

SNAKE ROBOT DESIGNS: A REVIEW

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Abstract : Robotics has always been a subject of constant fascination and experimentation for researchers. Research in the field of Snake Robots began as early as 1972, with Shigeo Hirose introducing the world's first ever snake robot- 'ACM' (active cord mechanism). Since then, researchers all over the world have tried to mimic the serpentine motion using a multitude of designs, in the hope of finding the best suitable design that can truly replicate the movement characteristics of a snake.

In this paper, a review of designs of such snake robots is being presented which managed to provide, not just a new direction, but also a newer approach to designing a Snake Robot that could best mimic the properties of a real snake.

Introduction:

In nature, there are plenty kinds of creatures. All of them, especially snakes, develop their own features to adapt different environments. Although snakes have no limbs, they can, however, move, crawl or swim in desert, trees or water. The mobility of a new type vehicle can be realized by understanding the key principle of locomotion performed by snakes. Taiwan is in the area that earthquakes happen frequently. Each time when earthquakes happen, buildings are destroyed and it is hard to explore and rescue the survivors. Hence, a snake-like rescue robot, which has a high degrees of freedom and excellent terrain adaptability, can be used for exploration, rescue, and even common transportation.

Real snakes develop a lot of locomotion postures to adapt to different terrains and environments. In general, there are four common modes of snake locomotion.

- (1) Serpentine: This is the most common locomotion mode. Snakes swing body to generate a propagating wave, and transform frictions from ground into push forces for moving.
- (2) Concertina: This locomotion mode is employed when a snake is in narrow spaces. Snakes contract and extend their body to move, just like a concertina.
- (3) Side-winding: Snakes usually perform side-winding locomotion in desert. They lift a lot of parts of their body and just put some parts on the ground as fulcrums to move in the lateral direction of their body.
- (4) Rectilinear: It is a locomotion mode for boa constrictor. Through interaction of their muscles and ribs, snakes move their giant body as a straight line. To mimic different kinds of postures of a real snake, snake robots are always designed to be modular with a high degrees of freedom and homogeneity.

We classify the general unit modules of snake robots to four classes:

- (a) Non-wheeled: There is no wheel equipped on the modules
- (b) Wheeled: Wheels are equipped on the modules
- (c) Expandable and contractible: The joint between two modules is not active, but rotated by expanding and contracting of the link that equipped on both sides of the module.
- (d) Reconfigurable: The modules are multi-functions. They can be not only configured to a snake robot, but also other three-dimensional structure.

1. Various Robot Designs:

- **ACM(Active Cord Mechanism):**

The snake-like robot "ACM" series with the small highly efficient, lightweight drive system newly developed in order to examine the various functionalities of Active Cord Mechanism. As a Shift control system, the serpentine locomotion which a living body snake performs, Sinus-Lifting, Side- Winding, Spiral-Swimming Motion, and Pedal-Wave could be realized. Lateral-Rolling was realized as a Rolling control system, and Lateral-Walking was done as special conditions, and promotion and Lateral-Rolling of each inclination state generable by combining each are possible. This Robot is one of the first ones to have been introduced to the research world. It is also one of the few robots that are capable of multiple types of motion patterns.

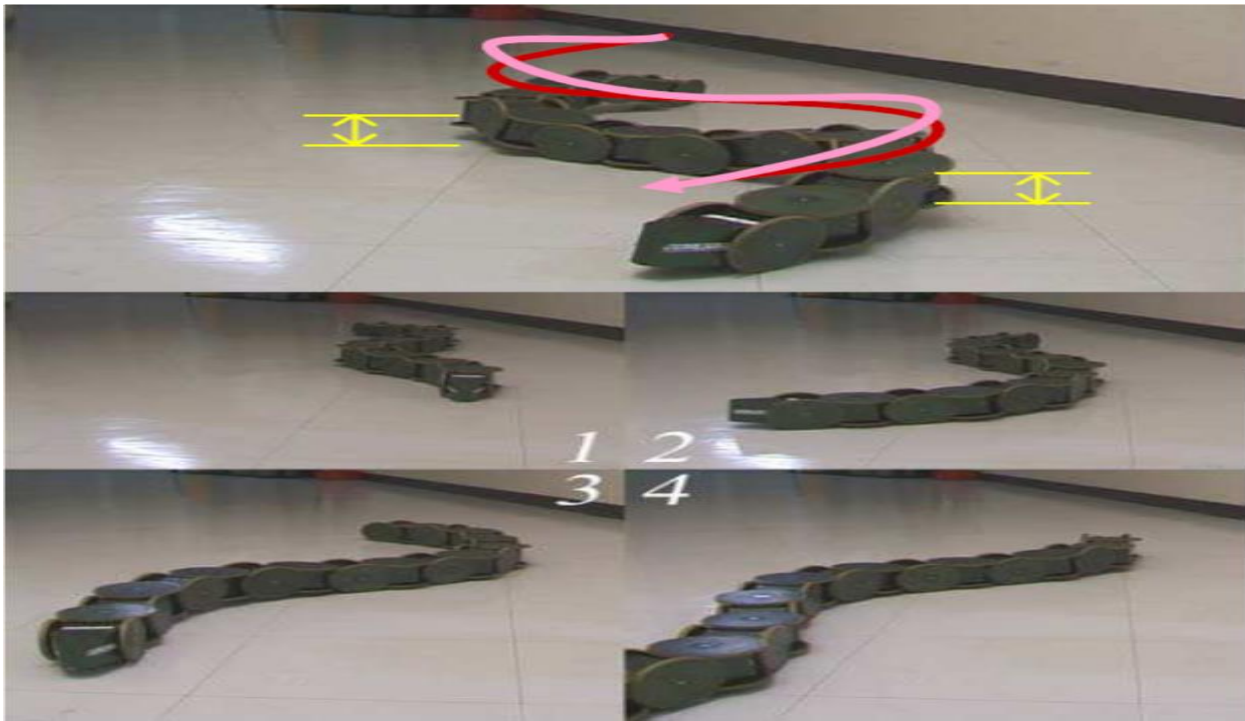


Fig.1: Gait patterns of ACM [20]

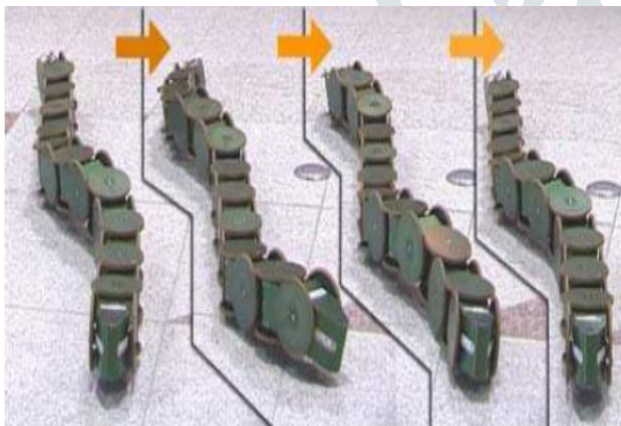


Fig.2: Sidewinding 1 [20]

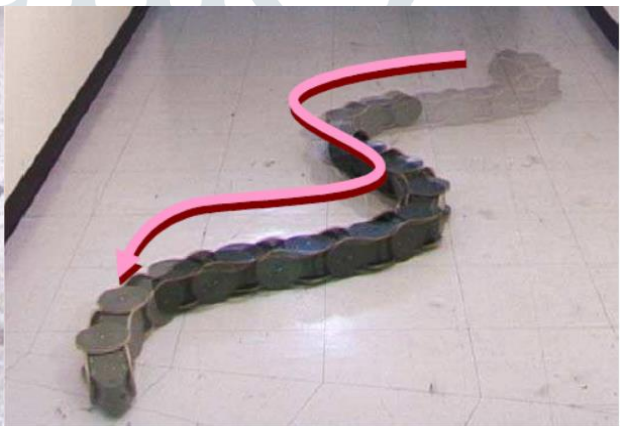


Fig.3: Sidewinding 2 [20]

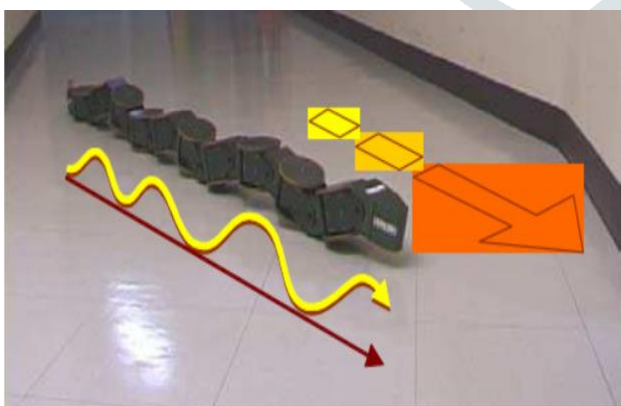


Fig.4: Vertical Wave [20]

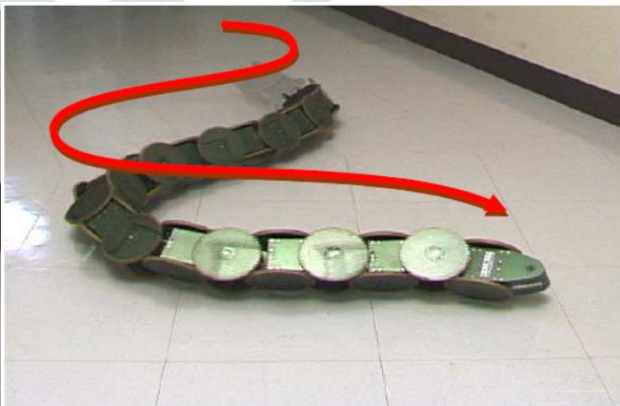


Fig.5: Lateral Rolling [20]

- **Genbu:**

One of the types of snake-like robots 'Genbu' is characterized by multi active wheels of large diameter and multi bodies connected by passive joints. Although Genbu is not able to go over the wide gap, the robot has performance at high-speed on rough terrain because of its passive joint mechanism. Autonomous Genbu would be very useful for several applications. The mechanism and basic experiment of the new Genbu are described in order to establish the control method of this type of snake-like robot. This robot also comes as the brain child of Shigeo Hirose, who put forward the concept of a new kind of design capable of faster locomotion on rough terrain. Many other variants of Genbu have now been made.



Fig.6: Design of GENBU [10]

- **Underwater Robot(SNAKEY):**

The robot's ability to swim has also been considered since the servo can be controlled to enable the robot to swim with desired direction. The speed of SNAKEY is 0.072 kmph on land and 0.18 kmph in water. The inspection activities can be very useful in investigating the material underwater or land that in the difficult and extreme situation. Plus with the ability to capture and record is very important to the user in order to re-check and revise the situation. The movement of the robot had some limitations but the side winding movement has been applied correctly. This robot is specifically designed for inspection purposes underwater.



Fig.7: Link mechanism of SNAKEY [8]

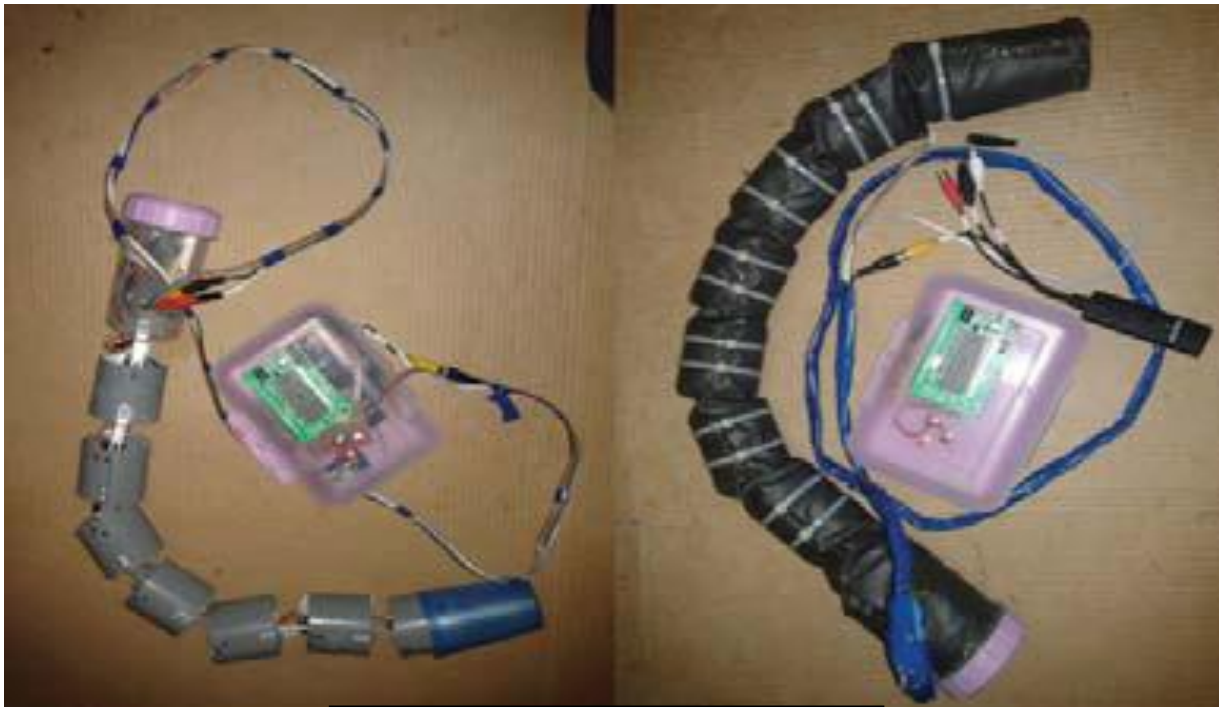


Fig.8: Design of SNAKEY [8]

• **PolyBot:**

This is a very special type of snake robot that was designed to specifically address the issues concerning locomotion. Two generations of these robots were developed to better understand and study the rolling chain theory of locomotion. The special feature of these robots is that the first and last segment can loop bind together to form a continuous chain. This structure can then move by segment realignment using servo motors.



Fig.9: Motion Pattern 1 [12]



Fig.10: Motion Pattern 2 [12]

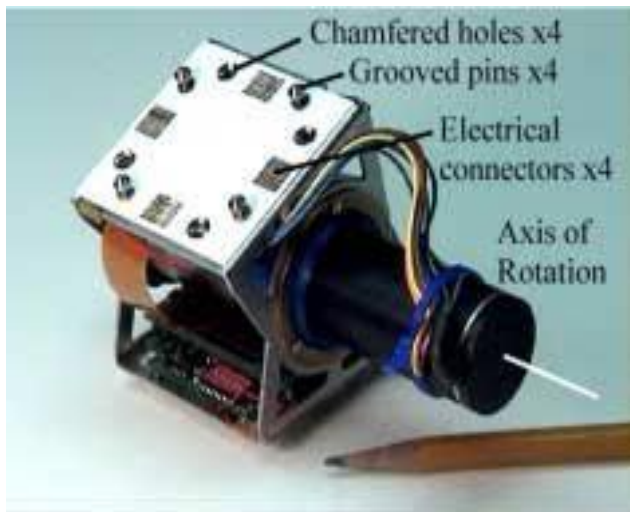


Fig.11: Design of single link. [12]

• Serpenoid Polygonal Rolling Chain:

This design, in theory, is a derivative of the PolyBot concept. But this design is special in terms that it is not restricted to a single closed configuration. This robot is made such that the alignment of individual links can be changed as per the requirements of the user(s). This design is currently being used by the US Military to design and develop next generation wheels for their armored vehicles.



Fig.12: Possible configurations of SPRC (1) [5]

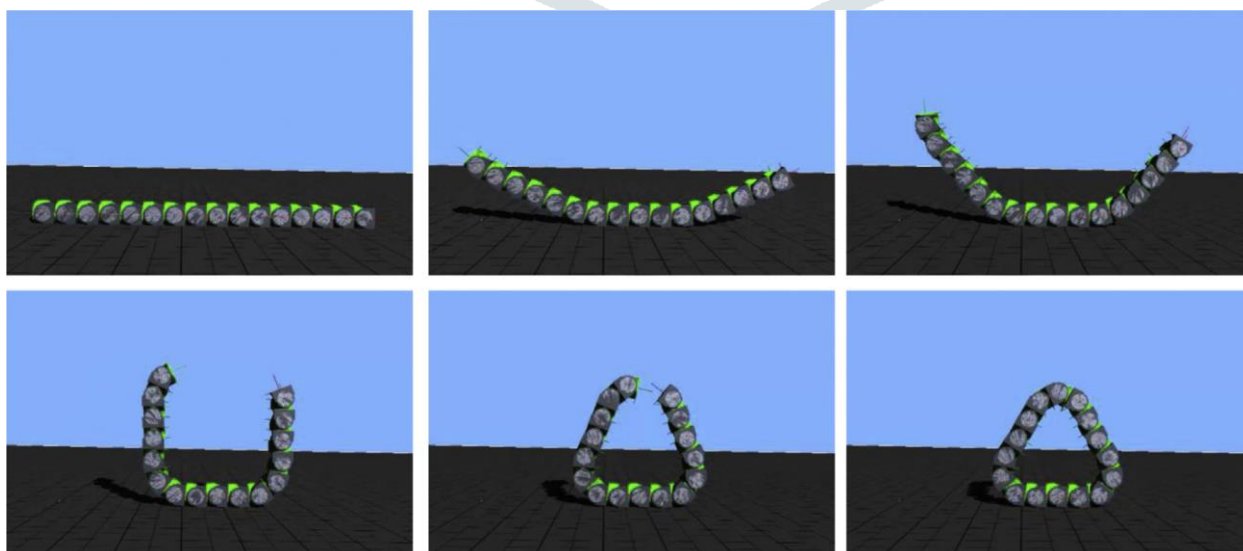
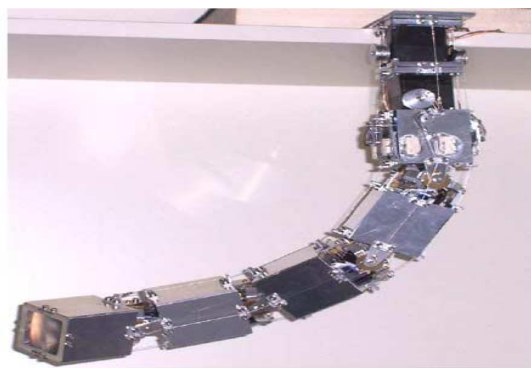


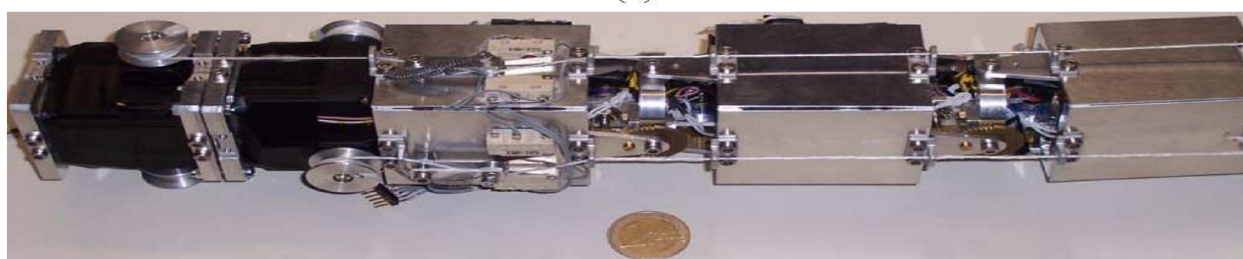
Fig.13: Possible configurations of SPRC (2) [5]

• **Hyper Redundant Chain Robot:**

This is another special design that uses cables mounted on the body to change the direction and orientation of the robot. Each segment is connected using these wires and all of these wires are manipulated using servo motors to achieve the desired motion.



(a)



(b)

Fig.14: Design of HRCR [13]

• **AmphiBot:**

This is a special design that serves the purpose of locomotion on both land and in water. This robot series is specially made to address the problems of locomotion in multiple media. Simple modular design makes it very easy to assemble and disassemble. Also, if a segment malfunctions, it can be bypassed without removal. These robots have a wide variety of applications due to their ability to move both on land and in fluids.



Fig.15: Design of single link of AmphiBot [2]



Fig.16: Testing of AmphiBot [2]

• **SMARS-1:**

This is a very special design that has been made using smart materials. This is currently the only design that delivers 3DOF motion in a single link. Hence the overall motion capability of this robot is very superior to any other robot seen so far. Use of smart materials has also enabled the researchers to keep the size of the robot quite small, with the option of scaling as per the requirements.



Fig.17: Single link of SMARS-1 [1]



Fig.18: Motion of SMARS-1 [1]

2. Conclusions and Future Scope:

- All the designs seen in this review have been pivotal in changing the direction of research in the field of biologically inspired snake robots.
- All these designs were made with a goal to target and eliminate a specific problem related to locomotion, design, gait pattern, control or other. But none of the designs have tried to incorporate and solve multiple problems.
- Researchers are still trying to figure out the best design to mimic snake like motion.
- Wheeled robots have better speed but are limited by the terrain. They can't climb trees or navigate deserts, etc.
- On the other hand, wheel-less robots show better locomotive properties and terrain adaptivity, but are too slow.
- Underwater robots suffer with the difficulty of wireless control. Since it is difficult to communicate in liquid medium, these robots are controlled with a wired controller.
- Most robots only manage to accomplish a singular task. It is not feasible to have a different robot for every application. Research should be focused in eliminating this problem.
- Due to the complexity of the basic design, researchers find it difficult to incorporate different kinds of sensors with the robot body. Mounting of various sensors is still an unsolved problem.
- Most of these designs are just prototypes with no experience of real world application. Even though they have been made to help humans with specific problems, there are no accounts whatsoever of these robots being used in normal day-to-day lives, either by the authorities or by civilians.

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