Autonomous Wheeling and Hopping Sphere BOT for Unknown Terrain Mission

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Abstract — This paper describes the development of small rolling and hopping robots that are useful for many tasks in unknown rugged terrain, and are especially suited to celestial exploration in small gravity environments. The family of hopping or jumping, described here are characterized by discontinuous motion, whereby the robot stops after each jump to regain the upright position, recharge its jumping mechanism and localize itself. We describe the evolution of our hopping robot concept by way of prototypes that can be developed. These theoretical prototypes show that a small robot can move effectively by hopping provided that it is equipped with steering, jumping and self-righting capabilities. This paper gives the detailed pictures and descriptions of the mechanism of various prototypes. A hopping robot can jump over the barrier several times higher than its own height. The combination of the hopping movement and the wheeling movement can greatly enhance the scope of robot’s activities. In this paper, a novel five-shank hopping mechanism was employed to build the wheeling hopping combination scout robot. The nonlinear character of the six-shank hopping mechanism was analyzed and then used in the proposed nonlinear spring mass model for the robot. The rules of robot’s movement were deduced, influencing factors of the jumping height were analyzed and the countermeasure was adopted. Finally, a simulation analysis and an experiment of the robot’s movement were carried out. The results showed that the robot has strong locomotives and survival ability.

Keywords — Hopping robots, spherical robots, planetary rovers, five shank mechanism, Non-linear spring Mass model, Elasticity, Autonomous robot.

I. INTRODUCTION

This paper describes the addition of hopping capabilities for small robots. At present the types of moving robot include wheeling, walking, tracking and so on. Wheeling movement is constrained by the roughness of relief, while walking movement is flexible and it is complicated to control all the walking attitudes. Even the tracking movement becomes useless when a barrier bigger than its own size is encountered. The hopping robot can jump over the barrier several and even ten times higher than its own height, and hopping movement with the sudden outbreak can help to avoid danger. It can be used in searching after disaster, interstellar probe, military scouting and anti-terrorism activities; robots need strong locomotives and survival ability to satisfy the more complicated environment, miscellaneous barriers and dangers.

The miniaturization of mobile robots inherently reduces their mass, which leads to low power consumption, low manufacturing cost, and agility. Miniature mobile robots with these characteristics are suitable for reconnaissance or sensing missions. Furthermore, miniature mobile robots allow a range of strategies when combined with larger scale carrier robots.

II. METHODOLOGY

A. Block Diagram

![Block Diagram of the model](image)

B. Path finding algorithm or Localization algorithm

![Context diagram for decision making algorithm](image)
The decision making algorithm has four main constraints which is checked before a path is chosen. It acts as localization algorithm and can be improved upon to enter the exact distance travelled and the direction of the robot since the starting point, also the position of the robot after certain amount of time.

As shown in the context diagram, decisions are made based on the position of the obstacle and bot’s movement. It was designed such a way that hopping movement was constrained to the height of the upright target (say 10 cm). Before a optimum path is chosen, all the conditions mentioned in the context diagram are checked. The coding was written using object oriented python programming. The decisions were made through the sensor data collected from the 3 ultrasonic sensors that were used (refer to block diagram). Each time for the decision the environmental characteristics are registered and then compared and compiled to find the optimum path.

III. THEORETICAL FOUNDATION

A. Need for the design

The available bio inspired robots and the designs as discussed in the literature survey made by the team, several drawbacks were found, the significant ones were noted down. The design of Bhattacharya et al. had a flawless architectural design for all terrain movement compared to wheeled rovers, the entire robots components was covered or housed in a spherical ball of polystyrene ball which was reliable, hence the proposed model for our project was first considered and modeled as a spherobot.

The six shank mechanism was the most simple and effective model for the hopping mechanism, compared to the San flea modeled with a compressed gas chamber for hopping action. Six-shank mechanism was remodeled i.e. spring model was replaced with an elastic model. The load analysis characterization was upheld, the testing was directly carried out for different load variants, as the software based analysis scheme was beyond our departmental expertise.

Hence a hopping cum rolling model was proposed and the field of its necessity is enormous, the design was mainly aimed at developing successful hopping robot which can position itself and set the direction of its hopping action, which was beyond the features in the existing models.

B. Proposed Prototype

The proposed model had a center disc as shown in the image 5.1, the center disc of 6 inches housed all the embedded design components, which included Microcontroller, H-Bridge, torque variant DC motors (Two torques was put into actions, motors with 1.5 & 3kg torques were used), servo and power source.

The gravity model as discussed in [2] & [7] were enhanced and entire hopping model was installed at the lower portion of the disc. The load on the elastic was set by 2 DC motors installed having 3kg torque each. The study suggested that a simple infant locking structure was required to hold the load at its compressed state as shown in the fig 5.2 (compressed and uncompressed states) and discussed in [5].

C. Model aids and functions

The conglomeration of models was a tedious task for the entire team, the hopping model was made out of aluminium with a shank of 3.25’ each (the model was set to the standard of a=b=c=d=3.25’ as discussed in eq (1)), the housing of the working components was made on a circular disc as shown in the fig 5.3. The circular disc served as an efficient platform to house all the components with gravity model as the main concern. Using the Template.
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D. Simulation prototype

This prototype is similar to proposed prototype except the sphere action was simulated using the dumble model, which was efficient and the results obtained was same as the sphere. The model is as shown in the fig 5.5. The functions was of no variation and the system was well capable of up righting itself and a significant delay in the program ruled out the use of gyros and accelerometers.

E. Limitations and Assumptions

The jumping/hopping elevation angle was set and varied accordingly with each Hop as the prototype mainly aimed at the development of combinational model rather than the accuracy of only the hopping action. Hence, though the Spherebot was set onto a hopping direction the landing of the bot in the same direction was not effective. Dumble model was best suited on flat surfaces and failed at protecting the components or housing, it was ruled out by the team as the analysis of combinational model was first necessary on flat terrains, the gravity conditions was mainly analyzed or compared only with lunar surfaces.

IV. EVALUATION

A. Comparison with other systems

Spherebot was superior to the other hopping models as the direction of the hop could be set and was capable of up righting itself. The robot could be programmed in two ways

a) Swift rolling in the flat terrains and hop when necessary. This showed that the action was efficient but had no change in the performance, power consumption.

b) Periodic hops with direction set. The power consumption was 40 % more efficient than rovers, and the target functions such as rescue missions, military strategy missions, space missions etc. could be incorporated easily with good working efficiency.

B. Metrics for measuring the performance

Hopping height: The distance/ displacement made by the robot were proportional to the height to which the robot jumps and hopping angle, which was maximum when the angle was set to 60deg.
Power consumption: The power consumption was significantly low as the entire robot worked at 12v, and the self-righting capability reduced the use of other calibrating components, thus again minimizing the NRE cost of the prototype.

CONCLUSION

A well working terrain vehicle was successfully developed by the team in low cost, and the robot was tested for its vigilance and adaptability for many terrains and the algorithm for navigation was put to its best use by exposing it to vivid terrain conditions.

REFERENCES


