FPGA-based assistive framework for smart home automation

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***Abstract*—This paper proposes a reconfigurable framework to automated reconfigurable secure home system. The proposed system has 3 main features: monitoring controlling of smart home automation through password-protected door lock system, the monitoring controlling of day-to-day electronic devices, fire safety with room temperature monitoring and antitheft system. In this paper, different sensor combinations are to be integrated with the FPGA board. For the Fire safety module, a temperature monitoring sensor has been used that will display the temperature continuously. If the temperature in the room exceeds 60 degree Celsius, then it will turn on the buzzer or alarm for fire safety. For the Anti-theft system, infrared (IR) sensors are fitted in each window. If any unauthorized person tries to breach through the window, both IR sensor signals will be turned ON and the output of the buzzer goes to high. For the door lock system, a finite state machine (FSM) has been implemented. This work focuses on a scalable smart home automation framework using the FPGA board that can be used for integration of multiple sensors in a cost-effective way. The research in this project is focused on processing multiple analog sensor inputs through the FPGA board.**

***Index Terms*—Home Automation, Security, FPGA board, Verilog, assisted living**

I. Introduction

In this robust proposed model, home automation is proposed with 3 main features such as Fire Safety, Electronic Device monitoring & Antitheft Module, and a Password Protected Door Module. In our thematic diagram figure 1, a module of the virtual house has been considered. The outputs are initiated to zero. The inputs of our system include room door IR sensor, room windows IR sensor, room door ultrasonic sensor, Smoke sensor, Temperature sensor, Door lock module which are essential modules for smart home automation [1] and assisted living [2], [3]. All input signals contain data such as a password to turn ON and OFF security, temperature, door, and window are in input to the IR sensor, smoke as an input to the smoke detector sensor, clocks for clock input, and so on. FSM reset is going to be implied to restart the state machines and transistion between each module. The output signals include door condition for opening and closing of a door, fire status to find if there is smoke present in the atmosphere, temperature status for checking the environment as well, window status for opening and closing window, output

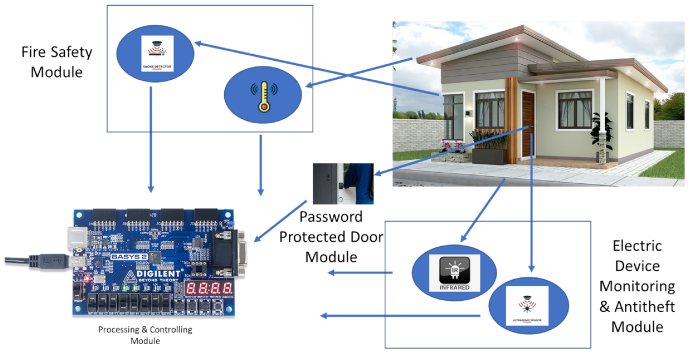

Fig. 1. Thematic picture of the proposed framework

on entering the wrong password. The FPGA is programmed using the hardware description language, Verilog. FPGA has multiple timing domains and there are plenty of asynchronous errors. These kinds of circumstances occur when different kinds of specific data patterns exist. It is difficult to include multiple sensors in a single FPGA platform due to the lower number of input-output ports. Also, Basys 3 FPGA board does not come with an integrated GSM, Wi-Fi module. Having so many limitations, our main challenge is to incorporate multiple sensors like IR, PIR, Ultrasonic, Temperature, and Gas sensors in a single platform which is rarely seen in the FPGA platform. This research will not only be used in home security but can also be installed in offices, schools, medical hospitals, and others.

II. System Level Modeling

A. Modeling the sub-blocks

Our proposed system consists of three different sub-modules named as Fire Safety Sub-module, Anti-theft sub-module password protection module. The fire safety module consists of a precision integrated-circuit temperature sensor and a buzzer as an audio signaling device. The temperature monitoring sensor is going to catch a glimpse of temperature and display that on the 4-digit 7-segment display mounted on the FPGA board. Anti-theft sub-module persistently monitors the state of the window and transmits the information from the interfaced

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infrared sensor to the connected input. The sensor is fitted to the window and when the window is open or broken, it turns on the buzzer to emit an audio signal. The password protection module is created for the owner of the house to go inside. If the password matches with the system, it opens the door. All the sensors are directly interfaced to the FPGA board without an intermediate circuit which makes this work cost-effective and highly efficient.

B. State Diagram of the proposed framework

The State Transition diagram has been developed for the Password module. An arbitrary password has been assumed as "1101" and the switches (2-5) have been employed for this. If the number matches, it will go to the next state, otherwise it will return to the same state. Fig. 3 presents the state transition diagram for the finite state machine.

Fig. 2. State Transitions of the proposed system

C. Flowchart

The flowchart for our project is shown in the figure 3.

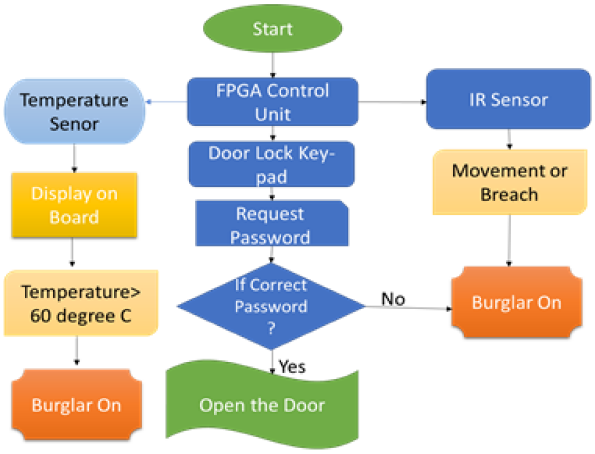

Fig. 3. Flowchart of the proposed reconfigurable assisted living framework

D. Proposed top level module

All the sensors have been integrated into the FPGA board and the FPGA board provides physical support to the development platform. The implementation has been easier by combining standard FPGA synthesis and implementation tools. To give physical support to the development platform, a digital circuit development platform based on the latest Artix®-7 Field Programmable Gate Array (FPGA) from XilinxBasys 3 board has been employed. This board includes 1,800 Kbits of fast block RAM, an On-chip analog-to-digital converter, 16 user switches 16 user LEDs, and a 4 digit 7- segment display. The XADC port of the Basys 3 is used for the receiving analog data from the LM35 sensor. Pmod JA port pin gives the source signal for the buzzer. Pmod JB is the input port that takes IR sensor output.

III. Implementation and Validation of the Proposed System

Different sensors have been integrated into a single system with the help of the FPGA board. Under the Fire safety module, the LM35 Temperature sensor has been used. This is a precision integrated-circuit temperature device with an output voltage linearly proportional to the Celsius temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. An infrared sensor (IR sensor) is a radiation-sensitive optoelectronic component with spectral sensitivity in the infrared wavelength range 780 nm to 50 µm. A buzzer has been included as the audio signaling alarm. The FPGA board has been integrated with the sensor and alarm system as shown in figure 4.

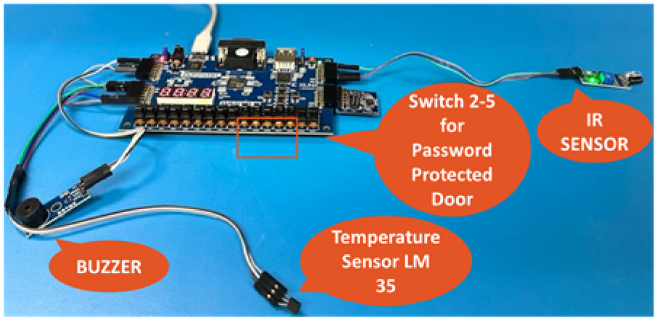

Fig. 4. Prototype of the proposed system

IV. Conclusions and Future Research

In this paper, we have developed a structure incorporating a highly efficient cost-effective smart home automation security system which can be integrated in any mobility assistive frameworks. Integrating sensors interfaced with an FPGA provides elevated efficiency. For future research, in addition to a temperature sensor, a smoke detector can be integrated for the fire safety module for better accuracy. Couple of motion sensors can be activated to achieve control over electronic devices that can be an assistive frameworks.

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