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DEVELOPMENT OF AN AUTONOMOUS GUARD DOG ROBOT WITH FACE RECOGNITION AND THREAT HANDLING

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Abstract:

The robotic watchdog integrates ESP32-CAM and ESP8266 with Edge Impulse AI to enable smart surveillance and security. It is remotely controlled via a mobile interface and employs facial recognition to differentiate between friendly and unknown individuals. Upon detecting an unauthorized face, it triggers response actions, including an attack mechanism for security enforcement. The system leverages AI-driven processing for real-time decision-making, ensuring efficient and autonomous monitoring. This cost-effective and adaptable solution enhances security for homes and businesses by providing intelligent threat detection and response capabilities.

Keywords — Robotic watchdog, ESP32-CAM, ESP8266, Edge Impulse AI, facial recognition, mobile control, smart surveillance, autonomous security, threat detection, response actions.

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I. INTRODUCTION

According to the Robot Institute of America, a robot is a reprogrammable manipulator that can do several jobs by moving materials, parts, tools, or specialised equipment through pre-programmed motions [1]. A robot is an autonomous device that can perceive its environment and process Information is used to make decisions and take action in the real world. An automated gadget can do specific tasks with minimal human intervention [2]. Robots are typically classified into two categories: locomotion and application. The application-specific robots include industrial and service robots. Industrial robots are employed for manufacturing and material logistics [3]. The International Organisation for Standards defines service robots as robots designed for personal or professional use that perform helpful functions in a variety of situations [4]. Robots can be classed based on their locomotion, which determines how they move in various settings. The robots could be stationary or mobile. Stationary robots are robots that perform activities at a fixed location and are not mobile in any sense [5]. Mobile robots are those that can move about their environment. Robots rely on software programming, sensors, and AI to navigate their surroundings [6]. Robots are classed by their locomotion, or how they move in various settings. They can be either stationary or mobile robots. Stationary robots do their work in a specific location and are not movable in any way [7]. Mobile robots can move around their environment. Robots rely on software programming, sensors, and AI to navigate their surroundings [8]. Home invasion has increased as a serious social vice across the globe. Burglary is primarily caused by poor security, poverty, drug addiction, peerpressure, and other factors [9]. Statistics for burglary show that 65% of people are aware of the burglars, and a neighbour or friend is more likely to try to steal from them. Only 13% of burglaries are solved by police due to the challenges in the identification of the perpetrator and the quick nature of the crime. In order to fight home invasions, we proposed the development of a home security robot that will alert homeowners about possible break-ins or burglars on their property. This discourages house invasions and makes it simple to identify and arrest the offender. A four-legged robot can identify intruders, record their images, and send SMS to the owner. When the robot identifies an intruder, it will produce canine sounds to notify the neighbourhood. The multifunctional home security robot has the simple modules of detecting intruders and recording images. It's also driven by rechargeable batteries. Legged robots are robots that are mobile and use mechanical legs to walk. They are the same as other robots, although their mobility system is more complicated than that of wheeled robots [10]. Quadruped robots have existed for quite some time now. Mobile robots were popular during the past 30 years because they can traverse difficult terrain, conduct rescue operations, and work on their own [11. In 1870, Chebyshev built the first legged robot system using dual-axis leg mobility and a straightforward 4-link structure. Rygg's mechanical horse in 1893 paved the way for innovations in legged robotic systems. This version comprised a pedal and was a mechanically complete machine. Ralph Mosher and General Electric developed the Walking Tuck in 1965. The electromechanical version was a big model and tracked mechanical motions and electrical inputs [12]. Motivation from nature helped the process of designing quadruped robots. Examples are the MIT Cheetah [13], Boston Dynamics Spot Mini, and Tekken [14], which develop excellent stability and smooth stride. A quadrupedal robot was designed inexpensively using 3D-printed parts or a combination of 3D-printed parts and carbon fibre. Low-cost servo motors replace hydraulics to power the legs and make use of PID-controlled brushless DC motors. The Stanford Pupper is a quadruped robot designed from carbon fibre and 3D-printed parts. It incorporates 12 high-voltage servo motors and aRaspberry Pi for managing gait logic. It was designed by the students of Stanford University. The spot tiny robot is a low-cost quadruped based on an Arduino, node MCU, teensy board, and Raspberry Pi. It has most of the components as 3D-printed parts. A low-cost and adjustable mobile home security system was developed by Efe and Ogun ere [15] by connecting sensors to an Arduino ATmega2560 microcontroller to receive signals. The PIR sensor detects invasions and informs the administrator application via an SMS alert. The system was comprised of a smartphone application communicating with the home security system, allowing homeowners to remotely lock their homes. The system used a passive infrared (PIR) sensor to detect intruders, which can be triggered by any object emitting infrared radiation. The device, however, could not record the facial profiles of the intruders. Dahlia et al. [16] designed a robot that could navigate in difficult terrain for surveillance and monitoring purposes. The technique used is comprised of a robotic arm powered by an ESP32 development kit, an Arduino Mega robot central processing unit, an ultrasonic sensor to sense obstacles, and a night vision camera with a radio receiver. Aluminium was used to build the robot's body. The study concluded that a walking robot with four legs is a valuable surveillance tool with widespread applications. In addition, an Internet of Things (IoT)-based home automation door security device was designed in [17]. The door locking mechanism included facial detection and recognition features, as well as an email notification system using a web camera to take a photograph and send it to the Raspberry Pi upon detection by a PIR sensor of movement. The system still verifies the taken photograph with the photographs in a database. In the event of a match found in the database, the door will automatically open; otherwise, an SMS notification will be sent to the user using a Global System for Mobile Communications (GSM) module such that the door is still locked. Al-Obaidi et al. [18] designed a wireless-controlled low-cost, low-power consumption mobile robot for surveillance applications. Arduino and Raspberry Pi (low-cost open-source hardware) were utilized for motion control and the central processing unit, respectively.

Sensors are used by the mobile robot to detect physical events in its surrounding environment and wirelessly transmit data to a control station. The robot can operate for 6.5 hours continuously at 25 rpm without recharging its battery.

Kim et al. [19] developed and designed an open-source quadruped robot using a single-board computer (SBC) with a graphical processing unit (GPU), and also a commercially purchased onboard depth sensor and off-the-shelf quasi-direct drive actuators. Perception operations and motion control were largely managed by two single-board computers (SBCs) that are different from one another. Specifically, motion is managed by a Lattepanda Alpha SBC and vision operations by an NVidia Xavier Jetson NX SBC. Actuators utilized in the design include the RMD-X8 and RMD-X8 Pro models. Three-cell LiPo batteries drove the single-board computers and actuators, respectively. Polylactic acid (PLA) filament was utilized to print the frame. The 12.7 kg quadruped robot was constructed with a 1.0 m/s front walk speed and 81.6 W average power consumption, with support for steady dynamic trot-walking. Shi et al. [20] also designed, simulated, and constructed a quadruped robot dog as a vehicle.

I.MATERIALS AND METHODS

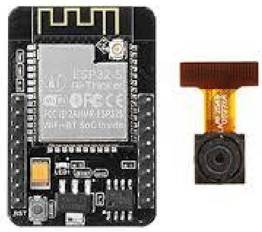
1. MG995 Servo Motor

Role: MG995 servos are used for movement in robotic systems. They are high-torque motors, which makes them suitable forcontrolling legs, head, or other movable parts of the robotic dog.

How it works: The MG995 servos will be responsible for moving the limbs of your robotic dog. They can rotate at precise angles based on the signals received from the ESP32 microcontroller.

Number Required: Depending on the complexity of the robot's design, you could use four or more MG995 servos for controlling the movement of the dog’s limbs, tail, head, etc.

1. ESP32-CAM (Camera Module)



Role: The ESP32-CAM module serves as the "brain" for controlling the surveillance camera functionality of the robot. The camera is useful for capturing video or images for surveillance purposes.

How it works: The ESP32-CAM is equipped with a camera and can stream live video over Wi-Fi. This camera can be

controlled using the ESP32's GPIO pins or via the ESP32's microcontroller.

Use case: You can program the ESP32-CAM to stream live video feed to a computer, smartphone, or cloud server for surveillance. Additionally, it can be used with AI tools like Edge Impulse for image recognition or other intelligent tasks.

1. ESP8266 (WiFiModule)

Role: The ESP8266 Wi-Fi module connects the robotic dog to the internet or local network. This will allow you to control the robot remotely or access the video feed.

How it works: The ESP8266 module will handle communication between the robot and your control device (such as a smartphone or computer). It provides the internet connectivity for remote control or surveillance purposes.

Use case: This can be used to connect the robot to an external system or server where the data (like video feed or sensor data) is transmitted and processed. Alternatively, it can be used to send commands from your smartphone to control the robot.

2. Lithium

Battery

Role: Powers the robotic dog's components, including servos, sensors, camera, and WiFi modules.

Features: High energy density, rechargeability, lightweight, and reliable.

How it works: Lithium-ion batteries are ideal because they provide high power output while maintaining a relatively low weight, which is critical for mobile robots.

Battery Selection:

Voltage: Typically, a **7.4V (2S)** or **11.1V (3S)** Li-ion battery is a good choice for robotics.

Capacity: Choose based on the expected runtime. For example, a 2200mAh or 4000mAh battery could give several hours of operation, depending on the power consumption of your robot.

5. Buzzer (for Alerts)

Role: The buzzer is used to produce sound alerts. It can be employed for notifying the presence of the robot or as an alarm system for surveillance.

How it works: The buzzer is typically activated by a digital signal from the ESP32 to produce different tones or patterns of sound when a specific event occurs (e.g., motion detection, intrusion alert, etc.).

Use case: The buzzer could go off when a certain condition is met, such as when the robot detects motion or when it is activated remotely by the user.

1) 6. Shock Response Weapon

Role: A non-lethal shock weapon can be added for self-defence or security purposes.

Features: A stun gun or taser that delivers an electrical shock to incapacitate a target.

How it works: This could be mounted on the robotic dog, and the weapon could be activated via an electronic circuit controlled by the ESP32 or ESP8266. This weapon could be triggered by AI models (e.g., Edge Impulse) detecting hostile behaviours or threats.

Electrical Circuit: You'll need a high-voltage circuit to generate and deliver the shock, which should be integrated into the robot's power system, using relays or MOSFETs to control activation.

Safety Considerations: Design the weapon system with strict safety protocols to avoid accidental activation and ensure it's only used in appropriate situations.

Assembly Process Overview:

1. **Design and 3D Printing**:

- Create 3D models of the body, limbs, and any other required parts for the robot.
- Print the parts and assemble the framework to house all the components.

1. **Servo Integration**:

- Attach the MG995 servos to the 3D-printed joints and limbs.
- Ensure that each servo is connected to the appropriate controller pins on the ESP32.

2. **Camera Setup**:

- Mount the ESP32-CAM in a fixed position (e.g., on the head or chest of the robotic dog).
- Connect it to the ESP32 for video streaming and potential AI processing via Edge Impulse.

3. **WiFi Setup**:

- Use the ESP8266 module to provide the necessary wireless connectivity for the robot.
- Ensure the network settings allow for remote communication with the robot.

4. **Power Supply**:

- Connect the LiPo battery to the power distribution board (if needed) and connect the board to the various components.
- Make sure the battery is properly sized to power the robot for an adequate amount of time.

5. **Sensor and AI Integration**:

- If using sensors (e.g., motion sensors, temperature sensors), connect them to the ESP32 for surveillance purposes.
- Use Edge Impulse to process data locally and make decisions based on real-time input (e.g., object detection or sound recognition).

1. **Testing and Calibration**:

- Test all functions (movement, video streaming, WiFi control, and AI model) to ensure that everything works together seamlessly.
- Adjust the software and hardware based on performance.

Software:

- **Arduino IDE or PlatformIO**: Use the Arduino IDE to write and upload the code to the ESP32, integrating all of the components (camera, WiFi, servos, and sensors).
- **Edge Impulse**: Use this platform for training and deploying machine learning models that can run directly on the ESP32 to enhance the surveillance capability.

WORKING PRINCIPLE:

This project focuses on developing an autonomous guard dog robot utilizing ESP32-CAM and ESP8266 integrated with Edge Impulse AI for facial recognition and threat detection. The system is designed to identify authorized personnel, detect potential intruders, and execute appropriate response actions, making it an effective automated security solution. The robot operates by capturing live video footage via ESP32-CAM, processing facial data, and classifying individuals using AI-driven models trained with Edge Impulse. When an unauthorized person is detected, the system can trigger alarms, send notifications via Wi-Fi, or engage in movement-based deterrence to warn or confront the intruder. The ESP8266 module enables seamless wireless communication for real-time monitoring and remote control. Key hardware components include servo motors for mobility, ultrasonic sensors for obstacle detection, LED indicators, and a battery-powered system for autonomous operation. Future improvements may involve integrating cloud-based recognition for better data processing, GPS tracking for location awareness, and enhanced AI models for behavioral threat assessment. This intelligent robotic system provides an advanced, efficient, and portable solution for modern security challenges.

I.CONCLUSIONS

The Robotic Surveillance Dog using ESP32-CAM, ESP8266, and Edge Impulse AI provides a powerful, autonomous surveillance system. The ESP32-CAM streams live video, while Edge Impulse AI enables real-time object detection and decision-making. ESP8266 ensures remote control and communication via Wi-Fi, allowing the robot to be monitored and controlled from anywhere. This setup offers mobility, flexibility, and adaptability for various security tasks. However, power efficiency, AI model accuracy, and network reliability must be considered for optimal performance. Overall, it's a versatile and intelligent solution for autonomous surveillance.

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