ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 4, October 2013

Research Paper

STUDY AND ANALYSIS OF SIDEWINDING LOCOMOTION TECHNIQUE FOR THE DEVELOPMENT OF BIO-INSPIRED ROBOT

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Sidewinding is a noble snake gait to locomot at wide and flat ground. It has broad range of advantage; it's very effective when crossing loose or slippery ground so if we like to build a snake like mechanical system which can walk in wide variety of terrain then we have to capture sidewinding motion in our device. In this paper we study and analyze sidewinding locomotion technique to capture this gait in our device, which can locomot over loose or slippery ground. To understand this locomotion technique we have studied sidewinding serpentine gait from biological aspect as well as their equivalent mechanical system. We use simulation technique and Lissajious figure to analyze the matter. From the study it's found, this form of locomotion can be generated by changing of phase of sinusoidal curve and this is explain in this paper through Lissajious figure and one analytical model also prepare for the development of robot.

Keywords: Sidewinding, Lissajious figure, Sinusoidal curve, Snake robot

INTRODUCTION

Limbless serpentine robot is a relatively new and upcoming subject in outdoor mobile robot. Biological snake locomot by their various techniques with the help of their strong muscle. Their all locomotion is generated by some critical biological mechanism (Kevin, 1997). Wheeled machine moves by rotating their wheel, walking machine moves by pushing their legs but snakes locomotion technique are not so easy. We watch it from the out side that a snake locomot through Varity techniques but its locomotion mechanism is understood, but it is difficult to copy in a mechanical system. To make a limbless serpentine robot, we have to face lots of problems and overcome lots of real challenges because simulation of a natural mechanism in a man-made device is really a challenging work. But if we are able to create a snake like device that could slide, glide and slither could open up many applications in exploration hazardous environments,

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inspection and medical interventions (Miller, 1988; Matsuno and Mogi, 2000; Massashi, 2002; and Nakhaei and Meghdari, 2002). Sidewinding locomotion technique have been understood and implemented and their viability demonstrates in our prototype. Serpentine robot is design by using a number of angular drives and creating Coupling at joints. For control the robot movement, we control the movement of head in such a way that other parts of the robot follow it. These types of robot is more acceptable for its stability, terrainability, high redundancy and completely for these properties it is useful in exploration, medical and inspection of pipelines and it's also efficient for search and rescue work (Hirose, 1993; and Hannan and Walker, 2001).

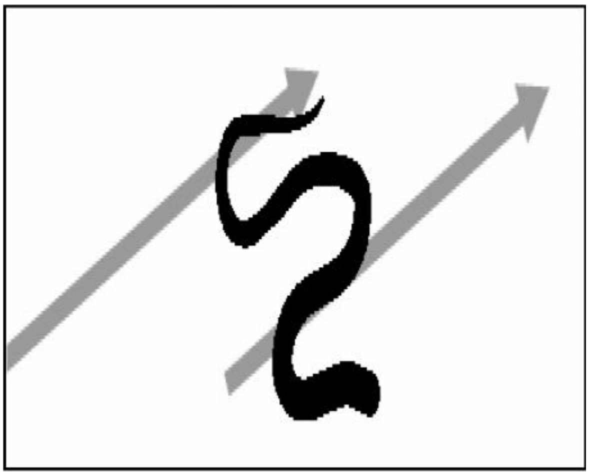
BIOLOGY OF A SNAKE

Understanding the snake physiology is an important step for developing a snake robot model. A short description about physical characteristics of a snake, snake skeleton and skin are stated here which are very important to design a snake like robot. The skeleton of a snake often consists of at least 130 vertebrae, and can exceed 400 vertebrae. The range of movement between each joint is limited to between 10° and 20° for rotation from side to side, and to a few degrees of rotation when moving up and down. A large total curvature of the snake body is still possible because of the high number of vertebrae. A very small rotation is also possible around the direction along the snake body. This property is employed when the snake moves sideways by side-winding. A snake skin consists of a scaly integument that protects the animal from abrasion and prevents water loss. The integument on the snake's back and sides is thinner than that of the belly. Scales on the back and sides are more numerous than belly scales and are either smooth or keeled with noticeable ridges. Snake scales are dry and highly polished with a coefficient of friction of between 0.3 and 0.4. The skin, to which the scales are attached, is highly elastic (Ghosh and Dutta, 2010).

DIFFERENT TYPES LOCOMOTION OF A SNAKE

Most biological snakes employ four major types of motion (1) Lateral Undulation: Lateral Undulation is the common serpentine locomotion of snakes. In lateral undulation, as in simple undulation, waves of lateral bending are propagated along the body from head to tail. (2) Sidewinding: Types of sinusoidal motion of snake. (3) Concertina: it is special types of snake motion unlike the continuous, simultaneous body movements in lateral undulation; the concertina gait uses a progressive, body extension pattern. In this type of motion body starts compressed, folded in a posture similar to an accordion. (4) Rectilinear: In this snake locomotion

Figure 1: Side Winding Motion of a Snake

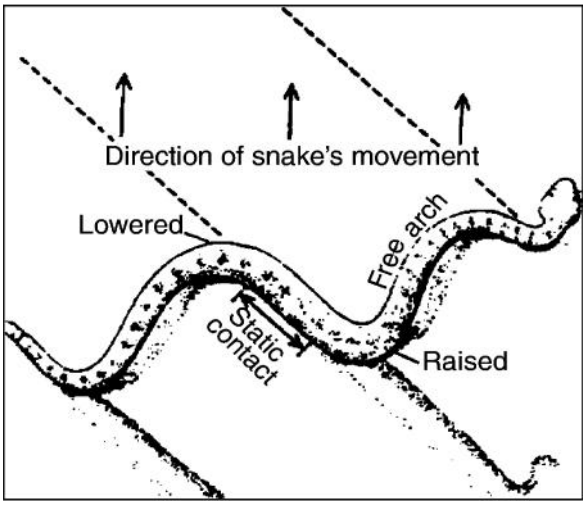


mechanism the snake propels itself in a straight line by moving scales on its stomach in a wave like motion. Rectilinear motion helps the snakes to access very confined spaces (www.voronoi.com). Slide pushing is used on flat grounds. The snake takes the shape of a 'S'. The curvature, result of the contraction wave, progresses through the snake tail ward and contacts with the environment in sequence on the left, then on the right, as the wave propagates, the curvature slips backward. as a reaction to the slip friction, a propulsion force appears which results in a sinusoid trajectory of the gravity center. Waves of bending pass backward along the body, exerting a thrust against vertical projections in the surroundings. This mode of displacement is very energy consuming since about two thirds of the movement quantity are lost (Hirose, 1993).

STUDY OF SIDE-WINDING MOTION

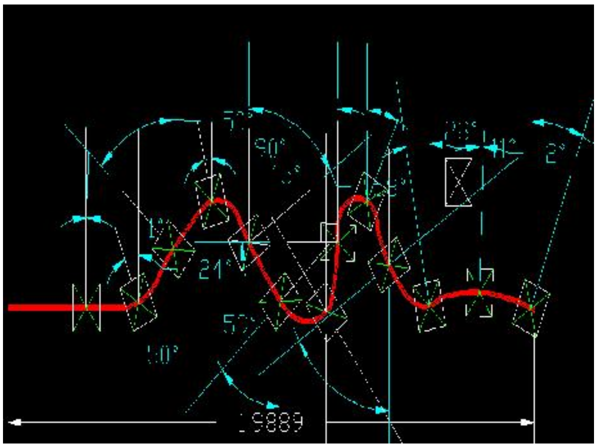
The snake makes contact with the ground at only two points while moving its body in a 'sinusoidal' motion. As a result of which the snake moves sideways rather than forward. Side winding is least dependent on friction with the surface. This mode of locomotion technique mainly uses those snakes that are living in the desert (though some non-desert dwellers also use it), where the sand simply gives way under any kind of push. In this motion, dwellers do not progress forward but actually go sideways. Relatively larger amount of energy is expended by attempting this type of motion. This motion is mostly used in low friction ground. In this motion, static contact with the ground is needed. Two points of contact are required for formation of this motion, the segment that is not connected with ground is lifted and simultaneously moved by side and a new contact point is made. Then the previous contact point is also lifted and moves in side and repeating this movement snake moves in a specific side. To perform this motion snake need a complex anatomy and skeleton structure with strong muscle. Snake can move up to 3 km/h by side-winding motion (Sir James, 1968; and Chirikjian and Burdick, 1995).

Figure 2: Side Winding Motion Technique



In this type of motion the body parts which are not in contact with the surfaces are lifted and moved to the side hence becoming the new contact points. The previous contact points are then lifted and moved. Repetition of this type of motion directs the snake to move sideways rather than forward. Thus as a result of this type of movement (i.e., the parts are lifted and moved) the snake performs its motion both in the horizontal as well as in the vertical planes. Thus in our eight link serpentine robot's prototype, the eight links that are required to keep the nine blocks together are fixed alternately on the horizontal plane and on the vertical plane. As a result of which the

Figure 3: Snap Shot of the Snake Robot Model



motors which are required to drive our robot have been classified as horizontal motors (denoted by H1, H2, and H3 and H4) and vertical motors (as V1, V2, V3 and V4), by rotation of those motor in vertical and horizontal direction we can simulate sidewinding motion in our robot.

ANALYSIS OF SIDE WENDING MOTION BY LISSAJIOUS FIGURE

A Lissajious figure is produced by taking two sine waves and displaying them at right angles to each other. This is easily done on an oscilloscope in *XY* mode. The outcome of figure is highly dependent on *a*/*b* ratio, in general for *a*/*b* = 1 outcome is circle. We use oscilloscope and result plotted for different *a*/*b* ratio. Lissajious figures are family of curves generated by parametric equations.

X = *a* sin (µ*t* + ¨) ...(1)

Y = *b* sin (µ*t* + ¨) ...(2)

Different kind of lissajious figures can be obtained by having different values of *a*, *b*, µ and ¨.

- When µ = 1, ¨ = 0, then the lissajiuos figure obtained is a straight line on the right hand side as shown in the Figure 4.
- When µ = 1, ¨ = ®, then the lissajious figure obtained is a straight line on the left hand side as shown in the Figure 5.
- When *a* = *b*, µ = 1, ¨= ®/2, then the lissajious figure obtained is a circle as shown in the Figure 6.

Figure 4: Lissajious Figure Obtained When µ = 1, ¨ = 0

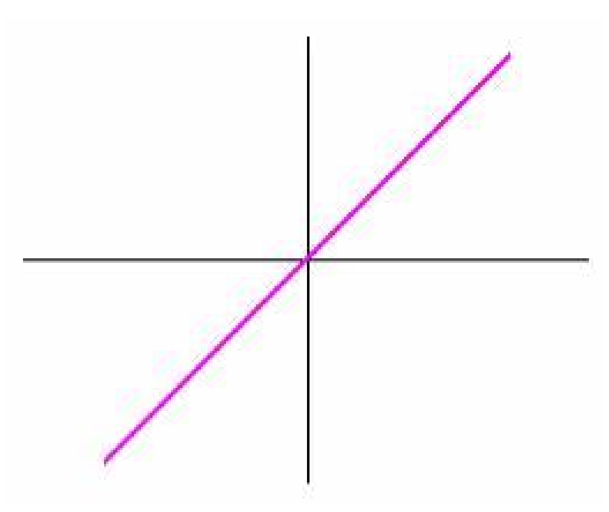


Figure 5: Lissajious Figure Obtained When µ = 1, ¨ = ®

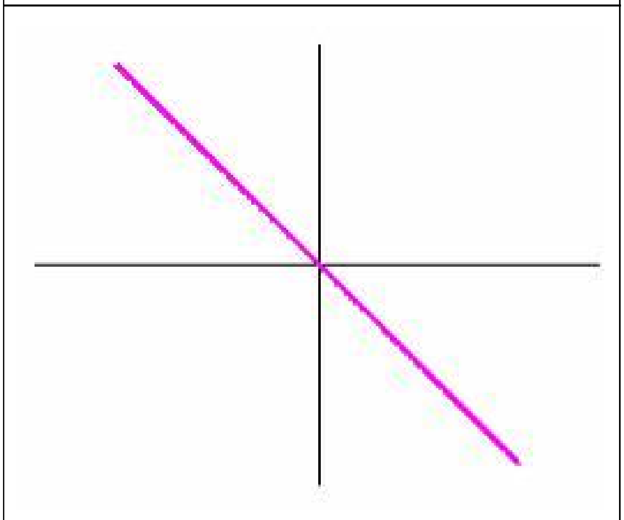
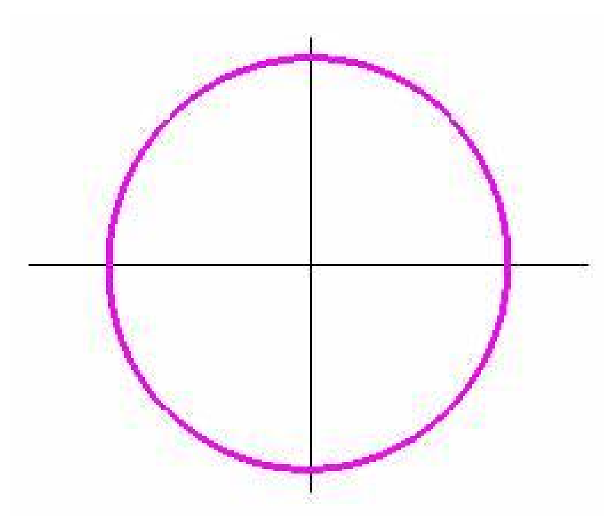


Figure 6: Lissajious Figure Obtained When a = b, µ = 1, ¨ = ®/2



Different lissajious figures can be obtained by different values of µ and ¨. We obtain an ellipse by varying the values of µ and ¨. When the value of ¨ is ®/2and $a \neq b$, then the lissajious figure is an ellipse.

The phenomena of lissajious figures are applicable in case of side winding motion. In case of side winding motion the first and last which are the principle blocks for executing the side winding motion are at a phase difference of ®/2 and the amplitudes of these blocks are also same. If we see the two blocks we can see that the blocks are at a phase difference of ®/2.If we fix one of the blocks and rotate the other block with respect to that block we can see that block forms a circle.

Because of formation of this circle the snake is able to move in sideward direction. The blocks form two circles which helps the snake to move in the side ward direction. When one of the blocks is in motion the other block is stationary and this moving block forms a circle with respect to the fixed block. To illustrate it further consider two links which are attached to each other with the help of a motor. One end of the link is fixed to a frame and other is attached to other link with the help of a motor and the motors are given motion with respect to each other, because of this induced motion the free end of system forms a circular path, which is illustrated in the following Figure:

Figure 7: This Arrangement is Used for Obtaining a Straight Line

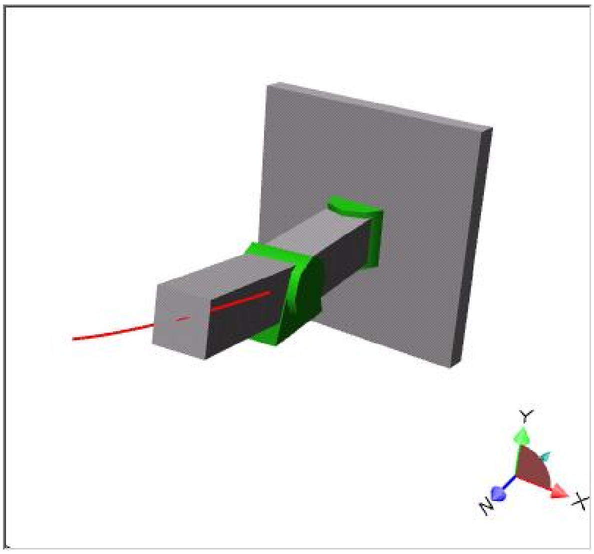
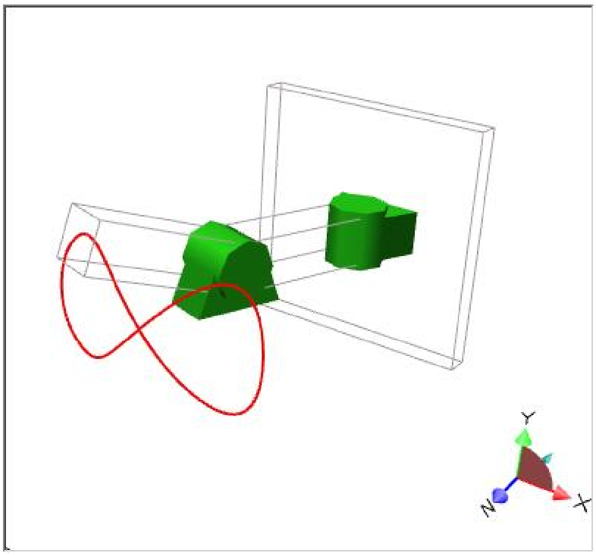


Figure 8: This Arrangement is Used for Obtaining an Ellipse



Thus all kinds of lissajious figures can be obtained with this kind of arrangement, which is illustrated in the above figures:

But we are concerned mainly with circular kind of lissajious figures because they are mainly responsible the side winding motion.

You must be wondering what the other intermediate blocks are doing? When the first and last blocks are in contact with the ground the intermediate blocks are slightly elevated which provides thrust for the continuity of the motion and when they release the ground the intermediate blocks are in contact with the ground. Thus in short the blocks are in contact with the ground in the form of a sinusoidal curve. Thus side winding motion is also a derivative of sinusoidal motion like lateral undulation motion.

CONCLUSION

We have studied all this things from various sources and develop one idea to simulate a serpentine robot and studied various mathematical models. We try to achieve a optimize model from both scientifically and economically. Up to this portion we studied all aspects of design and mathematical optimization process. . We are yet to apply these things and make the physical model. So, whatever realistic and practical changes necessary we are going to bring in it in our physical model. Some possible applications of this serpentine robot are:

- Fully autonomous search for survivors of earthquakes and other disasters underneath the rubble of collapsed buildings, military applications in very rugged terrain.

The serpentine robot design is also suitable in principle to crawling through pipes or burrowing through soft soil.

ACKNOWLEDGEMENT

This work was supported by Kalyani Government Engineering College (KGEC) and Central Mechanical Engineering Research Institute and it's a part of my undergraduate thesis work. I would like to thanks to my guide Dr. Atanu Maity, Scientist, CMERI for his encouragement and throughout guidance.

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