HARDWARE DESCRIPTION LANGUAGES

(ECP 401)

BINARY CLASSIFIER ON FPGA

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AIM:

To deploy a trained binary classifier model on an FPGA using VHDL.

COMPONENTS:

1) FPGA Kit
2) JTAG Cable

THEORY:-

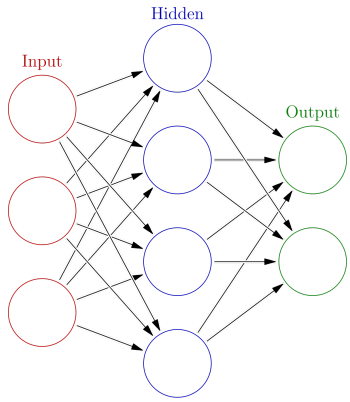
The idea behind this project was to deploy a trained neural network to an FPGA using VHDL. User inputs data with the 10 available toggle keys which represent two 5-bit vector input features. This is passed through a function approximator (Neural Network) which has been previously trained on a given dataset. The output of this model is a 2-bit vector with activations for each class. The final label is the one that has a maximum value of activation. This classifier has various practical applications like determining condition based on the input features.

FPGA:
A field-programmable gate array (FPGA) is an integrated circuit (IC) that can be programmed in the field after manufacture. FPGAs are similar in principle but have a vastly wider potential application than, programmable read-only memory (PROM) chips. FPGAs are used by engineers in the design of specialized ICs that can later be produced hard-wired in large quantities for distribution to computer manufacturers and end-users. Ultimately, FPGAs might allow computer users to tailor microprocessors to meet their own individual needs.

MACHINE LEARNING:
Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves.

The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers to learn automatically without human intervention or assistance and adjust actions accordingly.

NEURAL NETWORK:

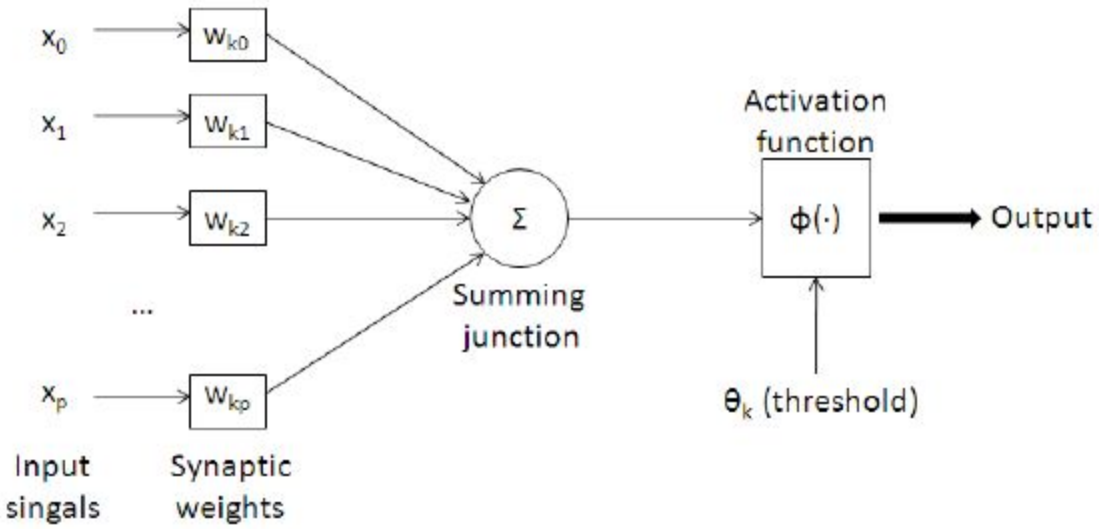


Predictive modeling is the problem of developing a model using historical data to make a prediction on new data where we do not have the answer. Predictive modeling can be described as the mathematical problem of approximating a mapping function (f) from input variables (X) to output variables (y). This is called the problem of function approximation. The job of the modeling algorithm is to find the best mapping function we can given the time and resources available. Neural Network is one such algorithm.

A neural network endeavors to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature.

CLASSIFIER:

Classification predictive modeling problems are different from regression predictive modeling problems. Classification is the task of predicting a discrete class label. Regression is the task of predicting a continuous quantity.



ALGORITHM:

1) User inputs a 10-bit vector.
2) Two 5 bit features are extracted from the 10-bit vector input.
3) These features are fed to the neural network.
4) Neural Network outputs two activations corresponding to each class.
5) The one which has the highest value is chosen to be the predicted class and the corresponding led is turned ON.

VHDL CODE:

```
library ieee;

use ieee.std_logic_1164.all;

use ieee.numeric_std.all;
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```
use ieee.std_logic_arith.all;
use ieee.math_real.all;
use ieee.std_logic_signed.all;
use ieee.std_logic_unsigned.all;
entity project is
port(a:In std_logic_vector(9 downto 0);
    w1,w2,w3,w4,w5,w6,w7,w8:in integer range 0 to 10;

    y: Out std_logic_vector(1 downto 0));
end project;

architecture behave of project is

--type flo is range 0.0 to 100.0lll ;



function bin2int(a:std_logic_vector(4 downto 0)) return integer is
variable f1,x,y,z,w,p:integer;
begin
        if a(4)='1' then
                x := 1;
                else
```

```
        x:= 0;
        end if;
if a(3)='1' then
        y := 1;
        else
        y:= 0;
        end if;
if a(2)='1' then
        z := 1;
        else
        z:= 0;
        end if;
if a(1)='1' then
        w := 1;
        else
        w:= 0;
        end if;
 if a(0)='1' then
        p := 1;
        else
        p:= 0;
        end if;
```

```
        f1:= x*16 + y*8 + z*4 + w*2 + p*1;
        return f1;
end bin2int;

function relu(b:integer) return integer is
variable q:integer;
        begin
        if b>0 then
         q:=b;
        else
         q:=0;
        end if;
        return q;
end relu;

signal s1,s2,s3,s4,s7,s8:integer;

begin
process(a)
begin
s1 <= ((bin2int(a(9 downto 5)))*w1) + ((bin2int(a(4 downto 0)))*w2);
s2 <= ((bin2int(a(9 downto 5)))*w3) + ((bin2int(a(4 downto 0)))*w4);
```

```
s3 <= relu(s1);

s4 <= relu(s2);

s7 <= (s3*w5) + (s4*w6) ;

s8 <= (s3*w7) + (s4*w8) ;



if s7>s8 then

        y<= "10";

else

   y<= "01";

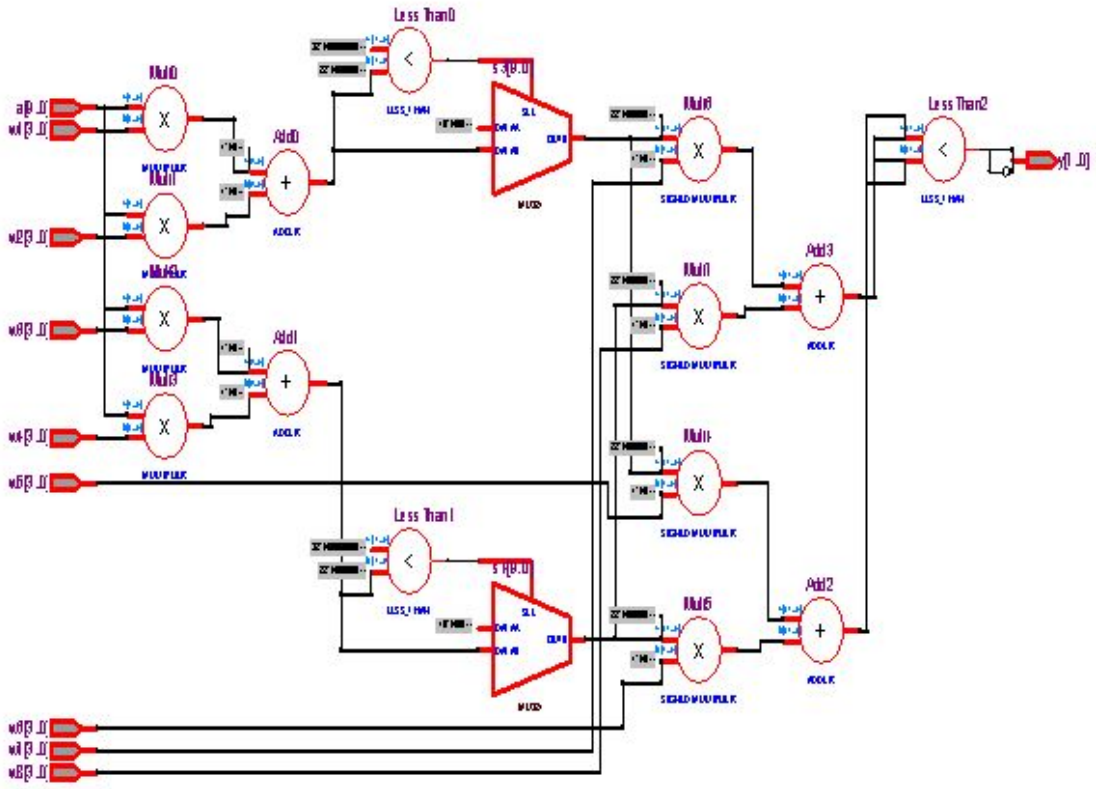
end if;

end process;

End behave;
```

RESULTS:

The RTL diagram of the above model is:



ADVANTAGES:

1) This system is useful for various classification tasks.
2) The system being a machine learning model is more robust to varions in data i.e. it generalizes better as compared to traditional systems.
3) The applications include error detection, face detection, etc.

CONCLUSION:

Thus, a neural network was used as a function approximator to model the classifier and it was tested for various values of features.