Snake Robots

From Biology - Through University - Towards Industry ☆

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Texte

Abstract

The inspiration for snake robots comes from biological snakes. Snakes can move over virtually any type of terrain, including narrow and confined locations. They are good climbers, very efficient swimmers, and some snakes can even fly by jumping off branches and using their body to glide through the air. In this plenary talk we will review recent results on modelling, analysis and control of snake robots. The talk will also describe a new research direction within snake robotics, where underwater snake robots are equipped with thrusters along the body to improve maneuverability and provide hovering capabilities, and how this robot addresses current needs for subsea resident robots in the oil and gas industry.

Keywords: Snake robots, modelling, analysis, control, swimming manipulators

1. Introduction

The inspiration for snake robots comes from biological snakes. The excellent locomotion capabilities of biological snakes have spurred an extensive research activity investigating the design and control of snake robots. A snake robot is a robotic mechanism designed to move like a biological snake. Inspired by the robustness and stability of biological snake locomotion, snake robots carry the potential of meeting the growing need for robotic mobility in unknown and challenging environments. These mechanisms typically consist of many serially connected joint modules capable of bending

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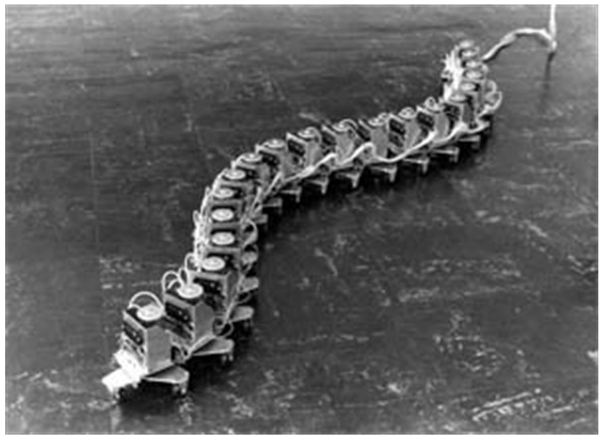

Figure 1: The snake robot *ACM III*, which was the world's first snake robot developed by Prof. Shigeo Hirose in 1972. Courtesy of Tokyo Institute of Technology.

in one or more planes. The many degrees of freedom of snake robots make them difficult to control, but provide potential locomotion skills in irregular and challenging environments which may surpass the mobility of wheeled, tracked and legged robots (Liljebäck et al. (2012, 2013)).

Research on snake robots has been conducted for several decades. The research field was pioneered about 40 years ago by Professor Shigeo Hirose at Tokyo Institute of Technology, who developed the world's first snake robot as early as 1972 (see Hirose, 1993). The robot, which is shown in Fig. 1, was equipped with passive wheels mounted tangentially along its body. The wheels enabled the robot to travel forward on a flat surface by controlling the joints according to a periodic body wave motion similar to the body waves displayed by biological snakes. In the decades following the pioneering research by Professor Hirose, several agile and impressive snake robots have been developed by research communities around the world in efforts to mimic the motion capabilities of their biological counterpart.

2. Mechatronics, Modeling and Control

The plenary talk will present a selection of our recent work on modelling, analysis and control of snake robots. A central goal of our work has been to understand the fundamental and inherent properties of snake robots, in order to efficiently control

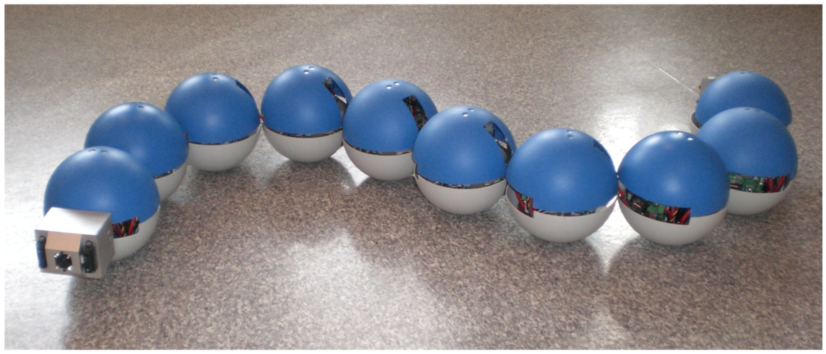

Figure 2: The snake robot *Kulko* developed for locomotion in uneven and cluttered environments.

them. When starting out our research, there was a high emphasis in the snake robotics literature on the mechanical design of these mechanisms, and the majority of the existing control design approaches used numerical simulations and empirical observations of biological snakes as the primary tools for investigating properties of the dynamics and validating the controllers. We believed that nonlinear analysis and control design had the potential of bringing the research on snake robots another step further, and the primary focus in our work has thus been on model-based nonlinear analysis and control design. For experimental verification of the theoretical results, we have developed several dedicated snake robots, including Kulko (Fig.2), a snake robot with force sensors designed for obstacle-aided locomotion; Wheeko (Fig. 3), a snake robot with passive wheels, developed to study snake robot locomotion across flat surfaces; and Mamba (Fig. 4), an amphibious snake robot for experimental validation of modelling and control theory of swimming snake robots.

A first goal was thus to derive analytically tractable mathematical models of the snake robots, and to utilize these to understand more about the properties of snake robots. The talk presents a mathematical model of a swimming snake robots. The kinematics is similar regardless of whether the snake robot moves on ground or in water, while the dynamics differs for land-based and underwater snake robots. Then we move on the question of how to make the snake robot move forward, and analysis results addressing this are reviewed. In particular, it is seen that undulatory motion will make the snake robot move forward if the robot has certain ground friction or drag

Figure 3: The snake robot *Wheeko* developed for locomotion across flat surfaces.

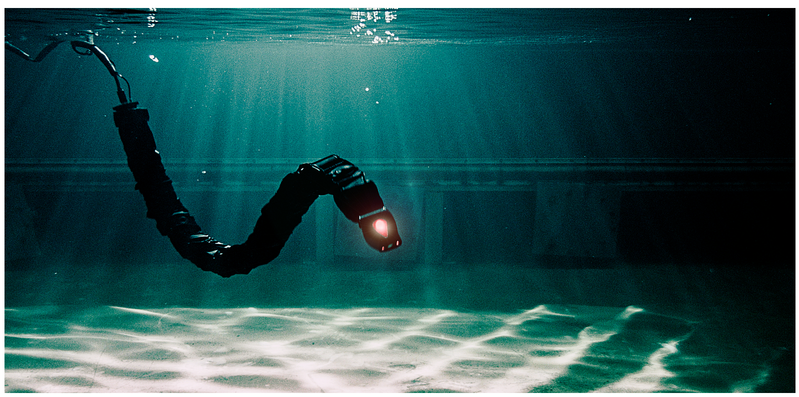

Figure 4: The snake robot *Wheeko* developed for locomotion across flat surfaces.

force properties. The talk will furthermore present results on locomotion efficiency and path following control. Then we will move on to consider swimming snake robots that are extended with thrusters along the body to improve maneuverability and provide hovering capabilities, and how this underwater robot can address current needs for subsea resident robots in the oil and gas industry, fish farming and similar.

References

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