Gesture based Home Automation using FPGA

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ABSTRACT
Gesture control and home automation have emerged as prominent areas of research, aiming to enhance the convenience and interactivity of smart homes. This project focuses on implementing gesture control for home automation on a Field-Programmable Gate Array (FPGA) using VHDL (Very High-Speed Integrated Circuit Hardware Description Language). By leveraging the capabilities of an FPGA, the project aims to develop a robust and real-time gesture recognition system that can interpret hand movements and trigger corresponding actions in a home automation setup. VHDL is employed to design and describe the hardware components required for gesture recognition, including image acquisition, preprocessing, feature extraction, and classification stages. The integration of gesture control with home automation offers a seamless and intuitive user experience, allowing homeowners to control various devices and systems through simple hand gestures, thereby increasing convenience, efficiency, and accessibility in smart home environments.

Keywords
Hand Gesture, FPGA, Home Automation.

1. INTRODUCTION
Gesture control brings a new level of interactivity and naturalness to human-computer interaction. It eliminates the need for physical contact or complex input devices, offering a more intuitive and fluid means of controlling electronicdevices. The advancements in computer vision, machine learning, and sensor technologies have propelled gesture control into various domains, including gaming, virtual reality, robotics, and healthcare. In the context of home automation, gesture control enhances the user experience by providing a hands-free and contactless interface. Users can easily adjust lighting, control entertainment systems, manage security devices, and perform other tasks with simple hand movements, making daily routines more convenient and efficient. Field-Programmable Gate Arrays (FPGAs) play a pivotal role in implementing gesture control and home automation systems. FPGAs offer reconfigurability, parallel processing capabilities, and high-speed data processing, making them ideal for real-time applications. These programmable hardware devices can be tailored to specific requirements, allowing the implementation of complex functionality and customization. By programming FPGAs using VHDL, a hardware description language, designers can describe the behavior, structure, and interconnections of hardware components in a modular and systematic manner. VHDL enables the development of sophisticated gesture recognition algorithms and the integration of various sensors and actuators into the home automation system. With the flexibility and computational power of FPGAs and the descriptive capabilities of VHDL, gesture control and home automation can be seamlessly combined to provide a cutting-edge and user-friendly smart home experience.

2. RELATED WORK
This survey provides an overview of various gesture recognition techniques used in human-computer interaction, including their applications, challenges, and recent advancements[1].

This review explores gesture-based human-computer interaction techniques specifically in the context of smart homes, focusing on the challenges, existing solutions, and future research directions[2].

This survey provides a comprehensive overview of hand gesture recognition techniques, including sensor- based and vision-based approaches, and discusses their applications in various fields, including home automation[3]. This survey presents an in-depth analysis of recent advances in hand gesture recognition techniques for human-computer interaction, highlighting their strengths, limitations, and potential applications[4]. This review paper focuses on gesture recognition techniques specifically for home automation systems, discussing the challenges, existing solutions, and future directions in this field[5]. This survey explores the use of hand gesture recognition in home automation applications, highlighting the different techniques and their performance evaluation in real-world scenarios[6].

3. PROPOSED SYSTEM
The proposed idea aims to integrate an FPGA Spartan- 6 with a gesture sensor in a home automation system, enabling gesture control for various devices and systems. The FPGA serves as the processing unit, implementing real-time gesture recognition algorithms, while the gesture sensor captures hand movements. The system analyzes the sensor input using VHDL or a responsiveness, while customization options allow for personalized gestures. By integrating gesture control, users can enhance their existing home automation systems with a convenient and efficient control mechanism.

Hand gestures are a natural and expressive form of non-verbal communication that humans have been using since ancient times. It involves the movement and positioning of the hands and fingers to convey messages, express emotions, or communicate specific commands or instructions. Hand gestures play a crucial role in face-to-face communication, enhancing the clarity and effectiveness of spoken language.

Hand gesture recognition systems typically rely on cameras or depth sensors to capture hand movements and extract relevant features. These captured gestures are then processed using sophisticated algorithms, which can be based on pattern recognition, machine learning, or a combination of both. The goal is to accurately interpret the hand gestures and map them to specific commands or actions in the digital or physical domain.

The fig1 shows the block diagram of proposed model, The hand gestures are the input to the hand gesture recognition The sensor converts the moments of hands into the digital data, this data Is send to the spartan6 if the data matches with the predefined data then the particular device is controlled.

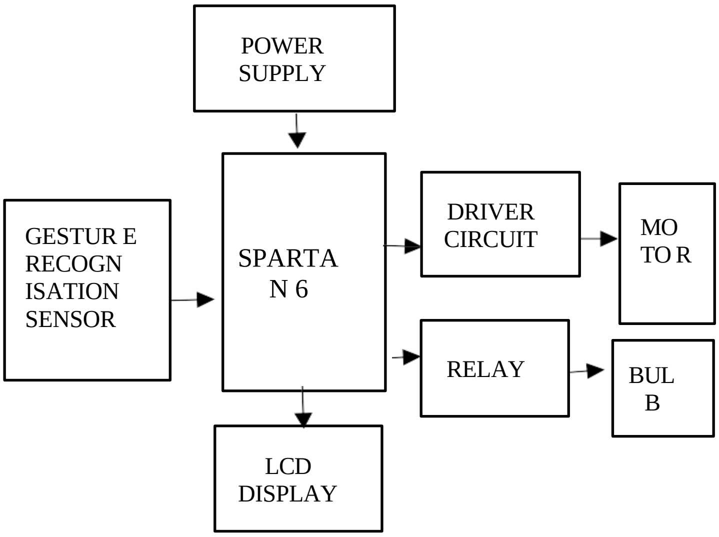

Fig 1: Block diagram of proposed module

4. HARDWARE DESCRIPTION

A. POWER SUPPLY

The supply provides the 5v DC to the spartan 6 FPGA board.

B. Spartan 6 FPGA

The FPGA will act as the core processing unit, responsible for implementing the gesture recognition algorithms and controlling the overall system. The Spartan-6 offers reconfigurability and high-speed data processing capabilities, making it suitable for real- time applications.

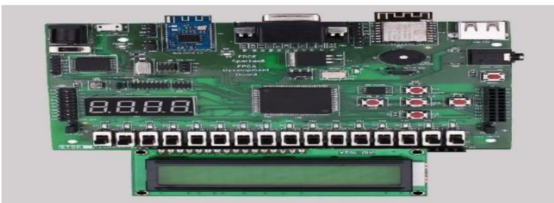

Fig 2: Spartan6 FPGA board

The features of spartan 6 fpga are EDGE Spartan6 FPGA Development board is the feature rich development board with Spartan6 FPGA, SPI FLASH, Wi-Fi, Bluetooth, ADC, DAC, LCD, 7 segment Display, VGA, PS2, Stereo Jack, buzzer, Push Button, Slide Switch, LED, Temperature Sensor and LDR. The Board also provides additional interface like CMOS Camera and TFT Display at the expansion connectors. The EDGE board provides USB JTAG interface for Programming and Debugging. It also provides USB UART interface.

C. Gesturer Sensor

PAJ7620U2 gesture recognition sensor. It can recognize 9 gestures including move up, move down, move left, move right, move forward, move backward, circle-clockwise, circle-counter clockwise, and wave. These gestures information can be simply accessed via the I2C bus. The PAJ7620U2 also offers built-in proximity detection for the purpose of sensing object approaching or departing. The PAJ7620U2 is designed with great flexibility in the power-saving mechanism. The PAJ7620U2 is designed to operate from 2.8V to 3.3V over -40°C to +85°C and the pull-up voltage for the I2C bus and interrupt line is from 1.8V to 3.3.

Fig 3:Gesture sensor

The features of gesture sensor are A typical supply voltage is 2.8V to 3.3V and I/O voltage is 1.8V~3.3V.

Nine gesture recognition (Up / Down / Left / Right / Push / Pull / CW / CCW / Wave)

Gesture speed is 60°/s to 600°/s in Normal Mode and 60°/s to 1200°/s in Gaming Mode. Ambient light immunity: < 100k Lux

Built-in proximity detection. Flexible power-saving scheme.I2C interface up to 400 kbit/s, Pull-up voltage from 1.8V to 3.3V.Ambient light noise cancellation. The application of gesture sensor are in Phone, Tablet, Personal Computer, Automobile.

D. Gesture Recognition Algorithms:

The FPGA will be programmed using VHDL or a similar hardware description language to implement gesture recognition algorithms. These algorithms will analyze the input data from the gesture sensor and classify different gestures based on predefined patterns or machine learning techniques.

E. Device Control

Once a gesture is recognized, the FPGA will send control signals to the respective devices or systems within the smart home. For example, a specific gesture could be associated with turning on/off lights, adjusting the temperature, controlling entertainment systems, or managing security devices.

F. User Interface:

A user-friendly interface will be developed to provide feedback and visual indications of recognized gestures. This can be implemented using graphical displays or LED indicators to enhance the user experience and provide immediate feedback on the recognized gestures.

5. SOFTWARE DESCRIPTION

The simulation tool used for used in this system is Isim simulator Isim provides a complete, full featured HDL stimulator integrated within ISE. HDL simulation now can be an even more fundamental step within you are design flow with the tight integration of the Isim within the design environment.

The key features of Isim simulator are mixed language support, power analysis and optimization using SA IF, native support for all RIP blocks, memory editor for viewing and debugging memory elements, no special license requirement single click recompile and relaunch of simulation, integrated with IS design suite and plan ahead application multithread complete compilation, post processing capabilities, easy to use one click compilation and simulation.

The synthesis tool used is Xlinix ISE 14.7

There are four fundamental steps in all digital logic,design. These consist of:

1. Design – The schematic or code that describes the circuit.
2. Synthesis – The intermediate conversion of human readable circuit description to FPGA code (EDIF) format. It involves syntax checking and combining of all the separate design files into a single file.
3. Place & Route – Where the layout of the circuit is finalized. This is the translation of the EDIF into logic gates on the FPGA.
4. Program – The FPGA is updated to reflect the design through the use of programming (.bit) files. The gesture code table is as shown below in table1.

Table 1: Gesture code

Gesture	code
up	0001
Down	0010
Right	0100
Left	0011
Forward	0101
Backward	0110
Colockwise	0111
Anticlockwise	1000

The flow chart for gesture recognition is as shown below

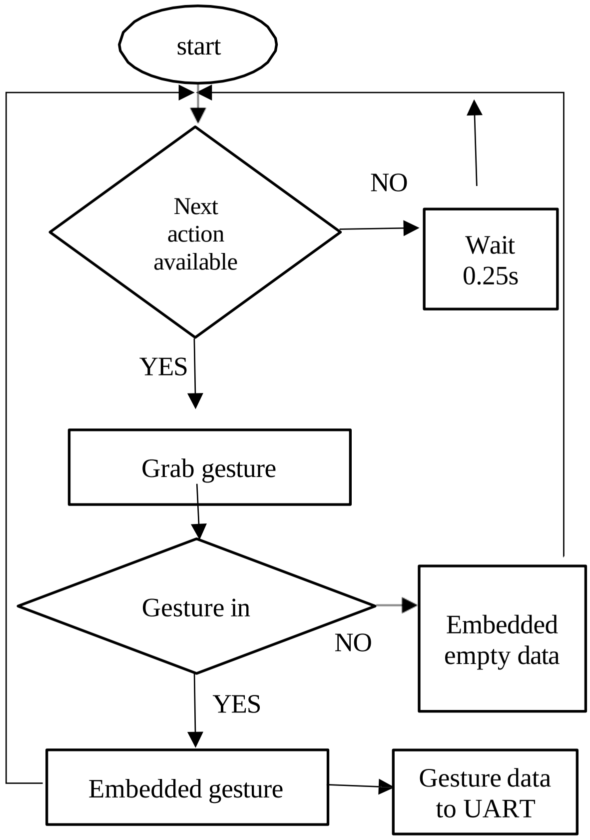

Fig 4: Flow chart of gesrure recognation

Initally the sensor waits to for identification of hand gesture.Once hand gesture identified by the sensor is send for the next action if the gesture input is matched with the embedded gesture then the data will be send to the UART,else the gesture sensor identifies another gesture.

6. IMPLEMENTATION SETUP

The implementation setup for hand gesture control home automation is as shown in the hardware.The implementation module consists of different hardware module connected to spartan6 FPGA board for conrolling the different home appliacences.

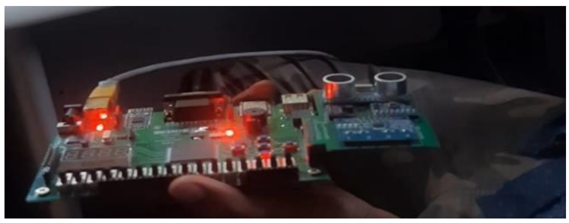

Fig 5: Hardware implemntation

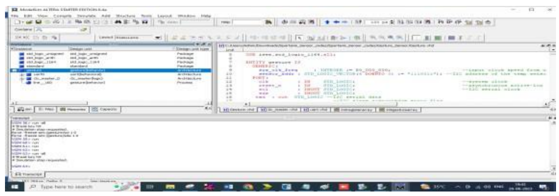

Fig 6: Synthesis of HDL code.

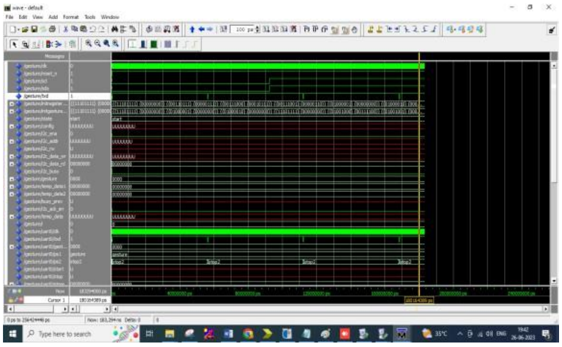

Fig 7: Simulation results

The fig 7 provides the simulation results of gesture input

RTLSchematic

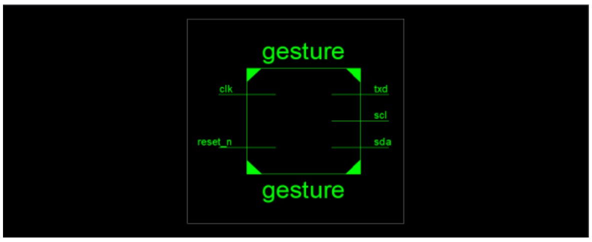

Fig 8: RTL schematic of Gesture module

Fig 8 provides the RTL schematic for gesrture modlue in which Clock signal and rest are considered as input and Sdl,Scl and txn are considerd as output.

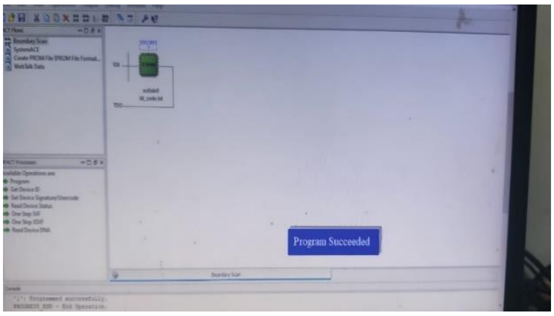

Fig 9:Program loaded to FPGA Board

Fig 9 describes that the gesture code has loaded into the Spartan 6 FPGA board successfully.

7. RESULTS

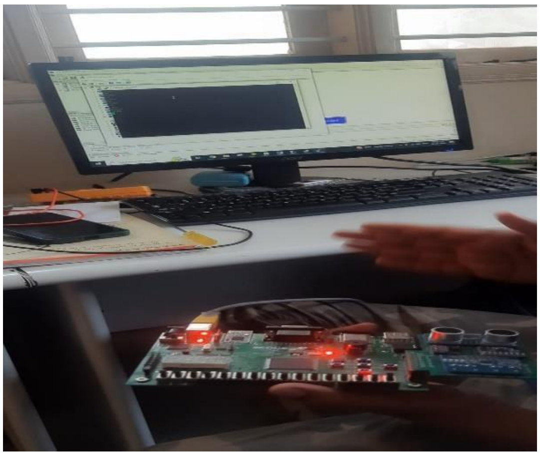

Fig10:Hand movement from rigth to left

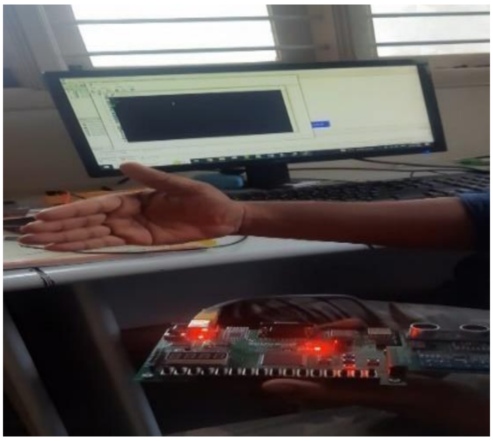

Fig11:Hand movement from rigth to left

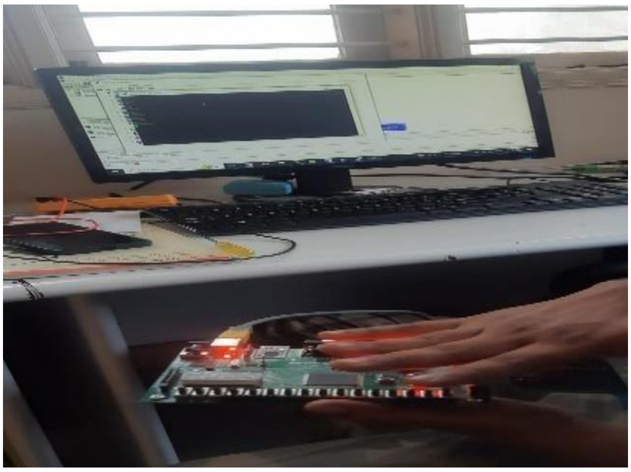

Fig12:Hand movement forward

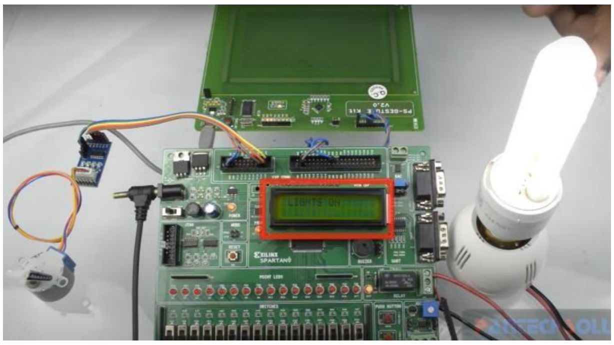

Fig13: Light ON when Hand movement to right

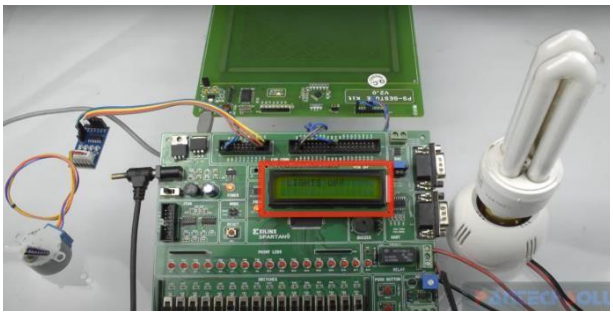

Fig14: Light OFFHand movement to left

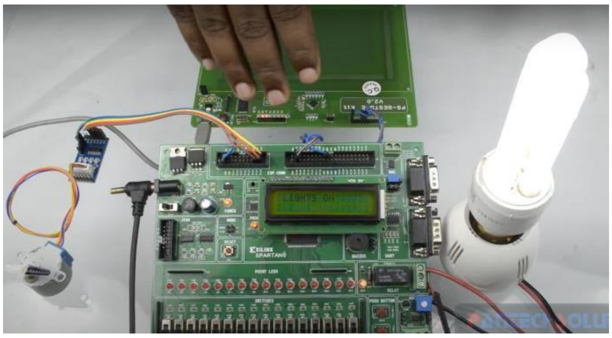

Fig15:Hand movement from right to left

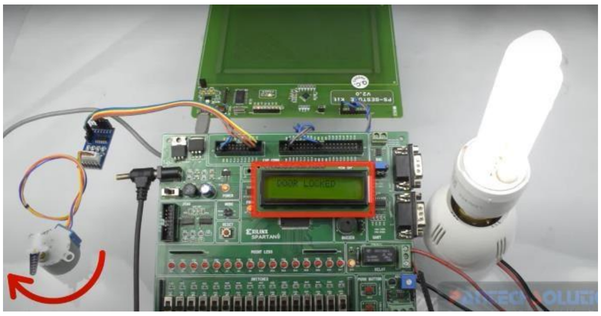

Fig16: Door locked for Hand movement from up

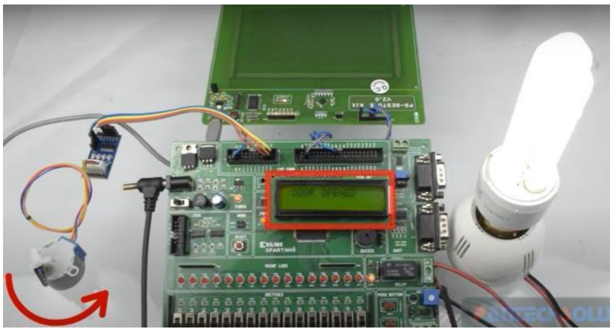

Fig17: Door oprned for Hand movement from down

8. CONCLUSION

In conclusion, the project focused on implementing gesture control in a home automation system using an FPGA Spartan-6 and a gesture sensor. The integration of these technologies aimed to enhance the user experience and provide intuitive control over various devices and systems within a smart home environment. Throughout the project, key objectives were achieved. The FPGA Spartan-6 served as the core processing unit, implementing real-time gesture recognition algorithms. The gesture sensor accurately captured hand movements, providing input data for gesture recognition. By utilizing VHDL or a similar language, the system successfully analyzed the sensor input, recognized specific gestures, and sent control signals to the corresponding devices. The project demonstrated the potential of gesture control in home automation, offering a seamless and user- friendly interaction method. By replacing physical switches with hand movements, users could control their smart home devices intuitively and efficiently. The real-time responsiveness achieved through the FPGA technology further enhanced the user experience, ensuring immediate feedback and control. Additionally, the project highlighted the customization and expandability of the system. The use of an FPGA allowed for flexibility in adding or modifying gestures, catering to individual user preferences. This customization aspect, combined with the integration capabilities of the proposed system, enabled seamless integration with existing home automation setups. While the project achieved its objectives, there are avenues for further improvement. Addressing challenges such as environmental sensitivity, processing time, and power consumption would enhance the overall performance and reliability of the system. Additionally, exploring advanced gesture recognition algorithms and incorporating machine learning techniques could potentially improve gesture recognition accuracy and expand the system's gesture vocabulary.

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