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Any Climb: A Wall Climbing Robot for Various Curvatures

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Abstract: *The main objective of the proposed work is to develop a wall climbing robot, which has the ability to perform various tasks. This can be performed by controlling the 6 DC motors through the microcontroller where 4 motors are for the legs while 2 are for vertical and horizontal movements which will be controlled through the assembly program written in Embedded C. In any sloped vertical plane, aerodynamic techniques are utilised to cling the robot to the plane. Also, this robot intends to have manual and automatic communication model. Manually it is done through a mobile app to which the microcontroller is connected through an ESP8266 Wi-Fi module. The alternate way to control the model is through the program code where the path as well as time is preset. This paper covers both the electrical and mechanical aspects of the project.*

Keywords: Embedded C, ESP8266 Wi-Fi module, Microcontroller

I. INTRODUCTION

Robots are one among the most dominant and revolutionary inventions made in the era of modern science. It is an electromechanical machine which has the ability to perform a variety of tasks automatically with respect to the dumped programmable commands. Robots can perform multiple tasks in the most difficult and unfriendly environment where human intervention is difficult. In this modern scientific era, robots are one of the most exclusive inventions which makes our life as easy as possible and provides a maximum comfort zone to us. There are a variety of techniques to moving vehicles in both two perpendicular directions with the same mechanism. Working against gravity is exhausting, and rolling the wheels on a surface that is sharply inclined with respect to the ground plane is quite difficult. The design and development of a wirelessly controlled motor vehicle that can travel in both vertical and horizontal directions is the subject of this research. In any sloped vertical plane, aerodynamic procedures are utilized to cling to the vehicle. Climbing robots are usually adopted in places where human intervention is very expensive because it is very dangerous or due to scaffolding purposes, due to the hostile environment in the destination. Wall crawler robots have been envisioned for a range of applications over the last few decades, almost in maintenance, technical inspection, space operations, surveillance, and failure or breakdown diagnostics in hazardous situations. These jobs are typically performed outdoors of tall buildings, nuclear power plants, bridges, or pipelines to scan the external surfaces of gas or oil tanks and offshore platforms, as well as in planes and ships to conduct nondestructive tests on industrial infrastructure. Furthermore, they have been applied in civil construction repair and maintenance, in anti-terrorist actions, prevention, and extinguisher actions, in cleaning operations in sky-scrapers, for cleaning walls and ceilings of hotels, for transportation of loads inside buildings, and for reconnaissance in urban areas.

II. RELATED WORKS

Riad Hossain Faisal and Nafiz Ahmed Chisty [1], designed and developed a wireless robot having the ability to move on both longitude and latitude planes and to hold the robot in an inclined vertical plane. Aerodynamic techniques are used, the paper covers both mechanical and electrical portions, solid works and 3D studio MAX is used for mechanical portion and proteus VSM tool for electrical portion, for mechanical portion a vacuum chamber is created along with suction cup to stick the robot to the inclined surface. Electrical portion is based on microcontroller and wireless technology. Android application's Arduino PC is used for sending commands from android to Bluetooth, ZS-040 receives command from device and solid work simulation is used for calculating stress, strain of various parts of robot. The goal of this work, given by Van-Tinh Nguyen et al.

[2] uses vacuum principle and wireless technology for robot's agile movement on wall. It works on the principle that minimum and required adhesion force(FMRA) has to be calculated and balanced with gravity and it's torque .the robot is driven remotely by wireless control system ,high speed RC brushes -dutched fan motor is used for generating enormous vacuum pressure, this method enhances the ability of robot to cling on wall & enhances.

Dezheng Jiang, Bing Zhus et al. [3] presented a method to use a large-load permanent wall climbing robot to implement a method for maintaining high pressure within steel tubes. The adsorption force is calculated, and the static restriction limit case condition is investigated, enabling the robot to achieve reliable adsorption at any point on the tension steel pipe where a large load is applied. Negative pressure adsorption uses a gas thrust at a specific inclination to the building's surface to generate an adsorption force on vertical surfaces, the ability to change a robot's movement direction.

Dingxin Ge et al. [4] presented a pressing method implemented to prevent the robot from falling ,here the magnetic adhesion robot will climb on non-ferromagnetic surface by implementing sandwich configuration but both the sides of climbing robot has to be equipped with climbing device to determine the forces acting on the model, Suction cups were utilized to estimate the least optimal pressing force and force distribution for the guide rail design, and a quasi-static model was built to prevent the robot from falling by using a pressing method. Although the suction cup has the ability to cling to the climbing surface and adjust the force magnitude and direction as it moves with regard to the guide rail, the robot can only climb in one direction.

Hritik Kshirsagar et al. [5] designed and developed a robot that can adhere to glass surface by using suction cup vacuum, brush attached to robot can clean glass surface of window ,as per the instruction provided to the microcontroller the robot will clean the wiper and climb ,it is constituted with Arduino UNO, Bluetooth controlling chip, jumping wires, suction pads, connecting pipes, vacuum pumps, plastic chassis, servo motors, batteries and brushes, the suction cup will help robot in clinging to glass and provides rigidity to robot, vacuum pump to generate the vacuum, servo motor creates the required torque robot, Bluetooth and 16 servo controller will control the16 servo motor that has Bluetooth connectivity, this is aided by a software that controls the motion sequence, Aluminum brackets will support the servos

Taoyu Han and Ruiming Qian [6] claimed that when a permanent magnet wheeled wall-climbing robot is adsorbed on the wall of a tank, the gap between the magnetic wheel and the tank is calculated using MATLAB, and they obtain the change law of the wheel- wall gap for various scenarios, after which a magnetic simulation is performed by ANSOFT depending on the value of the gap, and they obtain the influence curve of the gap on the magnetic adsorption force.

Liu Xiaoguang, Zhou Yong et al. [7] introduced control and welding operation process planning. It may show omni-directional motion for automatic seam tracking, and it uses laser vision. The results of the simulation and automatic welding tests show that robots can finish automatic welding of big parts. The distance between the welding torch and the seam is determined, the XY platform at the top of the wall climbing robot's workspace is enabled, a laser is placed at the welding start point, and seam tracking is established for track welding. The wall climbing robot's dolly moves in a straight path, and the y and xy platforms move as well, but the location of the welding flame remains the same. This procedure is used until the welding is completed.

Yu Zhang et al. [8] proposed that the stability of wall climbing robots on ship surfaces is investigated, and the link between stability, adsorption force, and motor driving force is determined. The magnetic adsorption force of the robot is used to calculate the relationship between external force and adsorption force, and the stability of the robot is assessed by using static wheels, positive pressure, and motor driving force for various limit conditions, as determined by the mechanical analysis of the robot's steering and obstacle crossing on the ship's outer surface. This paper calculates the association between these two force and robotics magnetic adsorption force under varying conditions, examines the positive pressure of main and slave wheels and motor driving force under numerous limit conditions, and jurists the stability of robot on wall utilising positive pressure of driving and driven wheels in various movement states.

Xu Fengyu et al. [9] proposed a methodology whaere the cable climbing robot wheels are attached to cable through compaction and not vacuum adsorption but specification of suspended cable must be known. In this mechanism traveling wheels rolls upwards along cable by motor driven friction wheel, sum of weight and load of robot must exceed friction, A cable detecting robot is used to inspect smooth and straight cables, it also analyzes the obstacle negotiating capabilities of a robot for finding important parameters which nudges these capabilities, climbing mechanism modes directed that this capacity is due to driving torque and small radius of wheel 3 and traveling wheel.

Dung Nguyen and Akira Shimada [10] developed an algorithm for motion planning of a humanoid robot for climbing vertical surfaces. This robot can climb vertical terrain independently. The best and right path for climbing is chosen by a particular algorithm, thus a graph method is offered on clustering, which determines whether target holds are useful or not. This algorithm is known as the Right Hand Search Algorithm (RHSA). This project is divided into three sections: vision, planning, and motion, with the second component focusing on this. The algorithm produces randomly "reachable areas" on the wall through "reference scan point s" in the scanning phase of RHSA. The Dijkstra method is used in the query phase to determine the best route from the roadmap created in the previous phase. The start and goal RHRHs of the roadmap are connected and the total cost is calculated, and the best route is picked.

Zihan Zhou and Xiaoqing Zhu [11] discussed the design of six legs of a hexapod robot, as well as the mechanical structure. The performance of step climbing and steep slopes is evaluated using MATLAB and VREP simulation platforms, and the average velocity curve of the centre of gravity when the fuselage moves. The leg structure of the robot is initially introduced, and simulations of robot walking modes such as triangle gait and wave gait are performed. Friction between the robot's contacts and the walls causes the robot to move. Suction cups and spikes are employed for centre of gravity stability during movement, while crescent shaped wheels are used for high speed mobility on both horizontal and vertical surfaces. Electromagnets allow the robot to stretch spikes to fit different walls. When the sensor detects a rough wall in front of the robot, the electromagnet in the robot's foot controls the spikes' expansion to climb the wall.

Weijin Huang et al. [12] presented a methodology where a ducted fan is employed to create a pressure adsorption climbing robot. The pressure adsorption rod climbing method is used to reduce weight and volume while ensuring adaptability. The torque generated by the fan will cause twisting movement in the robot, which will lead to biased rotation when the control device is driven; ducted adsorption has enormous adsorption force for the same weight and can operate for various conditions; ducted adsorption has enormous adsorption force for the same weight and can operate for various conditions; the torque generated by the fan will cause twisting movement in the robot, which will lead to biased rotation when the control device is driven; the dual fan used will generate torque in opposite directions to cancel each other and the effect of torque is suppressed. But thrust and load capacity is increased, thrust is equal to the flow of incoming and outgoing gas. The fan must be placed at an optimal height to have maximum thrust. If the height of the fan is adjusted with respect to the body the computer calculates the thrust value that the fan can provide at the same speed and same power.

Wenkai Huang et al. [13] constructed a bionic crawling modular wall climbing robot based on leech peristalsis and internal soft bone connectivity. It has the ability to manage varied load characteristics by adjusting the number of modules. Internal soft bone is connected with motion modules to offer the robot with variable-step distance capabilities. Two module robots were found to be more stable than single module robots in steering movements and have the ability to complete an attitude. Internal soft bones are long enough to allow each module to be directed upward or downward, while other modules are adsorbed on the wall, preventing cartilage deformation. ISB MVCR features a changeable load bearing capacity for the robot. When a significant number of modules are connected in series, the total weight of N modules is approximately 1.3 times the weight of the robot.

The algorithm for a quasi-static model of three limbed climbing robots in vertical natural terrain is provided in this study by Timothy Bretl et al. [14] The robot has three limbs with two joints, one at the center of the robot and the other at the midway of the leg, and quasi-static motion in the vertical plane is assumed to compute one- step motion while considering equilibrium restrictions. The terrain is represented as a vertical plane attached to a flat surface known as holds, and the robot's reduced complexity aids in the study of climbing motion planning. The terminus of each robot can push or pull a single point on each hold, preventing sliding by using friction. When one limb moves from one hold to the next, the robot can use the degrees of freedom created by two limbs to retain quasi-static balance and prevent unnecessary sliding on either of the two supporting grips. The actuator's limits must not be exceeded at any joint, and the limbs must not collide. This subset path characterizes one-step motion.

A. Albagul et al. [15] presented their work which deals with the design and development of a quadrupled climbing robot. In this process, the suction is considered to adhere to the wall surface. The control of the robot is regulated by the stamp and movements of its legs is controlled by two servo motors .these servo motors will control the left and right leg of the robot. The leg rotation imitates the stepping motion by using a slider and crank. The two vacuum pumps will generate the suction force intermediately. Main body has all components except the compressor which makes it mobile.

III. PROPOSED METHODOLOGY

The robotics concept and primary knowledge are derived from a variety of research and journal papers. First and foremost, a list of various components is created. Theoretical research on electric and electronic components was carried out. The aim here is to build a light weighted body which contributes for comparatively easy vertical motion against gravity.

3.1 Mechanical

The mechanical section is built using aerodynamic technologies and an electrical suction cup is positioned to keep the robot attached to the sloped surface. The robotic propeller contains a couple of arms attached to it which in turn has DC motors operating at 12 V, the code written in embedded C nudges the microcontroller to drive the DC motors alternatively which in turn results in arm movement and the suction cups attached to arm are made of rubber and this force generated helps the robotic body to cling on to wall surface.

We have another DC motor operating for driving the cleaning brush which fulfils the cleaning purpose. The robot designed is agile and to make it move on the horizontal plane the suction cups can be removed from the propeller and a wheel can be attached to it.

3.2 Electrical

The robot's electrical system is built around a microcontroller and wireless technology (Arduino IDE code). We can integrate a Wi-Fi module if required for communication and it can be used if isn’t necessary to dump the command in the code. We have IR sensors used to detect the obstacle that is approaching in the vicinity of 5-10 cm and the robot changes the direction accordingly by ensuring the backward movement. We contain 4 relay modules containing 3 pins each (NO, C, NC). The NC of all the pins are shorted, the C is connected to NO for the robot to have a movement, and if the C is connected to NC the robot doesn’t move.

3.3 Simulation and Design

We use Arduino IDE platform to dump the code written in embedded C, the code is written considering 3 important constraints in picture

1. When the IR sensor detects the object the robot needs to change direction ensuring a backward movement
2. The robotic arm movement is ensured alternatively by generating a delay of 5000s each arm moves and the suction cup sticks to the wall surface then the other arm will be stagnant and the same process will be repeated alternatively to ensure same movement

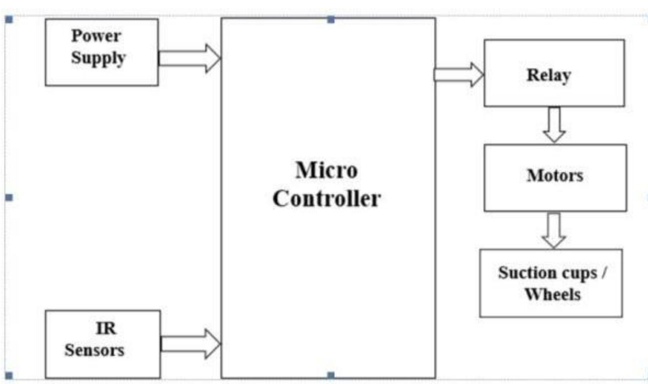

Fig 3.1: Block diagram of the proposed methodology

IV. RESULTS

Most of the Industrial robots are very expensive and use complicated components and methods to fulfil the desired work. Keeping these constraints in picture we designed and developed a wall climbing robot which is less expensive and it is designed considering simple inexpensive components

Test case 1: Horizontal Movement of the Robot

When the robot has to move on horizontal direction the wheels can be attached to the robotic propeller and the movement can happen as desired.

1. When relay input is low the NC is connected to C the motor does not rotate
2. When relay input is high NO is connected to C the motor will rotate clockwise

If both the motors will rotate in clockwise direction then the robot moves in forward direction, if both the motors rotate in anticlockwise direction the robot will move in backward direction

1. To move robot right first motor need to rotate in clockwise direction, other rotates in anticlockwise direction
2. To move the robot left, first motor needs to rotate in anticlockwise direction, other rotates in clockwise direction.

Test Case 2: Movement of Robot on Vertical Direction

The wheels will be replaced with Rubber suction cups during Vertical Movement. The arm movement and its mechanism are given more importance in this section as this plays an important role in the vertical movement. The mechanism implemented here has the propeller arms which contains 2 DC motors attached to it working at 60rpm each. These arm rotate alternatively to stick to the wall surface and when they rotate the force generated pull the air from surroundings and help the suction cups on clinging on wall surface.

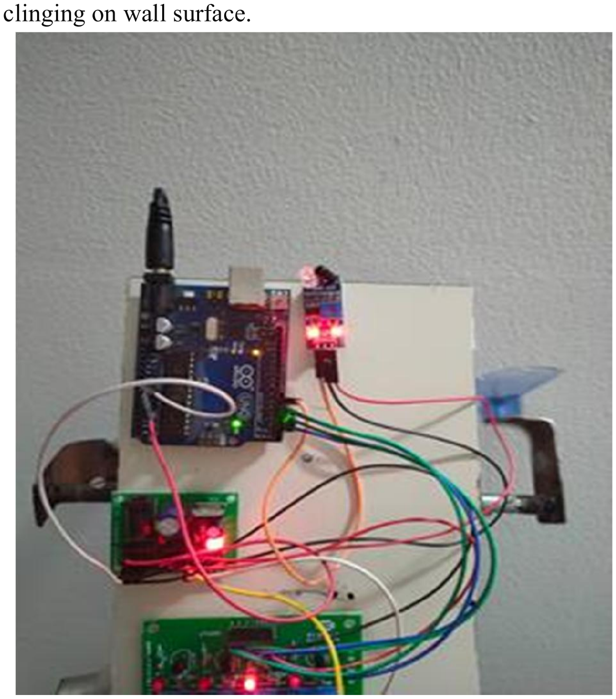

Figure: Model Trying to climb the wall

Test Case 3: Cleaning the Surface of the Wall by Robot

We have the DC motors attached to the cleaning material (brush) that cleans the wall surface by rotating the brush the mechanism in which they depict the above process in provided in the below flowchart

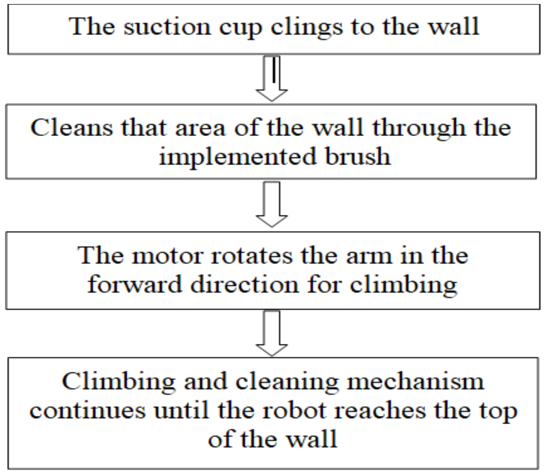

Figure: Flowchart of the cleaning wall surface

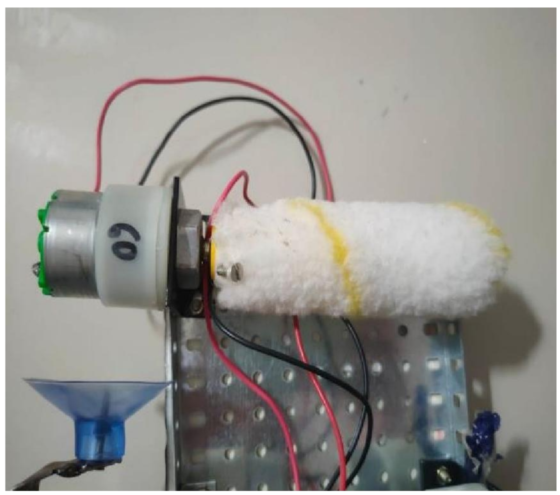

Figure: Cleaning brush attached

Test Case 4: Detecting the Obstacle in Front of the Robot

The IR sensors attached to the robot helps in obstacle detection and results in change in direction through backward movement of the arm that result in backward movement of the robot in this scenario

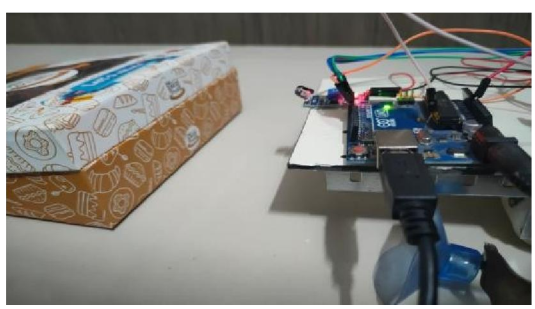

Figure: Robot detecting the obstacle in front of it

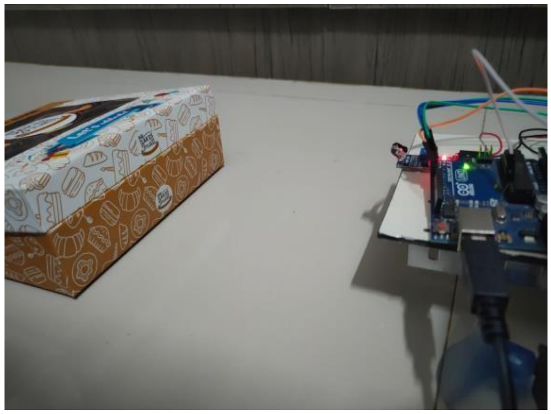

Figure: Robot moving backwards after detecting the obstacle.

V. CONCLUSION

This robotic platform is simpler, lighter, and more compact, making it a safe and effective way to handle hazardous duty jobs. It is designed to climb on reasonably smooth surfaces where cleaning tools, painting tools, drilling tools, and other work-related instruments or tools can be put on it to carry and climb on the wall. The whit worth quick return mechanism is depicted in the prototype, which has a circular disc attached to a driving crank, which is connected to a motor, which drives the disc to initiate the motion required for the syringes to create a vacuum, and two motors connecting to the pinions, which are located inside the legs of the robot to perform locomotion. This concept could be enhanced by extending the range by using GPS or satellites to control the robot from afar. By adding a microphone, camera, and wireless transmitter to stream multimedia, it can be used to collect data from multiple locations. In the near future, an arm could be added to collect and pick the objects. For security and fire rescue operations, an X-RAY scanner, fire extinguisher, or night vision camcorder can be attached. Artificial Intelligence (AI) can be implemented, which will then make spontaneous decisions under diverse conditions.

VI. ACKNOWLEDGEMENT

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