Neuro-Fuzzy Gait Generator for a Biped Robot

Abdallah Zaidi, Nizar Rokbani, Adel. M. Alimi
REGIM: Research group on intelligent machines
University of Sfax
École Nationale d'Ingénieurs de Sfax
BP w, Route de Soukra, Sfax, TUNISIA

ABSTRACT: *The control of walking robots has improved dramatically over the last few years. Several methodologies have been developed for this. As one of them, in this work, we used fuzzy logic controller that generates angular of the knees in order to active a desired position of the center of mass. We present a fuzzy gait generator, FGG, that generates the angular trajectories of a biped robot. The FGG, is a neuro-fuzzy gait generator that used a classical geometric model of a 5 segments representation and replicated its comportment. The obtained controller has the same comportment of a classical geometric model and could be an alternative to it.*

Keywords: Neuro-Fuzzy Control, Biped Robot, Gait Generation

Received: 5 March 2012, Revised 10 April 2012, Accepted 17 April 2012

1. Introduction

During the last few years, the number of research and development projects aimed at building bipedal and humanoid robots has been increasing at a rapid rate [1-2]. The main motivations for using bipedal robots are introduced, and we then proceed to consider bipedal locomotion as well as other behaviors.

Classical modeling methodology such as direct and reverse kinematics or Lagrange based approaches are used to obtain the gait generation, GG. These approaches are cost computing and very close to a robot model. Intelligent approaches are based partially on the "*model free paradigm*".

It is still necessary to further improve their capabilities such that humanoid robots must be more autonomous intelligent and adaptable to human environment [9].

There are several good reasons for developing bipedal walking robots, despite the fact that it is technically more difficult to implement algorithms for reliable locomotion in such robots than in e.g. wheeled robots. Gaits generation is a key issue in humanoid robotics, in most cases the gaits are designed to fit a specific machine with a specific mechanical and control parameters [9].

The motivation of research is the suitability of the biped structure for tasks in the human environment. The control of a humanoid robot is a challenging task due to the hard-to stabilize. In previous command, the big disadvantage is that the trajectories are pre-calculated [5_7_10].

We present at the first section the description of the biped robot. In the second section, we show the fuzzy gait generator, FGG. Finally, we present our conclusions and our further work.

2. Description of the System

2.1 Introduction to neuro-fuzzy approach

Artificial neural networks (ANN) and fuzzy inference system (FIS) are generally considered to be complementary areas of research. The combination of FIS and ANN define a neuro-fuzzy system in such a way that the parameters of FIS are determined by using the neural network learning algorithms [13].

The neuro-fuzzy system uses the linguistic knowledge of fuzzy inference system and the learning capability of neural network. To describe the architecture a neurofuzzy system, consider Figure 1. For simplicity, we assume that our fuzzy system has two inputs and one output. Furthermore, we assume that the defuzzification of the variables is a linear combination of the first order of input variables (approach of Takagi - Sugeno).

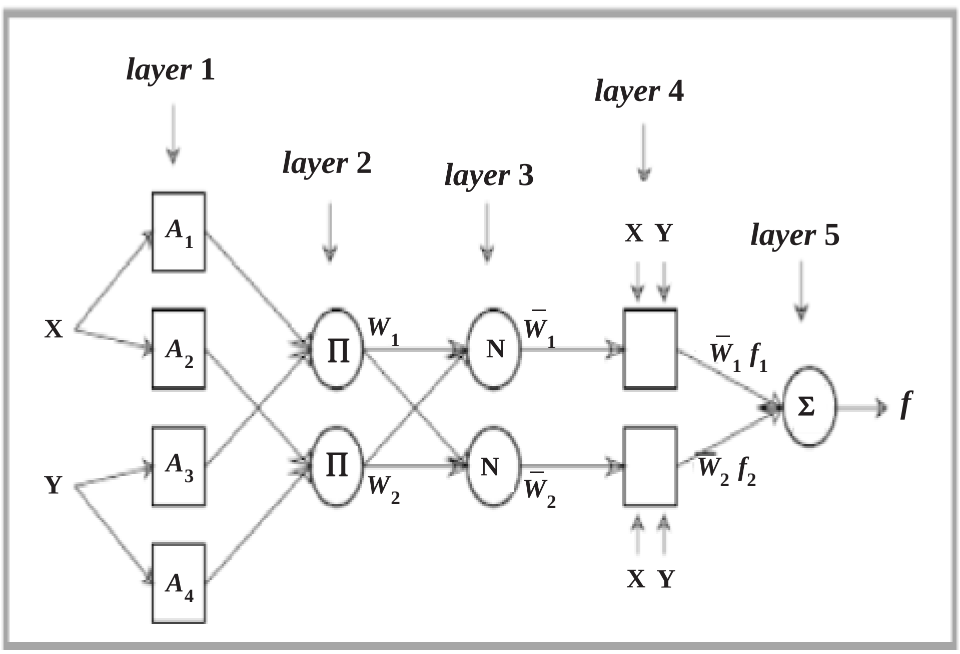

Figure 1. Neuro-Fuzzy System Architecture

For an application of prediction (i.e. approximation), we determine the output f corresponding to the inputs X and Y

2.2 System overview

Typically a control schema is composed by the gait generator, the robot controllers [9], see Figure 2.

The biped model is a seven segment one, the foot prints are not considered in this model. Motion analyses are made on two plans separately, the sagital and the frontal one. The fuzzy gait generator is build offline, the gait generated from are fitted for human size robots.

For this proposal a neuro fuzzy controller was investigated as an alternative gait generator. In order to ensure the learning process for the controller, a classical simulated geometric model was used, see figure 3.

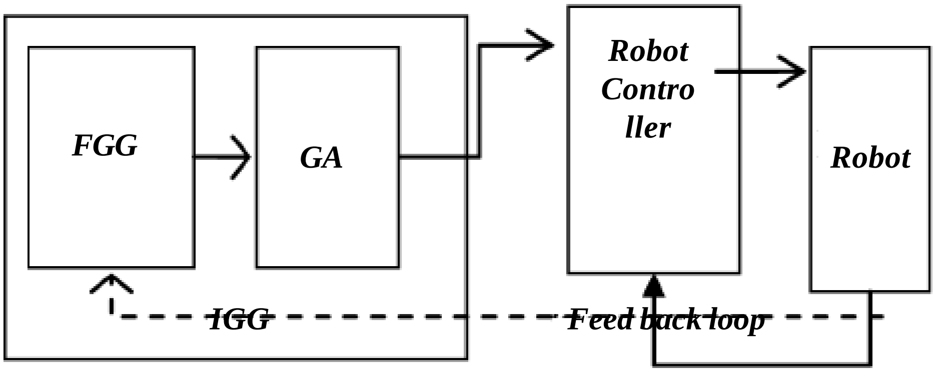

Figure 2. Robot control flow, FGG fuzzy gait generator, GA Gait Adaptation Module

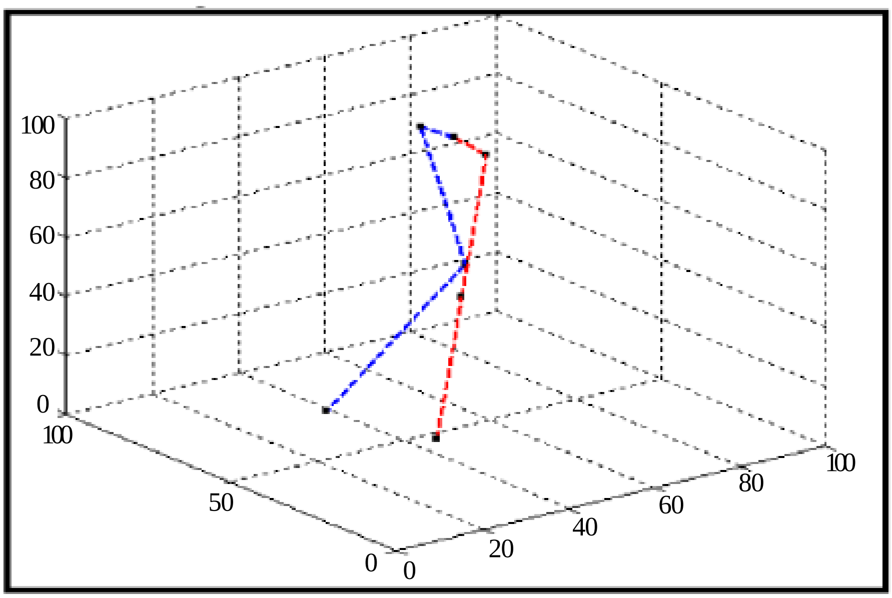

Figure 3. The 3D graphical simulator

The IZIMAN is a research projects that conducting in REGIM laboratory, "*Research group on Intelligent Machines*". The main challenge of the project is to propose an intelligent architecture and controller that are "*humanly*" inspired [7].

3. Fuzzy GAIT Generator Design

3.1 FGG learning process

The joints issued from classical geometric model simulation, see figure 4, are introduced as inputs into a fuzzy learning module; the module has to generate his own gaits according to a set of characteristics such as total body height and locomotion system dimensions.

To generate the fuzzy gait generation, we need the trajectories of the COM of the biped robot model as input for this system that generates the angular trajectories of a biped robot.

The scheme proposed for the FGG is as follows:

The FGG is obtained using the ANFIS, Adaptive-Network-based Fuzzy Inference Systems ; to train the FGG we introduced a set (Input/output), a Sugeno-inference system is build using the matlab fuzzy logic toolbox [11], in some way the FGG has to reproduce the human joints trajectories, given a target position the FGG will produce a set a coordinates representing the joints coordinates in (X,Y,Z). It is important to remark that the generated gait covers only the forward walking. The learning process needs the generation of the curves of ankle, the knee, the hip and the center of mass, COM [10]. The COM is a key issue in biped control since it allows the estimation of the robot stability [12].

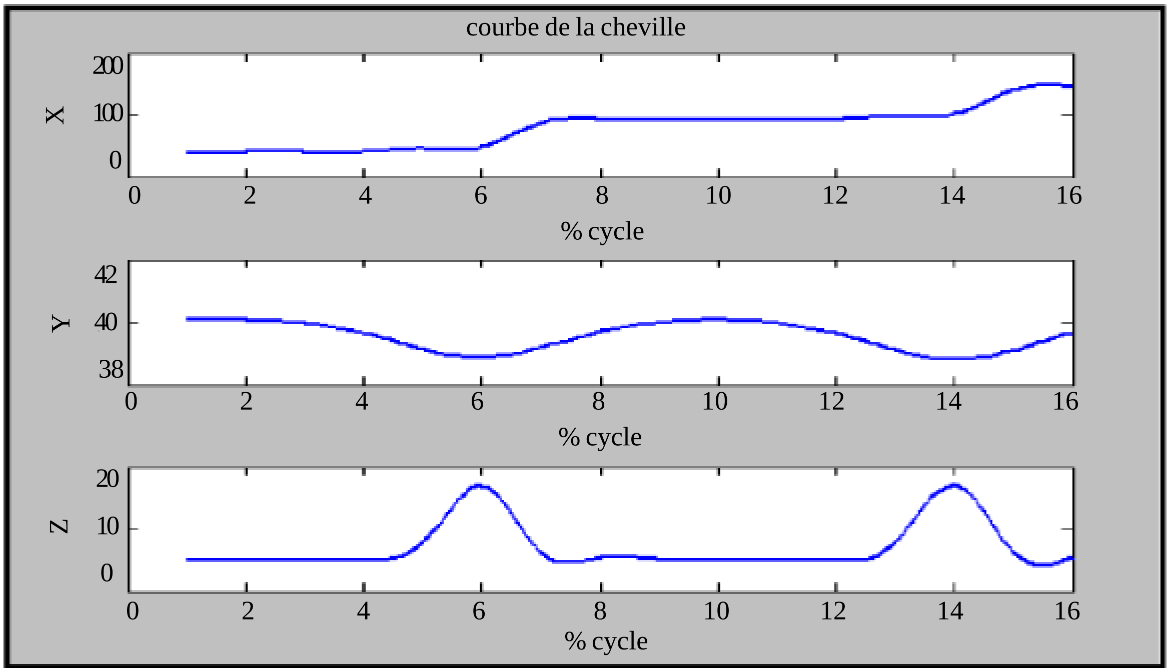

Figure 4. Classical modeling output of biped (X,Y, Z) coordinate system

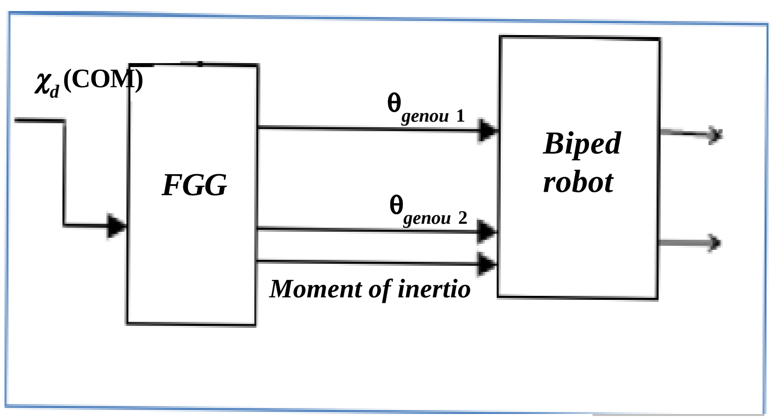

Figure 5. Structure of the proposed FGG

3.2 Generated FGG parameters

In our application we will use the curve center of mass as input for the FGG and the curves of knees as output. Therefore, we obtained a Sugeno type fuzzy system that has 6 rules to calculate its outputs. We present, its block diagram (Figure 6) and membership functions (Figure 7).

3.3 Results & discussion

To test the FGG, we take two vectors of the basic sets of data and they are taken as inputs to this system and the system output is the curve representing the path of the knee illustrated in Figure 8. The behavior of the FGG is represented in the following figure(Figure 9).There's no linearization on the surface of work of the FGG.

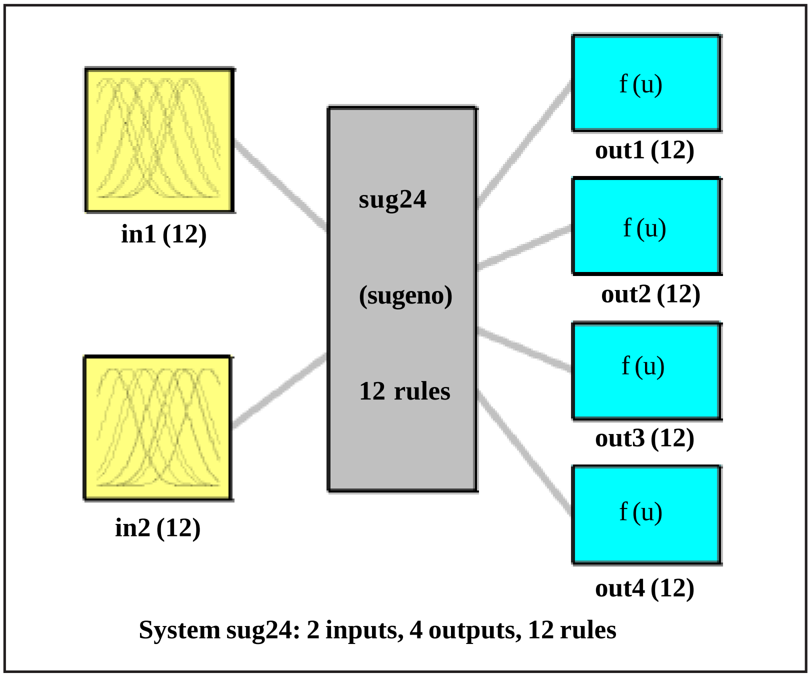

Figure 6. General diagram of the FGG

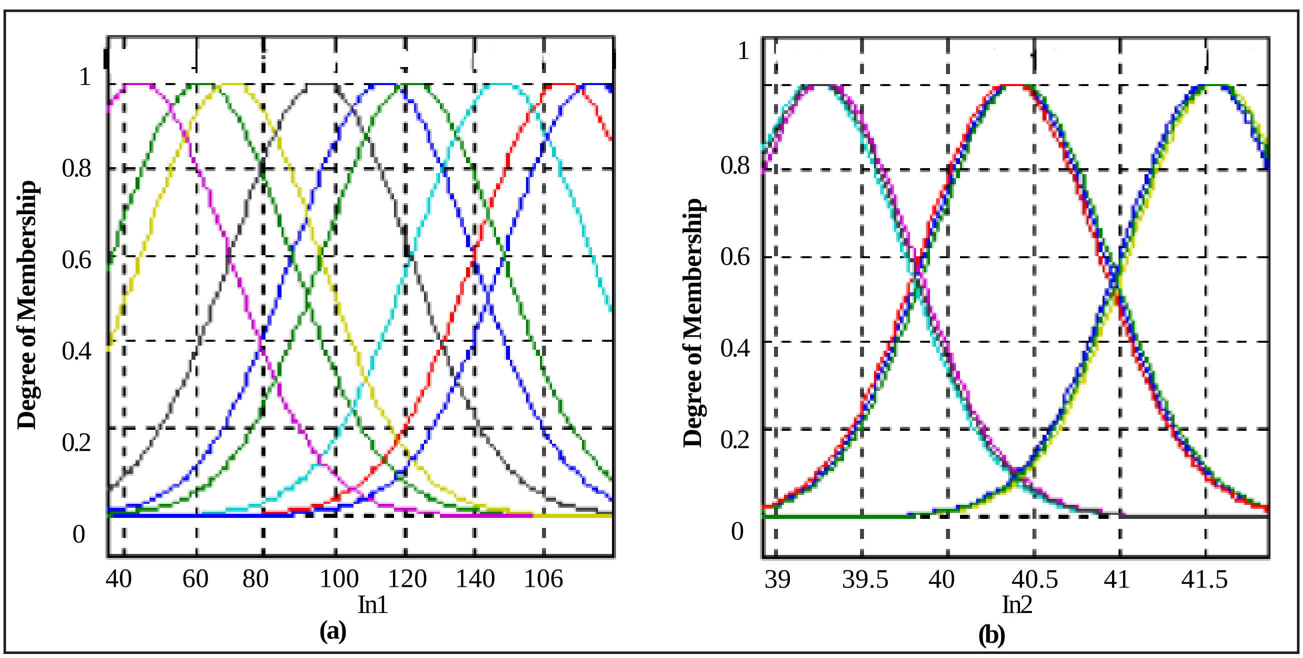

Figure 7. (a) Memberships Functions of the input In1. (b) Memberships functions of the input In2

Since the gaits generated from the FGG are in Cartesian (X, Y, Z) coordinates system, to control the joints we need to convert them into rotations.

To evaluate the error of the introduced FGG, we will calculate the normal error according to the following equation:

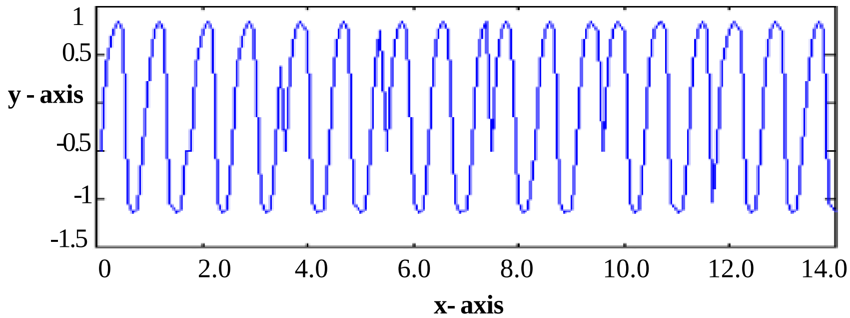

Figure 8. Path of the knee calculated by the FGG

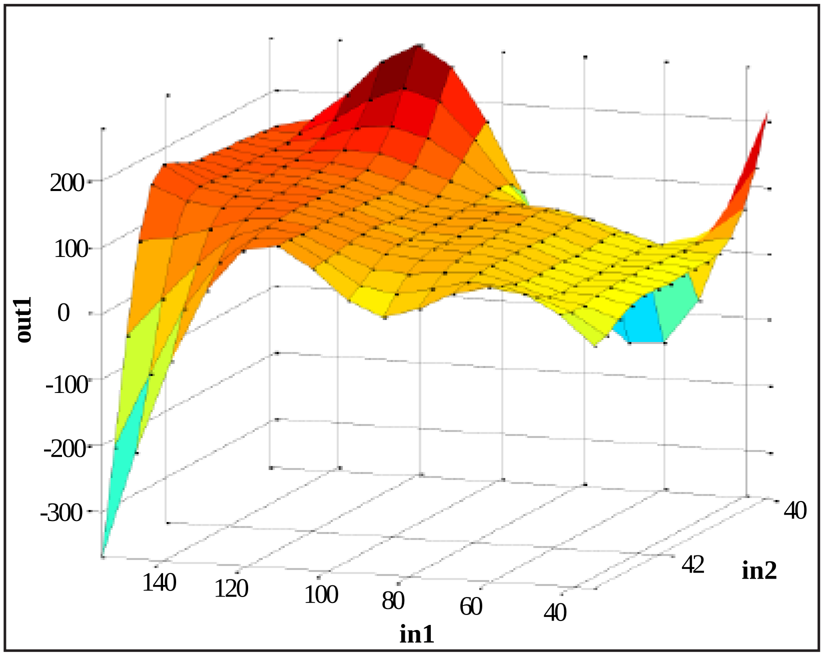

Figure 9. Surface behaviours of the FGG

Normal_error = error (output_FGG-output_test) / output_FGG

$$NMSE = \frac{1}{N.M}\sqrt{(output\_FGG - FGG\text{-}output\_test)^2}$$

with *N*, *M* the size of the output FGG matrix.

NMSE: Normalized Mean Square Error.

Output_FGG: trajectories of the knees(blue in Figure 9)

Output_test: behavior of the classical model(red in Figure 9)

Now, we present the eror of the proposed FGG

The FGG presents an error enough to nival stages of the impact of the feet during the various phases of the gait cycle.

4. Discussion and Further Work

In this paper, we have proposed a fuzzy gait generator FGG in order to make the model of the biped robot more flexible. We show, in this work, how to train fuzzy systems from input output data from humain gaits.

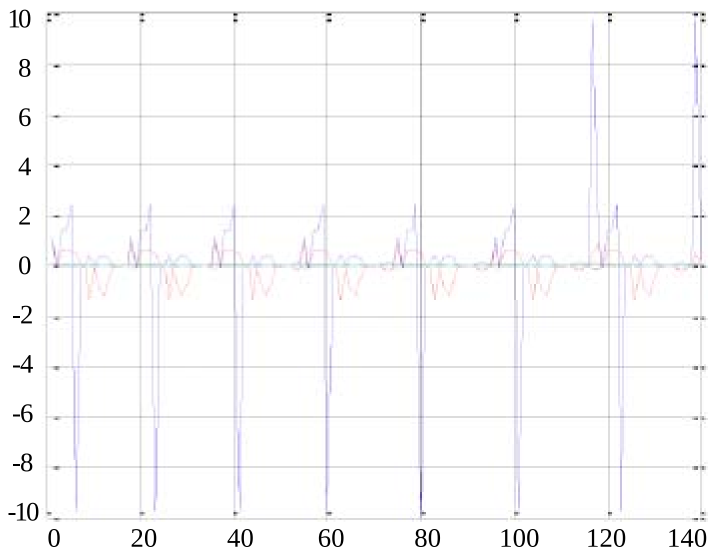

Figure 10. representation of the error of the propose FGG

The geometric model proposed is becoming more flexible. The proposed method could handle the variation of the width of the hip and the size of the tibia. Currently a hierarchical fuzzy architecture is under experimentation.

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