the literature survey simple, we have briefly summarised the work carried out by researchers.

A generalized kinematic modeling approach for mobile robots with the articulated steering mechanism was exhibited by F. Le Menn et. al., [1]. The proposed formulation for inferring the I/O equations of such kinematic structures extends the reciprocating screw method of asymmetric and constrained parallel mechanisms. The efficiency of this methodology in establishing the differential kinematics model is demonstrated by an application: the "RobuRoc" mobile robot. Its intricate kinematic structure is initially transformed into a parallel spatial mechanism encapsulating the differential drive wheel system. The analytical shape of the reciprocating screw system corresponding to the active control wrenches applied to the controlled body is established. The reciprocal screw system is the analytical form that fits in the actively managed wrenches used to establish regulated functions in the body. Conversely, it outlines how wheel speeds are transferred to the output body. It also provides geometric information for an exhaustive analysis of the singularity and optimizes traction distribution when highly irregular surfaces evolve. From the differential drive kinematic model, the traction ellipsoid concept is utilized for evaluating the impediment clearance capabilities quantitatively when the pattern of the total system and the contact circumstances are notably variable.

Valjaots et. al., [2] examined the energy efficiency of Unmanned Ground Vehicles (UGVs). The vehicle platform's energy efficiency depends entirely on the designed elements and the surrounding environment where it is to be used. The efficiency also depends on the navigation algorithms used. For confirmation of all UGV design factors that have a measurable effect on energy efficiency comprises an integrated measuring system to obtain the vehicle's dynamic motion and interaction with environmental factors during the real-time test mission. Various design profiles are used to improvise and optimize the efficiency of UGV and a control system. The results obtained are applied to the development, simulation, and testing library used as a product design medium in an early phase.

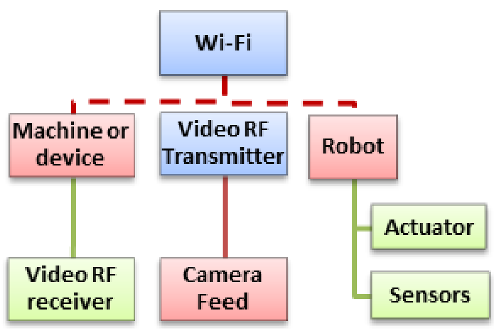

Figure 1. Block Diagram.

3. System and Control Architecture

The above block diagram in Figure 1 illustrates system architecture. A wireless router, also called a Wi-Fi router, combines a wireless access point and a router's networking functions. The router helps guide the robot for free movement in the hospital wards. Here, the Wi-Fi router acts as a bridge between the client and the robot. The next part explains the onboard components used in building the robot.

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3.1 On-Board Components

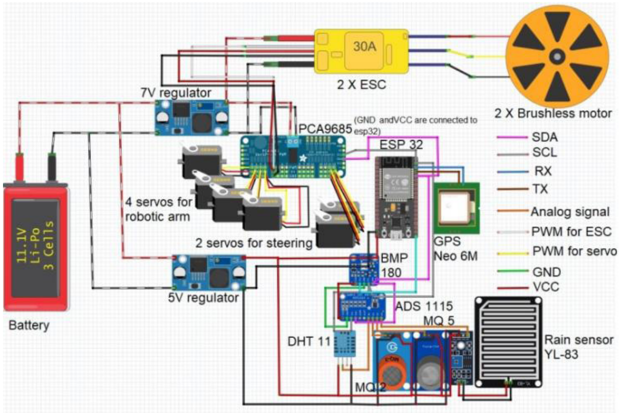

Figure 2. On Board components.

Figure 2 describes the components used in building our Robot, and Figure 3 illustrates the devices used to create the base station. The onboard device used are ESP 32, BMP 180 Pressure Sensor, NEO-6MV2 GPS Sensor, Gas Sensor MQ2 and MQ7, DHT11 temperature and humidity sensor, Raindrop Sensor, DC step down module 12 volts to 7volts and 12 volts to 5 volts, 25A ESC, 4 Poles 4800 KV BLDC, 7-volt Power Supply, MG995 Servos for Steering.

Figure 3. Possible devices for Base Station.

3.2 Base Station Components

Figure 3 shows the possible base station components. They consist of any machine or device on any OS platform having modern browsers (IE10+, Chrome 16+, Firefox 11+, Safari 6+). In addition, they can run HTTP to become a WebSocket client to control the Robot when connected over standard Wi-Fi.

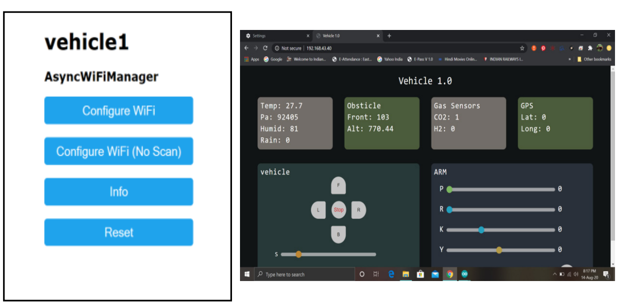

Figure 4. Login Page and Control Panel.

3.2.1 GUI

WebSocket in JavaScript and HTML5, CSS for web-page design runs only on present-day programs like IE10+, Chrome 16+, Firefox 11+, and Safari 6+. A web-site page that keeps up a WebSocket customer association with a WebSocket worker can frequently trade information by operating continuously and with low latency over a steady, full-duplex network. The method is used to implement a web-based GUI using JavaScript. A web socket server-based login page and control panel [8] is shown in Fig 4. This GUI assists operator with live distance from the vehicle to an obstacle in the front with altitude reading and GPS location. The car decelerates near the obstacle for safety, and it can be overridden by reviewing the situation. WebSocket server connects to the endpoint via a URL ws://126.25.3.1:8080/WebSocketServer/echo.

3.2.2 Object Detection and Assistance Program

To assist the user in low light, extremely bright, blur vision of FPV camera in surroundings, the program designed in Visual Studio renders the live feed with essential services like object detection, edge detection, and detecting the object's shape on the computer. Thus, it avoids the usage of an expensive graphics processor on the vehicle. Figure 5 shows the object detection user interface used for assistance.

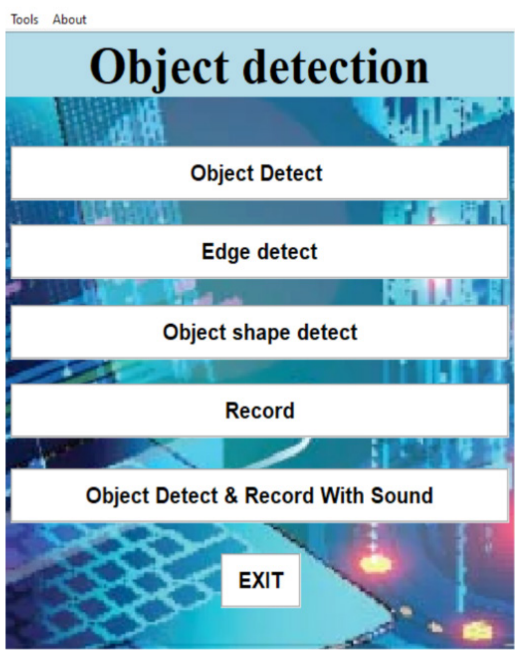

Figure 5. Program for Object detection for user assistance.

3.3 Software

The software used for the development of the Robot

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include, Arduino IDE, XCTU, Autodesk Fusion 360, Cura 4.6, Auto CAD, 2020, Adobe XD, Visual Studio Code.

3.4 Design of Mechanical System

The design's first steps consisted of evaluating the existing Robot by analyzing the different operations and considering the available space for mounting the sensors, motors, and drivers. Then, the development of several design configurations was done and also evaluated. Finally, it led to the selection and implementation of optimal arrangement with the following criteria:

1) Robot modification should be minimal to bring back quickly to its initial state.
2) Modular system design should be adopted for easy maintenance.
3) Simple part configurations can bring down the cost of manufacturing.
4) Materials available locally should be used.
5) Automated control for deceleration.
6) Automated control of the steering.
7) Obstacle detection.
8) Easily travel on rough terrains.
9) Efficient use of the Camera.
10) It uses 7 V to supply all of the necessary power.
11) Robotic arm to perform simple tasks.
12) The Robot uses a sturdy and stable design to support all the other onboard components.
13) Study the environmental parameters.

3.4.1 Traversing capability till 45-degree inclination

A mechanical coupler [12] between two vehicle bodies gives adaptive motion providing adjustment to the body's total bend in a safe zone using limiters to have better traction over rough terrains. A servo for suspension allows adjustment to the body's complete bend to have better traction and maneuver over rough terrains. For instance, different robots have every one of the four wheels similar for a forward movement. If there should arise an occurrence of left or right turns, the wheels' speed should be eased back down or reversed depending on the velocity. To overcome the drawbacks, we intend to accomplish all the movements by keeping the wheels' speed the same and performing more extreme turns even at a higher rate by changing the wheels' speed.

3.4.2 Flexibility to twist and turn movements

Different robots will, in general, alter wheel speed or course to take turns. We intend to accomplish more extensive turns by having an articulation steering system with a mechanical differential. It doesn't affect motor rpm keeping momentum reserved, which helps to decrease power consumption. Thus the overall range and average speed are increased while maintaining the necessary abilities fully functional.

3.4.3 Greater length to width ratio

The complete Robot is designed to have two hexagonal units, each of 20*20 cm, covering a total rectangular plane of 46*20 cm, which gives better stability and flexibility than other robots.

3.4.4 Environmental parameters and human assistance

The sensors are placed on the Robot to capture the ecological parameter readings. Sensors send information such as Hydrogen and Carbon monoxide concentration, co-fixations noticeable in the environment, and co-gas recognition in the range of 20 to 2000ppm. Further, they sense a reduction in the resistance in transmitter power due to raindrops in the environment and nearness of water interface nickel lines equal to the sensor, thus decreasing opposition and lessens voltage drop. It utilizes a capacitive humidity sensor and a thermistor to analyze surrounding air, hence sensing its temperature and humidity. The system's prime objective is to assist humans in critical circumstances where human life is a threat.

3.5 Forward Kinematics Equations

In this section, forward kinematics infers conditions for articulated steering vehicles. This type of vehicle comprises two separate wagons associated with an articulated joint in the center. Steering is achieved by exerting force (push or pull) on the wagon's edge closest to the central joint. Articulated vehicles are generally used as actual working vehicles, such as road rollers and various woodland or construction vehicles.

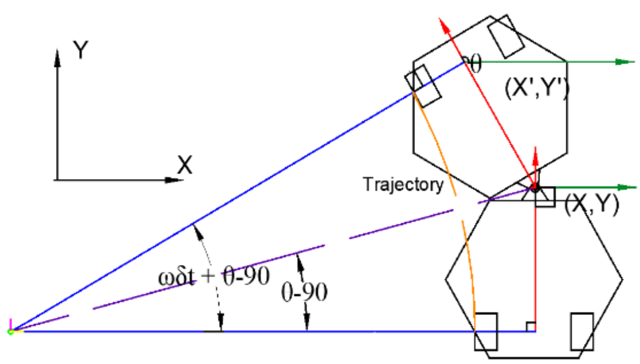

Figure 6. Articulated system.

All wheels move toward a path opposite its pivot while taking a turn with full contact on the ground to achieve

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slip-free movement. The separation obtained can be processed using available data like the wheel diameter and its rotational speed. For some reason, this itself is a romanticized circumstance. Nevertheless, slip is regularly noteworthy and challenging to display. Thus, slip-free movement is regularly accepted when taking care of the issues expressed previously.

For a multi-axle vehicle, the axle axes' intersection point is known as the middle point for the turn when the vehicle maneuvers was proposed by Hellström et. al., [3]. This specific point is known as ICC, which means the Instantaneous Center of Curvature. It is also known as ICR, which means the Instantaneous Center of Rotation. As a rule, thoroughly slip-free movement isn't mathematically conceivable. The circumstance for this vehicle with three axes is outlined in Figure 6.

The shifting guiding edge φ, as shown in Figure 7, makes it challenging to develop the vehicle with the end goal that the axes meet at one point. A typical methodology accepts two virtual axes situated in the middle of the genuine axes in the vehicle's front and back to abstain from displaying slip. The external piece of a wheel travels in more drawn-out separation than the internal part in all bends. Subsequently, they might slip. Moreover, all wheels' velocities must be wholly controlled to achieve the end goal of slip-free movement in any event around conceivable. The furthest wheels need to pivot quicker than the deepest ones, and the back ones need to turn slower than the front ones (expecting a more drawn-out back part as in Figure 7). Contingent upon mechanical development and vehicle's control arrangement, this is a pretty much legitimate suspicion. The accompanying kinematics conditions are inferred with all previously mentioned glorified presumptions.

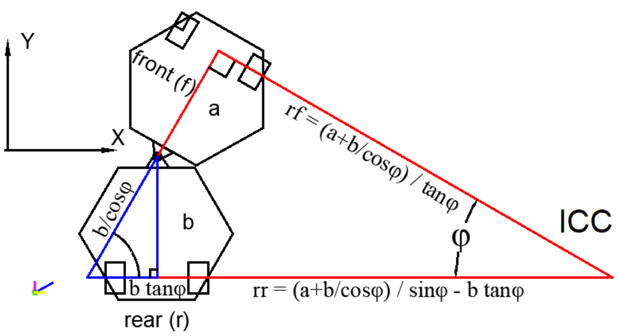

Figure7. Rotational radius of a vehicle with articulated steering of angle φ, front length as a, and rear length as b.

The distance from a circle (ICC) center to the end of either of the virtual axis is the radius with notation r. For an articulated vehicle, 'r' is derived using the vehicle's geometric equations and the steering angle, as illustrated in Figure 7. For the front axis, radius rf is given by,

$$rf = (a + b/\cos\varphi) / \tan\varphi \tag{1}$$

For the rear axis, radius rr is given by,

$$rr = (a + b/\cos\varphi) / \sin\varphi - b\tan\varphi. \tag{2}$$

We can consider the forward portion of the vehicle's movement with an assumption of the above equations since the vehicle's calculation gives the rear part's indication. By taking an example where a vehicle present (x,y,θ) are estimated at the center of the virtual front pivot at time t to obtain (XICC, YICC) for ICC, the equation used is:

$$(XICC, YICC) = (x - r\sin\theta, y + r\cos\theta) \tag{3}$$

where r for the straightforwardness of the reading list means the range rf.

A movement from the present (x,y,θ) at time t to present (x', y', θ') at time 't + δt' is represented in Figure 8. Since the vehicle moves along a circle, it might be useful to articulate the current speed 'ω,' characterized as 2π/T radians/second. T is the total time it would take to complete one complete pivot ICC. The realized vehicle speed v is thought to be the speed at which the front pivot moves (this is another presumption that could be appropriately verified). It would thus be able to be interpreted as 2πr/T that provides accompanying articulation for ω:

$$\omega = v/r. \tag{4}$$

The new angle θ' at time t + δt can be given as

$$\theta' = \omega\delta t + \theta \tag{5}$$

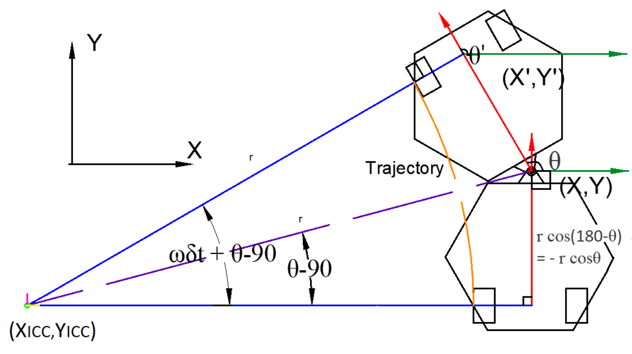

Figure 8. Rotation of vehicle around ICC with angle ωδt. Here position changes from (x,y,θ) to (x', y',θ') which is represented in a global coordinate system (top left). The ICC coordinates are (x – r sinθ, y + r cosθ).

The new position (x',y') at time t + δt is registered by a two dimensional pivot of the point (x,y) by ωδt degrees around the point ICC:

$$x' = \cos(\omega\delta t)(x - XICC) - \sin(\omega\delta t)(y - YICC) + XICC \tag{6}$$

$$y' = \sin(\omega\delta t)(x - XICC) + \cos(\omega\delta t)(y - YICC) + YICC. \tag{7}$$

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To sum up and come back to the first issue for the enunciated vehicle in Figure 8 an underlying posture (x,y,θ), a detailed vehicle speed v and a guiding point φ at time t, the posture (x',y',θ') at time t + δt can be assessed by the calculations (1) to (7). As referenced over, the introduction of the new posture makes a few presumptions:

1. Assuming a completely slip-free motion (ignoring geometrical difficulties, tires with width, the conflict between the front and rear-wheel speed, and other terrain conditions).

2. The deduction of the conditions utilizes two virtual wheel axes situated in the middle of the genuine wheel axes.

3. The velocity v is assumed to be the forward portion's speed. The vehicle's total assessed speed is calculated with the motor RPM and the transmission. This real speed is different from that of the forward portion's rate.

4. Results and Discussion

The proposed system includes an application that controls the development of the Robot. The implanted equipment is created on ESP-32 and managed based on Android, IOS, or Windows. ESP regulator is to get and takes the information and supervises the Robot engines using ESC. As a result, the Robot can push ahead, opposite, left, and right developments. Figure 9 (a) illustrates the UGV prototype. Wi-Fi module is inbuilt to receive commands. A remote camera is mounted on the robot body for security reasons.

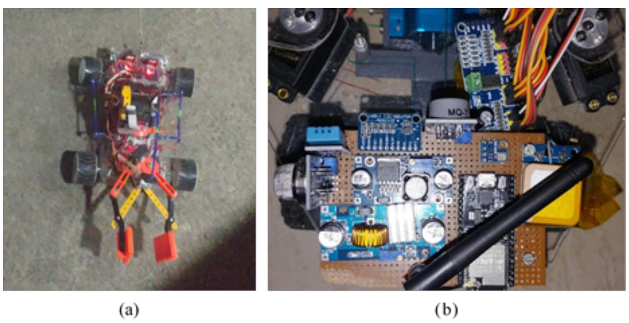

Figure 9. UGV (a) First prototype of the mechanical system for UGV. (b) Its main control boards.

Tele operation is achieved using a web-based GUI on any machine connected to standard Wi-Fi. The base station trans receives a request via a hypertext transfer protocol using a web socket. At the beneficiary end, these orders are utilized for controlling the Robot. Main control board Figure 9 (b) highlights the hardware components used in UGV. The circuit board consists of various sensors, voltage regulators, Microprocessor, a GPS module, an ADC chip, PWM driver controllers to control the Robot.

4.1 Preliminary Test

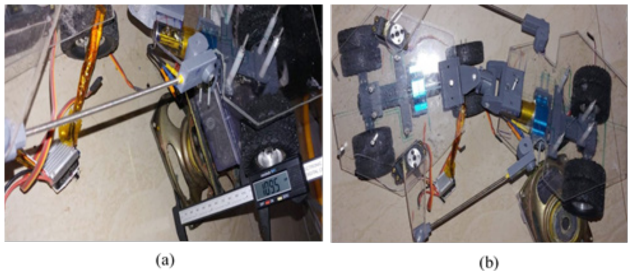

Figure 10. Vehicle body (a) Total height from ground the front body can be raised keeping the rear body intact. (b) Rotating movement.

The ground's height provides a [12] twisting and lifting or lowering angle of 33 degrees. Figure 10 (a) shows raised the height of the body from the ground. Thus, the maximum lowering or raising pitch is 33 degrees for each body. Suppose the Robot is taken on a graph paper vertically aligned on the y axis. The front end and rear end are parallel to the y axis. Then, the front or rear body can freely rotate around the y-axis, keeping the other body's angle intact [9]. The maximum twisting angle is 55 degrees. The rotating movement is demonstrated in Figure 10 (b). The communication between the base station and Robot over the Wi-Fi network minimizes a full-duplex connection.

Figure 11. Robotic arm and UGV (a) Robotic arm with 5 degrees of freedom [6] used for assistance in critical circumstances (b) Unmanned vehicle carrying drugs for contactless delivery.

The development of adaptive traction gives the Robot the ability to maneuver over any terrain. Applications like surveillance, medicine, and equipment delivery systems assist humans in critical circumstances with a Robotic arm. A robotic arm with a freedom of 5 degrees helps in vital cases, as illustrated in Figure 11 (a). Figure 11(b) shows the UGV employed for contactless drug delivery.

4.2 Vehicles Design Validation

Figure 12 (a) shows our vehicle's adaptive pitch positions at different climb angles from the ground to the surface, and Figure 12 (b) highlights the adaptive roll positions between the front and read the body.

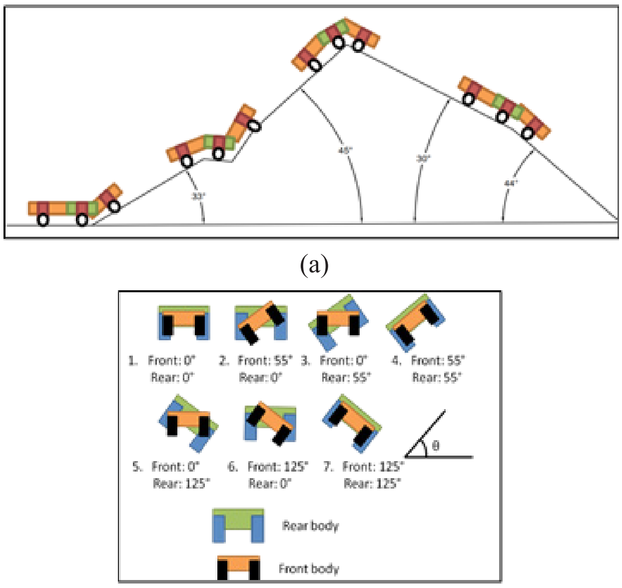

Figure 12. Moving vehicle pitch positions (a) Adaptive pitch in different positions (b) Adaptive Roll positions.

Similarly, a plot in Figure 13 (a) describes the vehicle's adaptive pitch angles of the front, mid, and rear axles during movement. The plot in Figure 13 (b) depicts the vehicle's adaptive roll angles of the front and rear axles. The constructed Robotic arms can is an independent wanderer fit for remote controlling applications. We have added the rotating Camera on this arm to view objects and control the path easily. We achieved obstacle detection and boundary detection to differentiate the objects for real-time tracking and GPS. Our proposed UGV provides current correspondence headway administrations to give simple and easy mobility [4,5,10,11]. The contactless drug delivery UGV can easily be deployed in COVID-19 hospital wards, as demonstrated in Figure 11 (b).

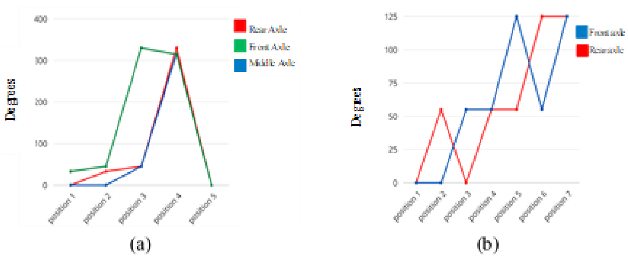

Figure 13. Vehicle pitch angles between axles (a) Adaptive pitch angle compared between all axles (b) Adaptive roll angle compared with front and rear axle.

5. Conclusions and Future Scope

The fusion of UGV technologies has given us the way to accomplish objectives that have never been acknowledged in such a productive way before. These advancements achieve a self-dependant and capable machine to handle Situations all alone and facilitate a human's activity in current situations. The vehicle assembling, configuration, and controlling abilities of a designer play an essential role in developing more complex UGV applications. The proposed UGV design provides the following advantages,

- The UGV can turn at extreme speeds or during climb without changing motor rpm and without losing traction.
- Utilize independent motors for wheels. It can maneuver using two 7V BLDC and two 7V SERVO with total continuous consumption of 2A current and the max peak of 4A while pulling 5-6Kg of load. As a result, the UGV is efficient and consumes less power.
- The hexagonal body, unlike other controlled vehicles, increases usable space onboard with a reduction of weight. In addition, the unique adaptive pitch and roll give excellent traction and maneuverability over any terrain.
- It provides an automatic deceleration safety feature in obstacle detection and null reading in case detection of edge cliff. However, this function can override user input after reviewing as this vehicle can climb most of the obstacles like stairs, riverbank, and elevated footpath. The vehicle can also be located in real-time via GPS positioning.
- The drive-train is not back-drivable, making vehicle and motor stay idle when need to stop on slopes without consuming any extra power.
- The body has fewer connecting and simple parts. As a result, the whole vehicle never fails at once, and any failed part can easily be replaced.

The proposed UGV has the following limitations,

- The system assists the operator in navigation, and the vehicle is semi-autonomous.
- The adaptive body motion has to be changed to an active state manually.
- Most of the parts are fabricated using additive manufacturing, and the surface becomes brittle over time.

The proposed model can be improved by making the vehicle completely autonomous. The vehicle's navigation system can be enhanced by using the waypoints method. The vehicle's robustness can be improved by building the body using carbon fibers. The proposed model can be further be improved by optimizing the battery power and testing load-carrying capacities after integrating solar power. The conversion of this prototype to full-scale UGV will be helpful in many situations similar to today's pandemic COVID-19.

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