Unified Modular Snake Robot: A Review

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***Abstract*— Every animal on earth has its own unique set of features and is capable of surviving on its own without any dependency. Throughout history, humans have been inspired by these characteristics and used them for their betterment. Reptiles possess a lot of distinct characteristics that could be used to solve societal problems when imparted in the form of a robot. Snakes hold versatile characteristics that can be used to our advantage. This paper concentrates on a study of factors behind the recreation of a physical snake [1]. The term 'unified' suggests a group of modules put together to work as one. Here we will be talking about a snake robot that will help humans carry out tedious rescue missions easily and efficiently.**

Index Terms—Snake robot, rescue, unified,modular.

Introduction

During the last 10–15 years, the published literature on snake robots has increased remarkably. Snake robots are highly redundant mechanisms with versatility in their body configuration, enabling them to move through constrained and diverse environments [2]. Research on making the modular structure of snakes more efficient is going on presently in various universities, but some of the essential work done at the early stages of snake robots can be traced to the nevis' CONRO robots from the Information Science Institute at the University of Southern California, Murata's self-reconfigurable robots, Borenstein's OmniTread and Omni-Pede, and the Millibot Train created at Carnegie Mellon. Mark Yim's PolyBots are versatile modular robotic systems that exhibit one degree of freedom joints and various connecting ports per module. The interchangeable modules allow the robot to support numerous configurations, including spider, snake, and rolling modes. Every single module contains a Motorola PowerPC processor. The communication system makes use of two CAN buses per module and the CAN standard. Through the connection plate, each module can also exchange power and signals. Sensors involve an accelerometer, potentiometer, tactile whiskers, and hall effect sensors.

These flexible robots can be configured to have legs or to resemble a snake. Three serially connected joints make up each module, which allows limited motion. Each module can be docked with any other module on any of the five sides. The modules contain sensors, actuators, and microprocessors. They also contain a built-in infrared communication link, which provides inter-module communication and helps guide the docking process. Much similar work is being conducted worldwide, including its version of the underwater snake. These kinds of robots provide superior mobility in unknown, irregular environments as compared to other types of mobile robots such as wheeled, tracked, and legged robots [3]. Since a snake robot can move by using any portion of its body, unlike wheeled or leg robots, it is well suited for congested or cramped spaces where it is likely to be encountered, e.g., search and rescue missions or inspection tasks.

Fig. 1. Illustration of using a snake robot for search and rescue tasks[4].

I. PROBLEM DEFINITION

Unnoticed humans caught below a collapsed architectural structure or during a natural calamity are reported to be the second leading cause of death. This happens because of the inadequate data passed to rescuers, missed identification of humans, or delays in receiving help. It raises the question of what actions can be taken to decrease the number of deaths and casualties. In this scenario, detection of humans or valuable substances trapped in an area too narrow or dangerous for rescuers to use results. There are some places where reconnaissance becomes extremely arduous for humans to conduct due to the complexity and close-packed nature of the area and terrain. With India's vast geographical diversity, they have been experiencing numerous natural and man-made disasters over the last few decades, such as tremendous earthquakes, fires, floods, aeroplane crashes, a tsunami in 2011, Uttarakhand floods in 2013, and military operations in cases such as the 26/11 Mumbai attack (2008) and recent terrorist attacks in Punjab (India), which needed assistance that could substitute for human intervention.

II. PROPOSED SOLUTION

It seems that the solution to these problems lies in an object that humans can operate. This object can therefore serve as a replacement for humans in conducting those operations. Among a wide variety of reptiles, snakes have some recognisable characteristics, such as their lateral undulation pattern and the use of their heads for major tasks. Snakes also exhibit their ability to move across harsh and uneven terrain due to their skin, movement pattern, and body type. These are some strong key features that can be imparted to a snake-type robot. The snake robot is thus composed of all the prominent characteristics of a snake and would work as humans would model it. Hence, it is even more competent and adaptable. The snake robot can be designed to act as efficiently as possible. When it comes to structural collapse rescue, victims are supposed to be rescued within 48 hours to have a positive chance of surviving. The depths in which humans get stuck are too problematic for humans to reach, even after advanced techniques are used. Snakes have sleek bodies that can be used for identifying trapped humans if they are stuck inside a collapsed structure. A few of the most crucial requirements for a human to stay conscious during such conditions include hydration, oxygen, mental stability, and hope..

The snake robots can conveniently carry water packets for humans who are trapped. Snake robots can be used not only for urban rescue missions but also for research and operations. When the cameras are camouflaged to capture the details of wildlife in regions that humans cannot access easily, there is a high likelihood of them getting broken up by climatic changes or by animals. Snakes are the most commonly found reptiles in the forests and thus can be one of the best options to use for capturing information. Snakes possess the ability to crawl on uneven terrain, climb trees, and, with some advancement, they might also be able to travel underwater, one of the main features of homogeneity and familiarity with forest wildlife. The proposed snake will be made up by building various modules and unifying them into one snake. Each module is trained and prepared to enact and can also be customised as per the requirements. The head of the snake will consist of various specifications like capturing, identification, and detection, and plenty of other features can be added to it by integrating the sensors, while the tail will work as a pusher and balancer.

III. WORKING

The Snake robot would have different modules with different features, which would work together as one, hence the term 'unified'. There will be servo motors attached to each of the module frames; each module includes one servo motor and one ball bearing, and the modules are constructed in such a way that they are interconnected with each other using servo motors. Each alternate module spins horizontally, while every subsequent module rotates vertically. The snake produces a sidewinding motion as all of the modules move in the vertical and horizontal planes. The whole process of the snake periodically pulling up portions of its body and propelling itself to the side is termed a sidewinder. A sine wave must be passed through one plane and a cosine wave through the other to generate the sidewinding motion. The modules can also have a spherical structure, where each of the spherical modules contains a control circuit for controlling the steering unit and propelling unit. [2].

Similarly, each of the modules can also act as a single-DOF unit, composed of a serial chain of four rigid links connected by parallel revolute joints. Its mechanism is actuated by three pairs of antagonistic cables, each of which is routed along circular grooves on the link exteriors rather than axially, constraining the cable displacements in agonist pairs to be approximately equal and opposite in value. Modules connect serially via a rigid male-female interface [5].

The snake robot could also have a gripper module that would stably grasp and manipulate a small object; the fingers of the module should not hinder the movements of the snake robot when it is attached to it; and finally, the size of the gripper module should be similar to the size of the driving module of the snake robot. The anthropomorphic robotic hand consists of 3–5 fingers, and it can grip and precisely manipulate various objects, including not only simple spherical and cylindrical objects but also irregular objects using numerous DOFs [4].

The snake robot modules can also have a cylindrical structure; the idea is simply to let the exterior cylinder surface rotate, where the cylindrical rotation will be controlled by a motor inside the cylinder. Because of external contact forces, each rotating cylinder will generate external forces in the normal direction of the link. By controlling the rotation of each cylinder as per the angle that each link forms with the forward direction, the rotating cylinders will generate external forces that propel the snake robot forward. A possible control principle is that the cylinders near the direction orthogonal to the forward direction are rotated faster than those near the forward direction. The proposed propulsion mechanism can easily be implemented without compromising the requirement of a smooth gliding surface along the body of the snake robot. Furthermore, the propulsion mechanism can be implemented in a mechanically simple and robust way.

IV. FEATURES

The number of features that can be integrated into this robot is limitless.

1) Different kinds of sensors like moisture, pressure, temperature, etc. can be integrated into the robotic body of the snake, which would broaden the scope and implementation of the robotic snake beyond the rescue information carrier.
2) An integrated battery or onboard power source can be implemented to make the unified modular snake robot more efficient, flexible, and wireless. This would increase the chances of the snake robot being safe from any problem that occurs due to the power supply or at the channel level. The onboard battery and power source would further lead to making it wireless. Making it wireless would increase the user experience and thus allow it to be further commercialised for local and domestic uses.
3) Using professional, high-grade servo motors would ensure the high scalability of work and the accuracy of moments and angles that the robotic snake performs.
4) The unified modular snake robot has the compatibility to climb trees, swim underwater, and move in any direction when commanded. This gives it the advantage of being heavily used in the armed forces and other critical investigative measures.
5) Further, to enhance its looks and to make it more realistic, skins with desirable friction can be added to the body. Features needed for camouflage can be added as per the needs and requirements of the user, without affecting the work of the robot. This further branches out numerous professional usages of this unified snake robot.

V. REVIEW OF LITERATURE

A Review Study on the Future Applicability of Snake Robots in India (2015) - Nidhi Chaudhry, Shruti Sharma, and the applications of the Snake robot in India were discussed in detail by the writers in their review paper. They made a great effort to present every conceivable usage structure plan for the Snake robot..

Path Planning for Perception-Driven Obstacle Aided Snake Robot Locomotion (2020 IEEE)-Kristian G. Hanssen, Aksel A. Transeth, Filippo Sanfilippo, Pal Lilijeback, Øyvind Stavdahl, The purpose of this paper is to describe a local path-planning algorithm for snake robots based on obstacle-aided locomotion (OAL). An essential feature of OAL is determining a suitable push point in the environment that the snake robot can use for locomotion. The proposed method is based on a set of criteria for evaluating a path and is a novel contribution to this paper..

Modelling and Simulation of a Wheel-Less Snake Robot (2020 IEEE) Yesim A. Baysal, Ismail H. Atlas In this paper, dynamic and kinematic modelling of a wheelless snake robot that has a lot of potential for adapting to its surroundings is implemented using Matlab and Simulink, and the effect of friction between its body and the ground, which plays a highly important role in some snake locomotion such as lateral undulation on motion, is analysed.

Snake Robot Gripper Module for Search and Rescue in Narrow Spaces Sang Chul Han , Sanguk Chon, JungYeong Kim , Associate Member , IEEE , Jae Hong Seo , Dong Gwan Shin , Sangshin Park , Jin Tak Kim , Jinhyeon Kim , Maolin Jin , and Jungsan Cho (2022), describe the snake robot, which has a gripper module with three features, namely, a camera and a joint sensor unit. The three features are: (1) It can accommodate the fingers inside its body. (2) It has three fingers that can stably grip objects with irregular surfaces. (3) One of the fingers is equipped with a camera on the fingertip to search in a narrow space.

Modular Snake Robot-Oriented Open Simulation Software Jose Monsalve , Juan Leon and Kamilo Melo (2014) the authors, present a brief description of an open-source modular snake robot-oriented simulation software conceived as an important tool for locomotion research with this kind of robot. The selection of relevant experiments to be performed with the real robot can be improved by the use of such software tools. This fact enhances the validation of locomotion models while reducing the possibility of robot mechanical damage.

Implementation of Motion Algorithm on a Snake Robot Prototype for Serpentine Locomotion Marwan A. Badran, MD Raisuddin Khan and Siti Fauziah Toha (2020) give us brief aspects of modelling analysis, locomotion, and control. This work describes the application of an algorithm to a snake robot prototype that enables serpentine mobility on rough terrain.

Design and Control of a Cable-Driven Articulated Modular Snake Robot Peter Racioppo, Student Member, IEEE and Pinhas Ben-Tzvi, Senior Member, IEEE (2018) present the development of a cable-driven snake robot with coupled joints that incorporates elastic elements as a means of producing both passive and controlled adaptation to obstacles. A simplified model of serpentine locomotion was developed and used to analyse how the propulsive force produced by a snake robot is related to the number of links it contains.

A Survey on Snake Robot Locomotion (2022 IEEE)-Seeja Girija, Arockia Selvakumar Arockia Doss and Berlin Hency Victor: This paper focuses on a study of factors behind the recreation of a physical snake, like kinematics and dynamics modelling, mechanical design, and locomotion control approaches from existing literature.

Design and Implementation of Omni-Directional Spherical Modular Snake Robot (OSMOS) (2017 IEEE) Akash Singh, Anshul Paigwar, Sai Teja Manchukanti, Manish Saroya, Manish Maurya This paper presents a revolutionary concept for an omnidirectional planar snake robot (OSMOS) composed of spherical robot modules that are mechanically and technically integrated.

VI. CONCLUSION

In this paper, we have discussed the various problems humans face during rescue missions and how snake robots prove to be the ideal solution to each one of them. Snake robots are an innovation that has a vast scope, and we should look forward to using them in a wide range of applications. These robots can be used in several areas, such as fields, agriculture, sanitation, fire fighting, surveillance, and maintenance of complex and possibly dangerous structures or systems, including pipelines or nuclear power plants, intelligent services, media, exploration, hazard mitigation, research, education, the military, and search and rescue missions. These unique features and degrees of freedom of snake robots make them a fascinating topic for research purposes and are worth investment and applicability.

VII. REFERENCES

[1] A survey on Snake robot locomotion (2022 IEEE)- Seeja Girija, Arockia Selvakumar Arockia Doss and Berlin Hency Victor.

[2] Design and Implementation of Omni-directional Spherical Modular Snake Robot (OSMOS)(2017 IEEE) Akash Singh, Anshul Paigwar,Sai Teja Manchukanti, Manish Saroya, Manish Maurya.

[3] Modelling and Simulation of a Wheel-Less Snake Robot Yesim A. Baysal, Ismail HAltas (2020 7th International Conference on Electrical and Electronics Engineering)

[4] Snake Robot Gripper Module for Search and Rescue in Narrow Spaces Sang Chul Han , Sanguk Chon, JungYeong Kim , Associate Member, IEEE, Jae Hong Seo , Dong Gwan Shin, Sangshin Park, Jin Tak Kim , Jinhyeon Kim, Maolin Jin , and Jungsan Cho (IEEE ROBOTICS AND AUTOMATION LETTERS, VOL. 7, NO. 2, APRIL 2022)

[5] Design and Control of a Cable Driven Articulated Modular Snake Robot Peter Racioppo, Student Member, IEEE and Pinhas Ben-Tzvi, Senior Member, IEEE (2018 IEEE).

[6] A Review Study on Future Applicability of Snake Robots in India (2015) - Nidhi Chaudhry, Shruti Sharma

[7] Path Planning for Perception-Driven Obstacle Aided Snake Robot Locomotion (2020 IEEE)-Kristian G.Hanssen,Aksel A. Transeth, Filippo Sanfilippo, Pal Liljeback, Øyvind Stavdahl

[8] Modular Snake Robot Oriented Open Simulation Software Jose Monsalve , Juan Leon and Kamilo Melo (2014)

[9] Implementation of Motion Algorithm on a Snake Robot Prototype for Serpentine Locomotion Marwan A. Badran, MD Raisuddin khan, Siti Fauziah Toha(2020)

[10] Motion Control Curve of Snake-like Robot Based on Centroid Stability Zhihao Zhou, Haiyan Wang, Dongfang Li, Hongbin Deng (2019)