Dynamically Balanced Optimal Gait Generations for the Biped Walking on Stairs Using GA and GA-NN

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Summary. The present paper deals with dynamically balanced gait generations of the 7-DOF biped walking on stairs. The two different optimization approaches are used, namely genetic algorithm (GA) and genetic neural (GA-NN). The effects of trunk mass and stair height on the energy consumption for both ascending and descending stairs are studied. The GA-NN is found to be more adaptive compared to GA in generating the optimal gaits for the biped walking on stairs.

Objectives

This paper aims to create optimal gaits for the biped of different trunk mass ascending and descending stairs with minimum energy consumption by using genetic algorithm (GA) and genetic neural (GA-NN).

Methods

The biped robot should have the ability to adapt themselves to multiple locomotion modes, including level-ground walking, stair ascending/descending, and ramp ascending/descending. Different optimization tools were used to produce optimized gaits in order to improve the energy efficiency and locomotion stability. Vundavilli and Pratihar [1] and Gong [2-4] generated the optimal bipedal gaits on different terrains with GA or GA-NN as the optimization tool. Other optimization tools were utilized in optimal gait generation of the biped, such as neural network (NN), fuzzy logic (FL) and combinations of NN, FL and GA. The analytical method, GA-trained NN and GA-trained FL were compared for proposing suitable gaits of the biped negotiating various terrains by Vundavilli et al. [5]. Gong and Schiehlen [6] and Gong [7] have proved the motion/force control strategy can be used to achieve stable walking for the biped impactless walking on slopes and stairs. Additionally, the determination of trunk motion is very important for the dynamic balance of the biped. Vundavilli et al. [8] found that the trunk mass of the biped robot had significant influence on the energy consumption. In the presented study, the optimal gaits of the biped of different trunk mass were generated with GA and GA-trained NN for staircase ascent/descent by ensuring low energy and the stability. The 7-linked bipedal impactless walking model with different trunk mass was used, which was built using the multibody formalism Neweul-M2 [9].

In GA-trained NN algorithm, genetic algorithm is utilized to create the initial optimal trajectories of the lower limb joints for the biped walking on stairs. The maximum height of the swing foot from the current stair level (h_A) and the speed (v) are considered as GA variables. Various trunk masses (m_T) and stair heights (h_{st}) are simulated in this study. In order to compare energetic performance [10], the minimum specific resistance (ε) is used as the objective function, which is defined as:

$$\varepsilon(v) = \frac{P(v)}{mgv} , \qquad (1)$$

where P is the mechanical power output and mg is the biped weight.

Then, the NN was used to create final optimal gaits. In this study, the optimal gait generation problem is solved using one module of NN. The module of NN consists of input layer, hidden layer and output layer (Fig. 1). GA creates the optimal trajectories of lower limb joints and connecting weights of the NN. The NN inputs are the coordinates of three intermediate points of the swing foot. The NN outputs are the final optimal coordinates of the swing foot.

Results and Discussions

The results indicate that it is computationally expensive and slow to generate optimal gaits by GA. However, the time to create optimal gaits by GA-NN is smaller, which is suitable for generating optimal gaits of the biped walking on different stairs.

The energy consumption of the biped walking on stairs utilizing GA-NN is smaller, compared to using GA approach. A suitable value of trunk mass can be obtained considering average energy consumption and the dynamic balance. The proposed optimization tool, GA-NN method, can create the optimal gaits for the biped walking on stairs. Further research will continue to generate optimal gaits with GA-NN for the biped walking across multiple locomotion modes, i.e. transition between the level-ground walking and stair ascending/descending.

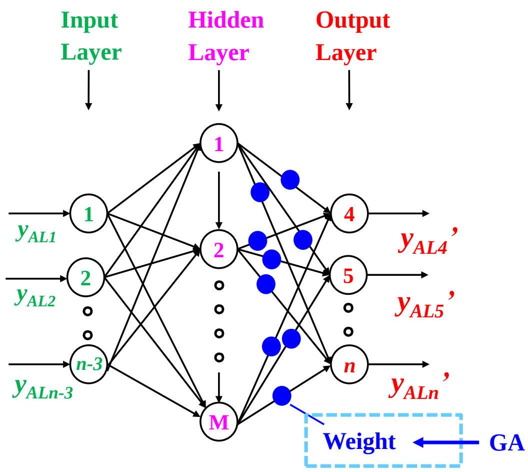

Figure 1: The structure of the artificial neural network.

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