Hierarchical Fuzzy Controller for a Biped Robot

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ABSTRACT: *The paper presents a method developed for control of walking robots. We used, in this work, a hierarchical fuzzy controller. We applied this method on the control of seven degrees of freedom planar biped into free area and without obstacles.*

First, we use a classical PID controller. Then, we used hierarchical fuzzy logic controller (HFLC) to command our system (the biped robot). The HFLC is introduced to monitor the control system by the conventional PID for position tracking of various joint biped robots driven by electric motors.

Keywords: Biped Robot, PID Controllers, Hierarchical Fuzzy Systems

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1. Introduction

The control of a humanoid robot is a challenging task due to the hard-to stabilize. In recent years, the control of biped robots has made great progress. The control of a biped walking robot is to find a control law that allows the coordination of movements of the various members of the articulated mechanical structure [2]. This enables the movement of the robot on a ground. Many researchers are interested in developing new approaches to control for such systems.

Different methods were developed for the control of biped robots. Several results have been provided for the stabilization of biped robot locomotion in recent years [1-2].

Faced with systems becoming more complex (e.g. nonlinear), control engineers are now forced to change their approaches to analysis and control systems. In fact, they soon realized that conventional methods used so far do not allow satisfying the desired performance indices [5-6-3].

It seems that the present solutions in terms of control of biped robots cannot meet the requirements adaptability of these systems. To remedy this defect, we will try to propose an alternative control strategy to control the biped robot that believes we need to better respond to our control system. [9].

As one of methodologies applied for biped and humanoid robot control, some researchers used fuzzy logic. Fuzzy logic was used dominantly as parts of control systems on executive control level, for generating and tuning PID gains.

We present at the first section the description of the biped robot. In the second section, we show the PID controller of the proposed biped robot. In the third section, we present the hierarchical fuzzy controller proposed in this work. Finally, we present our conclusions and our further work.

2. Description of the System

The biped model is a Five seven segment one, the foot prints are not considered in this model (figure 2). Motion analyses are made on two plans separately, the sagital and the frontal one. We have developed a fuzzy gait generator (FGG), see figure 1. The FGG is build offline, the gait generated from are fitted for human size robots.

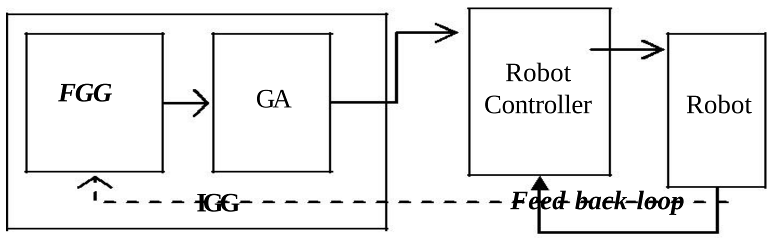

Figure 1. Robot control flow, FGG fuzzy gait generator, GA Gait Adaptation Module

In order to ensure the learning process for the controller, a classical simulated geometric model was used, see figure 2.

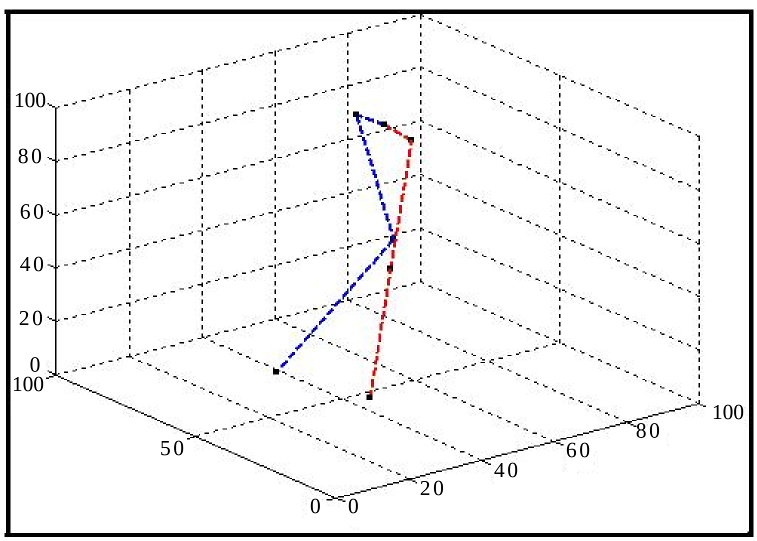

Figure 2. The 3D graphical simulator

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 [7-12]. The inputs of our system (biped robot) are generated by the engines couples. The outputs are the positions of the different angles of joints.

The inputs of the FGG are the curve center of mass as of the simulator. The outputs present the curves of knees. The obtained system is a Sugeno type fuzzy that has 16 rules. Figure 3 and figure 4 shows the block diagram and the output of the proposed FGG.

The output of the FGG represents knee movement of biped robot.

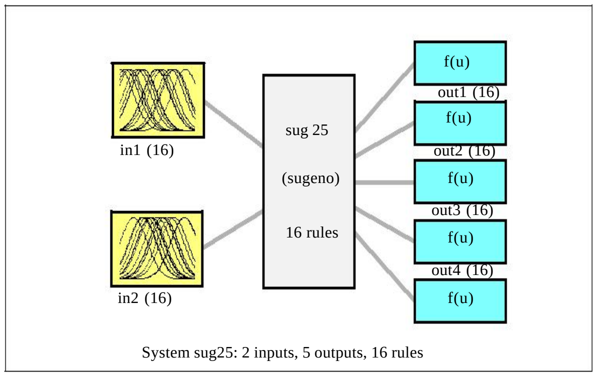

Figure 3. General diagram of the FGG

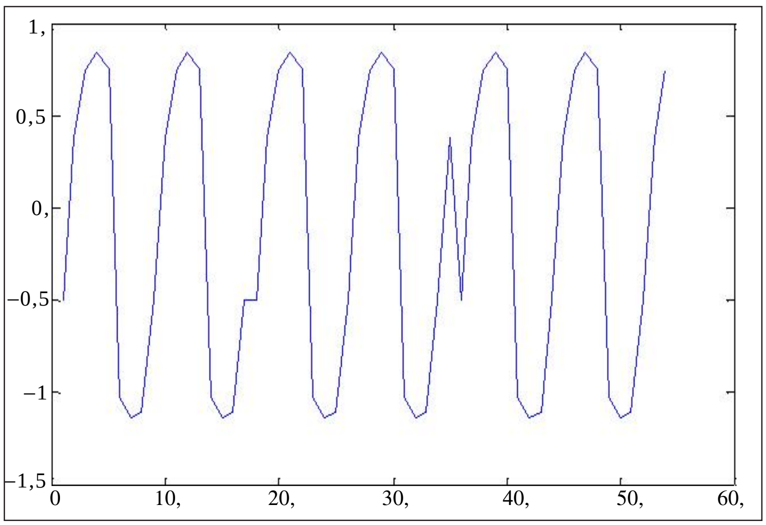

Figure 4. Output of the FGG (Path of the knee)

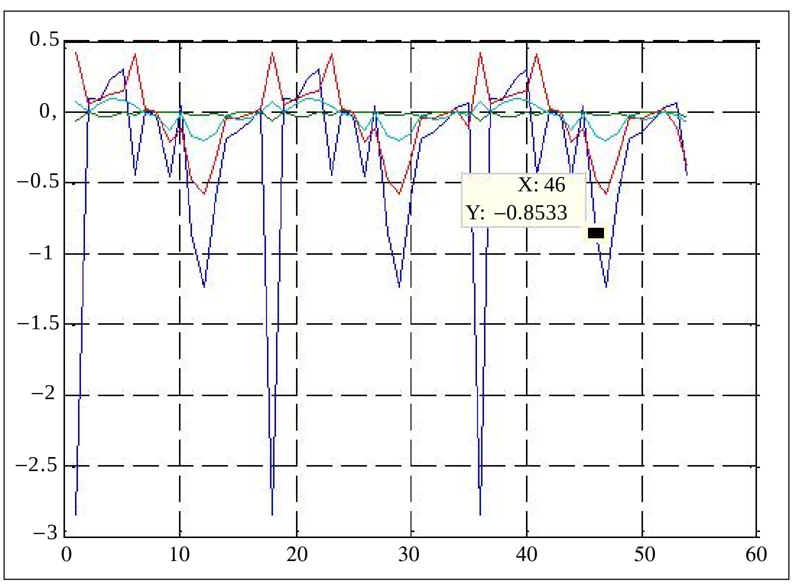

Figure 5. Representation of the error of the propose FGG

We note in the last figure(Figure 5), the presence of postures that involve discontinuities in the command of state transitions.

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

3. PID Controller

PID controllers are the most widely used in industrial control. It is a simple implementation of feedback (feedback). It has the ability to eliminate the compensation balance with integral action state, and can anticipate the future through derivative action. We can described the output of the PID controller by the equation (1) [8-20].

$$u = -k_p e_\theta -$$

Where k_p is the integral of tracking error e_θ are proportional, derivative and integral gains of the PID controllers "–" is the difference between the desired position angle and the real position angle. Many methods are used to calculate the optimal gains of the PID controllers. In our work, we use the Ziegler-Nichols rule using nonlinear block-set in MATLAB package. Figure 6 show the PID controllers for the Biped model.

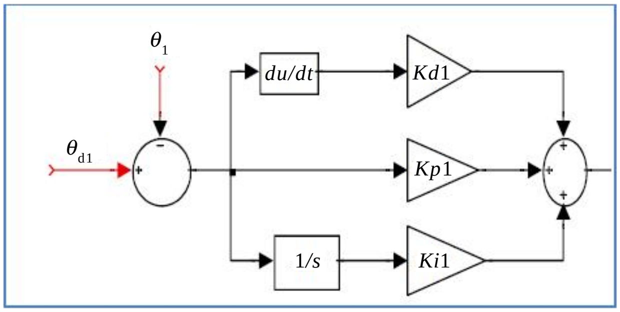

Figure 6. Structure of the PID controllers

Conventional methods used, such us the PID controller, are not sufficient to satisfy the desired performance indices to the control of the complex systems. [16-8]

Fuzzy techniques provide a general framework to control complex processes that are difficult to describe by mathematical equations but can be controlled by expert men. [11-13]

Based on this idea, we introduced fuzzy systems in our control strategy to overcome the problems encountered in the conventional approach developed.

In the next section, we employ a hierarchical fuzzy system with the PID controllers to command the biped robot.

4. Control of the Biped Robot

Control of biped robots presents several challenges. These are closely related to the dynamics of this kind of complex systems and their interaction with the environment. Faced with these complexities and challenges we are facing, we need to find the right approach control that handles these problems in order to achieve stable walking biped robot.

In the literature for the control of walking robots, the approach most commonly used is the continuation of pre-calculated reference trajectories that describe the desired behavior to the robot.

In this work, the FGG makes the command not depending on a reference trajectory but is calculated based on the conditions encountered and the state of the robot. Status of the robot is known through its various sensors angular encoders, pressure sensors on the feet, camera, etc.. can also predict future states in which the robot is based on the dynamic model.

Applications show the advantages of fuzzy systems when the model is difficult to implemented. With the increase in model complexity of the existence of the process, we encountered a difficulty for developing fuzzy rules and membership functions [13].

Among the recent developments in techniques for the automatic, introduction of new formalisms such as fuzzy logic. Indeed, the interest of this approach lies in its ability to deal with the imprecise and uncertain. Therefore, the synthesis of fuzzy controllers for controlling the multi variables, requires the development of a large number of fuzzy rules and tuning of many parameters.

One of the solutions in this framework is the hierarchical rule bases descriptive.

In this work, we decided to formulate a methodology for the design of optimized fuzzy controllers based on a hierarchical configuration minimum rule bases.

Hierarchical fuzzy systems have created to address one of the major problems sudden to fuzzy systems standard multiple variables which is actually the exponential growth in the number of rules based on the number of variables entered in the system which leads to the problem impractical for the purposes of its implementation for the dimension of the basic rules.

As one of the hierarchical fuzzy systems cited in the literature, we will use, in our work, the structure proposed in [19] (see Figure 7).

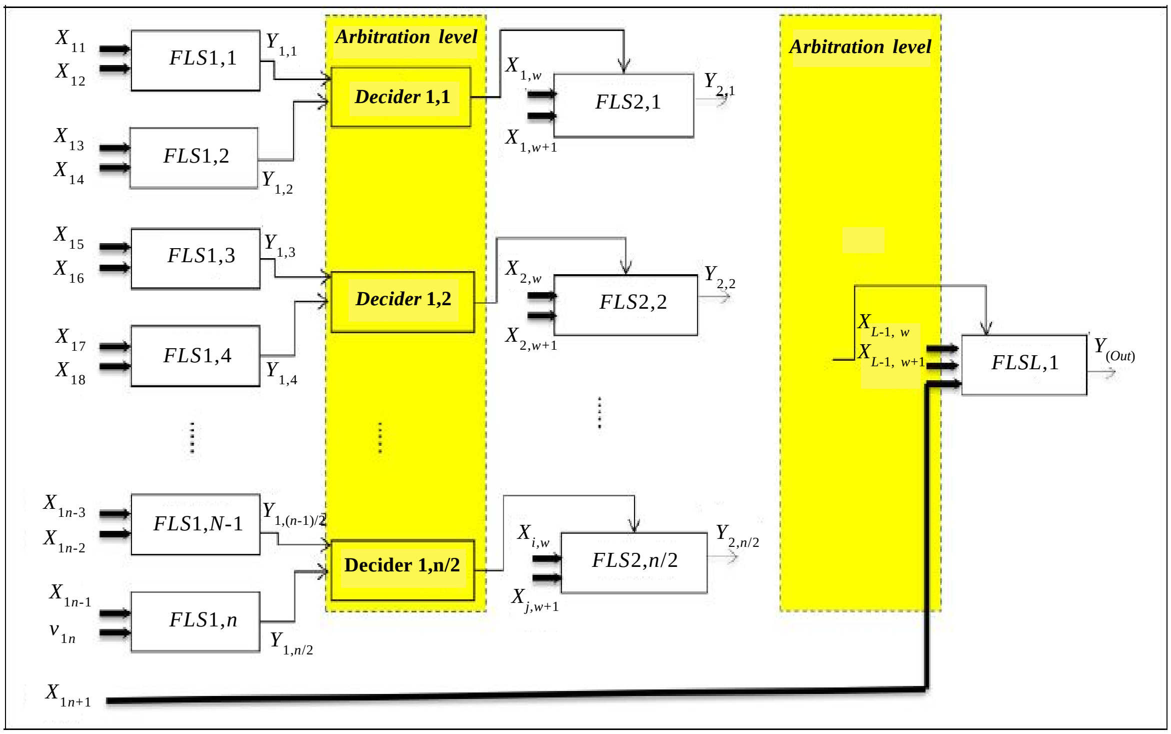

Figure 7. Structure of the hierarchical fuzzy system

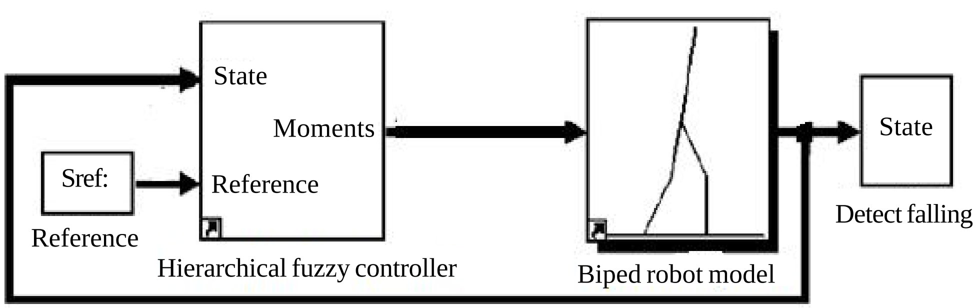

Figure 8. Closed loup control system

To control the biped robot walk, we will propose the following control scheme (Figure 8). The inputs of the robot, which are themselves the output of the hierarchical fuzzy controller are the moments generated by the actuators of the robot which are DC motors. The outputs of our system are the states of the robot which includes all the possible positions of the knees and hips and the center of mass.

Figure 9 show the structure of the hierarchical fuzzy controllers mixed with the PID controllers that we use to the control of the biped robot that we proposed.

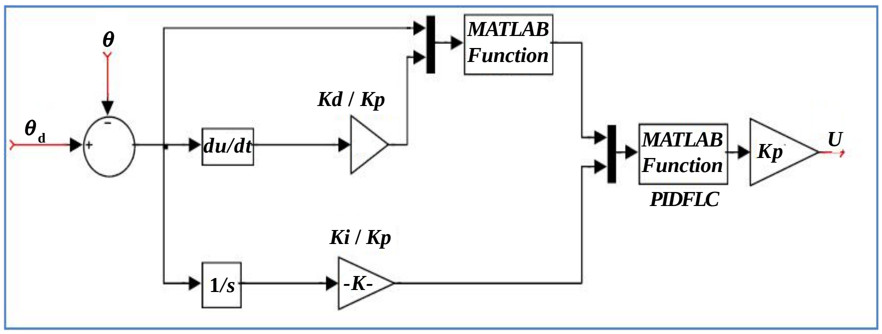

Figure 9. The structure of the hierarchical fuzzy controllers

5. Discussion and Further Work

The development of control approaches and algorithms have not kept pace with technological development in spite of the many approaches proposed to control biped robots.

In this paper, we have proposed a hierarchical fuzzy controller of the biped robot. We show, in this work, how to train fuzzy systems from input output data from humain gaits.

The geometric model proposed is becoming more flexible. We have proposed a hierarchical fuzzy controller which will consider and resolve problems related to the number of very pupil rules for a fuzzy system.

The hierarchical FLC overcame the curse of dimensionality problem for the fuzzy system and helped to reduce the complexity of the model due to reduction of the used rules.

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