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AUTOMATED SMART CITY: SMART SYSTEM FOR HOMES, POWER AND ENVIRONMENT

Muhammad Noorulhassan[*1], Muhammad Usman[2], Sadeema Fatima[3], Mehak Shoukat[4], Muhammad Naeem[5]

[*1,2,3,4,5]*Department of Physics, Thal University Bhakkar*

[*1]noorulhassan.phy.edu.pk@gmail.com, [2]muhammadusman.physics01@gmail.com, [3]sadeemafatima045@gmail.com, [4]sbirsaim@gmail.com, [5]physicist4113@gmail.com

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Corresponding Author: *
Muhammad Noorulhassan

Abstract

In order to improve safety, automation, and energy efficiency, this project shows an Integrated Smart City and Home Automation System that was created using Arduino Uno boards.
This project fully automates the Home using four Arduinos and many other connected modules. The first Arduino manages a smart parking and street lighting system that uses ultrasonic sensors to identify cars in order to automate gate operation and effectively control street lights. Gas detection, stair lighting, alarm indicators, an LCD display, and a buzzer for real-time notifications are all included in the second Arduino, which is devoted to a home automation and safety system, in order to protect outdoor objects like clothing, it also has a rain detecting device that automatically closes protective coverings when rainfall is detected. By automating indoor lighting and sending out instant notifications in the event of a gas leak, this module guarantees household safety. The third Arduino focuses on water management and environmental response, where temperature sensing triggers a servo motor to deploy shading when hot water is detected. Additionally, a motorized system handles water exhaust, and multiple indicator lights represent different operational modes. A flood detection mechanism monitors water levels and activates alerts at various thresholds. By integrating IoT capabilities, Wi-Fi module with Arduino allows for remote lighting control via a mobile device and real-time weather monitoring, including temperature and humidity. Additionally, it allows for ambient-condition-based automated lighting, especially at night. Overall, this project shows a scalable and affordable smart system that combines home automation and urban infrastructure, enhancing resource management, safety, and convenience through intelligent control and real-time monitoring.

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1. Introduction:

A smart home automation system based on Arduino & internet of thing (IoT) Technology make daily life easier & more comfortable by using modern technology. Smart home model not only improves comfort & convenience but also provides great support for elders disabled people by making home control simple, automatic & efficient. This project represents a complete model that show a smart home. The project is based on an Arduino Uno & microcontroller ESP8266 which act the brain of the home. The Arduino is programmed in C++ language using Arduino IDE Software, it communicates through serial port. This system can perform many useful tasks automatically such as controlling lights, opening & controlling doors, managing street lights, monitoring temperature & humanity, detecting gas and activating alarm (buzzer), detecting flood and give alarm, detecting rain.[1]

The proposed smart home system works in two different modes. The first mode is called manual-automated mode. In this mode, the user can monitor & control home applications from anywhere in the world using a mobile phone through Wi-Fi. This mean you can turn on or off check their status & manage your home even when you are for away. The second made is called self-automated mode. In this mode the system works automatically without needing human instructions. It receives signals from sensors (like rain & temperature sensor) control home applications by itself based on those signals. In simple words, the system gives you two options.[2] Control your home yourself from anywhere or let the smart system to control everything automatically.[3]

1.1 Hardware:

Arduino is an open-source computer hardware and software company, project, and user community that designs and manufactures microcontroller-based development boards. These boards help us make electronic projects easily like robots, smart lights, alarms and sensors. Arduino is microcontroller board. It has a small computer chip called ATmega328 microcontroller that controls everything. Arduino IDE, which use C programming language. This gives access to an enormous Arduino library that is constantly growing thanks to open-source via USB port. Arduino Uno also has on-board 6 analog pins and 14 digital pins for input and output operations supporting SPI and I2C which can be used to interface with other devices. Where Arduino is used. Arduino is mostly used in subjects like Technology, physics programming and science experiments. It helps coding and electronics.

Fig1.Arduino Uno

1.2 Sensors Analysis with Working Specifications & Limits:

The Automated Home for Weather Energy and Smart Navigation system integrates five key sensors to ensure safety, automation, and

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environmental monitoring. These sensors collectively enable smart entry control, automated lighting, weather observation, gas detection, and water level monitoring. Each sensor plays a specific functional role based on its detection capability and operating range. Ultrasonic and IR sensors support proximity and obstacle detection, while the DHT11 and rain sensor monitor environmental conditions. The MQ-2 sensor enhances safety through gas leakage detection. Proper calibration and operation within specified technical limits are essential to ensure accuracy, reliability, and long-term system Performance.

Fig2.MQ-2

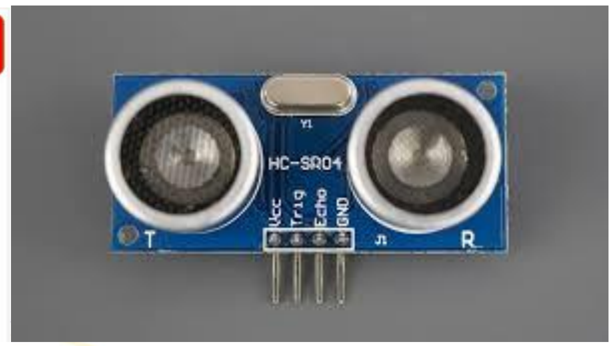

Fig 3.Ultrasonic Sensor

The Ultrasonic Sensor provides accurate non-contact distance measurement using high-frequency sound waves, operating within a range of 2cm to 400cm with ±3mm accuracy at 5V. It detects objects by calculating the time taken for an echo to return after transmitting a pulse. In this system, it enables automatic activation of doors and lights through proximity detection, while also monitoring water tank levels and triggering flood alerts when thresholds are exceeded. It additionally supports obstacle detection in the smart navigation module. However, its performance may reduce under heavy rain, soft surfaces, or extreme temperature conditions, making proper placement and calibration essential for reliable operation.

The DHT11 Sensor monitors environmental temperature and humidity as part of the live weather monitoring module, covering a temperature range of 0°C to 50°C with ±2°C accuracy and humidity from 20% to 90% RH with ±5% accuracy at 3.3V to 5V. It provides digital output, making it easy to interface with Arduino or ESP-based IoT modules for seamless data processing. In this system, it supports climate-based automation such as controlling ventilation and generating live environmental reports. Although cost-effective and reliable for basic indoor use, it is not suitable for extreme outdoor conditions or high-precision applications, but provides sufficient data for the purposes of this smart home system.

Fig4.LDR sensor

Fig5.DHT 11 Sensor

Fig6.Rain Sensor

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The Rain Sensor is used for real-time rainfall detection by sensing water droplets on a conductive plate, where contact changes resistance and generates an electrical signal sent to the microcontroller. It operates on 3.3V to 5V with both analog and digital outputs, offering flexible integration with Arduino or ESP-based IoT modules. In this system, it activates automated responses such as closing smart windows, adjusting outdoor systems, and generating rainfall alerts for home protection. It also assists in early flood prevention by detecting heavy rainfall before conditions worsen. However, regular maintenance is required to prevent corrosion on the sensing plate, which can otherwise lead to false or inaccurate readings over time.

The MQ-2 Gas Sensor is the safety-critical component of this system, capable of detecting combustible gases including LPG, methane, propane, hydrogen, and smoke by measuring resistance changes upon gas exposure. It operates within a detection range of 300 ppm to 10,000 ppm at 5V, making it highly suitable for domestic safety applications. In this system, it triggers alarms, activates ventilation systems, and sends real-time IoT alerts when gas levels exceed safe thresholds, providing early warning before conditions become hazardous. However, it requires a preheating time of 20 to 60 seconds for stable and accurate readings, which must be considered during system startup. Overall, the MQ-2 Sensor is a fundamental safety component ensuring reliable gas hazard detection at all times.

A Light Dependent Resistor (LDR) is a type of sensor that changes its resistance according to the intensity of light falling on it. When more light falls on the LDR, its resistance decreases, and when there is less light, its resistance increases. In a line follower robot, the LDR is used to detect the difference between light and dark surfaces.[4] A jumper wire which is also known as jump wire, DuPont wire or connecting wire is an electrical wire or a group that connects two terminals. A jumper wire contains a connector or a pin on both ends and sometimes simple "tinned" which is mostly used in a breadboard to interconnect the components to create a circuit. It is also useful for prototype and test circuits. It is useful to interconnect components with other equipment's without soldering. Jumper wires are connected by inserting their ends into the slots given in the breadboard.[5]

Photovoltaic PV water pump is very typical application in developing countries. In many countries are not connected with electric grid and face many problems for drinking water. There are many models of pumps and motor. We have decided to use an empirical model for the complete motor pump system in which parameters are obtained in a pumping test facility.[6]

Fig 7.9V DC PUMP

Fig8.DS18B20 sensor

In the documents, particularly the paper on "Visible Electricity," the breadboard is described as a solderless platform. This is the foundation where you build your prototype. It allows you to make or "erase" physical wirings by hand without permanent soldering. A "Visible Breadboard" that uses solid-state relays and micro-controllers to connect 36 different holes. It acts as an interface for developing and sharing circuits quickly. It's where the Arduino Nano or Uno is mounted to

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"talk" to the other parts. The information hub; The papers highlight the Liquid Crystal Display (LCD) as the primary way a system communicates with a human. Whether it's measuring distance or greenhouse climate, the LCD is the "screen." In the motion detection study, the LCD is interfaced with an Arduino Uno to show exactly how far away an object is in centimeters. For the humidity and temperature system, the LCD provides a "real-time" readout of the environment. Instead of just hearing a beep, the user can look at the screen to see specific numbers (like 150 cm or 30°C), making the data easy to understand at a glance.

The LEDs in these studies are used for indication and alarming mechanisms. They serve as a simple, color-coded language for the user. In the distance-sensing project, the LEDs are programmed with specific logic:

- Green: Indicates a safe distance (greater than 150 cm).
- Blue: Indicates an object is getting closer (70 cm).
- Red: Acts as a warning that an object is very close (40 cm).

The papers show that LEDs often work alongside a piezo buzzer. While the buzzer gives a sound signal, the LED provides a visual "light-coded signal" to confirm the status of the system.

The Breadboard holds the Arduino Nano, the LCD shows the humidity percentage, and the LED flashes to indicate if the conditions are optimal or if an alarm has been triggered.[7]

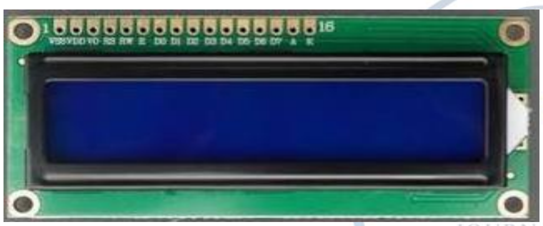

Fig9.LCD

Fig10. Servo Motor

Fig11. Bread Board

Fig12. LED's

1.2 APPLICATION OF HOME AUTOMATION SYSTEM USING ARDUINO:

Home automation with Arduino is used to control and monitor home appliances automatically using smartphone or computer. It improves comforts, security, energy efficiency and convenience in residential buildings. The system mainly focuses on lighting control, door control, security monitoring, temperature and humidity control and sessional management.

One of the most important application of Arduino based home automation is lightning control. Lights in different rooms can be turned on or off using a smartphone application or a desktop interface. The system can also work automatically using an LDR (light dependent resistor). The LDR detects daylight intensity. When it becomes dark the light turned on automatically and when there is enough sunlight the lights turn off. This reduces unnecessary

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electricity usage and saves energy.[1]The system can control doors through the mobile application a user can open or close the door automatically. The motor rotates in one direction to open the door and in the opposite direction to close it. This application increases home security and provides comfort especially for elderly or disabled persons.[1] The Arduino system uses a DHT11 sensor to measure temperature and humidity inside the home. The sensor Provides digital signals the Arduino. Based on the temperature level cooling or heating devices can be controlled automatically. This helps maintain a comfortable environment and improves living conditions.[1]
Motion sensors, gas sensors, and door sensors can be connected with Arduino. If any unusual activity is detected, the system sends an alert to the user's mobile phone.[1]Gas sensors can detect leakage of LPG or smoke. The system can give an alarm or notification to prevent accidents.[1] The system monitors power usage and automatically turns OFF unused devices to reduce energy waste and lower electricity bills. Arduino can be used to check the water level in tanks and automatically switch the motor ON or OFF. Using internet connectivity (Ethernet/Wi-Fi), users can control and monitor their home appliances from anywhere in the world.[1]

2 Methodology:

Arduino works like a main control unit in home automation system. It connects with sensors and devices like lights, fan, temperature sensor and motion sensor. First, Arduino take input from sensors. For example, if motion sensor detect human or temperature sensor detect heat, then Arduino read this data. After that, the microcontroller process this input and decide what action should be done.
Then Arduino give output signals. Like:
Turn ON light when dark, Turn OFF fan when temperature is low, start alarm if motion detected
This working is continuous and automatic. Arduino keep checking inputs and giving outputs again and again. It uses programming which is uploaded using Arduino IDE.
So we can say:
Input → Processing → Output
Why We Use Arduino in Home Automation System, there are many reasons to use Arduino in home automation. First, it is very easy to use. Beginners can easily understand it because it uses simple programming language. Second, Arduino is low cost. It is cheap and easily available, so students can use it easily. Third, it is flexible. It can connect with many sensors and devices, so we can make different types of automation systems. Also Arduino is open source. Many codes and projects are available online, so it helps students to learn fast. Another reason is cross platform support. It can run on Windows, Linux and Mac, so anyone can use it. Lastly, Arduino is reliable and efficient for small automation systems. It works automatically without human effort which is main goal of home automation.
Many researchers have worked on Arduino based home automation systems. In one study, Arduino is used as a central controller which reads sensor data and controls home appliances automatically. It also shows that these systems are low cost and easy to implement for smart homes, and this make them suitable for beginners and students[8]. Another study explains that Arduino can be integrated with IoT to control home devices remotely. In this system, users can manage appliances using internet, and Arduino work as a bridge between sensors and network. It also highlights that Arduino is simple and compatible with many sensors which make it very useful in automation systems[9].
In addition, another research discussed that Arduino helps in automation by continuously monitoring environment and taking quick decisions. The system automatically responds to changes like temperature or motion, and reduce human effort in daily tasks which improve efficiency of system[10].
Another research shows that Arduino is widely used because of its low cost and open source nature. It can control multiple appliances at same

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time and gives good performance in home automation systems. This makes Arduino a strong option for developing smart systems[11]. From these research papers, it is clear that Arduino is very useful for home automation because it is simple, low cost and flexible. Many researchers agree that it is best choice for students and beginners.

2.1 Smart Street Light and Automatic Gate Control System:

Three ultrasonic sensors, a servo motor, eight LEDs, a buzzer, and an Arduino Uno microcontroller were used in the design of the entire subsystem, which was intended to reduce electrical energy consumption, improve road safety, automate gate management, and minimize human involvement in traffic control operations. The design methodology focused on sequential vehicle detection and automated response generation according to vehicle movement on the road model. Prior to implementation, the necessary hardware components were carefully chosen based on availability, compatibility, affordability, and ease of integration with Arduino boards. This subsystem was designed to eliminate human involvement in traffic control operations, automate gate management, increase road safety, and reduce electrical energy consumption. Three ultrasonic sensors, a servo motor, eight LEDs, a buzzer, and an Arduino Uno microcontroller were used in the construction of the complete subsystem. Sequential vehicle identification and automated reaction generation based on vehicle movement on the road model were the main focuses of the design process. The necessary hardware components were carefully chosen prior to implementation based on factors including cost-effectiveness, compatibility, availability, and simplicity of integration with Arduino boards.
Because they offer precise distance measurement and dependable item detection without requiring physical touch, ultrasonic sensors were used. Because servo motors provide exact angular movement for automated gate opening and shutting operations, they were chosen. Because of its extended operating life and low power usage, LEDs were utilized to mimic streetlights. This subsystem's circuit design process included correctly connecting sensors and actuators to the Arduino Uno board. To continuously track vehicle movement, ultrasonic sensors were positioned at various points along the road model. Three ultrasonic sensors were installed: one near the entry gate, one in the middle of the road, and one near the exit. Every ultrasonic sensor had an echo and a trigger pins. A servo motor was connected to the gate mechanism to automate opening and closing operations; a buzzer was integrated into the circuit to provide audio notifications whenever a vehicle was detected; the Arduino IDE and Embedded C programming language were used to complete the software development methodology for this subsystem. The trigger pin transmitted ultrasonic sound waves while the echo pin received reflected signals from nearby objects. The Arduino continuously measured the travel time of these sound waves and calculated the distance between the object and the sensor using mathematical calculations.
The Arduino used mathematical calculations to determine the distance between the object and the sensor by continually measuring the sound waves' travel time. Along the road course, the LEDs that represented streetlights were joined sequentially. The gate mechanism was equipped with a servo motor to automate opening and shutting. In order to offer audible alerts anytime a car was detected, a buzzer was built into the circuit. The Arduino IDE and the Embedded C programming language were used to finish the software development process for this subsystem. Sequential vehicle movement detection and automatic reaction creation served as the foundation for the programming logic. Every ultrasonic sensor's readings were continuously checked by the loop function. The operational methodology of the subsystem began when the first ultrasonic sensor detected a vehicle near the entrance gate. The sensor continuously measured the distance

between the sensor and the approaching object; when the measured distance became smaller than the predefined threshold value, the Arduino interpreted the condition as vehicle detection. The Arduino immediately activated the buzzer to generate a short notification sound; at that time, the servo motor rotated to open the gate for vehicle entry. This methodology eliminated the need for manual gate operation and improved automation efficiency. To guarantee appropriate coordination between sensors and outputs, conditional statements and state management strategies were put into practice. When the first ultrasonic sensor identified a car close to the entrance gate, the subsystem's operating approach began. The distance between the sensor and the incoming object was continually measured. The Arduino regarded the situation as vehicle detection when the measured distance dropped below the predetermined threshold value. The buzzer was instantly turned on by the Arduino to produce a brief alert. The gate was opened for vehicle entry at that time by an automatic rotation of the servo motor. This approach increased automation efficiency and eliminated the need for manual gate operation.

For testing and debugging purposes, serial monitoring messages were also generated. Once the vehicle entered the road section, the second ultrasonic sensor detected its movement. When the vehicle reached the second sensor, the Arduino activated the street LEDs sequentially, each LED turning ON with a slight delay to create a smooth lighting sequence effect. This intelligent lighting methodology can significantly reduce electricity consumption in modern smart cities because only the necessary streetlights remained active during vehicle movement, illuminating only the specific area where the vehicle was present. The servo motor automatically rotated back to its original position and closed the entrance gate. The second ultrasonic sensor picked up movement as soon as the car entered the road segment. The Arduino sequentially turned on the street lights when the car got to the second sensor. To provide a seamless lighting sequence effect, each LED switched on with a small delay. Because only the necessary lighting remained on while vehicles were moving, this methodology was used to save electrical energy. The technology just illuminated the area where the car was present, rather than keeping all lights on all the time. In contemporary smart cities, this intelligent lighting approach can drastically save electricity consumption. The servo motor closed the entrance gate and automatically turned back to its initial position once the car passed the second sensor region.

When the vehicle arrived at the exit section, the third ultrasonic sensor detected its presence. The Arduino processed the sensor signal and turned off the street LEDs sequentially in reverse order. This methodology ensured that lights remained active only when necessary and automatically switched OFF after vehicle movement. As a result, unnecessary energy consumption was minimized and overall power efficiency improved. The reverse vehicle movement methodology was also implemented in the system to provide bidirectional automation. This automatic gate closing methodology improved security and prevented unauthorized entry into the road section. After then, the system went into the next operating state, where it used the third ultrasonic sensor to continuously monitor the exit region. The third ultrasonic sensor picked up the car when it got to the departure portion. After processing the sensor signal, the Arduino consecutively shut off the street lights in reverse order. This process made sure that lights only turned on when necessary and turned off automatically when the car moved. As a result, total power efficiency increased and needless energy use was reduced. In order to achieve bidirectional automation, the system also incorporated the reverse vehicle movement methodology.

This subsystem's testing methodology included individual sensor testing, actuator testing, and full system evaluation. The third ultrasonic sensor detected movement once more and activated the street LEDs in reverse sequence when a vehicle returned from the opposite direction. The second sensor then monitored the returning vehicle and automatically turned off the LEDs after vehicle passage. Finally, when the first sensor detected the vehicle leaving the area, the servo motor reopened the gate and later closed it after complete exit. The system then returned to its initial waiting condition, ready for the next operation cycle. After the car passed, the second sensor automatically turned down the LEDs while keeping an eye on the returning vehicle. Ultimately, the servo motor reopened the gate upon detecting the car's departure from the area by the first sensor, and it closed once the vehicle had fully left. After that, the system went back to its starting state of waiting, prepared for the subsequent cycle of operations. This subsystem was tested using a combination of individual sensor testing, actuator testing, and system evaluation. To confirm measurement accuracy, the ultrasonic sensors were tested at various object distances. The servo motor's ability to rotate and operate the gate was tested.

Following successful individual testing, the entire subsystem was integrated and assessed under continuous operating conditions. The system successfully demonstrated automatic gate management, intelligent street lighting, reduced energy consumption, and real-time vehicle detection. The methodology of this subsystem demonstrated that Arduino-based embedded systems can effectively implement intelligent transportation and smart street lighting solutions. The subsystem can be further expanded in the future by integrating IoT technology, wireless communication modules, and cloud-based monitoring systems for large-scale smart city applications. Additionally, the buzzer's ability to generate notifications correctly was examined. The entire subsystem was integrated and assessed under continuous working conditions following the completion of successful individual testing. Automatic gate management, smarter street lighting, lower energy consumption, and real-time vehicle identification were all successfully proven by the system. This subsystem's technique demonstrated that intelligent transportation and smart street lighting solutions may be successfully implemented using Arduino-based embedded systems. By incorporating IoT technologies, wireless communication modules, and cloud-based monitoring systems for extensive smart city applications, the subsystem can be further enhanced in the future.

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Diagram:

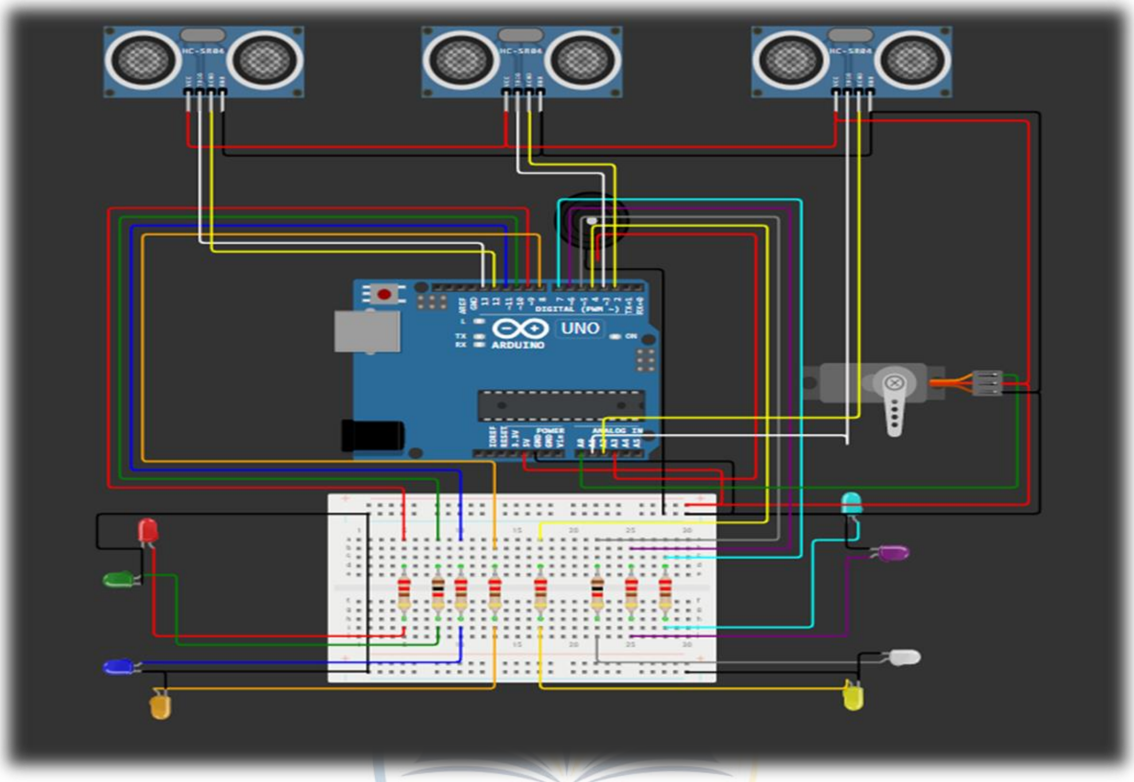

Figure 13 Smart Street and Automation System

2.2 Smart Home Security and Automation System:

An MQ gas sensor, rain sensor, ultrasonic sensor, servo motor, LCD display, LEDs, buzzer, and Arduino Uno microcontroller are just a few of the sensors and automation devices that the subsystem integrated. The entire methodology was based on real-time monitoring and automatic response generation according to environmental conditions. The subsystem was implemented using low-cost electronic components so that it could be easily adopted for domestic applications and small-scale smart home environments. The main goals of this subsystem were to develop an intelligent, energy-efficient, and safety-oriented home automation model. This subsystem's primary goals were to increase smart control of household appliances, decrease human labor, improve domestic safety, and provide automatic environmental monitoring. An MQ gas sensor, rain sensor, ultrasonic sensor, servo motor, LCD display, LEDs, buzzer, and Arduino Uno microcontroller were among the sensors and automation devices that the subsystem included. Real-time monitoring and automatic response generation based on environmental circumstances formed the foundation of the entire process. Low-cost electronic components were used to create the subsystem, making it simple to implement for small-scale smart home setups and domestic applications.[12]

System planning and hardware selection were the main focus of the first stage of the methodology. The Arduino Uno was chosen as the main controller because it has enough digital and analog input/output pins to interface multiple sensors and output devices; the Arduino platform also offers easy programming capabilities and compatibility with various libraries required for automation systems; the MQ gas sensor was chosen because it can detect combustible gases like LPG, methane, propane, and smoke; the rain sensor was chosen for automatic rainwater detection and protection of household items; the ultrasonic sensor was integrated for motion detection and automatic lighting control; and servo motors were chosen because they offer precise angular rotation appropriate for opening and closing protective covers. Because it has enough digital and analog input/output pins to interface numerous sensors and output devices, the Arduino Uno was chosen as the primary controller. Additionally, the Arduino platform provides simple programming and compatibility with a number of libraries needed for automation systems. Because it can identify flammable gases like LPG, methane, propane, and smoke, the MQ gas sensor was chosen. For automatic precipitation detection and household object safety, the rain sensor was selected. Motion detection and automated lighting control were made possible by the integration of the ultrasonic sensor. Because servo motors offer accurate angular rotation appropriate for opening and closing protective coverings, they were chosen. A 16x2 LCD display with I2C communication was utilized to provide real-time information and minimize wiring complexity. LEDs and buzzers were utilized as visual and audio indicators to enhance user awareness during emergency situations. The circuit design methodology involved the proper interfacing of all sensors and output devices with the Arduino Uno microcontroller. The MQ gas sensor was connected using both digital and analog outputs; the digital output pin was connected to a digital input pin for threshold-based emergency detection. The rain sensor module was connected to the Arduino via digital communication pins to monitor rainfall conditions in real time. To give real-time information and simplify wiring, a 16x2 LCD display with I2C connection was utilized. All sensors and output devices have to be properly interfaced with the Arduino Uno microcontroller as part of the circuit design technique. Both analog and digital outputs were used to link the MQ gas sensor. While the digital output pin was linked to a digital input pin for threshold-based emergency detection, the analog output pin was connected to an analog input of the Arduino to measure gas concentration levels continually. To track rainfall conditions in real time, the rain sensor module was linked to the Arduino using digital communication pins.[13]

The Arduino IDE and Embedded C programming language were used to implement the software development methodology for this subsystem. Several Arduino libraries, such as Servo.h, Wire.h, and LiquidCrystal_I2C.h, were integrated into the program to simplify hardware communication and control operations. The servo motor was connected to a PWM pin of the Arduino to enable smooth rotational control; LEDs and buzzers were connected using current-limiting resistors to protect the components from excessive current flow. To achieve smooth rotational control, the servo motor was linked to an Arduino PWM pin. Current-limiting resistors were used to link LEDs and buzzers in order to prevent excessive current flow. The I2C communication protocol was used to link the LCD display, which simplified circuit implementation and decreased the amount of wiring connections needed. The Arduino IDE and the Embedded C programming language were used to implement the software development approach for this subsystem. To make hardware communication and control tasks easier, the software incorporated several Arduino libraries, such as Servo.h, Wire.h, and LiquidCrystal_I2C.h. Real-time sensor measurements were continuously monitored using the loop () method. To automate system operations in accordance with predetermined threshold conditions, conditional statements and logical decision-making procedures were used. Because gas leaks are a significant safety risk in homes and businesses, the gas leak detection mechanism was one of the most crucial components of the subsystem. The MQ gas sensor kept an eye out for smoke and dangerous gasses in

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the surrounding area. Analog voltage values were produced by the sensor based on the levels of gas concentration. The map () method in the Arduino program was used to transform these analog values, which varied from 0 to 1023, into percentage form. In order to give users real-time monitoring information, the gas percentage values were continuously shown on the LCD display.[14]

This methodology ensured early detection of hazardous gas conditions and greatly improved domestic safety. The rain protection methodology was developed to protect clothing and household items from rainfall using automatic mechanical control. When the gas concentration remained within the safe range, the Arduino activated the green LED to indicate safe environmental conditions; the buzzer remained OFF and the LCD displayed normal status messages. However, when the gas concentration exceeded the predefined safety threshold, the Arduino activated emergency responses automatically; the red LED turned ON to indicate danger conditions, while the green LED turned OFF to indicate danger. The LCD showed standard status messages while the buzzer stayed off. However, the Arduino automatically triggered emergency responses when the gas concentration over the predetermined safety level. When danger conditions were present, the green LED shut off and the red LED turned on. In order to warn consumers about potential gas leaks, the buzzer simultaneously produced a warning alarm sound. "Gas Leak Alert" messages were shown on the LCD to give clear visual warning information. This approach greatly increased home safety and guaranteed early identification of dangerous gas conditions. The rain protection methodology was created to use automatic mechanical control to shield clothing and household goods from precipitation.[15]

The rain sensor kept an eye out for water droplets on its conducting surface. The sensor sent regular signals to the Arduino controller in dry conditions. Rainwater contact with the sensor's surface altered its conductivity, causing it to send a LOW signal to the Arduino. After processing this signal, the Arduino turned on the servo motor on its own. The protective shade or cloth cover mechanism was closed by rotating the servo motor. Without the need for human interaction, this mechanical movement prevented rainwater damage to clothing and other exposed household objects. The Arduino disabled the rain warning status and put the servo motor back in its normal position after the downpour ended and the rain sensor surface dried up. The system went back to regular working mode when the cover automatically reopened. Multiple LEDs and an ultrasonic sensor were used to execute the motion detection and automatic lighting methods. The ultrasonic sensor continuously sent out ultrasonic sound waves and picked up signals that were reflected from surrounding objects. Using sound wave travel time, the Arduino determined the distance between the sensor and objects. The Arduino detected human presence when a person reached the predetermined detection range. The Arduino automatically turned on the LEDs when it recognized a human. To enhance room visibility and create clever lighting effects, the LEDs turned on one after the other. By ensuring that lights only turned on when essential, this approach cut down on needless electricity use. To conserve electricity, the LEDs stayed off when there was no activity in the monitored area.[16]

This motion-based lighting control methodology enhanced energy efficiency and decreased electricity waste in residential settings. The LCD display methodology concentrated on giving users real-time monitoring information and system status updates. The LCD continuously displayed gas percentage values, environmental conditions, safety messages, and alert notifications. During gas leakage conditions, the LCD displayed warning messages like "Gas Leak Alert." During regular operation, the LCD displayed safe status information and gas concentration percentages. This methodology enhanced user interaction with the automation system and offered convenient environmental monitoring. The LCD display methodology concentrated on giving users access to real-time monitoring data and system status updates. Gas percentage information, environmental conditions, safety instructions, and alert notifications were all continuously shown on the LCD. The LCD showed alerts like "Gas Leak Alert" when there was a gas leak. The LCD showed percentages of gas concentration and safe status information when it was operating normally. This approach offered practical environmental monitoring and enhanced user involvement with the automation system. In an emergency, the buzzer mechanism was used to deliver audible alerts. When gas leaks and other alert conditions were detected, the buzzer produced alarm noises. The combination of visual and audio indications enhanced overall system safety and user awareness. The testing and validation methodology of this subsystem involved testing each sensor and output device separately prior to final system integration. The MQ gas sensor was tested using gas sources like smoke and lighter gas to assess gas detection sensitivity and response time; the rain sensor was tested by applying water droplets to its conductive surface and observing servo motor operation; the ultrasonic sensor was tested using moving objects at various distances to verify motion detection accuracy; LEDs, buzzer, servo motor, and LCD display operations. Overall system safety and user awareness were enhanced by the combination of visual and auditory cues. Before the final system integration, each sensor and output device was tested separately as part of the testing and validation process for this subsystem. To assess gas detection sensitivity and response time, the MQ gas sensor was tested with gas sources such smoke and lighter gas. Water droplets were applied to the rain sensor's conducting surface, and the servo motor's operation was monitored. To confirm the accuracy of motion detection, the ultrasonic sensor was tested with moving objects at various distances. The functions of the LCD display, buzzer, servo motor, and LEDs were also confirmed separately.[17]

The system effectively identified hazardous gas levels during the gas leakage simulation and immediately triggered emergency measures. During rainfall simulation, the servo motor successfully controlled the protective cover mechanism. When a human was present, the motion detecting system precisely turned on and off LEDs. The subsystem showed dependable automation performance, quick response times, and steady real-time operation. This smart house security and automation subsystem's methodology demonstrated that intelligent home safety and environmental monitoring solutions can be successfully implemented using Arduino-based embedded devices. The subsystem offered automated control of domestic systems, decreased human labor, enhanced home security, and used less electricity.[18]

The project also showed how important it is to integrate various sensors and automation techniques in order to develop modern smart home technologies. In the future, the subsystem can be further enhanced by incorporating wireless communication technologies like Wi-Fi, GSM, Bluetooth, and IoT cloud platforms; mobile application control can be implemented to enable remote monitoring and operation of the system from smartphones; artificial intelligence algorithms can be integrated to improve environmental prediction and decision-making capabilities; solar energy systems can be added to improve energy efficiency and sustainability. By incorporating wireless communication technologies like Wi-Fi, GSM, Bluetooth, and IoT cloud platforms, the subsystem can be further enhanced in further improvements. Mobile application control can also be implemented to allow remote monitoring and operation of the system from smartphones. Artificial intelligence algorithms can be integrated to improve decision-making capabilities and environmental prediction. To increase sustainability and energy efficiency, solar energy systems can also be included. These future enhancements can transform the subsystem into a complete industrial-level smart home automation solution.[19]

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Diagram:

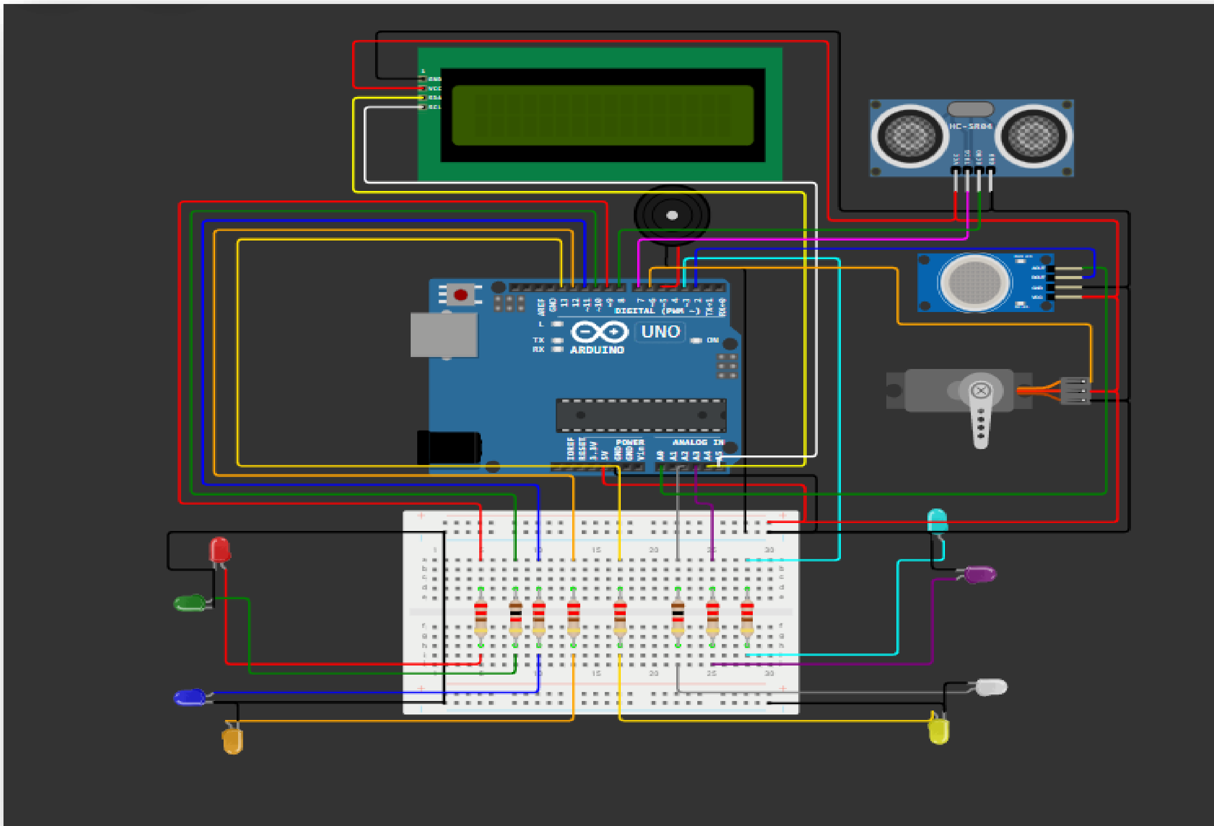

Figure 14 Smart Home Security and Automation System

2.3 Day and Night Automation System:

An LDR sensor, DHT11 temperature and humidity sensor, relay module, LEDs, buzzer, LCD display, and Arduino Uno microcontroller were integrated into the day and night automation system, which was designed to provide automatic operation without human intervention and to demonstrate the practical implementation of smart home automation using low-cost embedded systems. The subsystem's main goals were to reduce electricity waste, automate lighting control, improve energy efficiency, and provide real-time environmental monitoring within a smart home environment. This subsystem's main goals were to decrease electricity waste, automate lighting management, increase energy efficiency, and offer real-time environmental monitoring in a smart home setting. An LDR sensor, DHT11 temperature and humidity sensor, relay module, LEDs, buzzer, LCD display, and Arduino Uno microcontroller were all integrated into the subsystem. The approach relied on measuring the amount of light in the surroundings and automatically adjusting electrical equipment for day and night. The system was designed to provide automatic operation without human intervention and to demonstrate the practical implementation of smart home automation using low-cost embedded systems. The first stage of the methodology involved system planning and hardware component selection. Because it has enough digital and analog connections, is simple

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to program, and works with a variety of sensors and automation devices, the Arduino Uno was chosen as the core controller. The LDR sensor was chosen due of its capacity to employ resistance fluctuations to detect changes in ambient light intensity. The DHT11 sensor was selected to detect humidity and temperature because it offers affordable, dependable environmental monitoring. In order to automatically regulate external electrical equipment like lightbulbs, the relay module was added. LEDs were used to simulate smart lighting systems while the buzzer provided audio indication during night mode operation.[12]

A 16×2 LCD display with I2C communication protocol was used to provide real-time environmental information and system status updates. The Arduino Uno microcontroller has to be properly connected to all sensors and output devices as part of the hardware integration approach. The LDR sensor was connected to a digital input pin to monitor light conditions continuously. In order to gather real-time environmental temperature and humidity data, the DHT11 sensor was connected. To enable automatic switching of electrical loads, the relay module was connected to a digital output pin. Multiple LEDs were connected through current-limiting resistors to represent room lighting systems. In order to offer audible alerts during nighttime operation, the buzzer was connected. The LCD display was connected using I2C communication to simplify wiring connections and reduce pin usage.[20]

The Arduino IDE and Embedded C programming language were used to complete the software development methodology. Several Arduino libraries, such as Wire.h and LiquidCrystal_I2C.h, were integrated into the program for effective communication with the LCD display. The entire software logic was based on continuous monitoring of environmental conditions and automatic response generation according to sensor readings. The loop () function continuously monitored light intensity from the LDR sensor and environmental conditions from the DHT11 sensor. Conditional statements and logical decision-making structures were implemented to automate system operation according to day and night detection methodology. For effective communication with the LCD display, the software integrated several Arduino libraries, such as Wire.h and LiquidCrystal_I2C.h. Continuous environmental condition monitoring and automatic reaction creation based on sensor data served as the foundation for the entire program logic. The LDR sensor's light intensity and the DHT11 sensor's ambient parameters were continually monitored by the loop () method. To automate system operation in accordance with day and night conditions, conditional statements and logical decision-making frameworks were put into place.

One of the most crucial components of the subsystem was the day and night detection mechanism. The LDR sensor continuously measured the amount of light in the surrounding area. The LDR sensor operates on the basis of resistance variations in response to ambient brightness. High light levels during the day caused the LDR sensor's resistance to decrease and produced certain voltage levels at the Arduino input pin. Low light levels at night caused the sensor's resistance to rise and resulted in distinct voltage indications. To ascertain whether the surroundings were bright or dark, the Arduino continuously examined these signals. The Arduino immediately entered night mode when it noticed that it was nighttime. LEDs and other associated electrical appliances were turned on by the relay module.[17]

All of the system's LEDs turned on simultaneously to mimic automated room or street lighting. To notify users that the system had switched to night mode, the buzzer produced an audible indication tone. "Night Mode" messages and environmental data were continuously displayed on the LCD panel. This approach eliminated the need for manual switching and guaranteed that electrical appliances would operate automatically in the

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dark. The automated method decreased human labor and increased convenience. The Arduino automatically turned off night mode during the day. To cut down on wasteful electricity use, the relay module turned off linked electrical loads. The buzzer stopped producing sound alarms, and all of the LEDs automatically switched off. "Day Mode" messages were displayed on the LCD display to signify regular daylight operation. The DHT11 temperature and humidity sensor was used to implement the environmental monitoring methodology. The sensor continuously measured the surrounding environmental conditions and transmitted digital temperature and humidity values to the Arduino controller, which processed these values and displayed them on the LCD screen in real time. The first line of the LCD displayed temperature and humidity information, while the second line displayed the current operating mode, such as "Day Mode" or "Night Mode." This methodology significantly improved energy management because electrical appliances operated only when needed. The automatic control system decreased overall energy efficiency. Overall energy efficiency was increased and electrical waste was decreased thanks to the automatic control system. The DHT11 temperature and humidity sensor was used to implement the environmental monitoring methodology. The sensor sent digital temperature and humidity readings to the Arduino controller while continuously measuring the surrounding environment. These values were processed by the Arduino and shown in real time on the LCD panel. The LCD's second line showed the current operating mode, such as "Day Mode" or "Night Mode," while the first line showed temperature and humidity data.[21]

The DHT11 temperature and humidity sensor was used to implement the environmental monitoring methodology. The sensor continuously measured the surrounding environmental conditions and transmitted digital temperature and humidity values to the Arduino controller, which processed these values and displayed them on the LCD screen in real time. The first line of the LCD displayed temperature and humidity information, while the second line displayed the current operating mode, such as "Day Mode" or "Night Mode." This methodology significantly improved energy management because electrical appliances operated only when needed. The automatic control system decreased overall energy efficiency. Overall energy efficiency was increased and electrical waste was decreased thanks to the automatic control system. The DHT11 temperature and humidity sensor was used to implement the environmental monitoring methodology. The sensor sent digital temperature and humidity readings to the Arduino controller while continuously measuring the surrounding environment. These values were processed by the Arduino and shown in real time on the LCD panel. The LCD's second line showed the current operating mode, such as "Day Mode" or "Night Mode," while the first line showed temperature and humidity data. The buzzer methodology was used to provide sound notifications during night mode operation; when the system entered night mode, the buzzer generated audio indications to alert users about environmental changes; during daytime conditions, the buzzer remained OFF. This methodology demonstrated energy-efficient lighting automation using environmental sensing technology. The LCD display methodology concentrated on providing real-time system information and environmental monitoring. The LCD continuously displayed temperature values, humidity levels, and current operating modes; during nighttime conditions, the display displayed "Night Mode." This approach used environmental sensing technology to demonstrate energy-efficient lighting automation. In order to offer audible alerts during night mode operation, the buzzer mechanism was used. The buzzer produced audible cues to notify users of environmental changes when the device went into night mode. The buzzer stayed off during the day. This methodology offered more notification capabilities and enhanced user interaction. Real-

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time system information and environmental monitoring were the main goals of the LCD display methodology. Temperature, humidity, and current working modes were all continuously shown on the LCD. The display displayed "Night Mode" texts at night and "Day Mode" messages during the day. The LCD's environmental data enhanced system monitoring capabilities and user convenience.[22]

Before the entire subsystem was integrated, all sensors and output devices were tested individually. The LDR sensor was tested in various lighting conditions, such as bright sunlight, indoor lighting, and total darkness; the response of the relay module and LEDs was carefully observed to verify automatic operation accuracy; the DHT11 sensor readings were compared with environmental conditions to evaluate measurement performance; and the buzzer and LCD display operations were also verified individually. Following successful individual testing, the entire subsystem was integrated and evaluated under real operating conditions. The LCD display continuously displayed accurate environmental information and operating modes. Bright sunlight, interior illumination, and total darkness were among the lighting conditions in which the LDR sensor was tested. To confirm the correctness of autonomous operation, the relay module's and the LEDs' responses were closely monitored. Measurement performance was assessed by comparing the DHT11 sensor data with ambient conditions. Additionally, the LCD display and buzzer functions were independently confirmed. The entire subsystem was combined and assessed under actual working conditions following the completion of successful individual testing. The relay module, LEDs, and buzzer were all successfully turned on by the system during the nighttime simulation. In order to save energy during the daytime simulation, all outputs were appropriately silenced. Accurate operating modes and environmental data were consistently displayed on the LCD panel.[23]

The methodology of this day and night automation subsystem proved that inexpensive Arduino-based embedded systems can successfully implement intelligent energy management and smart lighting control solutions. The subsystem reduced electricity waste, improved automation efficiency, and provided environmental monitoring capabilities appropriate for modern smart homes and smart city applications. It also demonstrated the practical significance of integrating sensors, microcontrollers, and automation devices into a unified control system. This day and night automation subsystem's technique demonstrated how inexpensive Arduino-based embedded systems can successfully deploy intelligent energy management and smart lighting control solutions. The subsystem offered environmental monitoring capabilities appropriate for contemporary smart homes and smart city applications, decreased electricity waste, and increased automation efficiency. Additionally, the subsystem illustrated the usefulness of combining automation devices, microcontrollers, and sensors into a single control system.[24]

Because they increase energy efficiency and lower operating costs, automatic day and night control systems are widely used in smart street lighting, home automation, industrial monitoring, and commercial building management. In future developments, the subsystem can be further improved by integrating IoT technology and wireless communication systems like Wi-Fi, GSM, or Bluetooth modules; mobile applications can be developed for remote appliance monitoring and control; solar-powered systems can be integrated to improve sustainability and reduce dependency on electrical grids; artificial intelligence algorithms can be implemented to predict environmental conditions and optimize automation performance. By incorporating IoT technologies and wireless communication systems like Wi-Fi, GSM, or Bluetooth modules, the subsystem can be further improved in subsequent iterations. Appliances can be remotely monitored and controlled through mobile applications. To

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increase sustainability and lessen reliance on electricity grids, solar-powered systems can also be incorporated. Automation performance may be maximized and environmental circumstances can be predicted using artificial intelligence algorithms. These enhancements have the potential to turn the subsystem into a comprehensive smart automation solution at the industrial level.[19]

Diagram:

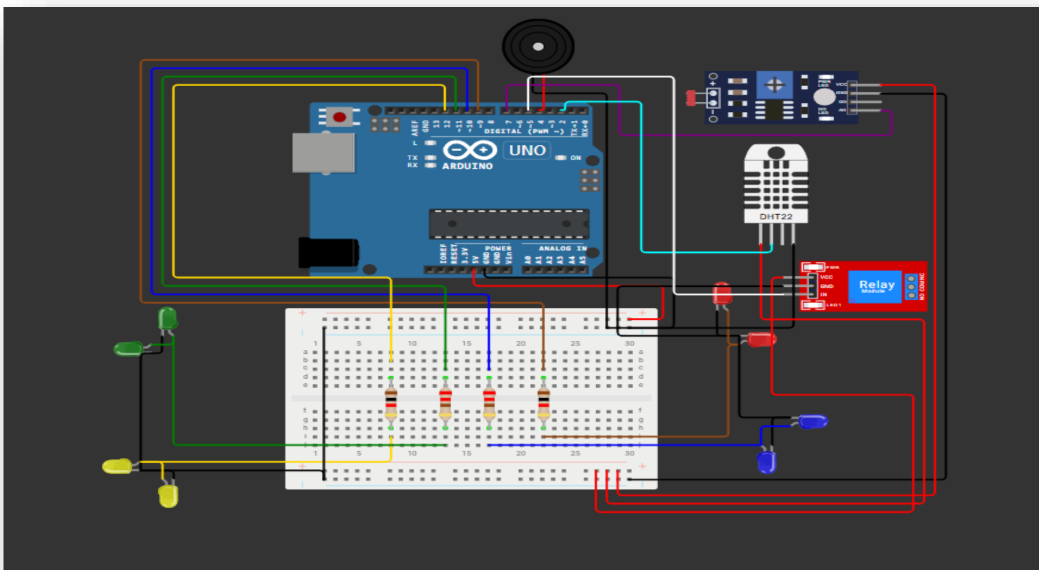

Figure 15 Day and Night Automation System

2.4 Water Level and Temperature Monitoring System:

An ultrasonic sensor, DS18B20 temperature sensor, servo motor, DC motor, LEDs, buzzer, LCD display, and Arduino Uno microcontroller were used in the design of the water level and temperature monitoring system. This subsystem's primary goals were to continuously monitor water levels, detect overflow or low water conditions, measure water temperature, and automatically control electrical and mechanical devices according to environmental conditions. The methodology focused on real-time monitoring, automatic decision-making, and intelligent control of water-related systems to improve safety, efficiency, and dependability in both home and commercial applications. This subsystem's primary goals were to assess water temperature, identify overflow or low water circumstances, continually monitor water levels, and automatically adjust mechanical and electrical components based on environmental conditions. An ultrasonic sensor, DS18B20 temperature sensor, servo motor, DC motor, LEDs, buzzer, LCD display, and Arduino Uno microcontroller were used in the system's construction. In order to increase safety, effectiveness, and dependability in both home and commercial applications, the methodology concentrated on real-time monitoring, automated decision-making, and intelligent control of water-related devices. System planning and hardware component selection were the first steps in the methodology. The Arduino Uno was chosen as the central processing unit because of its

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simplicity, dependability, and compatibility with various sensors and actuators; the ultrasonic sensor was chosen for water level measurement because it provides accurate non-contact distance sensing using sound wave reflection; the DS18B20 temperature sensor was chosen because of its high accuracy in measuring liquid temperature and digital output capability, which reduces signal noise; LEDs were used to visually represent various water level conditions; a buzzer was included to generate warning alerts during critical situations; the servo motor was used to control shade or protective mechanisms; and the DC motor was integrated for water exhaust or cooling operations. Because of its ease of use, dependability, and capacity to work with a variety of sensors and actuators, the Arduino Uno was chosen as the central processing unit. The ultrasonic sensor was used to monitor the water level because it uses sound wave reflection to give precise non-contact distance sensing. The DS18B20 temperature sensor was chosen because of its digital output capability, which lowers signal noise, and its high accuracy in monitoring liquid temperature. A buzzer was added to provide warning warnings in emergency scenarios, and LEDs were used to visually depict various water level conditions. The DC motor was included for cooling or water exhaust, while the servo motor controlled shade or protective devices.[25]

The hardware integration methodology involved properly interfacing all sensors and output devices with the Arduino Uno microcontroller; an ultrasonic sensor was installed at the top of the water tank to measure the distance between the sensor and the water surface; the trigger pin of the ultrasonic sensor transmitted ultrasonic pulses, while the echo pin received reflected signals; the Arduino determined the water level by measuring the time it took for sound waves to return after reflection. A 16x2 LCD display was used for real-time monitoring of system parameters and status messages. All sensors and output devices have to be properly interfaced with the Arduino Uno microcontroller as part of the hardware integration process. To measure the distance between the ultrasonic sensor and the water's surface, it was mounted at the top of the water tank. The ultrasonic sensor's trigger pin sent out ultrasonic pulses, while the echo pin picked up signals that were reflected. By timing how long it took for sound waves to return after reflection, the Arduino determined the water level. The Arduino IDE and Embedded C programming language were used to implement the software development methodology. The DS18B20 temperature sensor was placed directly in contact with water to continuously monitor temperature variations; LEDs were connected to digital output pins through resistors to indicate different water level conditions, such as low, medium, and danger levels; the buzzer was connected for audio alerts; the servo motor and DC motor were connected through appropriate control pins for automatic operation; and the LCD display was connected through I2C communication to simplify wiring and increase efficiency. To show various water level conditions, including low, medium, and danger levels, LEDs were coupled to digital output pins via resistors. While the DC motor and servo motor were connected via the proper control pins for autonomous operation, the buzzer was connected for audio notifications. I2C connection was used to link the LCD display in order to streamline wiring and boost productivity. The Arduino IDE and the Embedded C programming language were used to implement the software development technique. The software was created to continually monitor sensor inputs and carry out control operations in response to predetermined situations.[26]

In order to continually read temperature sensor data and ultrasonic sensor readings in real time, the loop function was essential. To categorize water levels into distinct groups and elicit the proper reactions, conditional phrases were employed. In order to guarantee the seamless operation of actuators including motors and servo mechanisms, the system also incorporated timer-based and state-based control logic. Ultrasonic

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distance measuring served as the foundation for the water level detecting technique. High-frequency sound waves were sent to the water's surface by the ultrasonic sensor. After striking the water's surface, these waves rebounded back to the sensor. In order to determine the water level inside the tank, the Arduino measured the time difference between the signal's transmission and reception and used the speed of sound formula to calculate the distance. A large distance indicated a low water level, a moderate distance indicated a normal water level, and a very small distance indicated a high or danger level condition. When the system detected a low water level condition, the Arduino activated the green LED to indicate safe or low-level warning conditions, the buzzer generated slow warning beeps to alert users about low water availability, and the LCD displayed "LOW WATER" status messages to inform users. The system calculated the water level in the tank based on this distance. A low water level was indicated by a significant distance. A normal water level was indicated when the distance was moderate. A high or dangerous level condition was indicated when the distance was very small. The Arduino turned on the green LED to signal safe or low-level warning circumstances when the system identified a low water level. Users were informed about low water availability by the buzzer's slow warning beeps. Users were informed via "LOW WATER" status alerts displayed on the LCD display.[27]

This methodology helped prevent water waste and structural damage caused by overflow situations. When the system detected a medium water level condition, the yellow LED was activated while other LEDs remained OFF. The buzzer remained silent, indicating normal operating conditions. The LCD displayed “MEDIUM LEVEL” messages to show that water was within an acceptable range, representing stable system operation without any risk. When the system detected a high or danger water level condition, the red LED was activated to indicate overflow risk. The buzzer generated fast warning alerts to notify users right away. The yellow LED turned on while the other LEDs stayed out when the system identified a medium water level. Normal operational conditions were indicated by the buzzer's silence. The water was within an acceptable range, as indicated by the LCD's "MEDIUM LEVEL" signals. In this state, the system operated steadily and risk-free. The red LED was turned on to show overflow risk when the system identified a high or dangerous water level condition. To alert consumers right away, the buzzer produced quick warning notifications. "DANGER LEVEL" alerts were shown on the LCD to warn of possible overflow or floods. This approach assisted in preventing overflow-related structural damage and water waste. The DS18B20 sensor, which continuously measured water temperature in real time, provided digital temperature values to the Arduino, which processed and displayed them on the LCD screen. The system classified temperature into various levels, such as normal, warm, and hot conditions; when the temperature remained within safe limits, the system operated normally without activating any output devices. When the temperature exceeded a predetermined threshold, the system activated automatic cooling and safety mechanisms. The servo motor adjusted the protective shade mechanism to control environmental exposure. The Arduino received digital temperature readings from the sensor, analyzed them, and presented the results on the LCD panel. The temperature was divided into three categories by the system: normal, warm, and hot. The system functioned normally without turning on any output devices as long as the temperature was within safe bounds. The technology triggered automated cooling and safety features when the temperature rose above a certain level. To start the cooling or water exhaust procedures, the DC motor was turned on. This assisted in lowering the system's too high water temperature. In order to regulate exposure to the environment, the servo motor simultaneously modified the protective shade mechanism.[28]

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When moderate temperature conditions were detected, the system maintained partial activation of control mechanisms; the green LED remained ON to indicate safe conditions, while motors remained OFF; the servo motor adjusted to a partial angle position to maintain system balance; the LCD displayed "WARM" messages indicating moderate temperature conditions; when normal temperature conditions were detected, all control devices remained in inactive mode, and the system displayed "OK" status on the LCD. This methodology ensured thermal safety and prevented overheating issues. This process avoided overheating problems and guaranteed thermal safety. The system continued to partially activate control mechanisms when mild temperature conditions were recognized. While the motors stayed off, the green LED stayed on to signify safe circumstances. To keep the system balanced, the servo motor was modified to a partial angle position. The "WARM" signals on the LCD indicated that the temperature was moderate. All control devices stayed in idle mode and the system showed "OK" status on the LCD when a normal temperature was measured. The LCD display methodology offered real-time monitoring of both water level and temperature conditions; the first line of the display showed distance values and temperature readings, while the second line displayed system status messages like LOW WATER, MEDIUM LEVEL, DANGER LEVEL, WARM, or HOT. The buzzer control methodology was implemented using different modes to represent various system conditions: slow intermittent beeping for low water levels, fast beeping for danger conditions, and continuous tone for high-temperature alerts. This multi-level alert system conditions. Low water levels were indicated by slow intermittent beeping, danger situations by quick beeping, and excessive temperature alerts by continuous tone. This multi-level alert system guaranteed prompt reaction to urgent situations and enhanced user awareness. Real-time temperature and water level monitoring was made possible by the LCD display technology. Distance and temperature measurements were shown on the first line of the display, and system status messages like LOW WATER, MEDIUM LEVEL, DANGER LEVEL, WARM, or HOT were shown on the second line.[29]

Before the system was integrated, all sensors and actuators were tested individually. The ultrasonic sensor was tested by measuring various water levels and comparing calculated distances with actual values; the DS18B20 temperature sensor was tested using hot and normal water conditions to verify accuracy; LEDs were tested for correct indication behavior under various conditions; the buzzer was tested for correct sound patterns in various alert scenarios; servo motor and DC motor operations were also tested individually to ensure proper mechanical response; and finally, the entire system was integrated and tested under actual operating conditions. Prior to system integration, each sensor and actuator was tested separately as part of the testing and validation process. In order to test the ultrasonic sensor, various water levels were measured and estimated and actual distances were compared. To confirm accuracy, the DS18B20 temperature sensor was tested under both hot and regular water circumstances. Under various circumstances, LEDs were evaluated for proper indication behavior. The buzzer's proper sound patterns in various alarm conditions were examined. To guarantee appropriate mechanical reaction, the operations of DC and servo motors were also evaluated separately. The entire system was combined and tested under actual operational settings following individual testing. The methodology of this water level and temperature monitoring system demonstrated that Arduino-based embedded systems can effectively manage water resources and ensure thermal safety in both domestic and industrial environments. The system reduced water waste, prevented overflow conditions, improved temperature control, and provided automated monitoring without human intervention. The temperature control system also operated correctly by activating motors and adjusting servo positions according to temperature

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changes. The system demonstrated stable performance, real-time responsiveness, and accurate environmental monitoring. The system showed precise environmental monitoring, real-time responsiveness, and steady functioning. This water level and temperature monitoring system's technique demonstrated how Arduino-based embedded systems can efficiently manage water resources and guarantee thermal safety in both residential and commercial settings. The system enhanced temperature control, decreased water waste, avoided overflow situations, and offered automated monitoring without human interaction.[30]

Future improvements to the system could include wireless sensor networks, mobile application control, and IoT-based cloud monitoring. To further sustainability, solar-powered energy solutions can also be incorporated. Algorithms based on artificial intelligence can be used for intelligent decision-making and predictive water management. These enhancements have the potential to turn the system into a fully automated smart water management system fit for extensive use.[31]

Diagram:

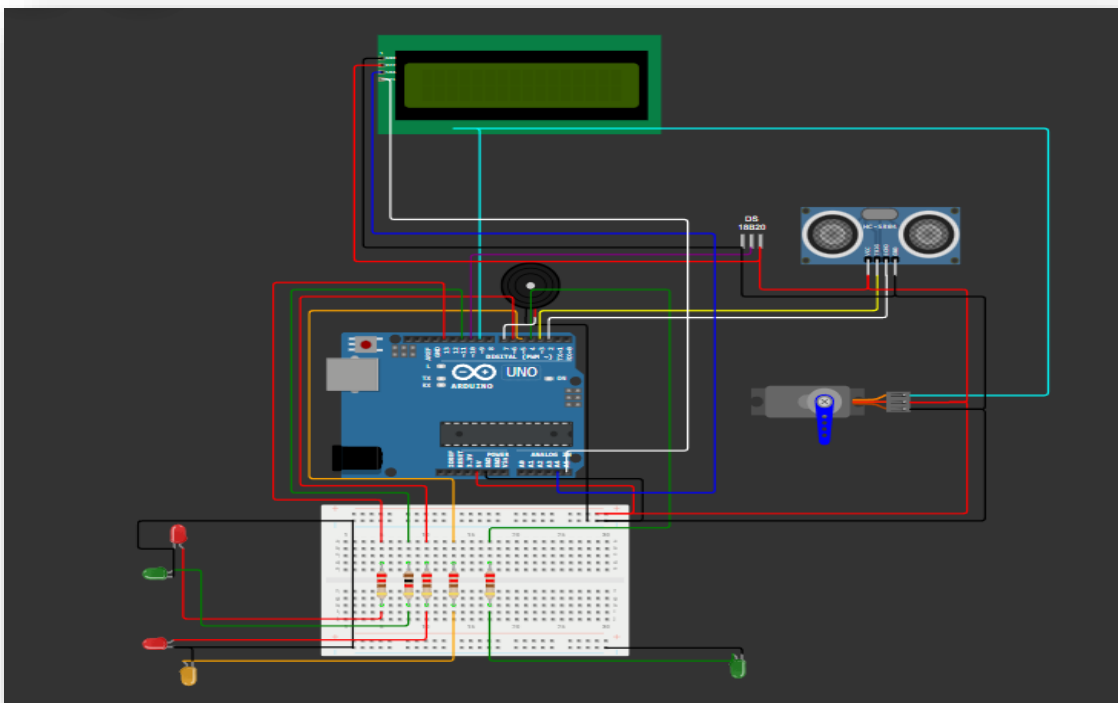

Figure 16 Water Level and Temperature Monitoring System

3 Results and Discussion:

Each subsystem was tested separately and then integrated to assess performance, accuracy, reliability, and responsiveness. The system achieved stable operation with minimal errors, confirming the efficacy of sensor-based automation for real-world applications. The discussion of results is divided according to each project to clearly evaluate system performance and practical outcomes. The implementation of the

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four subsystems demonstrated successful development of an integrated smart city and smart home automation system using Arduino-based embedded technology. The overall results show that all designed modules performed their intended functions effectively under real-time operating conditions. All planned modules successfully carried out their intended tasks under real-time operational conditions, according to the overall results. Performance, accuracy, dependability, and responsiveness were assessed by testing each subsystem separately before integrating them. The system operated steadily and with few faults, demonstrating the practicality of sensor-based automation. To properly assess system performance and useful outcomes, the results discussion is broken down by project. Using ultrasonic sensors positioned at various points, the smart street light and automatic gate control system in the first subsystem demonstrated accurate vehicle detection, successfully identifying the presence of vehicles at entry, middle, and exit points; when a vehicle approached the entry point, the gate opened automatically using a servo motor without any delay, confirming the system's fast response time; the buzzer also provided immediate notification, validating correct sensor-trigger interaction; the sequential activation of streetlights demonstrated smooth lighting transition, suitable for smart road systems; each LED turned ON in a controlled sequence, demonstrating proper execution of programmed logic. Vehicles were correctly detected by the system at the entry, middle, and exit locations. The system's quick response time was confirmed when a car reached the entry point and the gate opened instantly utilizing a servo motor. Additionally, the buzzer confirmed proper sensor-trigger engagement by instantly notifying the user. The streetlights' successive activation showed a seamless illumination transition that is appropriate for smart road systems. Each LED turned on in a predetermined order, demonstrating that the logic in the program was correctly executed. This behavior shown that by turning on lights only when necessary, the system may drastically cut down on energy use.

The system successfully controlled both forward and backward vehicle movement during testing; the lights turned on sequentially when the vehicle moved forward, and the system successfully reversed the lighting pattern when the vehicle moved backward. The gate also reacted appropriately during the entry and exit phases, guaranteeing a smooth traffic flow simulation. The results verify that ultrasonic sensor-based detection in conjunction with Arduino processing can be used for smart transportation systems; however, there were minor delays during sequential LED transitions because of programmed delay functions, which can be improved in the future using non-blocking code techniques. The lights turned on sequentially as the car went forward, and the system correctly reversed the lighting pattern when the car went backward. In order to ensure a smooth traffic flow simulation, the gate also reacted appropriately during the entry and leave phases. The findings demonstrate that smart transportation systems can benefit from the combination of Arduino processing and ultrasonic sensor-based detection. However, programmed delay functions caused minor delays during consecutive LED changes; these can be improved in the future by employing non-blocking coding techniques. The smart home automation and security system in the second subsystem showed effective safety control and environmental monitoring. Emergency responses were triggered by the gas detection system's successful identification of gas leaking situations. The buzzer produced alarm signals, the LCD showed warning messages, and the red LED switched on when the gas levels over the threshold. This demonstrated that the system offers real-time safety notifications, which are crucial in residential settings. Users were able to continuously monitor gas concentration levels because to the LCD's gas percentage display, which enhanced awareness and safety management.

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During testing, the rain detecting device also demonstrated accurate performance. The servo motor instantly turned on and shut the protective cover when water droplets were put on the sensor. The system reverted to its initial state after the sensor dried. This demonstrated that the system is capable of adapting to changes in the environment without the need for human involvement. The ultrasonic sensor-based motion detection system was also effective. The LEDs automatically turned on when a human reached the detection range and shut off when no movement was detected. This demonstrated reduced electricity waste and energy-efficient operation in indoor settings. By displaying gas levels, safety alerts, and system status, the LCD display was crucial to system monitoring. The findings demonstrated that integrating several sensors into a single system enhances the overall performance of home automation. However, it was discovered during testing that sensor sensitivity may change based on ambient factors like temperature and humidity, which may have a minor impact on accuracy. The system functioned dependably under typical operating circumstances in spite of this drawback. In the third subsystem, the day and night automation system successfully demonstrated intelligent lighting control based on environmental brightness. The LDR sensor accurately detected changes in light intensity between day and night conditions; at night, the system automatically activated the relay module, turning ON lights and LEDs; the LCD displayed "Night Mode," confirming correct system behavior; during daytime, the system automatically switched OFF all lighting devices, reducing unnecessary electricity consumption; this demonstrated the efficacy of automatic energy-saving mechanisms. Changes in light intensity between day and night circumstances were precisely recognized by the LDR sensor. The technology turned on the lights and LEDs by automatically activating the relay module at night. The LCD showed "Night Mode," verifying proper system operation, and the buzzer also gave an auditory alert. The technology reduced needless electricity consumption by automatically turning off all lighting gadgets during the day. This demonstrated the efficacy of automated energy-saving systems. The system demonstrated strong energy efficiency performance because electrical loads were only active during necessary conditions. The relay switching response was fast and reliable, indicating proper hardware integration. However, minor fluctuations in LDR readings were observed in partially lit environments, which occasionally caused slight delays in mode switching. This issue can be improved using calibrated threshold values or digital filtering techniques. Overall, the system demonstrated high efficiency in energy management and smart lighting automation. The DHT11 sensor also provided stable temperature and humidity readings, which were displayed on the LCD in real-time. This made automation control and ongoing environmental monitoring possible. Because electrical loads were only active when necessary, the system demonstrated great energy efficiency performance. The quick and dependable relay switching reaction suggests that the hardware integration was done correctly. However, in partially illuminated situations, small variations in LDR readings were noted, which occasionally resulted in tiny mode switching delays. Digital filtering methods or calibrated threshold values can be used to improve this problem. In terms of energy management and smart lighting automation, the system overall showed excellent efficiency.

The water level and temperature monitoring system in the fourth subsystem demonstrated extremely accurate performance in real-time water management applications. The ultrasonic sensor effectively measured water levels and classified them into low, medium, and danger levels; the system remained stable without alarms during medium levels; the red LED and fast buzzer alerts activated immediately during danger conditions, confirming effective overflow prevention; and the green LED and buzzer produced slow warning signals during low water conditions. Water levels were successfully monitored by the ultrasonic sensor, which then classified them into hazardous, medium, and low levels. The buzzer generated gradual warning sounds and the green LED turned on when the water level was low. At medium levels, there were no alerts and the system stayed steady. The red LED and quick buzzer alerts turned on instantly in dangerous situations, demonstrating successful overflow prevention. The LCD display continuously displayed real-time water level and temperature data, improving system monitoring efficiency. The DS18B20 temperature sensor provided accurate temperature readings, which were used to control system behavior. When temperature exceeded safe limits, the DC motor activated automatically to initiate water cooling or exhaust processes. The servo motor also adjusted the protective shade mechanism, demonstrating coordinated multi-actuator control. The results confirmed that the system is capable of preventing water overflow and managing thermal safety effectively. The ultrasonic sensor's response time was quick and dependable; however, a slight delay in motor response was noted due to mechanical movement time, which is expected in physical actuator systems. The DC motor automatically started the exhaust or water cooling operations when the temperature rose above safe limits. Additionally, the servo motor demonstrated coordinated multi-actuator control by adjusting the protective shade mechanism. The system monitoring efficiency was increased by the LCD panel's continuous presentation of temperature and water level data. The outcomes demonstrated that the system can successfully manage thermal safety and stop water overflow. Real-time detection was ensured by the ultrasonic sensor's quick and dependable response time. However, as is typical in physical actuator systems, a slight delay in motor response was noted as a result of mechanical movement time.

Overall, the combined outcomes of all four subsystems show that Arduino-based smart automation systems are very successful for smart city and smart home applications. The system effectively combines a variety of sensors, actuators, and control logic to carry out real-time monitoring and automation tasks. Accurate environmental data collection was ensured by the use of ultrasonic, gas, LDR, and temperature sensors, and dependable physical responses were provided by actuators like servo motors, relays, and DC motors. To carry out automation and real-time monitoring, the system effectively combines a number of sensors, actuators, and control logic. While actuators like servo motors, relays, and DC motors provide dependable physical reactions, the utilization of ultrasonic sensors, gas sensors, LDR sensors, and temperature sensors guaranteed accurate environmental data collecting. The conversation makes it abundantly evident that the technology increases safety, minimizes human labor, and improves energy efficiency. Additionally, it highlights the significance of modular design, in which every subsystem functions separately but contributes to a cohesive smart system. Variations in sensor sensitivity, actuator mechanical delays, and dependency on connected connections are the primary constraints noted. Future updates can overcome these constraints by incorporating IoT platforms, wireless communication, and AI-based decision-making systems.

4 Conclusion:

The project integrates four distinct subsystems, each intended to carry out a specific function related to automation, safety, environmental monitoring, and energy management. These subsystems include smart street light and automatic gate control, smart home security and automation, day and night lighting control, and water level and temperature monitoring. Together, they form a unified intelligent system capable of operating in real-time without continuous human intervention. The development of this multifunctional smart automation system based on Arduino technology successfully demonstrates the practical implementation of smart city and smart home

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concepts using inexpensive embedded systems. The project incorporates four distinct subsystems, each of which is intended to carry out a certain task pertaining to energy management, automation, safety, and environmental monitoring. These subsystems include water level and temperature monitoring, smart home security and automation, smart street light and automatic gate management, and day and night lighting control. When combined, they create a cohesive intelligent system that can function in real time without constant human interaction. By effectively automating a number of functions, including vehicle identification, street lighting management, gas leak detection, rain protection, motion-based lighting, day and night switching, and water level monitoring, the system as a whole was able to accomplish its main goals. The seamless integration of all sensors and actuators while preserving system stability and dependability was made possible by the use of an Arduino Uno as the core controller. The study showed how embedded systems can use straightforward programming logic to efficiently evaluate real-time environmental input and produce suitable automated responses.

The substantial increase in energy efficiency is one of the project's main accomplishments. Relay-based automation in the day and night system further contributes to effective power management by turning devices ON and OFF in response to environmental conditions, and automatic lighting systems in both street and home environments ensure that electrical devices operate only when necessary, reducing unnecessary power consumption and supporting energy-saving solutions, which are essential in modern smart city development. In both household and street settings, automated lighting systems make sure that electrical gadgets only run when necessary. This lowers wasteful power use and promotes energy-saving measures, which are crucial for the development of contemporary smart cities. Similarly, by turning devices on and off in response to environmental factors, the relay-based automation in the day and night system further enhances effective power management. Enhanced safety and security is another significant result of this project. The temperature control system prevents overheating conditions, the water level monitoring system protects against overflow and water waste, the smart street system enhances road safety by automating lighting and gate control based on vehicle movement, and the gas leakage detection system provides early warning signals that help prevent hazardous situations in domestic environments. The early warning signals provided by the gas leak detecting system aid in averting dangerous circumstances in residential settings. While the temperature control system guards against overheating, the water level monitoring system guarantees protection against overflow and water waste. By automating lighting and gate management based on vehicle movement, the smart street system increases road safety. Together, these characteristics make the environment safer and smarter.

From a technical standpoint, the project successfully illustrates the efficacy of modular design in embedded systems; each subsystem was developed and tested separately before integration, which improved system reliability and reduced complexity; the use of state-based programming and conditional logic ensured proper coordination between different system components; and sensors like ultrasonic, gas, LDR, and temperature sensors played a crucial role in collecting accurate environmental data. The LCD display further improved user interaction by providing continuous feedback about system status and environmental conditions. Accurate environmental data collection was made possible by sensors like temperature, gas, ultrasonic, and LDR sensors. The system was able to respond intelligently to changing conditions thanks to the integration of these sensors with actuators such as servo motors, relays, LEDs, and buzzers. By offering constant feedback regarding system status and ambient variables, the LCD display enhanced user interaction even more. Technically speaking, the project effectively illustrates how modular architecture works in embedded systems. Before integration, each subsystem was created and tested separately, which decreased complexity and increased system reliability. Proper coordination between various system components was guaranteed by the use of conditional logic and state-based programming

The system has some drawbacks despite its success. Extreme climatic conditions can affect sensor accuracy, and mechanical parts like DC motors and servo motors cause small reaction delays. Furthermore, the system's current wired connections may restrict its scalability. These restrictions offer chances for upcoming advancements. Internet of Things (IoT) technology can be integrated into the system in the future to provide remote monitoring and control via mobile applications. To increase connectivity, wireless communication devices like Bluetooth, GSM, and Wi-Fi can be added. Predictive automation and more intelligent decision-making can also be made possible by using artificial intelligence approaches. Integration of solar energy can further improve sustainability and energy efficiency, increasing the system's suitability for extensive smart city applications.

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