Review on Snake Robot for Search and Rescue in Narrow Spaces

Jyothi. M[1], Subi B.S[2], Akshaya S[3], Varsha J.S[4], Divya Madhu[5]

[1,2,3,4]UG Scholar, Department of Electronics and Communication Engineering, Dr. APJ Abdul Kalam Technological University Kerala, India
[5]Assistant Professor, Department of Electronics and Communication Engineering, Dr. APJ Abdul Kalam Technological University Kerala, India

ABSTRACT

The motivation for snake robots originates from natural snakes. Snakes show better versatility abilities and can move over basically any kind of landscape, including limited and restricted spaces. Like a snake, robot has an exceptionally expressed robot controller arm with the capacity of giving its own drive. Wheel-less, limbless secluded Snake-like robot (Snake Robot) has superior capacities in flexibility and adoptability to nature in examination with the most haggled vehicles. Some helpful highlights of snake-like robots incorporate smaller size of the cross-sectional regions, steadiness, capacity to work in troublesome landscape, great footing, high redundancy and complete fixing of the inside systems. Our model consists of multiple links joined together to create propulsion on its own in a spatial environment. The first Link (head) can have various configurations like camera, gripper, etc. This makes the snake robot ideal for search and rescue operation.

INTRODUCTION

Snake robots are innovative, limbless machines designed to mimic the movement of snakes. Their flexibility and ability to traverse rough terrain make them ideal for search and rescue missions in environments inaccessible to humans. These robots can navigate through rubble, narrow spaces, and uneven surfaces, equipped with cameras and sensors to locate survivors or hazards while minimizing risk to human responders. Their adaptability and agility make snake robots invaluable assets in challenging rescue operations. Snake robots are designed with a series of linked segments, resembling the body of a snake. This modular structure allows them to move in a wave-like fashion, enabling them to navigate various terrains and tight spaces that traditional wheeled or tracked robots might find difficult or impossible to access. Their ability to bend and twist allows them to maneuver through cluttered or uneven environments such as collapsed buildings, rubble, or narrow passages. Many snake robots are composed of individual segments, which can move independently. This modularity enhances their adaptability to different situations and terrains. Equipped with sensors like cameras, thermal imaging, gas detectors, and microphones, these robots provide valuable data to rescue teams. They can locate survivors, assess the structural integrity of buildings, or identify hazards like gas leaks or fires. Snake robots are an innovative form of robotics inspired by the locomotion of serpents. These machines are designed with a series of connected modules that mimic the movements of a snake's body. Their flexible structure allows them to navigate through complex environments such as rubble, tight spaces, or uneven terrains, making them valuable in tasks ranging from search and rescue missions to exploration in hazardous or inaccessible areas. Equipped with sensors and cameras, these robots provide crucial data while reducing risks for human responders, showcasing their versatility and potential across various industries.

LITERATURE REVIEW

M. Tesch, A. O'Neill and H. Choset [1] Snake robots have enormous potential to thread through tightly packed spaces and relay knowledge to search and rescue workers which is currently unattainable during the first hours of rescue operations. However, the existing approaches to snake robot locomotion in three dimensions is primarily limited to cyclic gaits, which lose effectiveness as the ratio of obstacle size to robot size or the irregularity of the environment increase. To this end, this work investigates a kinesthetic input approach to developing joint angle trajectories for overcoming these obstacles for which gaits are inadequate. The second contribution of this paper is the presentation and validation of a method to simplify these trajectories so that they can be easily stored, parameterized, and adjusted. Finally, we demonstrate that a simple sensor deviation filtering and thresholding approach can be used to quickly detect failure when overcoming an obstacle.

D. Rollinson et al., [2] This paper details the design and architecture of a series elastic actuated snake robot, the SEA Snake. The robot consists of a series chain of 1-DOF modules that are capable of torque, velocity and position control. Additionally, each module includes a high-speed Ethernet communications bus, internal IMU, modular electro-mechanical interface, and ARM based on-board control electronics.

K. Lipkin et al.[3] This paper describes a series of gaits which we developed for a free crawling snake robot. Snake robots, a class of hyper-redundant mechanisms, can use their many degrees of freedom to achieve a variety of locomotion capabilities. Like their biological counterparts, snake robots locomote using cyclic motions called gaits. These cyclic motions directly control the snake robot's internal degrees of freedom which causes a net motion (e.g. sining moves the robot forward, strafing moves the robot laterally, and spinning rotates the robot about its center). The gaits described in this paper fall into two categories: differentiable and piecewise differentiable. The differentiable gaits, as their name suggests, can be described by a differentiable function whereas the piecewise cannot. This paper describes the functions we prescribed for gait generation and our experiencesin making these robots operate in real experiments.

S. Hirose and M. Mori,[4] Here they developed the snake-like robot since 1972. The body of snake has "the function of an arm" when it holds something by coiling itself and also has "the function of legs" when it moves by creeping. The body of ACM has several functions, which are fulfilled one after another according to the situation. Especially in this paper, it introduces about the various move method realized about the move function using 3- dimensional type ACM, and its feature.

R. Ariizumi and F. Matsuno, [5] In this paper, a dynamical analysis of sidewinding locomotion by a snake like robot is presented. Sidewinding locomotion is treated as a planar movement for simplicity, and the normal forces acting on the grounded links and the torques applied on pitch joints are calculated by solving equilibrium equations. Energy efficiency of sidewinding locomotion is compared with that of lateral undulation.

Simulation results show that the sidewinding locomotion is, generally, energetically more efficient, and in the case where the viscous coefficient is small, there is a lower bound in the mean velocity of center of mass for sidewinding locomotion to be more efficient than lateral undulation.

K. Melo, [6] This paper considers a kinematic model that captures the speed and heading angle of a modular snake robot performing side-winding gaits. Modular snake robot locomotion is controlled in joint space. Consequently, the motion is achieved by continuous changes of the robot's body shape. In light of this behavior, this work describes a method to determine the position and orientation of a floating frame of reference to capture the robot's attitude in real-time, while executing side-winding gaits. A simple velocity model based on ground static contacts that determine the magnitude and direction of the robot's motion is proposed based on that frame. This model is validated by comparisons with experiments. The benefit of the proposed floating frame formulation and the velocity model for side-winding gaits depends on the fact that their calculation relied only in the gait control parameters, hence they could be determined analytically on-line.

M.Tanaka and K. Tanaka, [7]This paper proposes control method for a snake robot to ascend and descend steps. In a multiplane step environment, it is necessary for locomotion to transfer from one plane to another. When a snake robot moves, it touches several planes as its body is long and thin. In this paper, we propose a control method to track the trajectory of a snake robot in a step environment. We decomposed the 3-D motion of the robot into two simple models by introducing an assumption that simplifies the model and controller, and derive a model of the robot as a hybrid system with switching. The control method consists of a tracking controller, a method for shifting

PAPER COMPARISON

PROJECT TITLE	AUTHORS	COMPARITIVE STUDY
Using kinesthetic input to overcome obstacles with snake robots	. O'Neill and H.Choset	Using kinesthetic input for joint angle trajectories in snake robots to navigate complex environments is a clever approach.Simplifying these trajectories for storage and adjustment sounds promising too. The idea of quickly detecting failures using sensor deviation filteringand thresholding is a great way to ensure effective obstacle navigation.

esign and architecture of aseries elastic snake robot	D. Rollinson et	The SEA Snake sounds like anincredibly sophisticated design! The inclusion of torque, velocity, and position control within each module, along with features like high-speed Ethernet communication, internal IMU,and ARM-based control electronics, must contribute significantly to its versatility and functionality.
Differentiable and piecewise differentiable gaits for snake robots	K. Lipkin et al	The diverse range of gaits developed for free crawling snake robots is impressive. Categorizing them into differentiable and piecewise differentiable gaits showcases a variety of locomotion capabilities. Creating functionsfor gait generation and sharingexperiences from real experiments provide valuable insights into operating these robots effectively
ly inspired snake-like robots.	S. Hirose and M. Mori	The multifunctionality of the snake-like robot, serving both as an arm to hold objects by coiling and as legs for creeping movements, demonstrates its adaptability. Introducing various movement methods using a 3-dimensional type ACM highlights the versatility and potential applications of this technology.
Dynamical analysis of sidewinding locomotion by a snake-like robot	R. Ariizumi and F. Matsuno	Studying the dynamical analysis of sidewinding locomotion in a snake-likerobot is fascinating. Simplifying it as a planar movement and calculating
		normal forces and torques provides insights into its mechanics. Comparing the energy efficiency of sidewinding with lateral undulation through simulation results highlights the potentialadvantages of sidewinding, particularly its greater efficiency in certain scenarios.
ular snake robot velocityfor side-winding gaits	K. Melo	The development of a kinematic model to track a modular snake robot’s speed and heading angle during side-winding gaits is impressive. Describing a method to determine the robot’s positionand orientation in real-time while it’s executing these gaits,and proposing a velocity model based on ground static contacts, showcases a significant advancement in understanding and controllingthe robot's motion. The analytical determination of these models based on gait control parameters seems promising for online calculations.
Control of a snake robot for ascending and descending steps	M.Tanaka and K. Tanaka,	The development of a controlmethod for snake robots to navigate steps, particularly inmultiplane environments, is a significant advancement. Decomposing the 3D motion into simplified models and creating a hybrid system with switching enables effective control strategies. The proposed methods, including tracking controllers, shifting parts connecting planes, and active lifting to control the robot’s shape, seem promising based on ascent and descent experiments

CONCLUSION

Snake robots show immense promise for search and rescue missions in confined spaces. Their ability to navigate through tight and complex environments, coupled with advancements in control methods for various motions like sidewinding, ascending/descending steps, and adapting to multiplane terrains, suggests their potential in aiding rescue operations. With continued research and development, snake robots could significantly enhance search and rescue efforts, providing access and relaying crucial information in situations where traditional methods fall short. This paper introduces a control method for snake robots navigating steps across multiple planes. It simplifies the 3D motion into two models, creating a hybrid system with switching. The method involves tracking control, shifting parts connecting planes, and actively lifting to control the robot's shape. Ascent and descent experiments confirm the effectiveness of the proposed controller and the method for shifting the robot's body parts.

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