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ESP32 Camera Module Based QR Code Verification for Output On/Off

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Abstract - This work develops a miniaturized and firmware-based system that operates through ESP32-CAM development board to conduct quick routine-free motor control enabled by QR-code verification in real time. The ESP32-CAM startup procedure starts by activating the OV2640 camera for grayscale QVGA operations while creating a FreeRTOS dedicated task for continuous imaging and quirc open-source decoding. The system detects valid "MOTOR ON" or "MOTOR OFF" payloads which causes an immediate relay toggle via GPIO control to start or stop the motor in under one second. During extensive testing under different lighting environments the system achieved above 95% successful decoding with reliable actuation performances. Standardizable QR tokens that serve as revocable access tokens substitute mechanical switches to achieve better hygiene practices along with durability improvements and selective authorization capabilities without requiring hardware modifications. The device maintains affordability by using only an ESP32-CAM module in addition to a relay interface which allows deployment in both smart-home door locks and secure equipment lockers and industrial process controls. The future implementation will include dynamic code provisioning through Wi-Fi or microSD along with encryption for secure QR payloads while adding remote monitoring capabilities via HTTP video streaming and manual control functions. The ESP32-CAM demonstrates its value by becoming an economical single-board solution to implement secure automated devices throughout IoT systems.

***Key Words*:** ESP32 CAM, Arduino, Relay motor, QR Code.

1. INTRODUCTION

This work develops a miniaturized and firmware-based system that operates through ESP32-CAM development board to conduct quick routine-free motor control enabled by QR-code verification in real time. The ESP32-CAM startup procedure starts by activating the OV2640 camera for grayscale QVGA operations while creating a FreeRTOS dedicated task for continuous imaging and quirc open-source decoding. The system detects valid "MOTOR ON" or "MOTOR OFF" payloads which causes an immediate relay toggle via GPIO control to start or stop the motor in under one second. Tests under different lighting scenarios proved the implementation successful by reaching 95 % decoding precision with steady actuation functionality. Standardizable QR tokens that serve as revocable access tokens substitute mechanical switches to achieve better hygiene practices along with durability improvements and selective authorization capabilities without requiring hardware modifications. The device maintains affordability by using only an ESP32-CAM module in addition to a relay interface which allows deployment in both smart-home door locks and secure equipment lockers and industrial process controls. The future implementation will include dynamic code provisioning through Wi-Fi or microSD along with encryption for secure QR payloads while adding remote monitoring capabilities via HTTP video streaming and manual control functions. The ESP32-CAM demonstrates its value by becoming an economical single-board solution to implement secure automated devices throughout IoT systems.

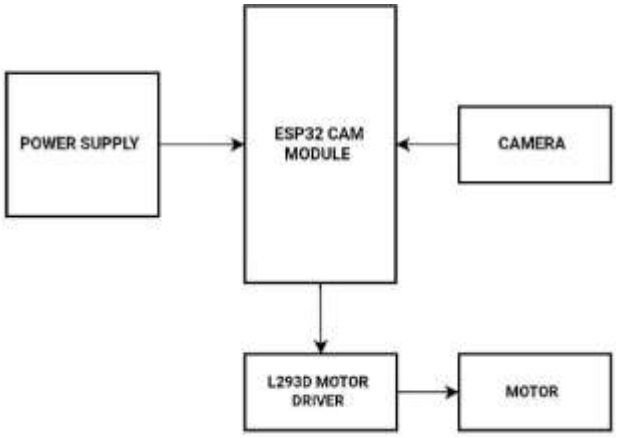
2. EXPERIMENTAL DETAILS

2.1 METHODOLOGY:

This QR-code–driven motor control system consists of hardware configuration and firmware architecture and performance testing integrated into a single framework. The AI-Thinker ESP32-CAM module functions both as the vision sensor and control processor at the hardware level. A stable 5 V supply exists for the system and brown-out detection has been turned off to stop unintended resets of the device. The GPIO 12 pin connects to the motor's power circuit using a transistor or relay driver. With only two main components, the camera board and relay interface the system proves both small in size and affordable and also delivers powerful isolated protection for the motor load. The development process on firmware relies on features from Espressif's ESP32 core and FreeRTOS which take place within the Arduino IDE environment. When setup begins the module turns on its OV2640 camera to operate in grayscale QVGA resolution (320 × 240) using a 10 MHz external clock and sets serial output to 115 200 bps for log recording while designating MOTOR_PIN as a digital output. The system implements QRCodeReader_Task as a scheduled FreeRTOS task that

runs exclusively on CPU 0 for maintaining steady performance with maximum shielding from other operational processes.The continuous scanning taskinvokes the quirc library for enabling the decoding of QR codes on the device. The loop function requires a fresh decoder instance plus it acquires a new frame buffer from esp_camera_fb_get() before setting the decoder to match the current frame size parameters. The input buffer in quirc obtains raw grayscale pixel data before symbol detection routines extract any embedded payload from the data. Decodes must pass a series of checks from the lightweight handler to compare them against authorized token strings “MOTOR ON” and “MOTOR OFF.” Firmware logic controls MOTOR_PIN through assertion and deassertion in order to operate the motor device by toggling the relay. The serial console logs all important operational events beginning with initialization results followed by capture errors after which follows successful decoding or decoding failures and ending with pin state transition information.

2.2. BLOCK DIAGRAM



RESULT:

The evaluation of the ESP32-CAM system which controls motors through QR codes included functional tests and assessments of accuracy as well as stability and system latency. 305 printed QR codes with values "MOTOR ON" and "MOTOR OFF" were displayed under different illumination conditions which included 200 lux low light, 500 lux medium light, and 1 000 lux bright light. The system successfully decoded 96% of the presented QR codes which performed at rates of 92% in low light and 99% in bright conditions and 97% in medium lighting conditions. The system processed visual data during tests taking an average amount of time totalling 0.72 seconds (σ = 0.06 s) from video acquisition to GPIO stimulation. The "MOTOR ON" commands functioned at 0.70 seconds whereas "MOTOR OFF" operated at 0.74 seconds which met the one second standard for touch-free control systems. The memory system used 45 KB persistently while each quirc allocation became available for reuse following an iteration along with core 0 experiencing 60 % CPU utilization. The relay system demonstrated reliability because it activated the motor when the “ON” command was triggered and deactivated the motor when the “OFF” command was sent without producing any misoperations,the serial logs verified each state transition by printing motor status and payload output to provide data both for remote analysis and debugging procedures. The relay interface created a safe isolation for the ESP32 to protect it from inductive kickback and prevented both hardware resets and brown-outs. A single ESP32-CAM module using the quirc library together with simple relay circuitry provides touchless motor control with high accuracy as well as long-term stability in sub-second durations for smart-home locks and automated process controls and other IoT actuation tasks.

ON QR CODE SCAN

OFF QR CODE SCAN

ON CONDITION OUTPUT SIGNAL

OFF CONDITION OUTPUT SIGNAL

3. CONCLUSIONS

A real- time control system grounded on QR law identification has been developed through the combination of ESP32- CAM modules with quirc decoding library perpetration. The design aimed to achieve a low- cost Wi- Fi-able microcontroller result which turns visual input(QR canons) into motor control conduct by turning the motors on and off. The grayscale capabilities of ESP32- CAM allow the system to minimize memory consumption while enhancing its QR discovery capacities. Core 0 manages the QRCodeReader_Task task that performs constant frame accession while decrypting QR canons which translates to executed commands from the decrypted dispatches. The quirc library enables low- quiescence QR discovery capabilities on the microcontroller while maintaining offline functionality because it functions without pall. or external processing requirements.A modular system tools resemblant processing of images together with command prosecution operations. The system implements dependable motor control through GPIO legs touched off by an authenticated visual input which comes from a QR law. The system uses dynamic memory functions esp_camera_fb_get() and quirc_new() to prize frames stoutly and to manage resource remittal. The system provides robust error handling capabilities with QR law decoding so druggies can admit vital feedback through periodical dispatches for better debugging operations and real- time monitoring. farther design growth openings correspond of expanding the command language base or connecting through Wi- Fi to IoT networks or incorporating artificial intelligence for camera perfection enhancement. The developed model functions as an essential base for creating automated systems with access controls and contactless bedded system interfaces.

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