Dynamic Modelling of Seven- Link Biped Robot on Matlab/Simulink: Survey

Padmini Sahu, Anurag Singh Tomer

Abstract— In this paper, we are going to propose an artificial neural network controller design based on radial basis neural network to control level walking of biped robot. The model used for the biped robot simulation consists of 7-links which are connected through revolute joins. The identical legs have hip, knee & ankle of both legs & torso. A PID controller is used on a linear model in state variable form in order to simulate the dynamic of the system in Matlab.

Index Terms— Gait cycle, Biped robot, dynamic modelling, neural network..

I. INTRODUCTION

Neural networks and learning methods prove to be very effective in controlling dynamic systems. A biped model of walking is characterized by an "inverted pendulum" movement in which the center of gravity over a stiff leg with each step. Application of Robotics in the field of medical has gained a strong footing apart from manufacturing industries, sheep-shearing, agriculture, nuclear power industries, fire-fighting, mining, under-seas applications, outer-space and other application. To improve human life and perform experiments in the environment where human works and tasks for which human like structure is only one choice, biped is the only solution.

A radial basis function network is an artificial neural network that uses redial basis functions as activation functions in the field of mathematical modeling. The output of the network is a linear combination of radial basis functions of the inputs and neuron parameters. Radial basis function networks have many uses, including, time series prediction, classification and control system. Radial basis functions (RBF) networks are also feed forward, but have only one hidden layer. A RBF network has any number of inputs, typically has only one hidden layer with any number of units, uses radial combination functions in the hidden layer, based on the squared Euclidean distance between the input vector and the weight vector and typically uses exponential or softmax activation functions in the hidden layer, in which case the network is a Gaussian RBF.

Jih-Gau Juang [2] presented a 5-link biped locomotion learning scheme using a fuzzy modeling neural network. The learning scheme can generate walking gaits by providing a reference trajectory which defines the desired step width, height and period in several stages. The proposed scheme used a fuzzy controller combined with a linearized inverse biped model.

A multi-layered fuzzy neural network is used as a controller; it provides the control signals in each stage of a walking gait. The algorithm used to train the network is the back-propagation through time. The linearized inverse biped model provides the error signals which will be used to back propagate through the controller in each stage.

Hasegawa, Arakawa and Fukuda [3] proposed a hierarchical evolutionary algorithm to generate natural motion for biped locomotion robot on the slope so as to minimize total energy. They formulated the trajectory generation problem as an optimization problem of energy with any constraints. To solve this problem with constraints, they utilized the hierarchical evolutionary algorithm which consists of two parts, one is the GA layer and the other is the EP layer. Furthermore, the obtained trajectory has been applied successfully to the biped locomotion robot on the flat plane. As a future work, the proposed algorithm must be improved to be a faster algorithm, because this algorithm takes much time to generate one motion and it is difficult to apply real-time motion generation.

Zhou and Meng [4] proposed a fuzzy reinforcement learning algorithm for biped gait synthesis. It can form the initial gait from fuzzy rules, which are obtained from human intuitive balancing knowledge, and then accumulate dynamic balancing knowledge through reinforcement learning, and thus constantly improve its gait during walking. The simulation results show that the fuzzy gait synthesizer can only roughly track the desired trajectory, while the gait can be significantly improved by the proposed reinforcement learning-based gait synthesizer. They also found that the gait synthesizer’s performance can be further improved using fuzzy evaluative feedback. The reinforcement learning with fuzzy evaluation feedback is much closer to the human biped.

Kim, Noh and Park [15] presented the smooth walking trajectory for a biped robot using genetic algorithm. Suitable velocities and accelerations at the via-points are required for dynamic smooth walking since the incorrect via-points data can cause the discontinuity on the trajectory and the unstable walking motion as a result. Optimal via-points data can be found by minimizing the sum of deviation of velocities and accelerations as well as jerks. Using genetic algorithm, we obtained the continuity on the entire trajectory interval and the energy distribution during the walking. In conclusion, it is shown that the proposed genetic algorithm guarantees a satisfactory smooth and stable walking through the experiment on the real biped robot. In this paper, objective is to propose redial basis neural network with PID controller is designed, modeled and its performance is simulated in Matlab-Simulink environment for controlling the walking activity of Biped Robot.

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Padmini Sahu, Dept. of EE, Rungta College of Engineering and Technology, Bhilai, C.G., India.

Anurag Singh Tomer, Dept. of EE, Rungta College of Engineering and Technology, Bhilai, C.G., India.

II. DYNAMIC MODELING OF BIPED ROBOT

In this paper, the concept of 7-link biped simulink model is proposed for walking activity. The biped structure given by Olli Haavisto & Heikki Hyötyniemi work [6] which has 5-link- 1 torso and 2 lower limbs with each limb having a thigh and shank. We have taken 7-links- 1 torso and 2 identical legs having a thigh, a shank and an ankle as shown in fig.1

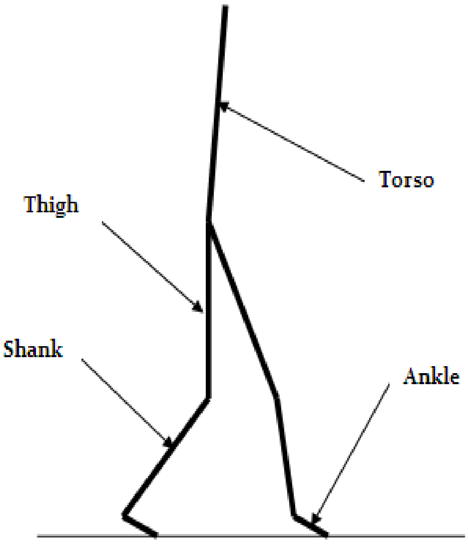

Fig.1Biped Robot

We are using the L-E formulation for the mathematical model for the dynamics of the robotic leg given by Eq. (1).This formulation is based on the motion of generalized co-ordinates, energy and generalized force.

$$\tau_i = \frac{d}{dt}\frac{\delta L}{\delta \theta_i} - \frac{\delta L}{\delta \theta_i} \qquad (1)$$

Where

L (Lagrangian function) = K (Kinetic Energy) – P (Potential Energy)

θ_i = Generalized coordinates limb,

$\dot{\theta}_i$ = First time derivative of generalized coordinate,

τ_i = Generalized torque applied to the system; at joint i to drive link i.

III. ARTIFICAL NEURAL NETWORK CONTROLLER (ANN)

An Artificial Neural Network (ANN) is an information processing framework based on biological science like functioning of human brains and their components to process information. ANN comprises huge amount of interconnected information processing elements (neurons) working together to solve specific problems. The ability of neural networks is to find meaning from complicated (training) data, can be used to detect trends, patterns etc. that are highly complex in nature to be identified by either human being or other computing algorithms. Given information, a trained neural network can be seen as an "expert" in that category of information to analyse it to predict queried information. The neuron is made up of three main parts- dendrites; cell body and axon as shown in figure 1. A neural network is used to train a network to perform a particular function by adjusting the values of connections (weights) between elements. Neural networks are composed of elements operating in parallel. Parallel processing allows increased speed of calculation compared to slower sequential processing. The science of artificial neural networks is based on the neuron. In order to understand the structure of artificial networks, the basic elements of the neuron should be understood. Neurons are the fundamental elements in the central nervous system. The diagram below (Fig. 2) shows the components of a neuron.

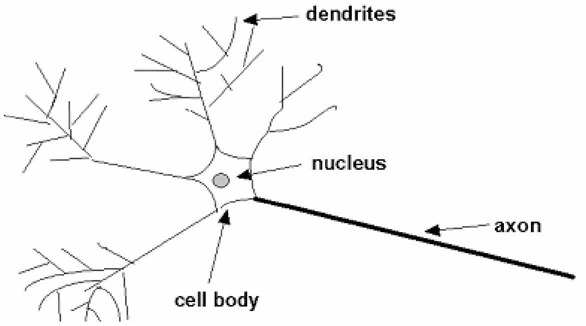

Fig.2 diagram shows the basic elements of a neuron

In this paper, we are going to use the concept of radial basis neural network to control walking activity of Biped Robot as shown in figure 3.

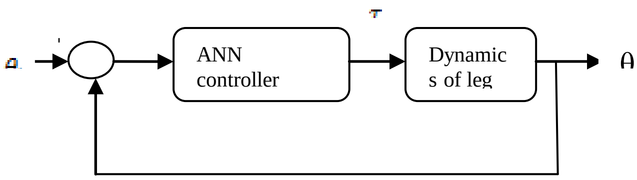

Fig.3 Dynamic Modal of Biped Robot

For a radial basis function network is an artificial neural network that uses radial basis functions as activation functions and is the radial basis function (Gaussian) given by (2).

$$\sigma(x) = e^{-(x-\mu)^2/2\rho} \qquad (2)$$

Where μ is the mean and ρ the variance.

The block diagram and waveform of redial neural network [13] is shown in Fig. 4 & Fig. 5, respectively.

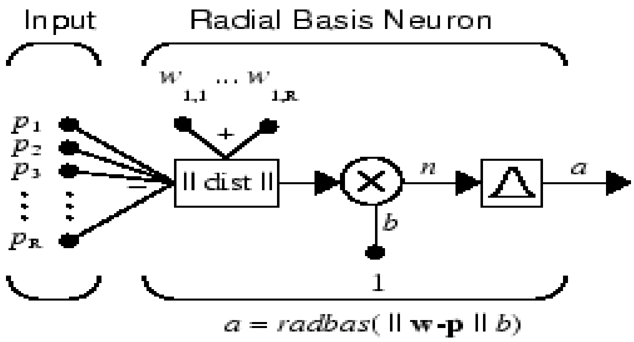

Fig.4 Block diagram of redial basis neural network

In above fig. 3, Radial basis neuron acts as a detector that produces 1 whenever the input **p** is identical to its weight vector **w**. The bias *b* allows the sensitivity of the radbas neuron to be adjusted

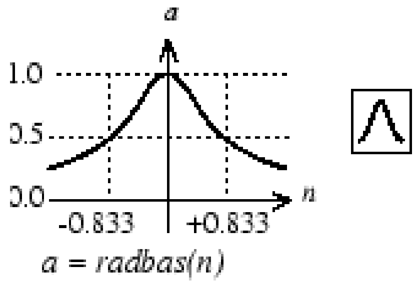

Fig. 5 Radial Basis Function

The architecture of radial basis function neural network [1] & [5] is shown in Fig. 5. It consist of two layers- a) the first one a hidden radial basis layer having S^1 neurons & b) the second an output linear layer with S^2 neurons. Radial basis network is selected because it adds neurons to the hidden layer until it meets the specified mean squared error goal. Initially training of neural network for inverse dynamics of leg is done by not taking any neurons in the first layer.

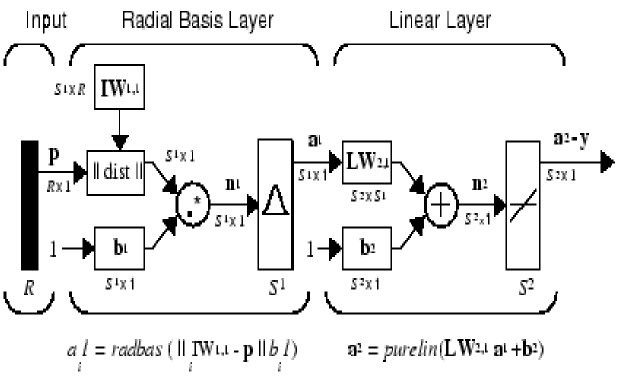

Fig. 6 Architecture of radial basis function neural network

R = number of elements in input vector,

S^1 = number of neurons in layer 1,

S^2 = number of neurons in layer 2,

$a_i 1$ = radial basis of ($(\|IW1,1 - P\| b_i 1)$,

a^2 = purely linear function of $(LW2,1\, a^1 + b^2)$,

$IW:\{\text{2x1 cell}\}$ containing 1 input weight matrix,

$LW:\{\text{2x2 cell}\}$ containing 1 layer weight matrix,

$b:\{\text{2x1 cell}\}$ containing 2 bias vectors.

IV. CONCLUSION

In this paper, we have studied different research papers. I have found that redial basis neural network gives better result. Thus, we will use redial basis neural network for improving walking activity of biped robot in Matlab/ Simulink

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