Jumping robot: A pneumatic jumping locomotion across rough terrain

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Abstract: This paper presents a jumping mechanism using pneumatic actuators adopted in a traditional robotic vehicle’s frame. This is a skeleton for future development on this technology. This is a simple mechanism to overcome obstacles on its way in a robotic vehicle. As we know a traditional wheeled robotic vehicle can not over come an obstacle on ease as it doesn’t have an effective mechanism or it might take an other alternative long route to reach the target. This mechanism has an effective design to overcome obstacles comparing to the traditional robot vehicles. So this model has a higher mobility, flexibility and rapidity. This design has a new type of locomotion to it that is jumping along with wheeled movement which is not present in a traditional robot. This mechanism works from the real time information from the sensors. There are 4 double acting cylinders placed at equidistant from each other and mass distribution of the whole model has been equally divided and each cylinder has the same load. These 4 cylinders are pneumatically actuated as compressed air as source. When these cylinders are actuated there is rapid pressurizing which causes the jump. These cylinders are actuated when the relay receives signal from the sensor module that there is an obstacle ahead. As we know there are many kind of locomotion of robots are been developed these days like wheeled, tracked, crawling, walking and so on but all these robots have difficulty in overcoming obstacle on their way, if it is modified to overcome obstacle too their would be a complex design which in this model is not the case as it has a very simple design. This mechanism is designed to take over rough terrains and uneven and unknown terrains. As a overall outcome we were able to make the robot overcome the obstacles on its way in its unique way.

1. Introduction

As we all know robots have a higher market these days and have started replacing humans in a few places. So in the near future there would be robots performing all the tasks which the humans were doing and even the things humans were not able to do. So for all these the robot must be very flexible and have a higher mobility. For these characteristics the method of locomotion of the robot was very important. There were many researches done in the field of locomotion of the robot. Many kinds of locomotion like wheeled, tracked, crawling, walking and many more.
Unique feature on Bio-stimulated Robotics by using Toshio Fukuda, Fei Chen and Qing Shi[1] shows different kinds of locomotion achieved like biped legged, quadruped legged, multi legged, wheeled, monkey inspired, snake inspired, fish inspired, plant inspired, flying robots. The mode of locomotion we have used in this model is a merge of wheeled and jump actuated by pneumatic cylinders. This model hence has a greater advantage to adapt itself to any uneven terrain or high obstacle on its way. This kind of locomotion has a higher mobility, flexibility, and rapidity as it is equipped with both wheels and a jumping motion. BJR: A Bipedal jumping robot the use of Double-performing Pneumatic Cylinders and Torsion Springs [2]. This paper shows a different approach of use of jumping by use of pneumatic and springs. When this model is going on an unknown terrain and the sensor detects any obstacle on it way it sends signal to the relay and the solenoid valve is actuated and causing rapid pressuring inside the double acting cylinder and making the piston extend at once, which causes it to jump. As it is already in a motion so the momentum is increased which leads to a longer coverage of the obstacle. So once the jumping action is performed and the model is in the air and the sensor doesn’t receive any signal the signal from the relay is cut off and the cylinder is pressurized in the other side of the cylinder causing it to retract its pistons.

Thermodynamic Modeling and motion Simulation of Pneumatic Wheeled leaping robotic [3]. This paper discuss the use of a pneumatic cylinder on a 2 wheeled robot to make it jump. These robots can be used in various field of use like is defence it can be used as spy robot to go to some location gather the needed information and come back, in disaster relief to squeeze into small place and check out for people who are in danger, simple performance Experiments for jumping Quadruped[4]. This shows a robot for disaster relief. We also got some idea of soft pneumatics and how it is used to move a body from [5] and [9]. Then we got some idea of how pneumatic robots was used in the rescue missions from [6] which was a major push for us regarding this project. Then we got to know about controlling a jumping robot and the use of pneumatic cylinders from [7] and [8] and [10] and [11]. Then we learnt of how the jumping locomotion can be inspired from nature and can be manipulated and be used in a robot from [12] and [13]. Then we got to how multiple actuation system can be fused to make the overall outcome or the desired outcome from [14] and [15].

2. Materials and Methodology

Body selection:-As there are many materials to choose from to make the basic frame like aluminium, Stainless steel, iron, and so on. Each material has its own characteristics so we had to choose a good material to withstand all these and have the characteristics which is in need. So we choose wood, which had the inheritance like less weight, high strength, less deformation on impact, availability and low cost. Cylinder selection:-As we know there is are many types of cylinders in the market like single acting, double acting, and spring return and so on. So we had to cut down from all these choices. So we noted down what was our need. We got to know that the cylinder had to be double acting cylinder because the cylinder had to both extract and retract on command and the double acting cylinder was available in the dimensions which we needed so we went with the double acting cylinder.

PRESSUR GUAGE:-Pressure Gauge indicating the pressure. Based on Varying Data from the Pressure gauge. Graph Results were plotted. The figure1 shows the pressure gauge indicating the pressure of compressed air used.
3. Sensor relay integration

The IR sensor which is mounted in the front of the model when detects any obstacle it sends signal to the IR sensor relay and from there it is given to the main relay control from there the solenoid valve relay is actuated and the solenoid valve is actuated and as a result there is rapid pressuring in the pistons causing the jumping action. The figure 2 shows the basic block diagram of the sensor relay integration.

4. Working flow

There is IR remote control for this device which is used to control the movement of this robot. When the signals are received from the remote the relay actuates the motor with the decoded polarity received from the receiver. The movements like forward, reverse, left and right are available from this remote. So, when the robot is in movement and the IR sensor detects any obstacle, it passes the signal to the IR sensor relay and from there it is given to the main relay control from there the solenoid valve relay is actuated and the solenoid valve is actuated and as a result there is rapid pressuring in the pistons causing the jumping action. The figure 3 shows the overall work flow of the robot and the specifications of the pneumatic model is given in Table 1.
Figure 3. Block diagram of working flow.

Table 1. The below table describes the specification of the robot model

| Description                  | Value       |
|------------------------------|-------------|
| Relay Voltage                | 12 v        |
| Piston Pressure              | 10 bar      |
| Hoses Dia                    | 8mm and 10mm|
| Mass                         | 2.4 Kg      |
| Piston Stroke length         | 100 mm      |
| Body Height                  | 28          |
| Ac to Dc Adapter(o/p)        | 12v- 5A     |
| Piston Bore Dia              | 16 mm       |
| Average Velocity             | 0.43 m/s    |
| Average Momentum             | 1.032 Kgm/s |
| Operating Temp               | 0 – 40 °C   |
5. Discussion and results

The graph (figure 4) shows the ratio of pressure (bar) versus time (sec).

![Figure 4](image4.png)

*Figure 4. Pressure vs time graph.*

It shows the rapid pressurization in the cylinder taking place to create a jumping motion. The pressurization is created when the IR sensor detects obstacle and the signal is processed and the solenoid valve is actuated, which creates the high pressure compressed air to enter the cylinder creating the piston to extend in this stroke at a high speed at once. Which means the piston pushes the ground as a resulting reaction of force the model is moved upwards which in other words are called jumping.

The above graph (figure 5) shows the ratio of pressure (bar) versus time (sec).

![Figure 5](image5.png)

*Figure 5. Pressure vs time.*

It shows the rapid pressurization in the cylinder taking place to retract the extended piston. The pressurization is created when the IR sensor once detects obstacle and the robot is jumped, when in air it receives no obstacle signal from the IR sensor so this signal is processed and the solenoid valve is actuated, which creates the high pressure compressed air to enter the cylinder creating the piston to retract in this stroke at a high speed at once. Which means the extended piston is retracted back so that there is no damage to the piston when landed.
The above graph (figure 6) shows the ratio of pressure (bar) versus time (sec).

This graph shows the whole cycle of pressures created when the extension and retraction is taking place. The red is signifies the extension of the piston and it reaches the maximum (which means the robot is in air now) and then stays constant for a small amount of time (until the IR sensor gives off the signal) then the retraction takes place which is indicated in the blue area, which means there is rapid pressurization to retract the piston.

This graph (figure 7) shows the ratio of height (inch) versus pressure (bar).

In this graph we can see that the pressure plays a very important role in terms of the height of jump. The higher the pressure the higher the height of jump. As seen from the graph when there is not enough pressure in the graph there isn’t much pressurization with in the cylinder making the stroke length of the piston low. As the pressure is increased the pressurization within the cylinder is been increased which created the stoke length to be increased. And when the maximum pressure of the cylinder is reached the piston’s stroke length is to full and from there onwards even if the pressure is increases the stroke length will to it’s full.
The above graph (figure 8) shows the ratio of distance (m) versus time (sec).

It comes to our knowledge from the graph that there is rapid acceleration and reaches the maximum of its speed within fraction of seconds. The 4 electric motors have a great acceleration which makes it to reach the maximum rpm in a short span of time.

As we all know that velocity $V$ is given by

$$V = \frac{\text{delta(x)}}{\text{delta(t)}}.$$  

Where delta(x) is the average distance travelled in meters 

delta(t) is the average time taken in seconds.

After applying the formula we got our average velocity as 0.43 m/s.

The momentum is required to jump over the obstacle. The momentum $p$ is given by

$$p = M V.$$  

Where $p$ is momentum of the object in Kgm/s.  

$M$ is the mass of the object in kg.  

$V$ is the velocity of the object given in m/s.

We know the weight of our model is 2.4 kg and velocity is 0.43 m/s.
So on substituting the values we get our momentum $p = 1.03 \text{Kgm/s}$. Which is the energy stored in the robot when in movement.

As our main objective was to perform jumping action we were able to perform it with an accuracy of 90% and attained an efficient jumping mechanism for the robot compared to the regular wheeled robot.

![Figure 10. (a). Model side view. (b). Top view of the model. (c). Model when in air.](image)

6. Conclusion

This robot has a strong ability to triumph over barriers. It may be carried out to the event with complicated and changeable environment, inclusive of detection of planet surface, post catastrophe alleviation, and army tasks. This form of locomotion has the advantages of both wheeled robots and the leaping robots which makes it suitable for all kind of terrains. These has many advantages compared to the wheeled robot like when the wheeled robots face any obstacle on its way to the target it either changes its path or stop there. The ability of jumping makes the robot reach terrains larger than its own height. Hence the use of relay helps us in controlling these jumping pressure. The only disadvantage or complexity at present is the weight ratio of the system where cylinder alone carries a lot of weight. Hence in future specially designed light weight composite cylinders can be used for better efficiency and results.
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