Arduino-Powered Snake Robot: A Smart Solution for Urban Infrastructure Inspection

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Abstract: **Robots are machines that perform mechanical and repetitive tasks with little to no interaction with humans. Robots are designed to remove human factors from dangerous workplaces and to act in an inaccessible environment. When it comes to pipeline inspection, snake robots can easily access a wide range of pipelines, including pipes in the oil industry (thick diameter) and sewer pipers (small diameter). Properties such as high trainability, redundancy, and the possibility of complete sealing of the body of the robot make snake robots very interesting for practical applications and hence as a research topic. During the last ten to fifteen years, the published literature on snake robots has increased vastly. However, no thorough review of the theory presented in this period regarding mathematical modelling techniques and the locomotion of snake robots has been found. The purpose of this paper is to give such a review. As a step towards enabling snake robots to move in cluttered environments, this paper proposes a control strategy that combines environment adaptation with directional control to achieve a straight-line path following control in environments with obstacles.**

Keywords — **Robotic snake, pipeline inspection, 3D Printer, IR sensor.**

1. INTRODUCTION

In nature, the snake is one of the creatures that exhibit excellent mobility in various terrains. It is able to move through narrow passages and climb on rough ground. This property of mobility is attempted recreated in robots that look and move like snakes. Snake robots most often have a high number of degrees of freedom (DOF) and they are able to locomote without using active wheels or legs.

One of many examples is rescue missions in earthquake areas. The snake robot can also be used for surveillance and maintenance of complex and possibly dangerous structures such as nuclear plants or pipelines. In a city, it could inspect the sewer system looking for leaks or aiding fire-fighters. Also, snake robots with one end fixed to a base may be used as a robot manipulator which can reach hard-to-get-to places.

Compared to wheeled and legged mobile mechanisms, the snake robot offers high stability and good terrain ability. The exterior can be completely sealed to keep dust and fluids out. Due to high redundancy and modularity, the snake robot is robust to mechanical failure. Some examples are: multi-link mobile robot, snake-like or snake robot, hyper-redundant robot and G-snake. To emphasize that this paper deals with robots that mainly resemble locomotion of snakes, the term "snake robot" will be employed. The snake robots presented are implemented either with passive wheels, or without wheels. The joints are mostly revolute, but extensible (prismatic) joints are also employed .Motion patterns of snakes, inch worms and caterpillars are used as an inspiration for how the snake robots should move. Mathematical models of the snake robots are needed to analyze the motion patterns and to simulate their motion. Because of the high number of DOF, the construction of such models is a challenge. During the last ten to fifteen years, the published literature on snake robots has increased vastly, and the purpose of this article is to provide an overview and comparison of the various mathematical models and locomotion principles of the snake robot presented during this period. The main intention of this study is to design a robot for inspecting certain areas which cannot be inspected by human beings. It was understood that the robot should be flexible enough to travel through tightly packed surrounding. Snake robots are agile enough to reach such areas with their different degrees of movements [2].

This Research consists of ten degree of motion snake robot with an inbuilt camera for inspection. There are ten brackets in the robot and each bracket holds a servo

motor. These brackets of the robot are designed using the software Fusion 360. The designed parts were 3D printed. The head of the snake was designed in such a way to house a microcontroller, a battery, a RF (Radio Frequency) module and a camera module. The tail of the snake was designed to house a battery pack for the servo motors.

2. LITERATURE REVIEW

Shigeo Hirose, Edwardo Fukushima (2003) concludes that due to snake-like design of snake robots they can be used in disaster management. Japanese government is taking steps to promote research in the field of snake robots. According to them technology can be used for developing snake robots which can walk through narrow spaces under collapsed buildings to supply energy, establish communication link. They pointed out the limitations of poor battery life and performance and their range.

Pal Liljeback, Kristin Y. Pettersen, et.al. (2010) conclude that snake robots have several limitations that they cannot climb, cannot walk over rough surfaces etc. So engineers are working to solve these problems. They also explained the locomotion of snake robots.

Blessy Markose , Harshitha Loke (2014) the researchers analyzed the adaptability of snake robots in search & rescue operations and how these robots can reach places like narrow cracks, rough terrains and extreme environments. But snake robots do have certain limitations like poor power efficiency and lesser control but the researchers conclude that innovation can overcome these limitations and snake robots can be a very successful mechanism.

Wong Cho Giap: he explained about the programming for the snake like movement but there are also some limitations like the robot could not predict which direction to take after overcoming an obstacle Again innovation can overcome these limitations.

3. METHODOLOGY/EXPERIMENTAL

The robot (Slyder) consists of 3D designed and printed brackets, where each bracket is controlled by a high torque servo motor. Arduino Mega was used as the main controller which commands the servo motors. This controller was programmed using the Arduino IDE program. The 3D designed model can make forward, backwards as well as turning movements.

The simulated Slyder is controlled by a Bluetooth module which has a range of 20m is sufficient for pipe inspections. Here is the block diagram of designed Slyder:
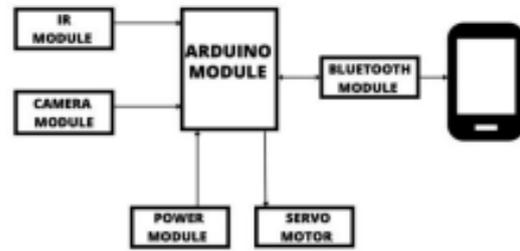

Fig. 1. Block Diagram of System

Basically, Snake Robot has Twelve 180 degree Robot Servo Motors used for the prototype.

The microcontroller was powered by a 10V battery. The twelve servo motors are powered by a 6V battery. Wi-Fi cameras were used to get the live video feed to the desired device, so that the robot can be remotely controlled. The microcontroller, LED lights and the Camera module are placed at the head of the 3D model.

One white light LEDs was placed at the head of Slyder as the Camera Module doesn't have night vision capabilities. LEDs were powered by Arduino Mega with output of 3V.
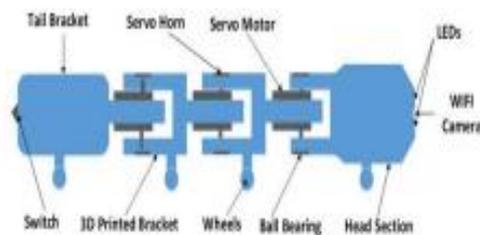
A. Model of Slyder

Fig. 2. 3D Model of Slyder

Figure reveals the side view of Slyder. This figure presents only three servo brackets but Slyder has 12 servo brackets for smooth locomotion. Wheels have been used to reduce the friction between the moving plane and Slyder. Small ball bearings have been used as wheels. Each servo motor moves freely inside the designed servo brackets. The selected motors have a freedom of 180 angle rotation.

The LEDs, Camera Module and Microcontroller are connected to the front holes of the head Slyder. The IR sensor is used to detect the objects which are in the

path of SnakeBot and are positioned at head of Slyder.

B. Motions implemented for Pipeline inspection
Bio-inspired movements like serpentine motion, slithering motion were implemented on Slyder.

Compared to other gaits of a real snake, these gaits are more suited for pipe motions. To make it move like serpentine motion two perpendicular sine waves are implemented on simulated Slyder.

Due to which, Slyder can move in forward and backward direction using this movement. The serpentine or slithering motion of Slyder was achieved by using a few variables to control the speed, amplitude and wavelength of the sinusoidal motion. PTC Creo Software is used for building 3D simulated SnakeBot.
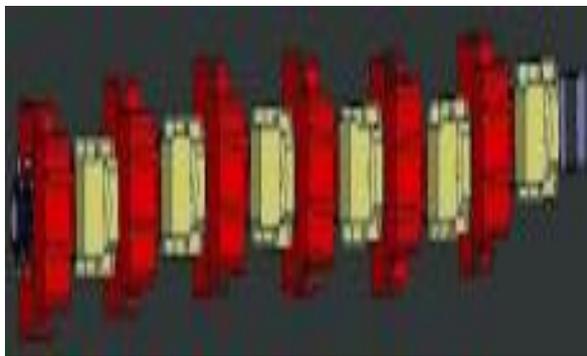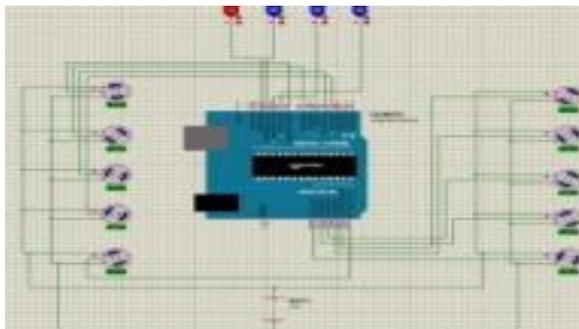

Fig. 3. Top View of Simulated SnakeBot

Fig. 4. Circuit Diagram of SnakeBot

C. Inspection Procedure

a) Liquid has to be drained: The pipe under inspection has to be completely dry as Slyder is not waterproof or water resistant.

b) Underground / Above ground inspection: Slyder has been controlled using a Bluetooth module which can help us to find the blockage in the pipes, which can be inspected at that time instant.

Fig. 5. Liquid Flow path

4. RESULTS AND DISCUSSIONS

Snake robot is an innovation that has a great scope in India and we should look forward to use snake robots in a wide range of applications. Snake robots, thus, holds a lot in future and great scope for India.

5. SIMULATION IN PROTEUS

The complete control circuit of Slyder was simulated in Proteus 8 program. A battery was selected to power the motors after the successful simulation. The simulation as presented in Fig. 4 ensured that the servo angles for each gait were correct. The servo angles were monitored in Proteus simulation before implementing the code in the actual controller. The motors had to be aligned to 900 to ensure that the motors doesn't make any random movements which could damage the brackets or the motor itself. A four button radio frequency remote controller was designed and simulated in Proteus. Fig. 10 depicts the results of the designed radio frequency controller.

Servo angle simulation result

The current draw for each gait with five link were recorded. Summarizes the results obtained by measuring the current draw required for each gait. A 10A rated ammeter was used to measure the current draw. The bar chart proves that concertina gait is the most efficient gait in terms of power consumption. Vertical sine wave gait is the least energy efficient gait.
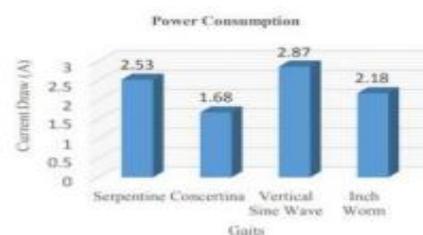

Fig.6. Current draw for each gait

6. LIMITATIONS

The control range of Bluetooth Controlled robot is limited as the range of Bluetooth communication of modules used is limited (maximum to 20 meters).The battery life and endurance are remarkable limitations for a snake robot. Some of the maintenance tasks require power supply from the platform or vessel on the surface. The snake type movements of the robot will demand very accurate motion sensors without latency to be used with survey and inspection sensors. This snake robot model uses heavy mechanical equipment like universal joints and threads which may affect the motor performance.

7. FUTURE SCOPE

Robotics is now being practically used in every field from agriculture to aeronautics, from education to medical, from production to entertainment, from domestic help to advance research.

For medical purposes, a snake robot has great scope. In 2015 the system had approved this robot for head and neck surgeries. The surgeon navigates the snake-like robot down the patient's throat to the surgical target, where the flex stiffens to provide a platform. Snake robots are not future technology rather a near future technology soon to become present technology and holds a lot of scope in India.

With future innovation, the potential of snake robots can be exploited and give way to infinite application.

8. CONCLUSION

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Inspection robot for indoor and outdoor purposes is common in industrial point of view. However, an inspection robot for a tightly packed area needs special design and development of a system.

Spotting a blockage or a damage inside a pipe line or any other tightly packed space is an impossible task for human beings. This prototype was designed to fit inside a pipeline which can be remotely controlled. The navigation was remotely controlled with the help of the video feedback from Wi-Fi camera. This prototype reduces the challenges faced by many industries which uses pipeline for certain production purposes. Certain aspects of this prototype can be modified and improved. The robot can be equipped with more sensors like ultrasonic, thermal, gas, smoke, alcohol and pressure. Night vision and 360° cameras could be used to improve the navigation and surveillance. GPS could be installed on the snake robot to get the exact location of the damages in the pipe. The segment alignment could be altered to achieve a 3D motion.

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