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Integration of Basic Mechatronic Principles in DIY Automatic Vacuum Cleaning Device Based on Suction Mechanism

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Abstract:
Automatic Vacuum Cleaning Robot is an intelligent, automated device that helps to maintain clean floors with the minimum or no human intervention needed. With the addition of numerous sensors, motors and smart path-planning algorithm the robot should be able to navigate through indoor environments, obstacles and do the cleaning job reasonably well. In the following paper, the design and implementation of an automatic vacuum cleaning robot is presented with major emphasis on the following dominant features: pitfalls and obstacles detection, scheduling, and adaptive cleaning patterns. Robotic vacuum cleaning robots are making a trend in the market due to the propelled demand of automated home solutions. The robot is designed to enhance the convenience of the users, to minimize manual work and to maintain a high level of cleanliness in the residential as well as in the commercial areas all the time.

Keywords: Suction mechanism, Vacuum Modes, Cliff Sensing, Scheduling, Remote Access.

1. Introduction:

Over the past few years, people have shown an interest in automation, convenience, and time-saving technologies, which is why the demand in smart home devices has risen. Among the most innovative and popular automated device used in the domestic sphere is the automatic vacuum robot programmed to clean floors automatically without being directly controlled by human [1]. Various technologies are combined in these robots including infrared sensors, gyroscopes, smart mapping among others to help them execute their duties optimally.

With the conventional vacuuming method, a lot of time is used up and at times we tend to forget because of our busy schedules. This problem is addressed by us through automatic vacuum robots that offer scheduled cleaning, smart navigation, identification of floor types, obstacle avoidance, generation of room layout maps etc.

Through this project/paper we will examine the structure and main parts of an automatic vacuum robot, we will study the current technologies and we will have a prototype that will be able to operate autonomously. The prime intent is to show how automation and smart control systems enhances our daily activity, saves time and manpower and is effective in working [2].

2. Block Diagram:

Figure 1: Block Diagram of Automatic Vacuum Cleaning Robot

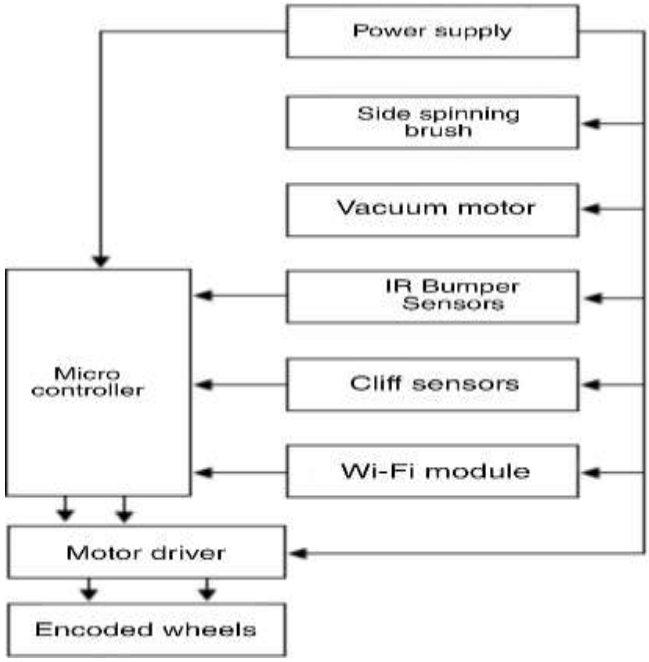
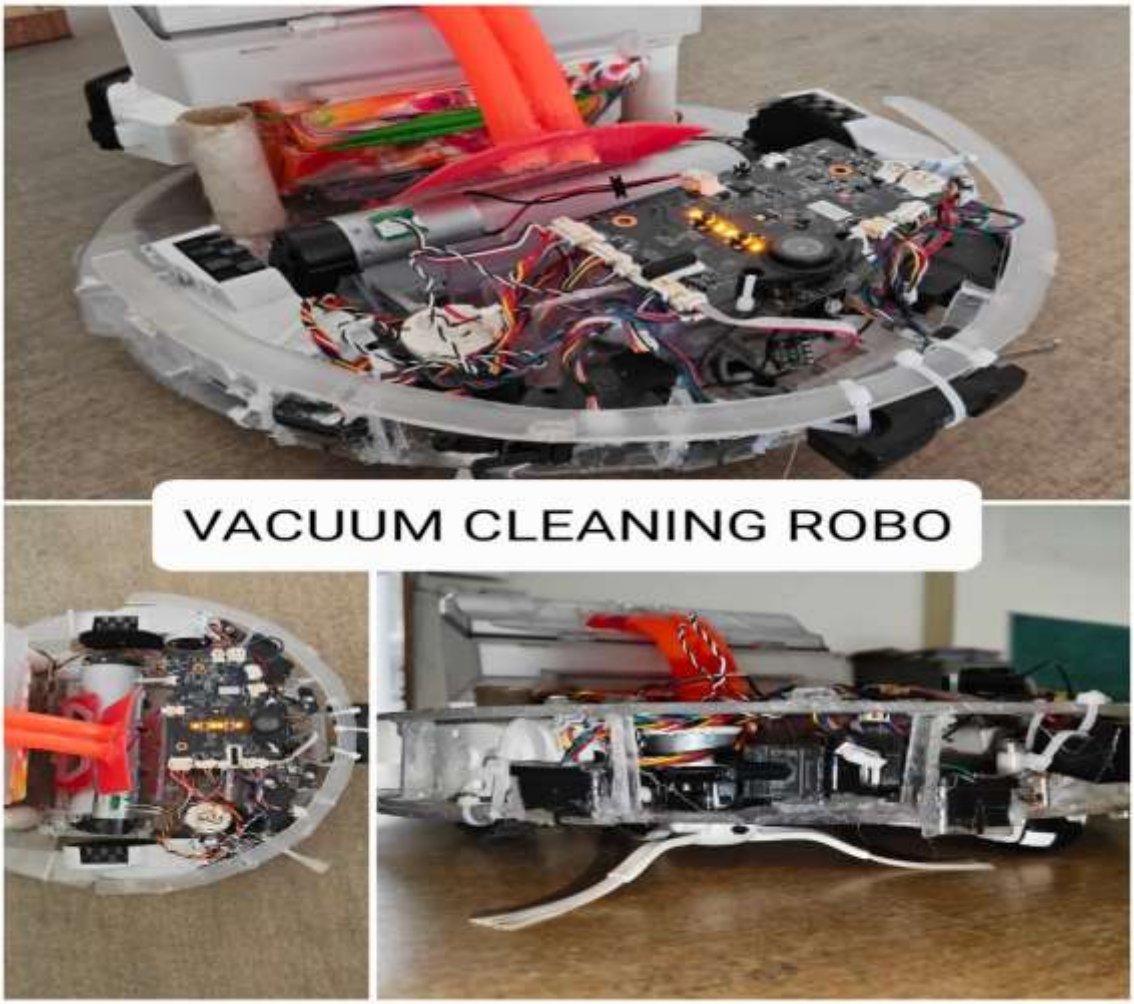


Figure 2: Complete Assembly of the Automatic Vacuum Cleaning Robot



3. Hardware Aspects:

3.1 Sensors:

Several high-precision sensors are installed in the device, among which there are:

- Side wheels and universal wheel inspection PCBA: It comprises wheel speed sensors (2 pcs) and a caster wheel sensor, used to detect wheel rotation and movement to navigate properly.
- Down facing Proximity sensors: These are cliff sensors (4 units) which senses possible drops from stairs or pits to avoid falling down, it usually senses distances beyond 8 cm [5].
- Limit switches connected to front crash bracket: The collision sensors (2 pcs.) are used to sense a physical obstacle to prevent collisions.

Some of the other sensors used are 2 wall sensors, 7 IR sensors, 1 dust compartment sensor. It also has a gyroscope and an optical sensor (camera with approximately 137 degrees' field of view) to aid navigation by inertial and visual positioning [3].

Figure 3: Sensors Enabling Smart Navigation and Obstacle Detection.

3.2 Motors:

The device has:

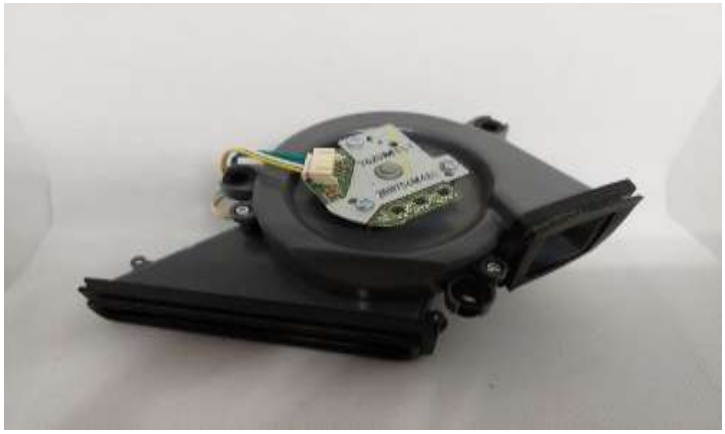
- A main brush motor (geared BLDC motor) which powers the roller brush to do a deep cleaning.
- A side brush motor (micro gearhead DC motor) which drives the side brush to collect debris into the suction path.
- The vacuum fan motor (NIDEC Brushless centrifugal motor) is utilized in driving the vacuum fan to produce necessary suction power.

Figure 4: Motor configuration in Vacuum Cleaning Robot

3.3 Suction Mechanism:

- The suction motor generates a very strong suction of 2200-2500 Pa, which is measured in Turbo mode with a battery voltage of 16.5 V or above156.
- Incorporates a large-diameter suction inlet and the brush system to suck dust, dirt, and hair efficiently.
- The dustbin volume is approximately 450 ml.

Figure 5: Vacuum Fan Assembly



3.4 Wi-Fi and Antenna:

- Wi-Fi 802.11 b/g/n (Wi-Fi4) is used operating at 2.4 GHz to provide remote control with the help of a software application.
- Wi-Fi module (SDJ01RM) frequency ranges around 2400-2483.5 MHz with the maximum transmitting power of 20 dBm EIRP.
- The product has a built-in antenna that supports wireless connection called as FPC antenna (flexible printed circuit antenna) [4].

Figure 6: Wi-Fi & FPC Antenna Module

3.5 Battery:

- It has a Lithium-Ion battery that is rated at 14.4 V.
- It has a capacity of nearly 2500 mAh (rated) and 2600 mAh (nominal).
- It has the capacity to run up to 100 minutes in a single session when fully charged, which can cover around 1200 square feet in a single session.

Figure 7: 14.4 V Li-ion Battery Pack Providing Power to drive & Suction Systems

4. Working:

The microcontroller is the main brain of the whole system in an automatic vacuum robot where the program is coded into the microcontroller itself. Sensors provide data to a microcontroller which reacts to it. The system is in idle state initially and therefore, pressing the start button is required to bootstrap the system. Once initialized, the robot comes into motion.

In case there is an obstacle ahead of the robot, it collides with it and the limit switches are operated when this collision occurs. These switches provide a signal to controller. The microcontroller receives the information of the limit switches and gives an instruction to the encoded wheels that move the robot. Behind the dust container is the vacuum generator which is useful in sucking all the dust and debris into the container. There is a brush fitted underneath the frame which aids to sweep dirt into the container effectively [6]

The design has three options of vacuum power:

- Mode 1 where Low Power Mode (600 to 800 Pa suction power)
- Mode 2 where Medium Power Mode (1200 to 1500 Pa suction power)
- Mode 3 where High Power Mode (up to 2200 Pa suction power)

Depth is measured by using a proximity sensor. As with real-world examples where the robot is working on the first floor, it can fall down the stairs. The proximity sensors generally sense the possible drops when the robot gets near a staircase. When the depth is greater than a certain pre-set value, a signal is sent to the microcontroller, which processes it and commands the encoded wheels to reverse direction thus causing the robot to avoid falling. This robot vacuum cleaner uses Wi-Fi 4, which makes it possible to use the device remotely and plan cleaning sessions ahead of time (scheduling). This robot comprises Bluetooth 4.2 in its design. Also in order to provide an optimal performance the device follows zig-zag path while performing cleaning operation [7].

Conclusion:

The robot has a huge potential in daily applications and it is not harmful to humans during its functioning which makes it a beneficial addition to the society. It is efficient and reliable in terms of the functions that it is intended to perform. It can be used in different settings like houses, restaurants, schools, offices and hospitals. With the further development of the technological realm the topicality and the influence of the robots of this type are most likely to increase significantly. Future expansion is also quite possible both on the level of possibility and the number of different fields it could be successfully applied to.

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