The Decision Making Circuit

Jean Seda
Department of Electrical and Computer Engineering
University of Central Florida
Orlando, FL 32816-2362

***Abstract*—The objective of this paper "the decision-making circuit" is to evaluate some of the fundamental metrics of the deep belief network and its implementations. Deep belief networks are circuit capable of learning and making decisions. In addition to deep belief network this paper includes a program that was designed to count how many words repeats in a statement. The input to this program would be a statement or a paragraph. The output would be a number identifying the times the word appeared in it along with the indexes where this word appeared in the statement. The code created was tested with different energy consumption assuming it was done with a deep belief network circuit. The design number one ended up being the best energy efficient design with a energy consumption of 216330pJ**

Keywords— Deep Belief Network(DBN), Restricted Boltz Mann (RBM), p-bit, Magnetic Tunnel Junction (MTJ), Non-Volatile Memory (NVM), Probabilistic Interpolation Recorder (PIR), sample and shift based PIR(SS-PIR), sample and count based PIR (SC-PIR)

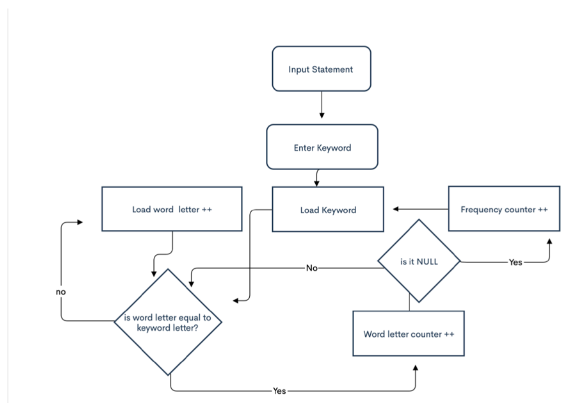

Fig.1: Flowchart of the assembly program.

I. Introduction

A. *Project Design*

The method of my coding was to implement branches to loop around the statements and the word. The statements and the word were loaded to the registers, and their characters were looped. Many conditions like if it's null, space, or capital letter were identified in the statement to make decisions whether or not the letter is a match. Functions to make capital letter to lowercase letter were implemented for both the word and the statement. Then a counter was implemented to count the indexes in the word. For this the SB instruction was used to make an array of the indexes that matches the indexes were the word were found.

B. *Test Cases*

The first input to my program was the word knights with the keyword knights, which was successfully counted as 1 frequency in index 1. The second input was the default statements provided in the assignment description, which was successfully identified as 6 frequency for the keyword Knights. The third output was used as the word KniGths to test the lowercase functionality in the loop, which was also successfully done with frequency one and index 1.

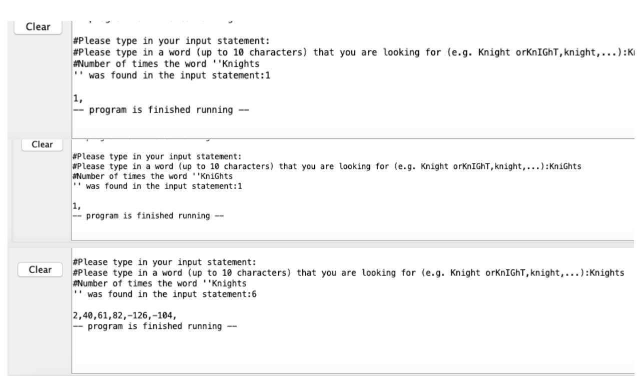

Fig.2: Sample outputs of the assembly program.

II. DBN CIRCUIT

There are different types of implementations of Deep Belief Circuits the followings that I will be mentioning here are the ones that stood out to me and that performed in an efficient manner. The Deep Belief Network can be created with Restrictive Boltzmann Machine (RBM) accommodated hierarchally. The RBM consists of layers in a crossbar architecture. There are outside layers called (visible) and there are inside layers called (hidden). The building block of this machine is non- volatile memory by interconnecting building blocks in RBM. RBM can reach a distribution of probability to be in a certain state V and another state U for example given enough time the system moves to the lower energy state choosing its objective or output. The MRAM based stochastic device (pbit) is a building block for RBM components. It consists of a Magnetic Tunnel Junction (MTJ). It has a free layer and a fixed layer. The fixed layer is fixed magnetically and acts as non-volatile storage and the free layer's orientation is done magnetically.

In the first research paper they mentioned different types of PIR circuits. These circuits are used to integrate the output of DBN. There are many ways this can be done efficiently with one way is using a sample and count based PIR (SC-PIR) this circuit is conventionally made by using an integrator resistor and capacitor to convert the outputs of the neuron to digital. In other words, it generates an n-bit output to every neuron. The neurons are sampled at every positive clock, and it's accumulated through a counter. After this is used as the interpolated output of the neuron.

The other circuit is called the sample and shift based PIR(SS-PIR) this circuit functions a little different from the previous and it was done on the pursue of a better energy consumption and a better error rate. It operates by guiding the outputs to a bidirectional shift register. The samples are shifted left or right depending on the input voltage vdd/2 whether is greater or smaller than. In other words this circuit divides or multiplies depending on the input signal to produce a neuron output.

III. RESULTS AND DISCUSSION

1) *ALU = 2 pJ*
2) *Branch = Refer to Table I*
3) *Jump = 4 pJ*
4) *Memory = 100 pJ*
5) *Other = 5 pJ*

i. (2pJ * 8528) + (.2pJ * 5579) + (4pJ*3362) + (100pJ * 1658) + (5pJ * 3782) = 216330pJ

ii. (2pJ * 8528) + (.03e^+5pJ * 5579) + (4pJ*3362) + (100pJ * 1658) + (5pJ * 3782) = 2400539pJ

iii. (2pJ * 8528) + (6e^+5pJ * 5579) + (4pJ*3362) + (100pJ * 1658) + (5pJ * 3782) = 5183196pJ

iv. (2pJ * 8528) + (5e^+5pJ * 5579) + (4pJ*3362) + (100pJ * 1658) + (5pJ * 3782) = 4355199pJ

Table I: Energy consumption for a branch instruction in the designs provided in [1-4].

Design	Energy Consumption For Each Branch Instruction
[1]	0.2 pJ
[2]	$0.03e^{+5}$ pJ
[3]	$6e^{+5}$ pJ
[4]	$5e^{+5}$ pJ

Table II: Total Energy consumption for the assembly program using designs provided in [1-4].

Design	Total Energy Consumption
[1]	216330pJ
[2]	2400539pJ
[3]	5183196pJ
[4]	4355199pJ

IV. CONCLUSION

The report project gave many insights about Deep Belief Networks. I always thought that this kind of topic were extremely difficult for me to understand however, it was not as bad as it thought. I learned how the circuit made decision using signals according to its voltage inputs. The different ways in which Deep Belief Network use circuits like PIR to combine the outputs of the neurons and provide a logical conclusion. I learned about the building blocks of a deep belief network which is the Restricted Boltzmann Machine and how this implement layers that aid in the identification of output. A building block of RBM is the p-bit devices which consists of two layers that act as non-volatile storage. In this device is found a magnetic junction MJT. This MJT randomly fluctuates between two resistive states also changing the drain source of the NMOS transistor modulated by the input voltage. In addition, how the most important designs are the ones that save space, energy and it's not of high complexity to implement. The most energy efficient design was design number 1 with the 0.2pJ branch energy, which gave a 216330 pJ total energy consumption for my program utilizing the default example given in the assignment.

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