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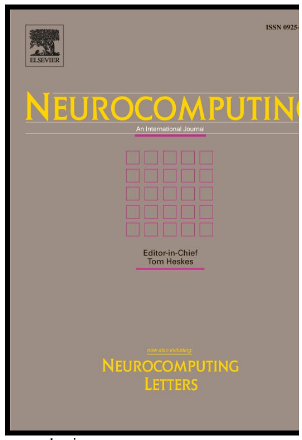

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A Unified Neural Oscillator Model for Various Rhythmic Locomotions of Snake-like Robot

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Abstract

This paper contributes to the understanding and implementation of different types of locomotion in a snake-like robot by using a proposed unified neural oscillator model as central pattern generator (CPG). A neural oscillator network is suggested so that several rhythmic movements can be generated in order to mimic the actual snake movements on land. The unified coupled neural oscillators in the network provide the desired orientation and displacement for the snake-like robot and they are applied to the different types of snake locomotion by just altering some of the parameters proposed in the paper. The design of snake-like robot, consisting of a series of wheeled links (links with active wheels) connected with each other using the passive prismatic and revolute joints, is also suggested in the paper. The passive prismatic joints facilitate the change of lengths of wheel-less links and in this way the robot can be elongated as well as shortened. In this paper the serpentine, rectilinear, and concertina types of actual snake locomotion are realized, through simulation studies, by using the unified neural oscillator model proposed for the snake-like robots.

Keywords: central pattern generator (CPG); neural oscillator; snake-like robots

Nomenclature

m	the number of wheeled links (links with active wheels) in snake-like robot
L	length of wheeled link
X-Y, X_S-Y_S	world and snake coordinate frames, respectively
P_{i_1}, P_{i_2}	passive prismatic joints b/w i^{th} and $(i+1)^{th}$ wheeled links
$P_{i_1,max}$, $P_{i_2,max}$	the maximum lengths of P_{i_1} and P_{i_2}
φ_s, $R(\varphi_s)$	rotation angle and matrix b/w world and snake coordinates, respectively
U_{i_1}, U_{i_2}	linear and angular velocity control of i^{th} wheeled link, respectively
x_i, y_i, φ_i	position and orientation of i^{th} wheeled link
$x_{d_i}, y_{d_i}, \varphi_{d_i}$	desired position and orientation of i^{th} wheeled link
$\varphi_{S_{di}}$, S_{di}	desired orientation and displacement of i^{th} wheeled link in snake coordinates
α_i, β_i	parameters to adjust $\varphi_{S_{di}}$ and S_{di} according to rigid body constraints of snake body, respectively
K_{ρ_i}, K_{σ_i}, K_{γ_i}	control gains for i^{th} wheeled link
ρ_i	desired displacement in world coordinate
σ_i, γ_i	angles of desired vector with respect to forward direction and world coordinate frame, respectively
n	the number of neural oscillators
θ_j, ω_j	phase and natural frequency of j^{th} oscillator
W_{jk}, ϕ_{jk}	coupling weight and phase difference b/w j^{th} and k^{th} oscillators, respectively
τ_j	neuron firing of j^{th} oscillator

1. Introduction

Taking inspirations from biological organisms and mimicking into robots is one of main research interests of many researchers in the field of robotics. The snake-like robot becomes one of the popular bio-inspired robots because it is helpful in implementing several applications such as rescue work, surveillance, and inspection. Major advantage of the snake is redundant nature of its limbless body, which has given it the potential to navigate in wide range of environments. Along with this, the dexterous movement of the snake body becomes another reason for extensive research on snake-like robots. The snake shows a variety of locomotions on land and in water such as the serpentine, rectilinear, concertina, and side-winding locomotions, especially, the rectilinear and the concertina types of locomotions are helpful in passing through the confined spaces.

Many snake-like robots have been designed and constructed and they all belong to a class of hyper-redundant mechanisms composed of kinematically constrained and chained links together in series. In the early 1970's, Hirose was one of the pioneers in the field of snake robot research. In [1], he had classified the snake-like robots into five types based on their designs as follows; the first type is the snake-like robots composed of series of links and connected with each other using active joints. The robots having active joints and passive wheels belong to this type. Some of most common snake robots of this category are ACM-R3 [2], Amphibot-I [3], Amphibot-II [4], unified modular snake robot [5] and the snake robot proposed in [6]. The swimming snake-like robots are also of this type. The second type is the snake-like robots formed by combination of series of joints that can bend sideways as well as elongate