International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

A Leg - Wheel Robot with Hybridlocomotion to Traverse on Unevenloose Sand Surface

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***Abstract*—Any surveillance robot needs to be maintainstability on all kinds of surfaces but now a days wheel or track type robots are commonly used for surveillance and exploration application, which will fail on the loose sand surfaces because of sinking and slipping possibility and is also difficult to control the movement on these surfaces. The proposed leg wheel type robot will efficiently traverse on loose sand surface using their legs, thus overcoming the sinking and slipping problem and the stability will be maintained on loose sand by providing a better physical contact between robot leg and loose sand surface. On the loose sand surface the robot will move using their legs while in normal flat surface it will fold their legs and move using their wheels. This type of control will improve the robot's locomotion in different terrain. The control system of this proposed robot will be designed based on NI-MYRIO system. This kind of multi terrain robot can be used in exploration and surveillance applications.**

Keywords— NI-MYRIO,Leg,Wheel,LABVIEW

I. INTRODUCTION

A surveillance Robots are usually an electro-mechanical machine guided by a computer program or electronic circuitry. Surveillance robots can be autonomous or semi-autonomous used for reconnaissance and doing work in places too dangerous for humans to enter, such as the site of a hazardous chemical/radioactive leakage or areas with high volcanic activities. Unmanned surveillance robots with wheels and tracks have carried out successful operations in the past. The thrust generated by a wheel and track mechanism relies on the cohesion of the terrain, which is dependent on the area of contact with the terrain, and the friction of the terrain, which is dependent on the angle of internal shearing resistance on the terrain and also the angle of normal load on the wheel/track relative to the terrain.

On a level surface that is soft or ―flowing‖, such as a ground covered with small pebbles or sandy dunes at the beach, a conventional wheel and track mechanism have a danger of slipping and sinking into the ground surface, and at a point the wheel or track is unable to move forward and become stuck. For wheels, the possibility of slipping on a soft flat ground could be reduced by designing and controlling the wheel such as the sinkage, the degree of which the wheel/track is ―buried under the sand surface (Fig. 1).

Fig.1 Sinkage of wheel

The sinkage increases the track/wheel's travelling resistance and decreases its travelling performance. The track mechanism however possesses higher travelling performance compared to wheels because of wheel's smaller contact surface that increases its amount of sinkage. As the sinkage of the wheel increases, the shear and normal stress distributions under the wheel move forward towards the travelling direction resulting in the increase of travelling resistance. The increase in vehicle sinkage and motion resistance due to slipping is known as the slip-sinkage effect. The increase in sinkage due to slipping heightens the danger of the wheel/track to get stuck On a slope made out of soft material such as sand, as the position of the sand in front of the wheel/track is higher facing upslope, it is considered that the wheel or track will experience the same effect as having a deeper sinkage when travelling upslope. The wheel/track is also more prone to dig deeper into the slope when the wheel/track is turned. Since the normal load from the mass of the rover is working further against the forward drawbar pull, the travelling resistance is also larger compared to when on level sand surface. The natural tendency of the soft sand to flow downwards the slope also affects the climbing efficiency as less friction from the internal shearing resistance by the sand could be obtained. For the above reasons, climbing steep slopes made out of uncompacted soft sand is considered extremely difficult.

In this paper, we propose a simple mechanism leg-wheel robot with ground piercing leg parts which angle is independently controllable while moving in loose sand surface and also climbing steep sand slope. The robot is designed to traverse on loose sand and climb over steep slopes made out of uncompact loose sand with the angle of between 30 to 35 degrees. The angle is the highest slope angle the sand could create naturally, at the loose sand surface the robot traverse using their four legs while on the normal flat terrain the robot fold their legs and traverse using their wheels which combined with the robot body, this transformation increase the robot efficiency while moving in unknown loose sand surface with efficient control.

II. DESIGN CONCEPT

In the natural world, it can be observed that legged animals such as camels are able to climb steep slopes of sand in their natural habitat. Legs possess the advantage in movement on sandy slopes because the legs can pierce through the sand to gain a grip. The legs can adjust its angle so that it will pierce the sand vertically and adjust the angle until the leg is lifted again. The leg allow the control of the forward/backward position of the body while climbing on a slope While moving forward the swinging leg is free to cross over any bumps and obstructions. Although the surface of a sand slope is so soft that it causes avalanche‖ of sand downwards the slope, the deeper layer of the sand is relatively rigid as there is a larger friction between the lower layers of sand. By concentrating the body load on the piercing supporting leg, a larger internal shearing resistance could be obtained from the deeper layer of sand. The upward lift and forward thrust for a plate such as a grouser moving in a granular media such as sand, is influenced by the plates depth in the sand, and also the angle of the plates orientation and movement direction. The difference between mounting grousers on the wheel/track and the piercing action of the legs is that, the leg could control its relative angle to the slope from the time of entry until the pulling out from the sand surface, while the grousers on wheel keeps rotating angles and so does the grousers on tracks during entry, under the tracks and pullout from the sand. The angle of the grousers is also fixed to the surface of the wheel and track, which might not be the most optimum angle to gain maximum thrust for surface with varying slope angles.While the supporting leg is firmly in the sand, the swinging leg is able to traverse over any obstructions or bumps on the way. This is important for climbing sand slopes, as the main reason wheels and tracks are unable to climb steep sand slopes is the deep sinkage, which is the difference of height between the lowest part of the wheel/track in the sand and the height of the sand at the upslope direction. A leg will be able to traverse over the steep local slope then pull out the supporting leg behind without continuously digging into the slope’s surface. However, a high Degree of freedom comes with a disadvantage of having complicated control schemes for carrying out simple tasks such traversing over a ground with bumps of various sizes. For that reason we had decided to adopt a leg-wheel mechanism that uses small number ofactuators and utilizes continuous rotating motion to move forward similar to wheels.

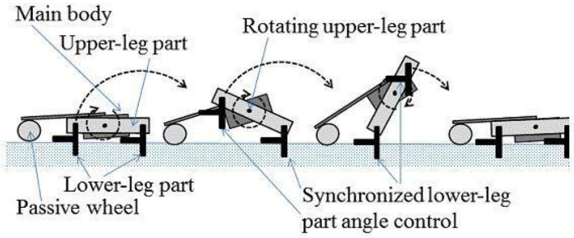

Fig.2 Movement of Proposed robot

The design of our proposed rover is aimed to possess all the listed advantages of leg walking above, while maintaining the simplicity of rotating leg-wheel mechanism. Our robot has two continuously rotating upper-leg parts on the sides of the main body (Fig. 2), and on each upper-leg part there are two lower-leg parts that is able to pierce the ground at an independently set angle.

III. MECHANISM OF ROBOT

A. Body Configuration

The robot consists of the main body that houses 6 DC motors inside, two to control the leg movement, two motors to control leg folding and other two motors control wheel movement. On the sides of the main body, there are two rotating upper-leg parts actuated by the hip joint, and attached to each of the upper-leg parts there are two lower-leg parts actuated by the two knee joints. Attached at the back of the main body is a ―tail‖ with a passive wheel.

Table I: Mechanical parts of the robot

S.No.	Part Name
1	Body frame
2	Geared DC motor frame
3	Lower Leg Part
4	Upper Leg Part
5	Tail
6	Timing belt
7	Gear arrangements
8	Bearing

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B. Leg-Wheel Mechanism

The knee joint and hip joint (fig 3) is independently rotating. The hip joint’s rotation will rotate the upper-leg part which houses the timing chains and sprockets that rotates the knee joint. Since the upper-leg part is rotated with the knee joint’s driving shaft as it’s center of rotation, the resulting angle of the knee joint relative to the main body is unaffected by the rotation of the hip joint For the current prototype, both the left and right upper-leg part is actuated in sync by the same hip joint motor, meaning the robot can only move forward or backward in one direction. All four lower-leg parts are actuated by the same knee joint motor, meaning all the lower-leg parts mechanically maintain the same angle relative to the main body as set by the knee joint

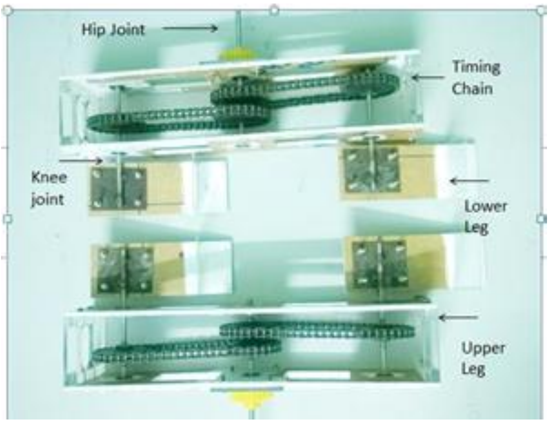

Fig.3. Leg Arrangement

C. Robot Traversing On Wheels

Inorder to traverse on the two motorised wheels the knee part of the robot leg is folded and supportedby wheels. Knee and hip joints are rotated and fixed in a position in such a way that the motorised wheel make contact with the ground surface in this configuration the robot can use the wheels instead of legs for locomotion and this wheel reduce the power consumption. This configuration is suitable for traverse on flat/normal terrain(not loose sand surface) like floors.

The robot left and right turning is achieved by rotating the two wheels in opposite direction.Two wheels driven control mechanism is known as differential drive. The third wheel connected with tail part is an uncontrolled support wheel (free running wheel).

D. MYRIO Device

The National Instruments MYRIO-1900 (Fig.4) is a portable reconfigurable Input/Output (RIO) device that can use to design control, robotics, and mechatronics systems. NI MYRIO places dual-core ARM Cortex-A9 real-time processing and Xilinx FPGA customizable I/O. LABVIEW software is used for MYRIO programming.

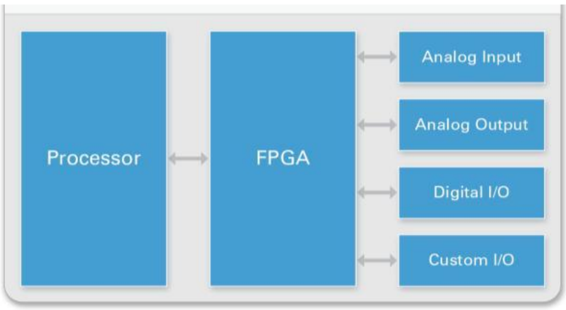

Fig.4. MYRIO Architecture

The full locomotion of the robot is going to be controlled by MYRIO device (Fig.5) and also the video acquired MYRIO, then the received information wirelessly transmitted to host

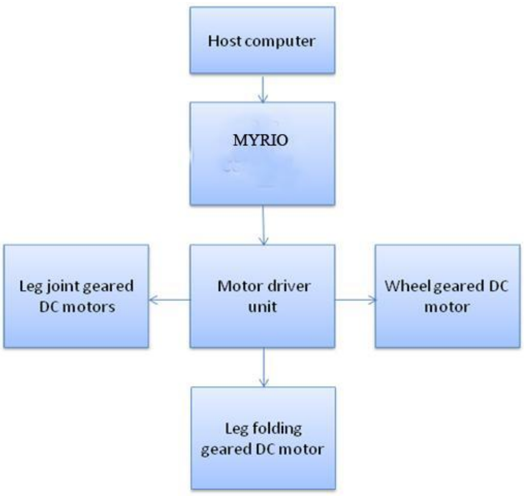

Fig.5. Block Diagram

Computer and also MYRIO receives command signal wirelessly from host computer.

IV. ROBOT MECHANICAL STRUCTURE

The robot mechanical arrangements are all completely designed and constructed. Robot chasse constructed for the leg locomotion and along the control circuitry and robot leg locomotion tested using MYRIO device. Two motors connected with upper leg to rotate the lower leg in circle motion. The center shaft of the body used to fold the leg while the robot traverse on wheel, this hybrid locomotion achieved from this proposed prototype. In this testing the lower leg and upper leg motion control is completely tested and the leg folding technique also tested. The Fig.6 shows the completed mechanical structure.

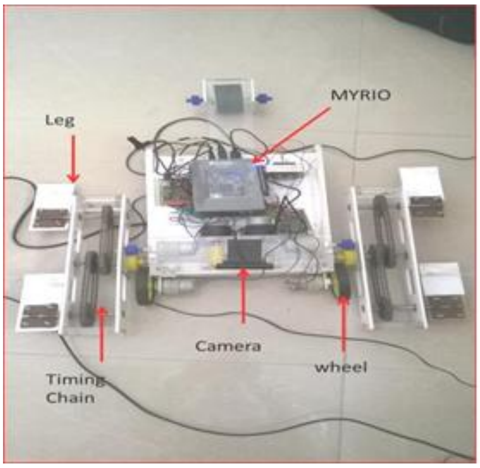

Fig.6. Leg-Wheel Robot

V. RESULTS

The mechanical arrangement of the surveillance robot is completely designed and the other supporting devices like USB camera placed in surveillance robot to monitor the robot movement on terrain. LABVIEW program is developed for Motor control and video acquire process.

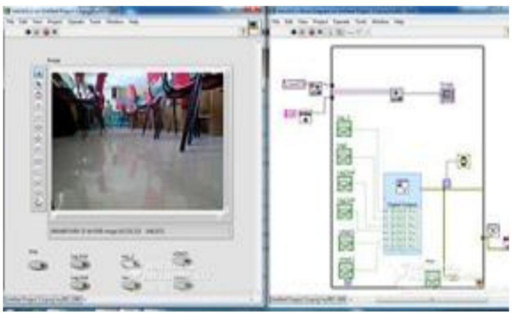

Fig.7. Graphical view of LABVIEW Output

VI. CONCLUSION

We had developed a prototype surveillance robot which utilizes a leg-wheel mechanism that could maintain stability on uneven loose sand surface and also climbing a steep slope made out of soft uncompacted loose sand. Based on the study, the leg-wheel mechanism proved to be more effective as it does not suffer from getting stuck and slip in the loose sand and the both wheel and leg mechanism effectively controlled by MYRIO using LABVIEW software.

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