Abstract of Doctoral Thesis

Title: CPG-based Locomotion Control of a Snake-like Robot

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Due to advantages of a natural snake, researchers have designed many control architectures to implement the unique movements into snake-like robots. In this study, we propose a novel control structure for a snake-like robot based on central pattern generator (CPG), which is inspired by a control mechanism in animal bodies. Based on the phase oscillator dynamical system, a simple network structure of coupled nonlinear oscillators or neural networks has been designed to produce rhythmic patterns. These rhythmic motions can be used to control the serpentine locomotion of a snake-like robot by manipulating control parameters of the phase oscillator model. Based on this simplified CPG network, the locomotion pattern like forward movement, backward movement or number of the *S*-shape is achievable. Feedback connections between oscillators and stability analysis for phase synchronization of the CPG network have also been analyzed. The proposed CPG network has a simple structure with less complexity, less mathematical computation, fast convergence speed and exhibits limit cycle behavior. Another uniqueness of our proposed control method is an easier parameter control based on only one parameter. With this parameter, all of the said movements can be realized on a snake-like robot.

Further analysis has been conducted for body shape control of a snake-like robot. The feature of body shape control is useful for adapting in various width of space such as tunnel, pipe and trench. This feature can be realized by modifying one of the CPG parameters. The control parameter, however, cannot be adjusted during the locomotion, because it results in unstable movements of the snake-like robot. To overcome this issue, we introduce an activation function so-called linear bipolar, which was developed from the relationship between the CPG parameter and the body shape control parameters. By adopting the activation function into the CPG model, online parameter modification can be achieved without any discontinuous CPG output. Simulation and experiment results and torque analysis confirmed the effectiveness of incorporating the activation function into the CPG model. Another contribution of this thesis is a turning control of a snake-like robot for obstacle avoidance, which is more general and can be implemented for any kinds of snake-like robot's design.

For a snake-like robot to maintain its direction while moving in the hallway with different space width, we propose a straight-path control strategy of a snake-like robot based on our CPG model. Even though maintaining the straight locomotion of a snake-like robot can be realized by the control architecture like sine-based, model-based or other, a problem occurs when one or more of the control parameters are modified online, results in deviation of the trajectory of the snake-like robot from its initial path. This is not desirable when we need the snake-like robot to move in a hallway with different space width, where online modification of parameter is required to change its body shape. The proposed simple control strategy of the straight-path locomotion can keep its locomotion direction while the robot moves in a changed width of the space. Computer simulation

and experiment verified its validity and effectiveness.