Monty, the Snake Robot

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Abstract

The goal of this project is to design an autonomous snake robot that will lead to future improved designs. The snake will avoid obstacles using IR emitters/detectors and bump sensors. It will also be able to detect motion using a security motion sensor.

Executive Summary

For this Robotics project I built a snake named Monty. Monty starts moving straight (rectilinear). If he detects an obstacle with his IR emitters, he will immediately turn the opposite way by bending all joints in that direction. When Monty gets bumped by an object, he coils right for a while, stops for a while, and then starts moving again. Every so often he stops moving and tries to detect motion both near and far. If motion is detected he turns in that direction. If the motion was up close he turns sharply if it was far it will turn in that direction gradually. He continues to avoid obstacles even if he is following the motion he detected. He will get around the object and then continue in the same motion as he was before he saw the object. When he gets bored he begins to slither for a while and then returns to rectilinear motion.

Introduction

In order to appear as though it is moving like a real snake, my snake can crawl “straight” forward and slither in order to move from place to place. While moving, Monty does the traditional robot detecting and avoiding obstacles.

Integrated System

Monty measures approximately 5 feet long and 15 inches in circumference. He is made up of 6 sections, four active sections that both bend and move forward, one head section, one brain section that doesn’t move and a limp tail. Each active section is 5 inches long and about 5” wide. In between two adjacent sections is 1½” of space that allow the “joint” to bend in both directions.

Sensors

The sensors are located in the head of the snake. Monty has ir emitters, ir detectors, bump switches and a motion detector. Both the ir and the bump switches are used for obstacle detection and avoidance. The motion sensor is meant for the snake to be able to chase a mechanical mouse, although there is no mechanical mouse for this purpose at this time.

Behaviors

The snake detects obstacles, avoids collisions, slithers (as opposed to mostly straight “crawling” movement), and coil, and chase “mice.”

Movement Theory

The snake begins moving straight forward (motion referred to as "rectilinear"). Upon detecting an object, it begins to turn left or right until it no longer sees the object. If it bumps an object it did not detect, the snake coils up, wait a few moments, and then starts moving again.

The segments and joints of the snake allow it to bend while moving forward, appearing to slither. They also allow it to coil up when all the joints are bent in the same direction. Every other segment moves forward at the same time. This movement closely represents the series of waves used to move a real snake when using serpentine locomotion (slithering).

One servo controls the bending of each joint, acting as a pivot. Each pivot holds two snake segments about 1½" apart, while set for straight forward movement. When a signal tells a particular joint to bend to the left, the pivot draws the two left sides of the segments together and pushes the right sides apart. This works similarly for bending right. Alternating or simultaneous bending will allow the slither effect and coiling (See Figure 1).

The snake moves forward using one servo to move a tank tread inside each active segment. The tank treads slide forward and grip while moving backward, causing the snake to move forward when they are moving backward. This movement represents the "snake scale" motion of a snake's belly(See Figure 1).

Mechanical Design

For the movement of my snake I have one servo to bend the joints, for creating the slithering effect and turning, and one servo to move the snake forward. The forward moving design looks similar to a tank tread only that is uses a material that slips in one direction and grips in the other, ideally. Since snakes don't move in reverse, my robot only needs the material to grip in one direction and will just simply turn around when necessary.

After deciding that I would design a robotic snake, I needed to come up with the size requirements before jumping into the actuation. I wanted to use the MRC11 processor board because it is the smallest board that didn't have extremely small memory restrictions. In order to fit this board into my robot, I need about 5" in diameter in the thickest section of the snake (3 ½" for the board and 1 ½" for busses).

To simulate the slithering motion of a snake, my robot needed to be made up of a discrete number of segments. The length of each section depended on what was required to be in each section.

Ideas Behind My Snake's Development

Structure

I wanted my snake to have a shape similar to that of a snake. This ruled out both the PVC piping and cardboard carpet tubes that I was considering. I needed a strong but flexible material for the frame of my snake so I could shape the material into a snake-like cross-section. I decide to use ½" chicken wire that has both these properties.

Bending and Turning

At first for the bending and turning of the snake, I came up with a design using on servo placed in the middle of an edge on a segment. This method used the servo like a pivot except that one side of the snake segments would be pulled together while the other was forced to stay in place with a spring. This would make the 1 ½" distance between segments be a maximum, desired to reduce the segmented look if a skin were placed over the snake. However, this method limited how tight one joint could bend; thus, limiting the turning or coiling radius of the snake. Based on this downfall and the advice of Dave Novick(MIL @ UF) I decided to make the servo a plain pivot which would allow tighter coiling.

Coiling

I mentioned above that using a plain pivot allows the snake to make a tighter coil. Figure 1 below shows the triangle in between two segments created when the joint between the two segments bends as much as possible. The peak of the triangle is the side of that the snake is turning toward (being pulled together by pivot) and the base is the side the snake is turning away from(being pushed apart by pivot).

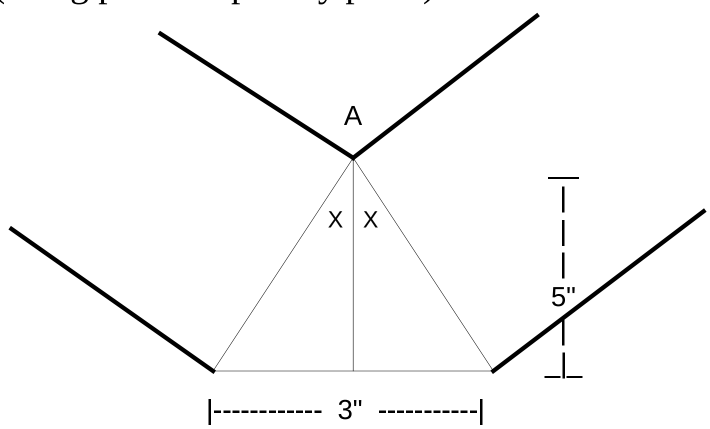


Figure 1 -- Snake Coiling

According to this figure, $\sin(X) = 1.5/5$ therefore, $X = 17.46°$

Since the snake is made up of segments, when it coils it will look similar to a polygon whose number of sides, n, depends on the angle between adjacent sides, *A*. The relationship between *A* and n is:

$An = 180(n-2)$ -- given *A* solve for n the # of sides in the polygon

A is also determined from the equation:

$$A = 360° - 90° - 90° - 2X = 145.08°$$

Solving for n in the other equation gives n = 10.29 sides to the polygon, or 10 segments to make one coil. Using the same method it can be proven that having a normal pivot as opposed to the original unidirectional “pivot” will allow for less segments to one coil. Using the unidirectional “pivot” $n \approx 20$.

Notice that the number of segments for one coil doesn't depend on the length of the segments, only on the diameter of the segments and the spacing between them. However, even though the distance between each segment and the length of each segment will be the same for the entire length of the snake, the diameter of the segments will get smaller toward each end of the snake. Thus, ten segments per coil is an upper bound, making it a bit more appealing than it seems originally.

Moving Forward

After speaking to Mechanical, electrical, and computer engineers about designs to make my snake move forward, I decided to go with one of my own ideas. To make the snake move forward, I wanted to use a tank tread. There would only need to be one tread because the pivot servo above controls bending/turning motion. I wanted to use a material that would slip in one direction and grip in the other. This simulates the way a real snake moves using his belly scales that slip forward and scoop backward, pulling the snake forward. I figured I needed about 3" of this material to touch the ground at one time to create enough friction to move the snake. This 3" along with the servo for bending and some spacing make each section about 5" long. This means the snake will have between 20-24 segments to make it 10'-12' long.

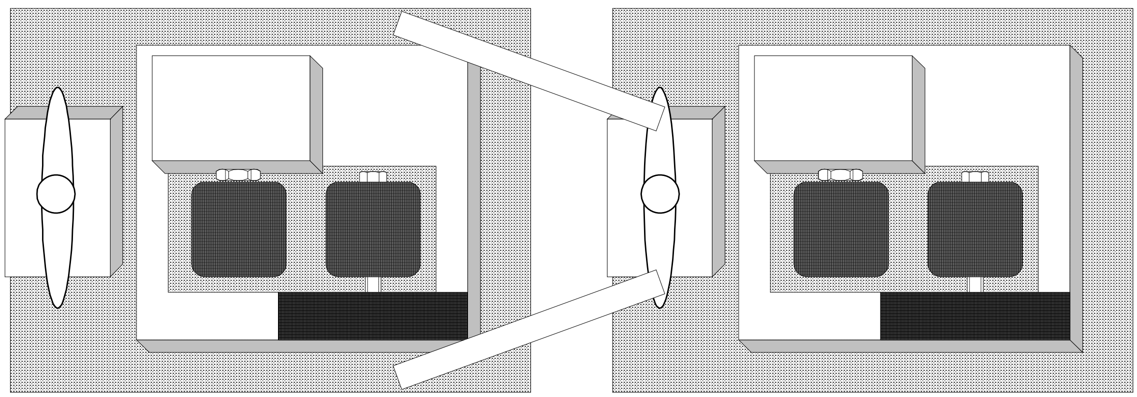
Actuation

The pivot servo would be realized with the longest servo horn that comes with the servo. I made a rod out of a ¼" wooden dowel with looped screws attached to each end. The ends of the wooden rod were attached to both the propeller and the chicken wire frame using lock washers found at Lowe's.

To move the snake forward, I initially tried to put rollers on the bottom of the chicken wire segment and have a servo on its side that would control the turning of the tread. However, when I implemented this design it failed miserably. It was not mechanically sturdy enough to move the tread as much as required. The servo moved instead of turning the tread, taking about half of the servo's torque.

Again, Scott Jantz helped me come up with a more sturdy method to implement the same basic idea of the rollers. I used one servo on its side screwed to a wooden platform with a rectangular hole in the middle for the tread. I connected a 1 ¾" dowel to the servo and nailed another dowel next to the servo. The tread material connects around both of these dowels to increase the area of tread material touching the ground at one time. This method proved much sturdier than having the servo attached to the side of the chicken wire segment with strong wire.

The following figure shows a top-view of the updated design.



I constructed three segments and tested their movement with a remote control. The remote control only had two channels so I placed them on the front and the back servos. I moved them in the same direction, both slipping then both gripping, alternating each time they reached their current destination. The robot did move forward although it was rather slow because when the treads were supposed to slip they actually moved it back some too. However the gripping moved them forward more than the slipping moved them backward.

When I had all four active segments built, I tested them for forward movement and this was better than with just the three servos. However, it did leave something to be desired. The snake needed more weight to move efficiently. I added a clay head and an inactive segment that held the Motorola 68HC11 microprocessor, and an inactive styrofoam tail.

In the head, I added a single servo in the head with the thermoplastic rubber around it to create more forward motion. This hacked-servo spins constantly in the "grip" direction.

Conclusions and Future Work

I ran into problems with the speed of the servos limiting the Monty's movement. I appear to have too light of a design, not utilizing the full potential of the sawtooth TPR tread material. Plus, I have run into many problems with the bending movement. The segments have twisted off of the ground, and have faced resistance when moving from one extreme to the next (from left to right or right to left), causing the body of the snake to raise off the ground or twist. I believe that the snake needs to be entirely re-designed taking into consideration the problems I have faced.