SNAKE ROBOT: CURRENT STATE OF THE ART AND FUTURE TREND

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Abstract

This paper discusses the current state of the art of research and future trend of research activity towards achieving mechanisms and technology for useful implementation of efficient snake robots. Snake robot is meant to mimic motion of a natural snake, which does not possess any limb. Natural snakes can undergo wide range of motion and are able to move over rough terrains without the danger of entanglement. Slender structure of the snake body helps a snake to go inside narrow holes. Thus a snake robot able to mimic these features of a natural snake will be of extreme use in handling search and rescue operations, minimal invasive surgery and inspection of pipeline defects in petrochemical industries. Snake robots, though seem to be a promising solution to wheel less locomotion, and hyper redundant robot mechanism in locating difficult to reach location, could not receive scientists? interest due to the involvement of multiple disciplines that require integration under some common umbrella. Due to the evolution of Mechatronics as an Engineering discipline during the last two decades, promising solutions to snake robot design are gradually coming out.

Key words: Snake Robot, Multiagent system, Disaster, Rescue, Minimal invasive surgery.

1. INTRODUCTION

Disaster management includes both post-catastrophe rehabilitation and rescue operation immediately after the catastrophe. Entrapment of humans inside buildings and under the debris is common in almost all kinds of disaster. In the case of rescue operation from such entrapment fast and effective measures are crucial in saving human lives. The common rescue practice so far is to dig out the whole savaged area without precisely knowing the location of the entrapped people. Such blind operations are time consuming and some times instead of saving lives take away lives. On the other hand some of the catastrophes are inaccessible, as for example breakdown inside mineshafts or inside the subways. In these kinds of catastrophes, rescuers require few days to reach to the victims, where the victims might not survive after long-time starvation or injuries. Sniffer dogs are sometimes used to detect humans inside the wreckages. However, dogs can not give any indication of the state of the victim like state of injury, level of oxygen and other harmful gases around the victim etc. As such priority can not be set in designing the rescue operation. It is evident from the above discussion that information mapping will play a vital role in designing and executing successful rescue operation. To undertake information mapping inside the entrapments scientist have taken small limbless autonomous robots into their consideration [1-4]. The main advantage of limbless robots over the legged robots is their ability to move in difficult terrains without entanglement.

Limbless robots are being assumed to mimic the natural snakes, are made slender so that narrow passages leading to entrapments can be used efficiently to gather information. Natural biological creatures use muscles for their motion. Natural muscles are so powerful that small size muscles can generate lot of power and help keep the size of the biological creatures small. Today퀄 technology has achieved little advancement in the development of artificial muscles [5,6]. Once technology supersedes the natural muscles, biomimitic robots powered with artificial muscles will be able to replace many of the current equipment used in rescue operation. In that case instead of using giant excavators or bulldozers swarm of small robots with collaborative behavior can be thought to handle rescue operations like the collaborative efforts found in natural ants as shown in Fig.1. These robots if featured with communication systems will be able to behave like the natural bees in terms of information exchange.

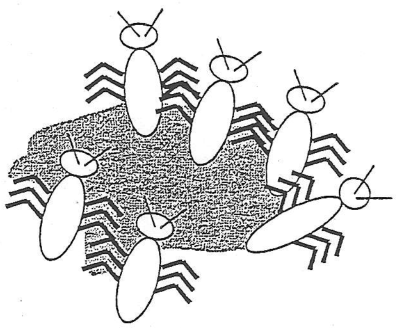
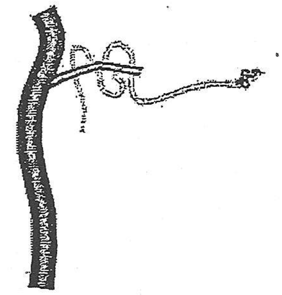


Fig.1 Collaborative activity in ants

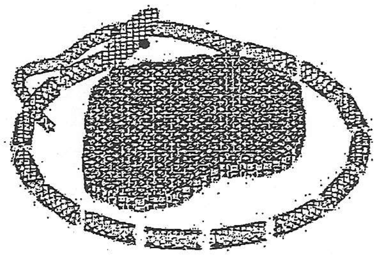
Multiple autonomous robots collaborating and communicating with each other to perform tasks are complex in nature and only achievable provided sufficient intelligence is built in, and a way of communication between them is established. In these approaches increasing robot autonomy allows robots to be delegated certain tasks for longer periods of time making it possible for a single operator to control more robots. We envision future disaster response to be performed with a mixture of humans performing high level decision-making, intelligent agents coordinating the response and humans and robots performing key physical tasks. These heterogeneous teams of robots and people will provide the safest and most effective means for quickly responding to a disaster.

2. NATURAL SNAKE

Snakes are mostly considered as terrifying and life threatening creature for human being albeit snake venom has some medicinal values. Unlike the other creatures snake has versatile motion capabilities. Snakes can reach almost any difficult nooks and crannies due to its slender shape and flexible body. They can also overcome versatile obstacles around its surroundings. Climbing poles or trees and swinging from overhangs are some additional features (Fig.2). Even snakes cane climb inside vertical pipes as shown Fig.3.



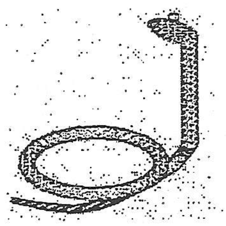
(a)



(b)

Fig.2 Various configuration of snake: (a) propped on a support and extending to reach nearby space (b) wrapping an object

(a)



(b)

Fig.3 (a) Snake climbing inside pipes (b) Snake keeps the head upright

Snakes can lock its different segments along the body and become stiff, can keep its head erect in the space. The later feature can be utilized in pushing objects as well as capturing images surrounding the snake.

3. SNAKE ROBOT RESEARCH

Snake robots started receiving scientist플attention during the early nineties. In addition to the title snake robot, serpentine robot and hyper redundant robot are the other titles that deal with similar researches. The main interest in snake robot research is to mimic snake motion through hyper redundant robotic structures. Snake motion analysis plays vital role in designing snake structure and mechanisms. The widely cited pioneer work of Hirose [7] is the one that analyzed snake motion and developed a snake motion curve called the serpenoid. He also developed Active Chord Mechanism (ACM) for implementing snake motion. In 1997 Dowling [8] presented a comprehensive literature survey on snake robot and pointed out that snake robot still needs extensive study in identifying the different snake motion algorithm. Dowling also undertook modeling and simulation of a few snake-like locomotion as well as few artificial non-snake like motion and at the end he developed snake prototype that can learn crawling motion. Shan and Koren [9] developed a snake prototype considering open loop mechanism at both ends of the snake and close loop mechanism at the middle. This snake is able to move without wheels.

The biorobotic research group of Carnegie Mellon University [10] developed new types of 2D joints for their snake robots. Joints play important role in robot motion control. Thus a compact joint with multiple degrees of freedom and capable of being locked in the event of configuring the flexible structure in to a rigid structure is necessary in the case of handling large payload. Few of their joints are shown in Fig.4.

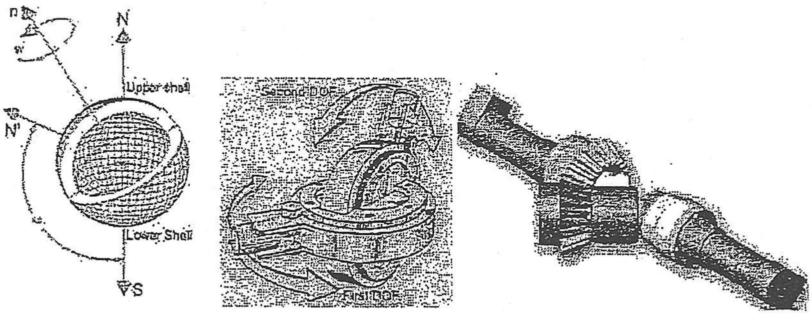


Fig.4 2D joints developed by Carnegie Mellon University

Department of Mechanical Engineering, University of Michigan developed OmniTread snake robot that can drive over sand and rocks, pass through small holes and climb over tall obstacles. The treaded tracks attached to this robot receive power from the central drive shaft and can execute versatile motion through the execution of different algorithms. Omni-Tread is shown in Fig. 5.

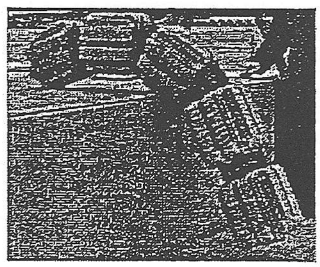


Fig. 5 Omni-Tread developed by University of Michigan

Robot business is mostly confined in industrial robots, only a few robot companies are trying to explore robot business in new kind of robots like snake robots. Recently robot companies are extending their business in the new direction of hyper redundant robots. OC robotics [12] has exhibited their Snake-Arm (Fig. 6) robot in the conferences in 2007. OC Robotics claims they are capable of making small as well as large snake robots capable of handling large payload.

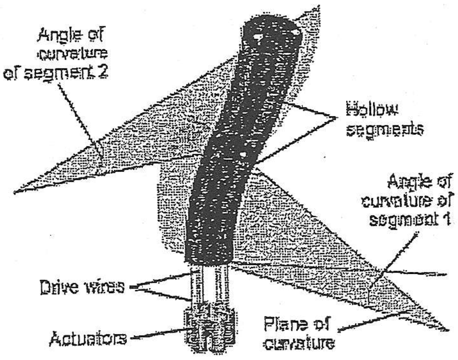


Fig.6 Snake-Arm robot from OC Robotics

Sintef [13], a Norwegian research organization has come up with the largest snake robot so far, called Anaconda which can handle large payload as well as spray water in fire fighting exercise. Anaconda is 3m long, weighs 75 kg with 20 DOF and actuated by hydraulic cylinders under maximum 100 bar pressure. Anaconda is shown in Fig. 7.

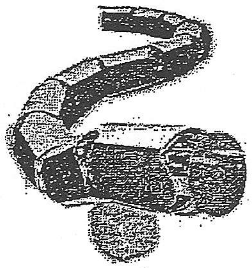


Fig.7 Anacoda developed by Sintef, Norway

4. SNAKE ROBOT AS AGENT

Multi-agent collaboration is natural in humans as well as in some other biological creatures. Multi-agent collaborative activity has got lots of advantages over single agent activity. In the case of multi-agent collaboration among robots redundancy, distributed sensing and actuation play vital role in achieving goals successfully and efficiently. Due to the redundancy in the system, multi-agent system is fault tolerant as well as robust. In a multi agent system different types of robots may be employed for executing different tasks. However, considering snakes as the building blocks like the cells in biological systems different types of actuating systems or robots can be developed on the cite instead of using different specialized robots. An idea of using the snake agents as legs of a single walking robot is depicted in Fig.8.

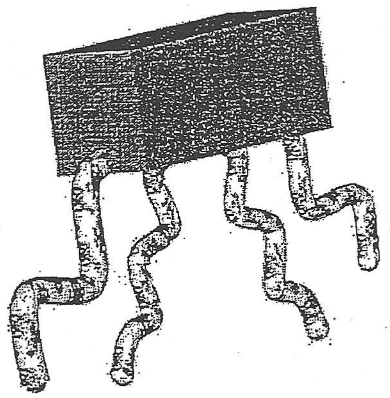


Fig.8 Four snakes collaborating as legs of quadruped robot

In Fig.9 parallel efforts of snakes in pulling a heavy load is shown. Handling of heavy loads from under the debris is very critical in rescue operation. Distributed actuation through swarms of snakes believed to be a feasible solution in this respect.

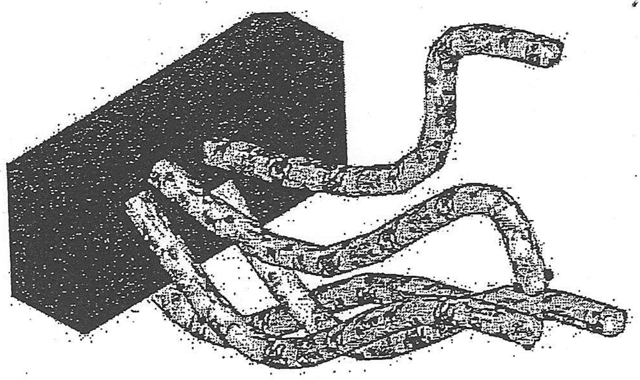


Fig.9 Snakes in parallel action in handling heavy load

5. FUTURE SNAKE ROBOT RESEARCH

Snake being a flexible structure mimicked through huge number of traditional mechanical joints is susceptible to short life. Thus new joints with less complicacy are the practical demand. Compliant mechanisms [4] are expected to come forward to overcome such joint problem. Distributed sensing and actuation are the two other areas that need attention. In the case of distributed actuation, Electrostrictive Polymer Artificial Muscle Actuators or Electroactive Polymers (EAP) can play vital role. However, these polymers need extensive research to develop high density actuators. On top of the mechanical issues efficient motion algorithms need to be developed.

6. CONCLUSIONS

Considering versatile motion capability and flexibility of shape of snake robots, it can be employed in rescue operation under multi-agent collaborative protocol. However, so far only few researches have been done in the design and development of efficient snake robots with versatile motion capabilities. To achieve such technology, efforts are necessary in the design of strong artificial muscles, efficient motion algorithm, design of powerful machine intelligence and efficient collaborative protocols.

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