International Journal of Latest Engineering Science (IJLES) E-ISSN: 2581-6659

Volume: 02 Issue: 06 November to December 2019 www.ijlesjournal.org

On An Application of High Order Multi-Interaction Cellular Neural Network in the Early Fire Warning System

Nguyen Tai Tuyen[#1], Nguyen Quang Hoan[2], Ngo Van Sy[3]

[#]*Posts and Telecommunications Institute of Technology, Hanoi, Viet Nam - PTIT*
[#]*Vietnam Research Institute of Electronics, Informatics and Automation - VIELINA*

Abstract: *This paper presents an application of High Order Multi-Interaction Cellular Neural Network-HoMiCNN [3] in the early fire warning system of high-rise buildings, car parks and factories. The proposed solution is to apply the first-order and multi-dimensional interoperability of the cellular neural network in collecting and synthesizing the results to give an early warning about the risk of fire from data sources of the user's behaviour, daily habits; Data information is received from the monitored surrounding area such as temperature, sound, images, smoke and gas. The paper also presents the result of data analysis of early fire alarm system designed with independent warning sensor cluster and a combination of 9 sensor clusters connected to the control centre and sending notifications to the hand device.*

Keywords: *HoMiCNN, early fire warning, FPGA, MiCNN*

I. Introduction

The integration of temperature rise sensors, smoke sensors, gas sensors and sound and image sensors in a fire alarm on the same unit is essential. Because the integration will give higher sensitivity and more accurate to overcome the current weaknesses. Current sensors are often built with individual functions such as: Temperature rise sensor only plays a role of knowing when the temperature increases, does not recognize sources of smoke, gases and strange noises emitted at area where fire is forming in a narrow range. Therefore, at the temperature sensing area, it is only possible to recognize when a fire has been formed, based on the increase in the temperature of the fire and vice versa, the area for vehicles (cars and motorcycles) usually contains excess fuel gas and smoke at start up if a gas and sound sensor is often inappropriate. In order to monitor the source of the spark, the spark sensor is combined with the sound sensor for more efficient use presented in (*) [4], [6], [7].

A. Sensors and FPGA

- Temperature sensors come in a variety of categories that are categorized by their sensor capabilities and application scope including: Thermocouples; Thermistors; Resistor Temperature detector; Semiconductors; Infrared sensor; Thermometer. Here, we refer to thermal sensors using semiconductors and infrared sensors.

- Below are sensors that measure temperature, gas and sound with high accuracy and FPGA [1], [2], [5], [8].

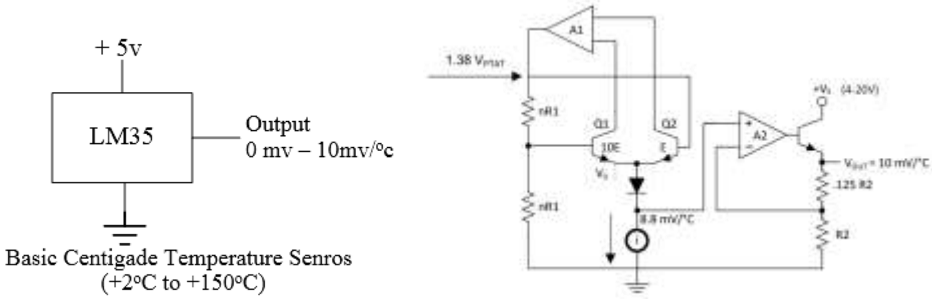

Figure 1. LM35 temperature sensor

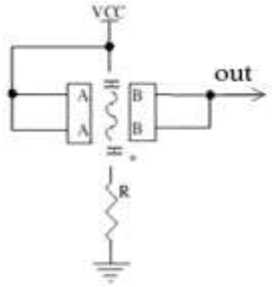

Figure 2. Interfacing Gas Sensor

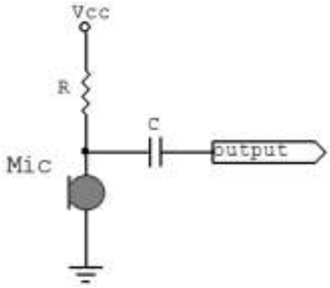

Figure 3. Sound Sensor

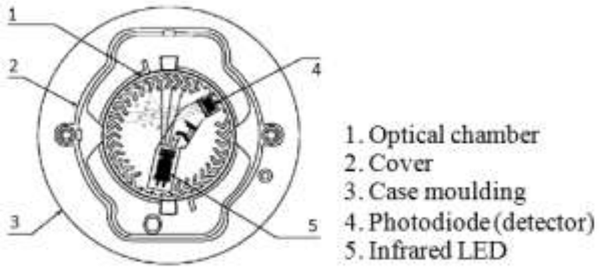

Figure 4. Smoke detector Sensor

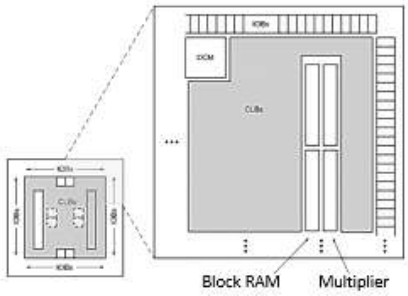

Figure 5: Spartan-3E Family Architecture

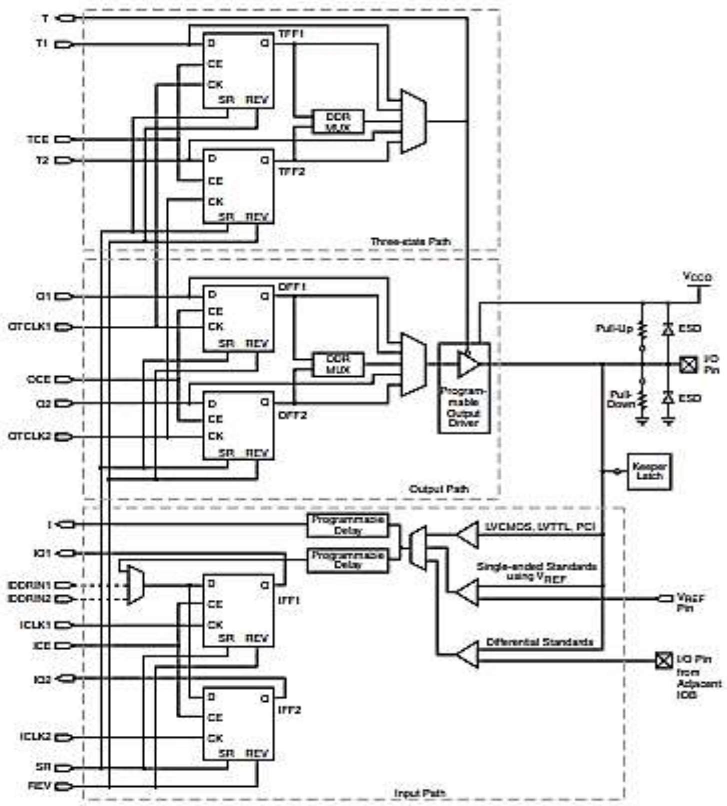

Figure 6: Simplified IOB Diagram of Spartan-3E FPGA

B. High Order Multi-Interaction Cellular Neural Network

High Order Multi-Interaction Cellular Neural Network [proposed network in the published article] is based on the standard cellular neural network given by Chua and Yang [3], [5] with low-order control and feedback links plus high-order feedback and control links. The element of the network is the sum of any control signal of point *i, j* with the product of the output signals and the product of any control signals of the point *(k, l)* and (m, n) nearby point *(i, j).*

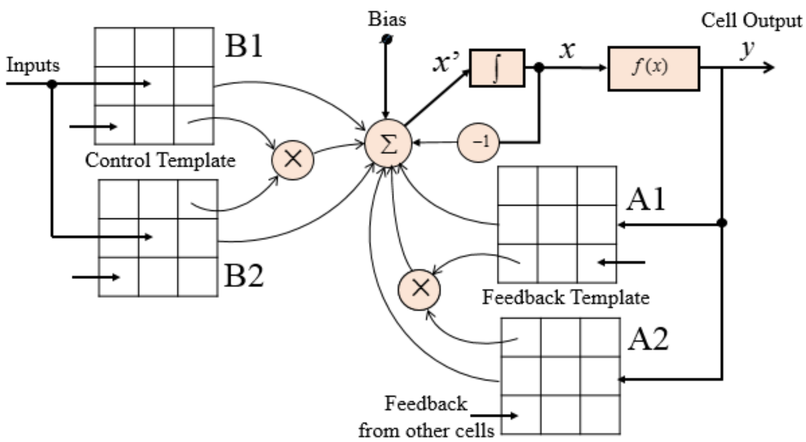

Figure 7. Schematic diagram of a High Order Multi-Interaction Cellular Neural Network

Dynamic equations of High Order Multi-Interaction Cellular Neural Network according to [3]

$$C\frac{dv_{xij}(t)}{dt} = -\frac{1}{R_x}v_{xij}(t) + \sum_{C(k,l)\in Nr(i,j)} A(i,j;k,l)v_{ykl}(t) + \sum_{C(k,l)\in Nr(i,j)} B(i,j;k,l)v_{ukl} + I + \sum_{C(k,l),C(m,n)\in Nr(i,j)} A(i,j;k,l,m,n)v_{ykl}(t)v_{ymn}(t) + \sum_{C(k,l),C(m,n)\in Nr(i,j)} B(i,j;k,l;m,n)v_{ukl}v_{umn} \qquad (*)$$

Output function:

$$v_{yij}(t) = \frac{1}{2}\left(\left|v_{xij}(t)+1\right| - \left|v_{xij}(t)-1\right|\right) \qquad (**)$$

In which:

- *A(i, j; k, l; m, n)* and *B(i, j; k, l; m, n)* are coefficients of the product of the two feedback signals from the respective outputs and controls. The application at point *(k, l)* and *(m, n)* at point *(i, j).*

- The input signals, assumptions and binding conditions are the same as in the configuration standard cellular neural network structure.

II. HIGH ORDER MULTI-INTERACTION CELLULAR NEURAL NETWORK IN EARLY FIRE WARNING

A. Designing a data source monitoring system for early warning

Monitoring module is integrated with multi sensors including gas sensors, temperature sensors, sound sensors (explosion), smoke sensors and image sensors (spark). The sensors are arranged on a 2.5D surface of the module, which is arranged according to the position of the senses on the human face. For Flavor, gas (Taste (T) has 2 sensors; Camera (Ci) observes or sees the sensor, designed with 2 sensors; Heat (H) - Thermal sensor with 2 sensors; Sensor Sound (explosion) Micro (Mi) with 2 sensors; Smoke sensor (Sm) with 1 sensor as shown ...

Taste (T) – gas
Camera (Ci) – observe
Heat (H) – heat sensor
Micro (Mi) – audio receiver
Smoke (Sm) – smoke sensor

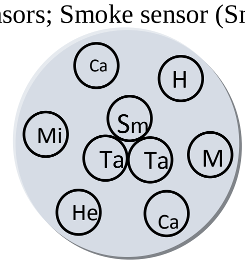

Figure 8. Sensor position on top of HoMiCNN early fire warning

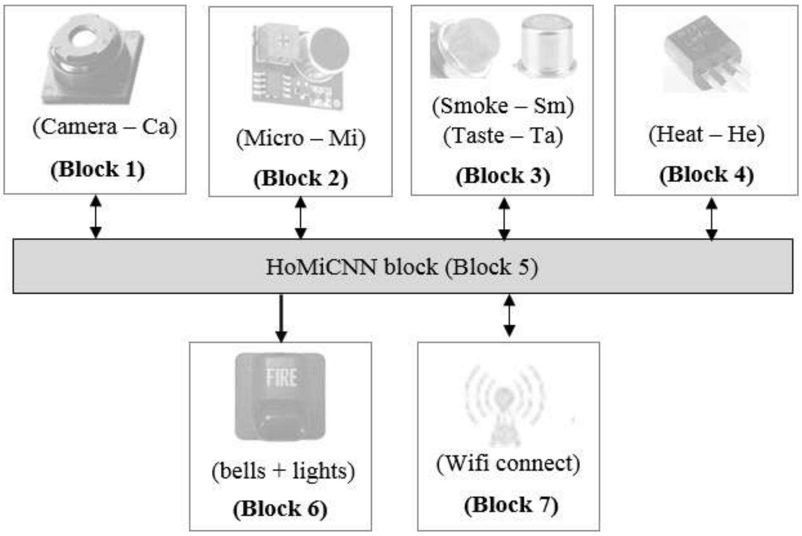

Figure 9. Block diagram of HoMiCNN for early fire warning

In Figure 7, designed with 7 blocks, the source block is the default (hidden), Block 1 is designed with 2 CCTV (can use spark sensor). This block has the function of collecting images or detecting ultraviolet rays in the flame when forming a fire. When it detects an object to be monitored, data is transferred to Block 5 for processing.

Block 2 is the sound sensor block (explosion) designed with 2 microphones arranged like the position of the human ear to capture sound (explosion) that occurs during a fire or pre-fire. Data is transmitted to block 5 for processing.

Block3 consists of 3 sensors with 2 gas sensors and 1 smoke sensor with the function of detecting gasoline in excess of the allowable value when a fire has not occurred and detecting smoke when forming a fire, sending data to block 5.

Block 4, the thermal sensor is designed with 2 semiconductor sensors with high stability and accuracy, two sensors have the function of detecting the ambient temperature exceeding the threshold which allows sending signals to block 5.

Block 5, receive signals from blocks 1, block2, block3, block4 and perform data processing, trigger on-site alerts according to different levels of danger from detecting sources of flammable gas exceeding the prescribed level. Highest level even when all 4 blocks appear warning signals.

Block 6, this block has the function of detecting sound and light alarm signals at other levels of warning according to the frequency so that the person on duty can sense and distinguish the danger level.

Block 7, has the function of transmitting warning signals via wifi network, telephone to send warning signals to the operator and the authorities in time for relief.

B. Operation of sensor units in HoMiCNN early fire warning

Under normal conditions, the sensor does not receive the trigger value to transmit a warning signal to block 5, at which time the input signal matrix is low:

Call the environment around the protected area Env, and is divided into different levels as follows:

Env1: normal surroundings,

Env2: surroundings contain flammable gas

Env3: surroundings have a small spark

Env4: surroundings appear smoke

Env5: surroundings have a small fire and smoke exists

Env6: the surrounding environment appears to be a big fire, the temperature rises, smoke exists.

Signal level from blocks 1,2,3,4 returns to block 5 valid (from 0 to 100)

According to the assumptions above we have:

- With Env1 the system will pull Vout = Block 1 = Block2 = Block3 = Block4 $\approx$ 0 (within the allowed threshold)

- With Env2, the system will follow Block 3 $\neq$ 0 (0 <Vout <100), at this time Block1 = Block2 = Block4 $\approx$ 0 (still in the allowed range).

- With Env3 the system will drag Block 3, Block 1, Block 2 $\neq$ 0 (0 <Vout <100), at this time Block4 $\approx$ 0 (still in the allowed range if far away from the occurrence of sparks).

- With Env4 the system will drag Block 3, Block 2, Block4 $\neq$ 0 (0 <Vout <100), at this time Block1 $\approx$ 0 (within the allowed range if far away from the place of smoke).

- With Env5 the system will drag Block 3, Block 1, Block 2 $\neq$ 0 (0 <Vout <100), at this time, Block4 $\neq$ 0 (the blocks are in the status of alert level confirmation).

- With Env6 the system will drag Block 1, Block 2, Block 3, Block 4 $\neq$ 0 (0 <Vout <100), (blocks send data in high alert state).

III. OPERATION OF HOMICNN BLOCK IN EARLY FIRE WARNING

Sensor blocks block1, block2, block3, block4 are connected to block 5 HoMiCNN according to High Order Multi-Interaction Cellular Neural Network in Figure 5 and use mathematical equation (*) to process data signals to overcome. Solution alerts are common in devices currently in use.

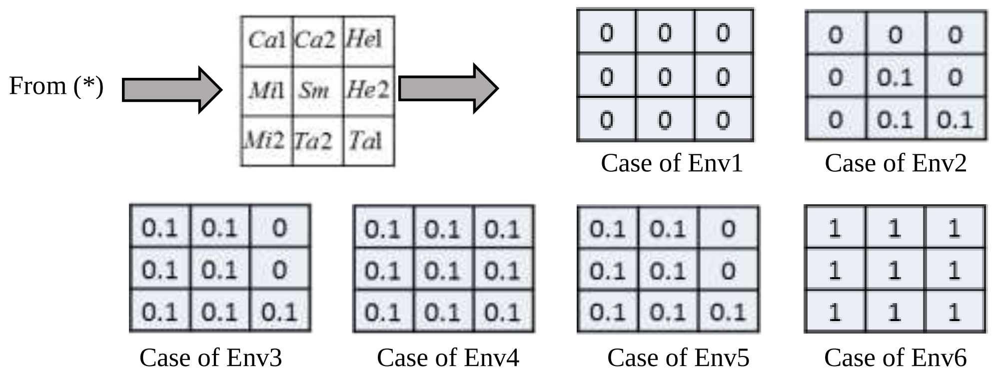

Figure 10. HoMiCNN control template for early fire warning

From the control templates of the Case of Envs in Figure 8, we have the output shown in Figure 11 and Figure 12.

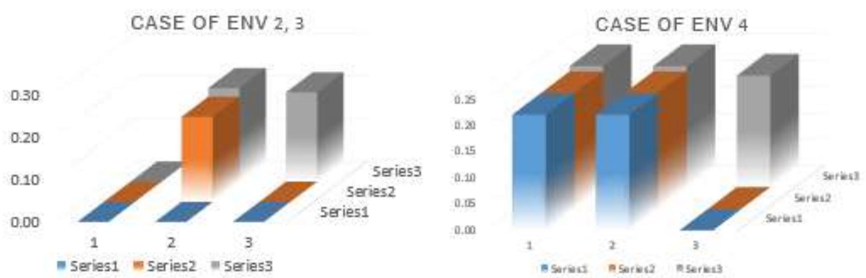

Figure 11. Output data of Case of Env 2,3 and Case of Env 4

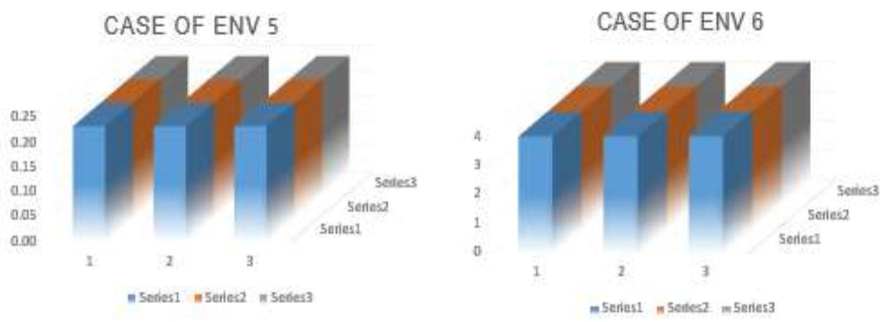

Figure 12. Output data of Case of Env 5 and Case of Env 6

IV. Conclusions

The paper presented an overview of the high order multi-interaction cellular neural network and smoke, gas, heat, spark and integrated circuit sensors for the implementation of the HoMiCNN algorithm applied in the early fire warning. We propose control templates for the system that corresponds to the alert levels using different sensor combinations as a test basis for a fire alarm monitoring system in residential areas, skyscrapers, garages, etc.

The author group embeds an algorithm on FPGA and STM to act as a processing centre, pairing to receive information, control and warnings as a centre for monitoring, processing, controlling the operating system in fire protection before explosion occurs.

References

[1] Byoungjun Kim and Joonwhoan LeeA, *Video-Based Fire Detection Using Deep Learning Models*, Appl. Sci. 2019, 9, 2862; doi:10.3390/app9142862

[2] Spartan-3E FPGA Family: Introduction and Ordering Information, DS312 (v4.2) December 14, 2018, https://www.xilinx.com/

[3] Nguyen Tai Tuyen, *On A Structure Of High Order Multi-Interaction Cellular Neural Network*, International Journal of Advanced Computational Engineering and Networking, pp 24-26, Volume-4, Issue-2, Feb.-2016.

[4] Faming Gong, Chuantao Li, Wenjuan Gong, Xin Li, Xiangbing Yuan, Yuhui Ma, and Tao Song, *A Real-Time Fire Detection Method from Video with Multifeature Fusion*, Computational Intelligence and Neuroscience Volume 2019, Article ID 1939171, 17 pages.

[5] Tuyen Nguyen Tai, Hoan Nguyen Quang, *An Application of Multi-Interaction Cellular Neural Network on the Basis of STM32 and FPGA*, International Journal for Research in Applied Science & Engineering Technology, pp 177-181, Volume 6 Issue I, January 2018.

[6] PHILIP KPAE, F .O., MACMAMMAH Michael, EZEKIEL Nsikak D., WOJI Chigozinum T., ABUBAKAR Abdullahi & KPAA Friday O.N, *Design and Implementation of a Smart Home (Smoke, Fire, Gas and Motion Detector)*, International Research Journal of Engineering and Technology, Volume: 05 Issue: 08 | Aug 2018

[7] R. J. (Bruce) Warmack, Marc Wise, Dennis Wolf, *Home Smoke Alarms*, Oak Ridge National Laboratory Oak Ridge, TN 37831March 2012

[8] Luis Soares, Marine Dumont, Dr. Thomas Petzsche, *Sensing Structural Borne Noise in Solid State Materials and Related Applications*, EuroRegio2016, June 13-15, Porto, Portugal.