# Experimental Study on Control of Redundant 3D Snake Robot based on Kinematic Model

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**Abstract**

Unique and interesting gait of the snakes makes them able to crawl, climb a hill, climb a tree by winding and move on very slippery floor. Snake does not have hands and legs, however it has many function. It is useful to consider and understand the mechanism of the gait of the snakes for mechanical design and control law of snake robots. Snake robots is active code mechanism and is usefule for rearch and rescue operation in disaster. Utilization of autonomous intelligent robots in Search and Rescue is a new challenging field of robotics dealing with tasks in extremely hazardous and complex disaster environments. Intelligent, biologically-inspired mobile robots, and, in particular, snake-like robots have turned out to be the widely used robot type, aiming at providing effective, immediate, and reliable response to many strategic planning for search and rescue operations.

The present research is looking for other variety of possible locomotion modes "Ring mode", "Inching mode", "Wheeled Locomotion mode" and "Bridge mode" as shown in Fig. 1.

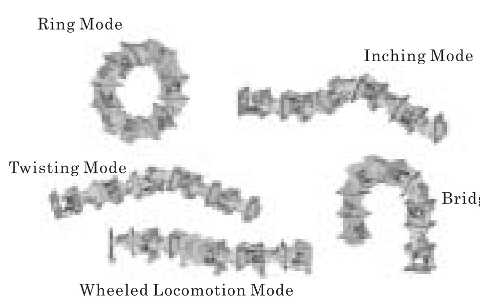


Fig. 1 Variety of possible locomotion of snake robot

Twisting mode: In this mode the robot mechanism folds certain joints to generate a twisting motion within its body, resulting in a side-wise movement.

Wheeled locomotion mode: This is one of the common wheeled locomotion mode where the passive wheels (without direct drive) are attached on the units resulting low friction along the tangential direction of the robot body line while increasing the friction in the direction perpendicular to that.

Bridge mode: In this mode the robot configures itself to "stand" on its two end units in a bridge like shape. This mode has the possibility of implementation of two-legged walking type locomotion. The basic movement consists of left-right swaying of the center of gravity in synchronism with by lifting and forwarding one of the supports, like bipedal locomotion. Motions such as somersaulting may also be some of the possibilities.

Ring mode: The two ends of the robot body are brought together by its own actuation to form a circular shape. The drive to make the uneven circular shape to rotate is expected to be achieved by proper deformation and shifting the center of gravity as necessary.

Inching mode: This is one of the common undulatory movements of serpentine mechanisms. The robot generates a vertical wave-shape using its units from the rear end and propagates the 'wave' along its body - resulting a net advancement in its position.

The feedback control law for the 2D snake robot using Lyapunov method can stabilize the head position to its desired value, but the configuration of it converges to a singular configuration. Singularity avoidance and development of 3D snake robots are challenging and important problems.

In this paper we consider the trajectory tracking and the singular configuration avoidance of a 3D snake robot. By introducing links without wheels the snake robot has redundancy. Using redundancy, it becomes possible to accomplish both the main objective of controlling the position and the posture of the snake robot head and the sub-objective of the singular configuration avoidance. Fig. 2 shows the 13-link snake robot (ACM-R3) that we use for experiments.

Fig. 2 A research platform robot (ACM-R3)

In experiments, to measure the position and the posture of the snake head we use Quick MAG IV stereo vision system with two fixed CCD cameras. Experimental results demonstrate the effectiveness of the proposed controller.