Chapter 25
Design and Implementation of a Fast General Purpose Fuzzy Processor

Mohamed Ibrahim Mahmoud
Menoufia University, Egypt

Safey Ahmed Shehata
NRC, Egyptian Atomic Energy Authority (EAEA), Egypt

Sayed Mohamed El-Araby
NRC, Egyptian Atomic Energy Authority (EAEA), Egypt

Refaat Mohamed Fikry AbouZaid
NRC, Egyptian Atomic Energy Authority (EAEA), Egypt

Fathi Abd El-Samie
Menoufia University, Egypt

ABSTRACT

In this paper, a Fast Fuzzy processor (FP) is proposed. This processor, which is implemented using FPGA, has four inputs and one output with 8-bits width for each. The proposed processor is synthesized, functionally verified and implemented using Xilinx Integrated Software Environment (ISE) and is tested using Xilinx Spartan 3E starter kit. A PC Graphical User Interface (GUI) is programmed using C# programming language to select and download the parameters of the processor through the serial port communication. The proposed processor is experimentally tested through water sprinkler system example. The experimental results approve the excellent performance of the proposed processor.

1. INTRODUCTION

Fuzzy inference is becoming an attractive approach to solve control and decision-making problems. This is mainly attributed to its inherent ability to manage the intuitive and ambiguous behavioral rules given by a human operator to describe a complex system. The application of fuzzy technologies to real-time control problems implies that hardware realizations can be adapted to the fuzzy paradigm (Azar, 2010). Many microelectronics implementations of fuzzy controllers have been proposed, recently. However, if fuzzy controllers are to be massively adopted in consumer products,

DOI: 10.4018/978-1-4666-7456-1.ch025

they must fulfill some additional characteristics. First, they must be flexible, that is, suitable for adapting their functionality to different applications. This implies the capability to program the knowledge base and select different inference mechanisms. On the other hand, considering fuzzy controllers as integrated circuits, they must be efficient in terms of silicon area and operational speed (Jimenez et al., 1998).

In this paper, one of the architectures of the general-purpose fuzzy processors is designed with high speed and degree of the parallelism and programmed by VHDL code and implemented on Spartan 3E starter kit. The characteristics of the proposed fuzzy processor are shown in Table 1. It has up to 4 inputs and one output with 8-bit width for each and a number of rules depending on the memory size. The parameters of the fuzzy processor such as the number of inputs, the number of rules, and the membership values for each input, are specified by a PC GUI, which is designed for simulating the fuzzy controller depending on the application and downloading the parameters to the fuzzy processor via the PC serial port communications.

Table 1. The proposed fuzzy processor characteristics

Fuzzy Inference System	Mamdani FIS
Inputs	4
Input Resolution	8-bit
Outputs	1
Output Resolution	8-bit
Antecedent Mf's	8 Trapezoidal per fuzzy set
Antecedent MF Degree of Truth Resolution	8-bit
Consequent MF's	8 Trapezoidal per fuzzy set
Consequent MF Degree of Truth Resolution	8-bit
Aggregation Method	MAX
Implication Method	MIN
MF Overlapping Degree	2
Defuzzification Method	Center of Gravity (COG)

2. PREVIOUS WORK

Most of the fuzzy logic applications with the physical systems require a real-time operation to interface high speed constraints. The simple and usual way to implement these systems is to realize it as a software program on general purpose computers, these ways can't be considered as a suitable design solution. And this case, the fuzzy algorithm needs a big data structure and much computational effort that leads to anon real time control.

Furthermore, the fuzzy algorithm must be linked with the main program and, because of the microprocessor's internal structure: such link is not so easy to achieve. Therefore the designer has to be aware of the internal structure to avoid conflicts in the management of the internal register (Giacalone et al., 1998).

For this reason, an analog technique for implementation of fuzzy processor was introduced, since the variables in fuzzy systems are analog by nature. Thus, analog implementation eliminates the need for analog-to-digital and digital-to-analog conversions. Also, the fuzzy systems also require massive parallelism, making analog circuits particularly suited for their implementation. Furthermore, the physical characteristics of transistors can be utilized in realizing the nonlinear functions required, whether it is a fuzzy operation, or a membership function. Analog implementations, however, have typically very restricted possibilities for programmability. Analog implementation techniques include voltage mode and current mode realizations, in addition to mixed mode (current and voltage) realizations. One difficult aspect of analog circuit implementations is devising a reliable analog memory module (Masetti et al., 1995;