이족 로봇을 위한 자기 회귀 신경 회로망 기반 슬라이딩 모드 제어

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Self-Recurrent Neural Network Based Sliding Mode Control of Biped Robot

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Abstract - In this paper, we design a robust controller of biped robot system with uncertainties, using recurrent neural network. In our proposed control system, we use the self-recurrent wavelet neural network (SRWNN). The SRWNN makes up for the weak points in wavelet neural network(WNN). While the WNN has fast convergence ability, it dose not have a memory. So the WNN cannot confront unexpected change of the system. However, the SRWNN, having advantage of WNN such as fast convergence, can easily encounter the unexpected change of the system. For stable walking control of biped robot, we use sliding mode control (SMC). Here, uncertainties are predicted by SRWNN. The weights of SRWNN are trained by adaptive laws based on Lyapunov stability theorem. Finally, we carry out computer simulations with a biped robot model to verify the effectiveness of the proposed control system,.

1. Introduction

A biped robot has designed for resemblant behavior which is similar to human. So, many scientists study motion of robot and make an effort for movement as motion of human. A biped robot model has been researched for the half century. At first, researchers study inverted pendulum concepts[1]. Later, they construct the 3-link model[2], and 5-link model[3],[4].

In control biped robots, we face some problems such as instability of locomotion, high-order dynamic equation, existence of different phases of the walking cycle and various uncertainties. To solve those problems, we use sliding mode control (SMC) [5]. This technique can easily control biped robot with uncertainties by contrast with standard PD control.

Also, recently, wavelet neural networks (WNNs) are used as the good tool for estimation. However, the WNN has some disadvantages. WNN has fast convergence ability, but dose not have a memory. To overcome that disadvantage of WNN, we use self-recurrent wavelet neural networks (SRWNNs) with memories [6]. These memories are primary role which can easily encounter the unexpected change of the system.

In this paper, we design a robust controller of biped robot system with uncertainties, using the SRWNN based on SMC for the stable walking of 5-link biped robot. All weights of SRWNN are trained by adaptive laws based on Lyapunov stability theorem, which is used to guarantee the stability of control system.

Finally, to verify the effectiveness of the proposed control system, we carry out computer simulations based on biped robot model. So, we prove the advantage of SRWNN by contrast with WNN.

2. The Model and control of 5-link Biped Robot

2.1. Self-recurrent wavelet neural network

The SRWNN structure is employed. The SRWNN is composed four layers as follows[6]:

The layer 1 is input layer.

The layer 2 is mother wavelet layer. Each node of this layer has a mother wavelet and a self-feedback loop.

The layer 3 is product layer.

The layer 4 is output layer.

The weight of SRWNN composed uncertainty term $\Upsilon(q,\dot{q},\tau)$.

2.2 Kinematic model

In this paper, the 5-link biped robot model[5] is employed. It is composed of five links, namely the torso, two upper legs, and two lower legs. Each link is connected by four rotating joints; two hip joints and two knee joints, which is driven by an independent DC motor. The motion of the biped robot is assumed to be constrained within the sagittal plane. The kinematic model is described the relation between the velocity of the foot of the swing leg and the change of generalized variables[5].

2.3. Control of the biped robot

We have dynamic model with parametric uncertainty expressed as the following form [5]:

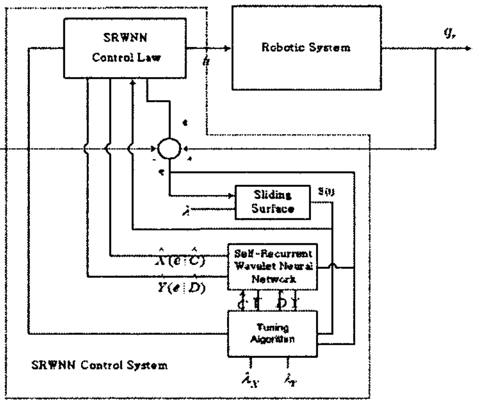
$$H(q)\ddot{q}+B(q,\dot{q})+G(q)+\Xi(q,\dot{q},\tau)=\tau_q \tag{1}$$

where, $\Xi(q,\dot{q},\tau)$ is the uncertainty of the robot system.

The above equation is rewritten as follows:

$$\begin{aligned}\ddot{q}&=H^{-1}(q)\left(\tau_q-B(q,\dot{q})-G(q)+\Xi(q,\dot{q},\tau)\right)\\&=H^{-1}(q)\left(\tau_q-B(q,\dot{q})-G(q)\right)+\Upsilon(q,\dot{q},\tau)\end{aligned}$$

Here the uncertainty term $\Upsilon(q,\dot{q},\tau)$ cannot be computed directly, so we use SRWNN[6]. The control structure which is approximated by SRWNN is shown in Figure 1.

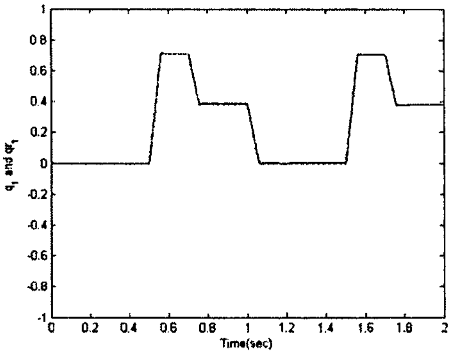


<Fig. 1> The control scheme

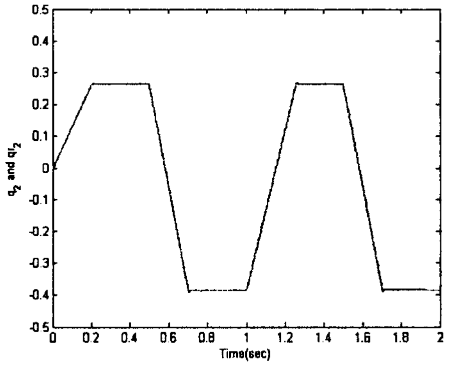
3. Simulations

In this simulations, we use the 5-link biped robot model presented in [5]. Also, the parameter of the robot model is used in [5]. We simulate SMC with 100% parametric uncertainty of which 100% each of parameter value add on mass and moment of inertia. We choose the control gain λ. Also, we simulate in final time 2 sec, and sampling time is chosen as 0.002 sec. In previous contents, we use the SRWNN to solve uncertainty problem. At this time, to guarantee the stability of our control system, we give the positive tuning gains, λ_c and λ_e.

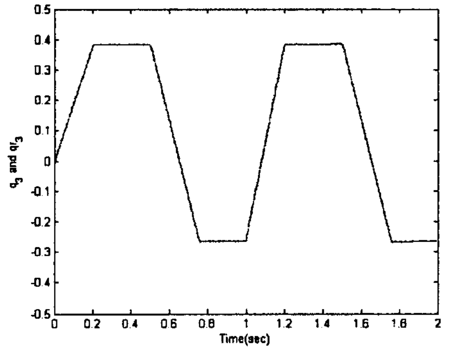
From Fig. 2 to Fig. 5, we can confirm the reference trajectory of q and reference tracking trajectory for a SMC and SRWNN. Figure 6 shows each of the driving torque and Fig. 7 shows squared error. This error is appeared to sum of squared error of each joints. Also, MSE of each joints is 0.0016, 0.0011, 0.0006, and 0.0007, respectively. From these results, it is verified that those controller and estimator can guarantee a good tracking performance.



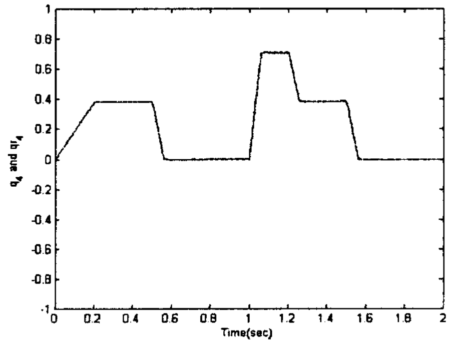
<Fig. 2> Reference trajectory of q_1 and tracking trajectory



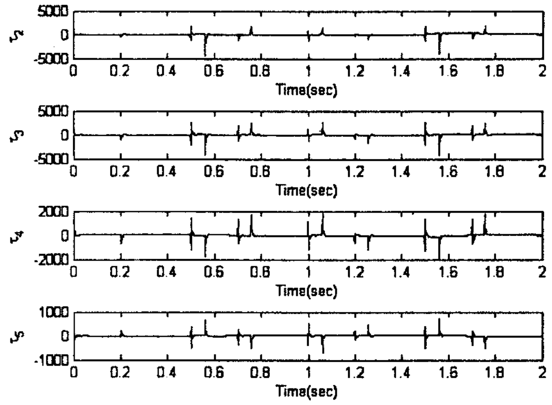
<Fig. 3> Reference trajectory of q_2 and tracking trajectory



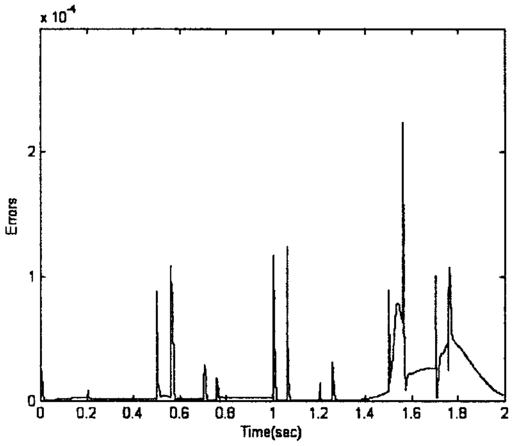
<Fig. 4> Reference trajectory of q_3 and tracking trajectory



<Fig. 5> Reference trajectory of q_4 and tracking trajectory



<Fig. 6> Each of the driving torque



<Fig. 7> Squared error

4. Conclusion

In this paper, we design a robust control system of 5-link biped robotic model with uncertainties, using self-recurrent wavelet neural network. Also, that control system is based on sliding mode control technique. This technique is used to improve the efficiency of position tracking performance of biped locomotion. In addition, by using SRWNN, the disadvantage of WNN which cannot confront unexpected change of the system is solved easily. In our control system, the SRWNN having simple structure is used to estimate the unknown uncertainties and nonlinear functions. The weights of SRWNN were trained by adaptation law and this law is based on the Lyapunov stability theorem which guarantee the stability of the designed control system. Finally, computer simulations show the good tracking performance and this efficiency of this system, directly.

[Reference]

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