Fabrication of Energy-Efficient Solar - AI Drone for Sustainable Aerial Applications.

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Abstract - The rapid growth of urban populations and large public gatherings has increased the need for efficient and real-time crowd monitoring systems. Traditional methods such as manual observation and fixed cameras are limited in coverage and mobility. To overcome these issues, this project proposes a solar-powered AI-based drone system for accurate people counting. The drone uses a mounted camera to capture aerial video, providing a wide field of view for better surveillance. The captured frames are processed using the SSD (Single Shot Detector) algorithm for real-time human detection and counting. An ESP32-CAM module is used for live video streaming and data acquisition. The integration of solar panels and a battery system helps extend flight time and reduce dependence on conventional power sources. The system also includes a real-time processing pipeline with image capture, pre-processing, detection, and counting. Its quadcopter design ensures stable flight and efficient performance. Overall, the system offers a scalable, energy-efficient, and intelligent solution for applications such as public safety, event management, and urban planning.

Keywords:
Solar-powered drone, Crowd monitoring, People counting, Artificial Intelligence (AI), Computer vision, SSD algorithm, ESP32-CAM, Aerial surveillance, Real-time detection,

1.INTRODUCTION

The rapid increase in population density and the growing frequency of large public gatherings have significantly increased the demand for efficient and reliable crowd monitoring systems. Accurate estimation of the number of people in a given area plays a vital role in ensuring public safety, managing large-scale events, planning urban infrastructure, and responding effectively to emergencies. Conventional people-counting methods, such as manual surveys and fixed surveillance cameras, often suffer from limitations including restricted coverage, lack of flexibility, and high operational effort. In recent years, advancements in unmanned aerial vehicles (drones), renewable energy, and artificial intelligence have enabled the development of smarter monitoring solutions. Drones provide key advantages such as mobility, wide-area coverage, and the ability to access remote or hazardous environments. However, their limited battery life restricts continuous operation and efficiency. To address this challenge, the integration of solar energy offers a sustainable solution by extending flight duration and reducing reliance on traditional charging methods. Furthermore, combining drones with computer vision and deep learning techniques allows real-time analysis of captured visual data. The SSD (Single Shot Detector) algorithm, in particular, has proven to be effective for fast and accurate human detection. In this project, a solar-powered AI camera-based drone system is proposed using the ESP32-CAM and SSD model for real-time people counting. The drone captures aerial video footage, which is processed to detect and count individuals within the coverage area. The use of solar panels enhances operational time and supports energy-efficient performance.

1.1 AIM OF THE PROJECT

The aim of this project is to design and develop a solar-powered AI-based drone system capable of performing real-time people counting using computer vision techniques. The system utilizes aerial video captured through a camera module and processes the visual data using the SSD (Single Shot Detector) algorithm to detect and count individuals present in a monitored area.

The proposed drone system is designed to provide flexible, energy-efficient, and efficient monitoring of large areas where traditional surveillance methods may be ineffective. The integration of solar energy with AI-based human detection enables extended flight duration and automated crowd analysis with minimal human intervention.

The project aims to develop a compact, cost-effective, and scalable monitoring solution suitable for applications such as public safety management, event supervision, traffic monitoring, disaster response, and smart city surveillance.

1.2 OBJECTIVES OF THE PROJECT

1. Real-Time People Detection:
To detect and count individuals using the SSD object detection algorithm.

2. Drone-Based Aerial Monitoring:
To develop a drone capable of capturing aerial video for large-area surveillance.

3. Solar Power Integration:
To utilize solar energy to extend flight duration and improve energy efficiency.

4. AI-Based Image Processing:
To process video frames using computer vision techniques for accurate detection.

5. Efficient Crowd Monitoring:
To provide reliable real-time crowd density analysis.

6. Wireless Video Streaming:
To enable live transmission of video data for real-time monitoring.

7. Portable and Flexible System:
To design a system usable in large and remote areas without fixed infrastructure.

8. Improved Safety and Security:
To assist authorities in managing crowds and reducing risks.

9. Scalable Solution:
To develop a cost-effective system adaptable for smart city applications.

1.3 SCOPE OF THE PROJECT

- Solar-Powered Drone System:
The drone integrates solar panels to support extended and sustainable operation.

- AI-Based People Detection:
SSD model is used for detecting and counting humans in real time.

- Wide Area Coverage:
Drone mobility enables monitoring of large public spaces and remote areas.

- Real-Time Surveillance:
Provides instant crowd data for quick decision-making.

- Flexible Deployment:
Can be used in different environments without permanent infrastructure.

- Public Safety Applications:
Useful in event management, traffic control, disaster response, and urban planning.

- Energy-Efficient Monitoring:
Solar integration reduces dependency on traditional power sources.

- Smart Surveillance System:
Supports development of intelligent and autonomous monitoring solutions.

LITERATURE REVIEW

Shaik et al. (2025) developed a solar-powered wireless surveillance system using the ESP32-CAM module. Their study emphasized low-cost implementation and real-time video streaming capabilities, making ESP32-CAM a suitable choice for lightweight and energy-efficient vision-based applications. This approach supports the feasibility of integrating compact embedded systems into UAV platforms.

Imron et al. (2024) and Mehendale (2022) explored object detection using ESP32-CAM, focusing on cloud-based and embedded processing techniques. Their work demonstrated the capability of ESP32-CAM in capturing and transmitting image data for further AI-based processing. However, limitations in onboard processing power suggest the need for optimized algorithms or external processing units for real-time performance.

Madasamy et al. (2021) implemented a drone-based surveillance system using the YOLO (You Only Look Once) algorithm. Their results showed high accuracy in object detection with real-time performance, proving the effectiveness of deep learning models in UAV applications. This provides a strong foundation for adopting similar techniques such as SSD (Single Shot Detector) for efficient human detection and counting.

Wong et al. (2018) introduced Tiny SSD, a lightweight version of the SSD algorithm optimized for embedded

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systems. Their work is particularly relevant for real-time applications where computational resources are limited. The SSD approach offers a balance between speed and accuracy, making it suitable for drone-based crowd monitoring systems.

Sun et al. (2018) investigated optimal trajectory design for solar-powered UAVs, highlighting how energy efficiency can be improved through intelligent flight path planning. Their research demonstrates that combining energy-aware algorithms with solar harvesting systems can significantly enhance UAV performance and operational time.

3.1.1 Hardware:

The hardware sub system consists of the following components:

1. **Frame**
2. Figure 2: Parts of the quad-copter frame

Colour: White & Red
Frame arm size: 21.5 * 3.8 * 5cm / 8.5 * 1.6 * 2.0inch Weight: 43g(Single)

Weight: 250g / 4pcs

Features:
The DJI F450 Flame Wheel frame arms are built from very strong materials, thesearms are made from the ultra-strong PA66+30GF material which provides better resistance to damage on hard landings.

Specification:

Colour: Black
Material: Fiber Glass & Plastic

Package Includes:
Flame Wheel (2 Red,2 White) x4F450 TOP Plate x1

F450 BOTTOM Plate x1

F-M3*8 Screws x16 F-M2.5*8 Screws x24

3. **Battery**

Figure 3: Li-Po battery used in the project

Features

- Gens ace Professional Li-Po Battery; Superior Japan and Korea LithiumPolymer raw materials.
- Quickly Recharged, Long Cycle Life (150 times minimum), up to 200Wh/kgenergy density.
- Parameter: Weight: 0.39lb; Dimension(L*W*H):4.17*1.32*0.9in; Connector,XT60 Plug, Balancer Connector, JST-XHR.
- Applications: Specially Designed for 800MM Warbirds, EPP 3D plane, smallheli, QAV180/210 Quad-copter, DJI Phantom FC40 Spare, Walkera E22.

3.1.2 FLIGHT AND SENSORS:

The second sub system consists of the following

1. **Controller**

Figure 4: KK-2.1 board

General information:

Kk2.1.5 Multi-rotor LCD Flight Control Board With 6050mpu And Atmel 644PA is nextbig evolution of the first generation KK flight control boards. The KK2.1.5 was engineered from the ground up to bring multi-rotor flight to everyone, not just the experts.

The LCD screen and built-in software make install and setup easier than ever. A host of multi-rotor craft types are pre-installed, simply select your craft type, check motor layout/propeller direction, calibrate your ESCs and radio and you're ready to go! All of which is done with easy to follow on-screen prompts! The original KK gyro system has been updated to an incredibly sensitive 6050 MPU system making this the most stable KK board ever and allowing for the addition of an auto-level function. At the heart of the KK2.1.5 is an Atmel Mega644PA 8-bit AVR RISC-based microcontrollerwith 64k of memory.

An additional polarity protected header has been added for voltage detection, so no need for on-board soldering. A handy piezo buzzer is also included for audio warning when activating and deactivating the board.The KK2.1.5 added polarity protection to the voltage sense header and a fuse protected buzzer outputs, in case something is accidentally plugged in incorrectly. The voltage sense line has been updated for betteraccuracy. The board is clearly labeled and the voltage sense line color has been changed to red for easy identification, making installation and connections a snap.If you're new to multi-rotor flight or have been unsure about how to setup a KK board then the KK2.1.5 was built for you. The 6 Pin USBasp AVR programming interface ensures future software updates will be quick and easy.

The KK gyro system has been updated to the incredibly sensitive 6050 MPU system making this the most stable KK board ever and adds the addition of an auto-level function. At the heart of the KK2.1 is the ATMEL Mega 644PA 8-bit AVR RISC- based microcontroller with 64k of memory. An additional header has been added for voltage detection, so now there is no need for onboard soldering. A handy piezo buzzer is also included with the board for audio warning when activating and deactivating the board, which can be supplemented with an LED for visual signaling. A host of multi-rotor craft types are pre-installed, simply select your craft type, check motor layout and propeller direction, calibrate your ESCs and radio and you're ready to go. All of which is done with easy-to follow on-screen prompts. If you're new to multi-rotor flight or have been unsure about how to set up a KK board then the KK2.1was built for you. The 6 Pin USB asp AVR programming interface ensures future software updates will be quick and easy.

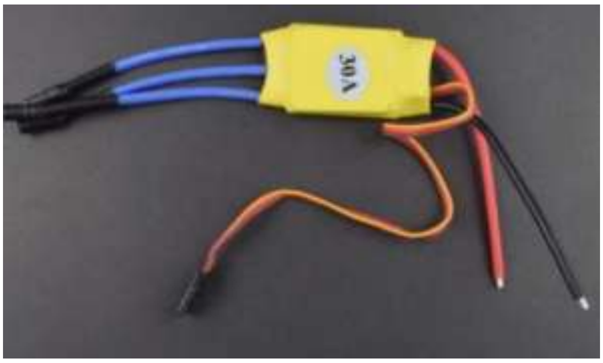


Figure 5: Electronic speed controller that is used in the project

1. Features:

1. This hardware, with the Simon K firmware, gives you the perfect solution for multi-rotoruse.
2. Highest efficiency 100% N-FET design.
3. Highest accuracy with Crystal Oscillator (Temperature won't affect the PWM operatingrange like other cheap ESC's).
4. No low voltage cut off, because any cutoff in a multi-rotor crash.
5. No over temp cutoff, because any cutoff in a multi-rotor crash.
6. Super high refresh rate, no buffering of the input signal, resulting in more than 490Hzresponse rate.
7. 16KHz motor frequency, giving fastest response of the motor, and quietest operation as well (no 8KHz squeal).

3.1.3 WIRELESS CONTROL:

This sub system has the following components

1. FlySky FS-i6 2.4G 6CH AFHDS RC Transmitter With FS-iA6 Receiver

Figure 6: Transmitter and receiver used in the project

Description:
Brand Name: Fly sky

FS-i6 Specifications:

Channels: 6 Channels

Model Type: Glider/Heli/AirplaneRF

Range: 2.40-2.48GHz

Bandwidth: 500KHz

Band: 142

RF Power: Less Than 20dBm

2.4 ghz System: AFHDS 2A and AFHDS
Code Type: GFSK
Sensitivity: 1024

Low Voltage Warning: less than 4.2V

DSC Port: PS2; Output: PPM

Charger Port: No

ANT length: 26mm*2(dual antenna)

Weight:392g

Power: 6V 1.5AA*4

Display mode: Transflective STN positive type, 128*64 dot matrix VA73*39mm, whitebacklight.

Size: 174x89x190mm

On-line update: yes

Color: Black

Certificate: CE0678, FCC

Model Memories: 20

Channel Order: Aileron-CH1, Elevator-CH2, Throttle-CH3, Rudder-CH4, Ch 5 & 6 open toassignment to other functions.

FS-iA6 Specifications:
Channels: 6 Channels

Model Type: Fixed-wing/Glider/AirplaneRF Range: 2.40-2.48GHz

Bandwidth: 500KHz

Band: 142

RF power: less than 20dBm

RF receiver sensitivity: -105dBm

2.4ghz System: AFHDS 2A

Code Type: GFSK

ANT length: 26mm

Weight:6.4g

Power:4.0-6.5V

Size: 40.4x21.1x7.35mm

Color: Black

Certificate: CE, FCC

i-BUS port: NO

Data Acquisition port: NO

3.1.4 FPV:

RECIEVER CHANNEL	FLIGHT CONTROLLER
Aileron	Aileron
Elevator	Elevator
Throttle	Throttle
Rudder	Rudder
AUX I	AUX

The FPV sub system has not yet been implemented in this semester and will be done inthe subsequent days.

3.2 IMPLEMENTATION:

The project was implemented in the following steps:

Step 1:
Mount the FC on the frame with the LCD facing front and the buttons facing back. You can use the supplied

antistatic foam container as a form of protective case for the Flight Controller on the craft.

Step 2:
Connect the receiver outputs to the corresponding left-hand side of the controller board.

The pins are defined as:

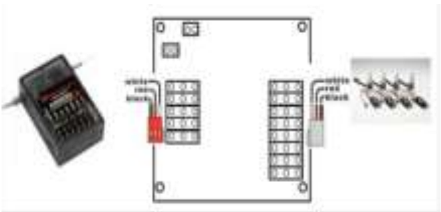
Table 2: Pin definition

Step 3:
Connect the ESC's to the right side of the Flight Controller Board. M1 is towards thefront of the board and M8 is nearest to the push buttons. The negative (black or brown) lead towards the edge of the FC. The negative (black or brown) lead is connected to the edge of the Flight Controller.

The Flight Controller Board must always have a source of +5v from an ESC, either one of themotors ESC or from a separate unit feeding the Receiver. If each ESC has a BEC (normal unless OPTO types) then it may be necessary to remove the power feed from the other ESC, usually by cutting the power line (RED) Cable on the other ESC.

Figure 7: Completed wiring at step 3

Step 4:
Set up a new model on your transmitter and use a normal airplane profile and bind the Receiver to the Transmitter.



Step5:
Turn on the power and press the 'Menu' button, then using the 'Up' and 'Down' buttons highlight 'Receiver Test sub-menu and press Enter. Now move each channel on your transmitter and check that the displayed direction corresponds with the stick movements on the Flight Controller, if any are reversed, then go to your Transmitter and reverse that channel. Check that the AUX channel is showing "ON" when you activate the AUX Switch on your transmitter, if not, reverse the AUX channel on your transmitter. Use the trim or sub- trim controls on your transmitter to adjust the channel values shown on the LCD to zero.

Step 6:
Scroll down to and enter the "Load Motor Layout" sub-menu and choose the configuration you want. If the configuration you want is not listed, use the "Mixer Editor" sub-menu to make one. See later for more on that.

Step 7:
Enter the "Show Motor Layout" sub-menu and confirm the following. Is the configuration correct? Are the motors and servos connected the correct output? Correct rotation direction? Does the motor speed up when dropping the arm it is mounted on?

Step 8:
Enter the "Receiver test" and check for nominal values on each channel, move your Transmitter sticks around to ensure they are all working, including AUX1.

Step9:
Enter the "Mode Settings" and check and adjust: "Self-Level": Determines how the self- leveling function will be controlled, either by STICK or an AUX Channel. "STICK MODE": Self-leveling is turned on by holding the aileron to the right when arming or disarming. Turn it off with left aileron. "AUX": Self- leveling is turned on/off by the AUX Channel. "Auto Disarm": If set to YES then Flight Control board will automatically disarm itself after 10-mins of inactivity. "CPPM Enabled": Determine if the Flight Control Board is to use CPPM data input.

Step 10:
Enter the "Stick Scaling" option, where you can adjust the response from the stick to your liking. Higher number gives higher response and lower numbers the converse. This is similar to the endpoint or volume adjustment on your transmitter, where you can adjust your transmitter to adjust the stick response and use the stick scaling if you want more or less response from stick inputs.

Assemble and connect:

1. The motors and ESC's can be connected to each other via direct soldering or usingBullet Connectors of 4mm dimension.
2. The ESC's are then connected to the power distribution board, or in this case directly to the frame which has an inbuilt power distribution board, by soldering (Make sure toknow if the ESC's are supposed to be flashed or not, mine did not required to do so).
3. Once this is done, solder the battery wire to the frame.
4. Once all the soldering work is done, and the hardware is setup, connect the KK Board(again flashed with the latest firmware) with the ESC servo wires, and Receiver.

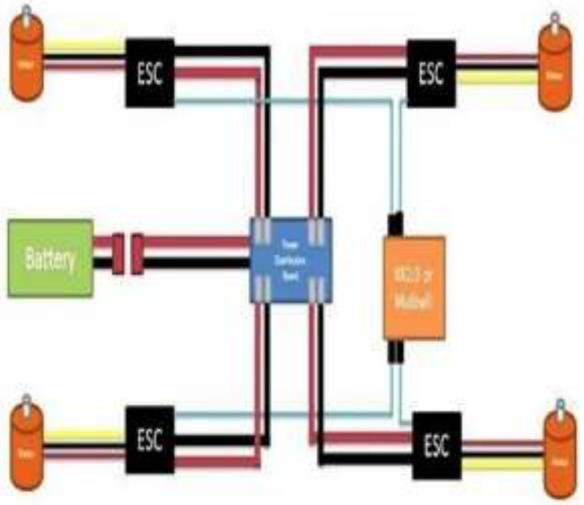


Figure 8: Connection diagram after assembly

5. The motors and ESC's can be connected to each other via direct soldering or usingBullet Connectors of 4mm dimension.
6. The ESC's are then connected to the power distribution board, or in this case directlyto the frame which has an inbuilt power distribution board, by soldering.
7. (Make sure to know if the ESC's are supposed to be flashed or not, mine did notrequired to do so.)
8. Once this is done, solder the battery wire to the frame.
9. Once all the soldering work is done, and the hardware is setup, connect the KK Board(again flashed with the latest firmware) with the ESC servo wires, and Receiver.

ESPRESSIF ESP32 CAM

SOFTWARE FEATURES:

1. **ESP32 Arduino Core:** The ESP32-CAM is compatible with the ESP32 Arduino Core, making it easy to program using the Arduino IDE.

2. **ESP-IDF:** The ESP32-CAM is also compatible with ESP-IDF, a development framework provided by Espressif.

3. **Camera Library:** The ESP32-CAM has a built-in camera library, making it easy to capture images and video.

SPECIFICATIONS:

MICROCONTROLLER (ESP32-S)

- Dual-core **Xtensa® 32-bit LX6** processor
- Clock speed: **up to 240 MHz**
- Built-in **Wi-Fi (802.11 b/g/n) & Bluetooth 4.2 BLE**
- Flash memory: **4 MB**
- SRAM: **520 KB**

CAMERA (OV2640)

- Resolution: **2 MP (1600×1200)**
- Supports **JPEG, BMP, and grayscale formats**
- Adjustable frame size (UXGA, SXGA, VGA, etc.)

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- Can interface with other cameras like **OV3660** (higher resolution)

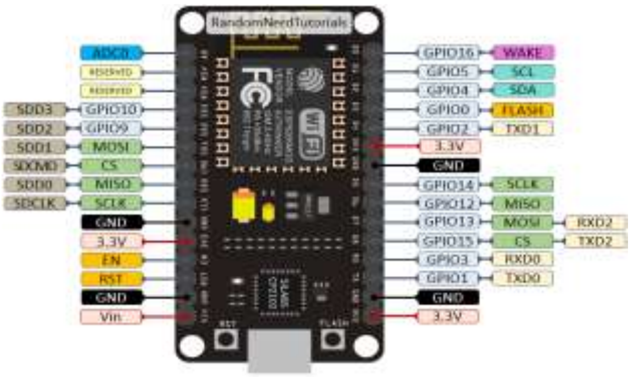
CONNECTIVITY & STORAGE

- **Wi-Fi & Bluetooth** for remote access
- **MicroSD card slot** (supports up to 4 GB for image/video storage)
- UART, SPI, I2C, PWM, ADC, DAC interfaces

POWER & CONSUMPTION

- Operating voltage: **3.3V to 5V**
- Average power consumption: **160 mA – 310 mA** (depends on Wi-Fi usage)
- **No onboard USB port** (requires FTDI programmer for programming)

PIN DIAGRAM:



GPIO PINS:

1. GPIO0 (D0): Input/Output
2. GPIO2 (D2): Input/Output
3. GPIO4 (D4): Input/Output
4. GPIO5 (D5): Input/Output
5. GPIO12 (D12): Input/Output
6. GPIO13 (D13): Input/Output
7. GPIO14 (D14): Input/Output
8. GPIO15 (D15): Input/Output
9. GPIO16 (D16): Input/Output
10. GPIO17 (D17): Input/Output
11. GPIO18 (D18): Input/Output
12. GPIO19 (D19): Input/Output
13. GPIO21 (D21): Input/Output
14. GPIO22 (D22): Input/Output
15. GPIO23 (D23): Input/Output

CAMERA PINS:

1. CAM_VSYNC (VSYNC): Vertical sync signal
2. CAM_HREF (HREF): Horizontal reference signal
3. CAM_PCLK (PCLK): Pixel clock signal
4. CAM_D0 (D0): Data bit 0
5. CAM_D1 (D1): Data bit 1
6. CAM_D2 (D2): Data bit 2
7. CAM_D3 (D3): Data bit 3
8. CAM_D4 (D4): Data bit 4
9. CAM_D5 (D5): Data bit 5
10. CAM_D6 (D6): Data bit 6
11. CAM_D7 (D7): Data bit 7

POWER PINS:

1. 3V3 (3.3V): Power supply
2. GND (Ground): Ground
3. VIN (5V): Power supply (optional)

OTHER PINS:

1. U0RXD (UART0 RX): UART0 receive
2. U0TXD (UART0 TX): UART0 transmit
3. U1RXD (UART1 RX): UART1 receive
4. U1TXD (UART1 TX): UART1 transmit

5. SDA (I2C SDA): I2C data

6. SCL (I2C SCL): I2C clock

SOLAR PANEL

ABOUT SOLAR PANEL:

A Solar Panel is a photovoltaic (PV) device that converts sunlight directly into electrical energy using semiconductor materials. It is widely used in renewable energy systems to generate clean and sustainable power for small electronic devices, battery charging units, and standalone energy applications.

Solar panels provide an eco-friendly alternative to conventional power sources by utilizing abundant solar radiation, making them an essential component in modern green energy solutions.

WORKING:

The solar panel operates based on the **photovoltaic effect**:

• Sunlight strikes the surface of the photovoltaic cells.
• The semiconductor material absorbs light energy and releases electrons.
• These free electrons create an electric current when they move through the material.
• The generated DC electricity is collected by metal contacts.
• This power is supplied directly to loads or stored in rechargeable batteries.

The output depends on sunlight intensity, exposure time, and panel orientation.

STRUCTURE OF A SOLAR PANEL:

Photovoltaic Cells:
Convert solar energy into electrical energy using silicon semiconductors.

Protective Glass Layer:
Allows sunlight to pass while protecting the cells from environmental damage.

Encapsulation Layer:
Provides insulation and prevents moisture entry.

Back Sheet:
Ensures mechanical strength and electrical safety.

Metal Contacts / Output Terminals:
Transfer generated electricity to external circuits.

Support Frame (if provided):
Adds durability and facilitates mounting.

SPECIFICATIONS (Typical Small Module):

Output Voltage: 5V – 6V DC
Output Current: 100 mA – 200 mA (in full sunlight)
Power Rating: Around 0.5 W – 1 W
Cell Type: Polycrystalline / Monocrystalline Silicon
Operating Temperature: −20°C to +65°C
Conversion Efficiency: Approximately 15%–20%

Fabrication Process

The fabrication process of the solar-powered AI drone is carried out through a systematic integration of mechanical structure, power systems, and intelligent processing units. The objective is to achieve a lightweight, energy-efficient, and high-performance drone capable of extended flight and real-time human detection.

Step 1: Structural Frame Development

The drone frame is fabricated based on the CAD model designed in SolidWorks. A quadcopter X-configuration is selected to ensure optimal stability and load distribution. The structure is designed to be lightweight while maintaining high strength to support onboard components, including solar panels and electronics.

Step 2: Propulsion System Integration

High-efficiency brushless DC motors are mounted at the ends of each arm, paired with aerodynamically optimized propellers. The propulsion system is configured to achieve an optimal thrust-to-weight ratio, ensuring stable lift and maneuverability under varying load conditions.

Step 3: Power System Assembly

The power subsystem includes a rechargeable battery integrated with a solar energy harvesting unit. Solar panels are strategically mounted to maximize sunlight exposure. A regulated power distribution system ensures stable voltage supply to motors, controller, and AI modules, minimizing energy losses and enhancing efficiency.

Step 4: Electronic Control Integration

Electronic Speed Controllers (ESCs) are connected to each motor for precise speed control. A flight controller is integrated to manage stabilization, navigation, and real-time control of the drone. Proper shielding and wiring management are implemented to avoid signal interference and ensure system reliability.

Step 5: AI Vision System Installation

An ESP32-CAM module is mounted to provide real-time aerial imaging. The module is positioned to achieve maximum field of view for effective surveillance. The camera system is interfaced with processing units to enable continuous data acquisition.

Step 6: AI Model Deployment

The SSD (Single Shot Detector) algorithm is implemented using Python for real-time human detection. The model processes incoming video frames, detects individuals, and generates bounding boxes with count estimation. The system is optimized for low latency and efficient computation.

Step 7: System Integration and Synchronization

All subsystems mechanical, electrical, and AI are integrated into a unified architecture. Synchronization between flight control and AI processing ensures stable operation without performance bottlenecks.

Step 8: Calibration and Optimization

The system undergoes calibration to fine-tune flight stability, power consumption, and detection accuracy. Parameters such as motor speed, weight balance, and processing latency are optimized to achieve peak performance.

Step 9: Testing and Performance Evaluation

Comprehensive testing is conducted under different operating conditions. Flight endurance, solar efficiency, and detection accuracy are evaluated. The system is tested for reliability in real-time scenarios.

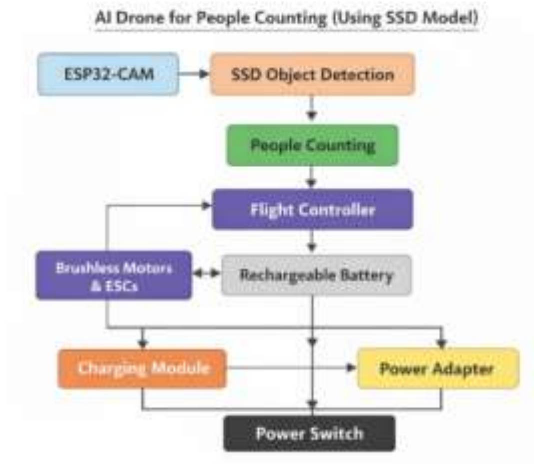
Step 10: Final Prototype Validation

The final prototype is validated for continuous operation, ensuring that it meets the design objectives of extended flight duration, real-time monitoring, and energy efficiency.

Outcome

The fabricated system demonstrates a high-performance solar-powered AI drone capable of long-duration operation, efficient energy utilization, and accurate real-time human detection, making it suitable for advanced surveillance and monitoring applications.

Block Diagram Description



The operational flow of the system is as follows:

1. The drone captures live video using the onboard camera module.
2. The captured frames are transmitted for processing and analysis.
3. The SSD algorithm processes frames and detects human objects in real time.
4. Detected individuals are counted based on detection results.
5. The flight controller maintains drone stability and navigation.
6. The battery supplies primary power to all components.
7. The solar panel generates additional power to support the battery and extend operation.
8. The charging module and adapter recharge the battery when required.

Future Scope

Future enhancements can include advanced deep learning models to improve detection accuracy in dense crowds. The system can be upgraded with autonomous navigation and multi-drone swarm technology for fully automated large-area monitoring. Improving solar efficiency and intelligent power management will further extend flight endurance. Integration with cloud platforms, smart city systems, and advanced sensors like thermal cameras can enable real-time analytics, behaviour prediction, and enhanced surveillance.

CONCLUSION

The solar-powered AI-based drone effectively integrates aerial monitoring, artificial intelligence, and renewable energy for efficient crowd analysis. It accurately detects and counts people in real time using the SSD algorithm and ESP32-CAM module. The use of solar energy enhances flight duration and reduces dependence on conventional power sources. The system demonstrates stable performance, reliable monitoring, and efficient power utilization. Overall, it offers a cost-effective, scalable, and sustainable solution for modern crowd surveillance applications.

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