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Integration of AI-Driven Facial Recognition and Robotics in Drone Systems for Critical Operations

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Abstract:
This paper explores the integration of drone technology with artificial intelligence (AI) and autonomous systems for emergency and military applications. It focuses specifically on drones equipped with Pixhawk flight controll ers, PX4 Autopilot software, and robotic arm control via Arduino and Raspberry Pi. The drone uses an FPV ca mera for facial recognition and delivers according to the time a face is detected. The system is designed to impr ove emergency response and military operations by increasing the efficiency of supplies and critical support in difficult areas. This study explores the use of facial recognition algorithms, their integration into robotic system s, and the potential benefits of this technology in the public sector and environmental protection.

Keywords - *Unmanned Aerial Vehicles (UAVs), Facial Recognition, Pixhawk, PX4 Autopilot, Robotic Arm, Arduino, Raspberry Pi, Emergency Response, Military Applications, AI.*

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I. Introduction

In recent years, UAVs have evolved far beyond their initial role in aerial surveillance. Today, they're becoming indispensable in emergency responses and military operations. This paper introduces a new kind of UAV system designed for precise deliveries and identifying people in critical situations. By combining advanced technology with smart design, this system aims to make a real difference in critical situations. At the core of this system is a sophisticated integration of a Pixhawk flight controller with PX4 Autopilot software, designed to ensure optimal flight stability and control over essential parameters such as yaw, pitch, and payload management.

The UAV system is further enhanced by a robotic arm interfaced with both an Arduino and a Raspberry Pi. This setup allows the Raspberry Pi to process real-time input from an FPV camera through advanced facial recognition algorithms. The capability to identify individuals and accurately release payloads to specific targets offers a transformative approach to emergency supply delivery and military operations. Such advancements in UAV technology and AI integration highlight a new era of autonomous systems, emphasizing increased precision, efficiency, and adaptability in mission-critical scenarios.

fig1.1 Drone with robotic arm

This paper explores the significant technological strides in UAVs, focusing on the convergence of flight control, robotics, and artificial intelligence to redefine the scope of aerial operations.

II. Material And Methods

To achieve high-precision delivery and identification using Unmanned Aerial Vehicles (UAVs), we developed a comprehensive system integrating both hardware and software components.

2.1 Hardware Components:

• **Drone Frame:** A lightweight, durable material of carbon fibre is used here. Carbon fiber is an exceptionally durable material that enhances the rigidity of components. Its excellent adhesion properties contribute to the production of high-quality objects. In addition to being lightweight, carbon fiber offers high resistance to chemicals, impressive tensile strength, and minimal thermal expansion. After further examining the metallurgical properties of carbon fiber and its composites, as well as analyzing market availability and cost-reduction strategies, we have developed this report.

• **Electronic Speed Controller (ESC):** The max current draw by the motor and propeller at highest thrust is 24 amp keeping safety margin of 40% we will be using ESC of 40A.

• **Motors and Propellers:** To meet the required thrust force for lifting the drone, we selected the EMAX GT2215-09 1180KV Outrunner Brushless Motor, a popular choice for RC models. According to the manufacturer's specifications and testing data, this motor, when paired with a 10x4.7 propeller, provides sufficient thrust to meet the drone's thrust-to-weight ratio requirements. High-torque servos or motors to control the Robotic arm's movement with precision.

Table 1: EMAX GT2215-09 1180KV Outrunner Brushless Motor specifications

No.Of cells	2-3xLi-Poly
Stator dimensions	22x15mm
Shaft diameter	4mm
Weight	70g/2.46oz
Recomended model weight	300-1100g
Recomended prop without gearbox	10x4.7 11x3.8

Model	Cell Count	RPM/V	Prop (APC)	RPM	MAX current (<60S)	Thrust
GT2215/12	3S	905	10x4.7	7450	15A	1000g 2.20lb
	3S	905	11x3.8	7000	18A	1050g 2.31lb
GT2215/09	3S	1180	10x4.7	8300	26A	1250g 2.76lb
	3S	1180	10x6	8850	24A	1140g 2.51lb

• **Pixhawk Flight Controller:** The Pixhawk 2.4.8 flight controller was chosen for this autonomous drone project due to its advanced features and proven reliability. Its strong computational capabilities and built-in sensors provide precise control and navigation. The use of a floating-point unit (FPU) enhances the accuracy of calculations involving floating-point numbers. As an open-source platform, it allows for extensive customization and the integration of sophisticated flight algorithms, ensuring stable and secure autonomous flight. Among flight controllers in its price range, the Pixhawk 2.4.8 stands out for its affordability, effectiveness, and availability. The main reason for selecting this flight controller is its ability to deliver stable autonomous flight, supported by its firmware and mission planning software. Its solid reputation and successful track record make it an ideal choice for ensuring accurate and efficient flight control in our project.

Fig 2.1 Pixhawk 2.4.8 flight controller

• **Raspberry Pi 4B:** The choice of the Raspberry Pi 4B (8GB) module was primarily influenced by its powerful computing capabilities. Its advanced processing power and ample memory make it well-suited for managing the complex algorithms and tasks necessary for autonomous navigation and payload management. With a wide array of GPIO pins and connectivity options, the Raspberry Pi 4B easily integrates with various sensors and peripherals, enhancing the precision and reliability of drone operations. When connected to the Pixhawk via the MAVLink protocol, it functions as an effective companion computer, enabling advanced onboard processing and decision-making—critical for executing complex autonomous missions with the Pixhawk-based drone at an affordable cost. Additionally, the Raspberry Pi 4B benefits from strong community support and widespread popularity, providing valuable resources and opportunities for future upgrades to our project.

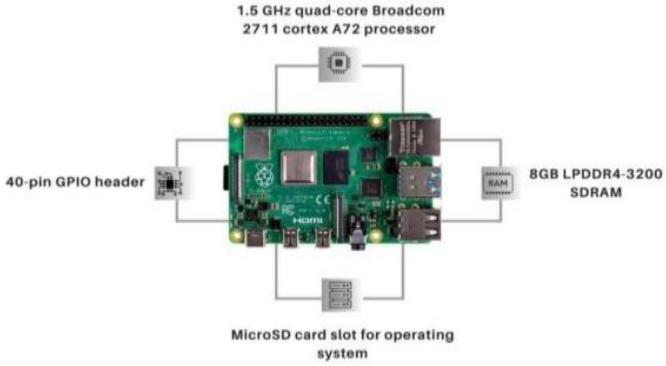

fig 2.2 Raspberry pi 4b

• **First Person View (FPV) Camera:** It is a compatible AI camera for Raspberry Pi that provides 1920x1080 pixels, offering superior image clarity and detail. Due to its high resolution and compatibility with the Raspberry Pi, it is the ideal choice for this project, enabling accurate facial recognition.

fig 2.3 FPV camera

• **Arduino Portenta H7:** The Arduino Portenta H7 was chosen for controlling the robotic arm in our project due to its powerful dual-core processing capabilities and versatility. It features an Arm Cortex-M7 core running at 480 MHz and a Cortex-M4 core running at 240 MHz, allowing it to handle complex tasks and real-time processing efficiently. This is crucial for precise control of the robotic arm, which requires handling multiple inputs and outputs simultaneously. The Portenta H7's extensive GPIO pins, compatibility with various communication protocols, and high processing power make it ideal for integrating the robotic arm with other components of the UAV system, ensuring reliable and responsive operation during mission-critical tasks.

fig 2.4 Arduino Portenta H7

• Battery: High-capacity LiPo battery to ensure extended flight time and support the additional load of the robotic arm.

fig 2.5 Lipobattery

2.2 Software Components:

• PX4 Autopilot: We selected PX4 Autopilot software for its advanced and versatile capabilities, making it a strong fit for our project. PX4 offers a range of features that are crucial for the sophisticated operations required by our drone. PX4 provides sophisticated flight control algorithms that are essential for achieving precise and stable flight.

• Arduino IDE: Arduino IDE is employed due to its extensive support for programming the Arduino board that controls the robotic arm.

• OpenCV: OpenCV is integral to our project for its advanced computer vision capabilities, which are essential for processing visual data from the FPV camera. A Python script is used to capture frames from the FPV camera and process them for face recognition. The script will use the camera feed to detect faces and compare them against a database of known faces stored on the Raspberry Pi.

2.3 System Integration:

To ensure seamless operation of the UAV system, we have followed an integrated approach which ensures that all the system components work harmoniously, enabling accurate facial recognition, effective flight control, and precise robotic arm operations, all orchestrated by the interconnected hardware and software components.

i. Face Recognition Setup:

- Image Collection: Prior to deployment, a set of images capturing various angles and expressions of the faces to be recognized is collected. These images are crucial for training the facial recognition model.
- Data Preparation: The collected images undergo preprocessing to standardize size and format, enhancing model accuracy. This step includes resizing, normalization, and augmentation.
- Model Training**:** Using OpenCV, a facial recognition model is trained on the processed dataset. This model learns to distinguish between different faces based on the labeled images. After training, the model is tested and refined to ensure high accuracy.
- Deployment: The trained model is stored on the Raspberry Pi, which will be used for real-time facial recognition. Reference images and labels are also saved on the Raspberry Pi for comparison during operations.

ii. UAV Integration with Pixhawk and Raspberry Pi:

- Flight Control: The UAV's flight dynamics are managed by the Pixhawk 2.4.8 flight controller. It processes commands and controls the drone’s stability and navigation, leveraging its advanced sensors and floating-point calculations for precise operations.
- Companion Computing**:** The Raspberry Pi 4B (8GB) serves as the companion computer, interfacing with the Pixhawk through the MAVLink protocol. It handles complex tasks such as real-time processing of the FPV camera feed and executing facial recognition algorithms.

iii. Robotic Arm Integration:

- Hardware Connection: The robotic arm is managed by an Arduino Portenta H7, which is directly connected to the Raspberry Pi. This setup allows the Raspberry Pi to control the robotic arm by sending commands through the Arduino.

- Software Coordination: The Arduino IDE is used to program the Arduino, allowing it to respond to commands from the Raspberry Pi. This integration ensures that the robotic arm can perform tasks such as object handling based on facial recognition results.

vi. FPV Camera Integration:

- Camera Feed: The FPV camera provides a live video feed that is processed by the Raspberry Pi. This feed is crucial for the face recognition system, as it allows the real-time capture and analysis of faces.
- Data Flow: The video feed is streamed to OpenCV running on the Raspberry Pi. The facial recognition model analyzes the feed, compares detected faces with the pre-trained model, and identifies individuals.

v. System Operation:

- Real-Time Processing: During the flight, the FPV camera continuously sends video data to the Raspberry Pi, where the face recognition model identifies faces. The Raspberry Pi then communicates with the Arduino to control the robotic arm based on the recognition results.
- Action Execution: If a recognized face is identified, the system triggers the robotic arm to perform specific actions, such as delivering objects, based on predefined protocols.

2.4 Implementation and Testing

The drone was tested in various scenarios to assess its recognition accuracy and the robotic arm's precision. In controlled environments, the facial recognition system demonstrated a high accuracy rate, successfully identifying individuals and performing tasks with the robotic arm in real-time. Field tests in simulated emergency and military operations validated the system's effectiveness in autonomous aid delivery and targeted actions.

fig. 2 drone with the robotic arm holding a cover

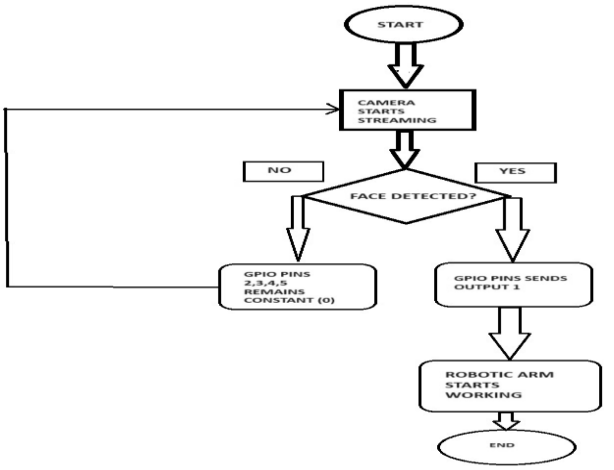

fig. 2.1 Flowchart of Facial Recognition

III. Discussion

The integration of advanced technologies into UAV systems for emergency response and military applications represents a significant advancement in autonomous operation and precision. Our research demonstrates how combining a high-performance Pixhawk flight controller, a powerful Raspberry Pi 4B, a sophisticated FPV camera, and a versatile robotic arm can enhance the functionality and effectiveness of UAV systems.

The Pixhawk 2.4.8 flight controller's selection was driven by its robust computing capabilities and reliability. Its open-source nature and advanced features, including floating-point computations, make it well-suited for managing complex flight dynamics and ensuring stable autonomous operation. The integration with the Raspberry Pi 4B, connected via MAVLink, leverages the Pi's processing power to handle intricate tasks such as facial recognition and real-time data analysis. This combination facilitates the efficient execution of autonomous flight plans while processing and interpreting sensory inputs.

The Raspberry Pi's role extends beyond merely handling computational tasks; it interfaces seamlessly with the FPV camera and the robotic arm. The FPV camera's real-time video feed is crucial for the facial recognition system implemented using OpenCV. By processing images captured by the camera, the system can identify individuals and execute corresponding actions with the robotic arm. The use of OpenCV for facial recognition allows for the precise and reliable identification of faces based on a pre-trained model, ensuring that the system performs accurately in dynamic environments.

The robotic arm, controlled by an Arduino Portenta H7, adds another layer of functionality by enabling physical interaction with objects. The integration of the Arduino IDE for programming the arm ensures that it can be precisely controlled in response to commands from the Raspberry Pi. This integration facilitates tasks such as object delivery, further enhancing the UAV's operational capabilities.

Overall, the integration of these components demonstrates a significant advancement in UAV technology, merging precise control, real-time processing, and automated physical actions. The successful implementation of this system highlights the potential for future enhancements, including increased accuracy in facial recognition, improved control algorithms, and expanded functionality of the robotic arm. These advancements could further elevate the effectiveness of UAV systems in critical applications, offering new possibilities for emergency response and military operations.

IV. Conclusion

The drone system developed in this study represents a significant step forward in the field of autonomous intervention technology, particularly in the contexts of emergency aid, delivery, and military operations. By effectively integrating AI-driven facial recognition, real-time video processing, and robotic manipulation, the drone is capable of performing complex, targeted tasks with minimal human intervention. This capability is particularly valuable in situations where rapid response and precision are critical, such as delivering medical supplies in disaster-stricken areas or executing targeted surveillance and actions in military operations.

The modular architecture of the system, leveraging the strengths of the Pixhawk flight controller, Raspberry Pi 4B, and Arduino Portenta H7, allows for specialized processing and control functions, contributing to the overall reliability and efficiency of the drone. This design also facilitates future enhancements, as each component can be upgraded or replaced without disrupting the entire system.

However, to fully realize the potential of this technology, further research and development are necessary. Enhancements to the facial recognition system, such as incorporating machine learning techniques to improve accuracy in varying conditions, would significantly increase the system's robustness. Additionally, improving the drone's operational range and flight stability through advanced navigation algorithms and more powerful hardware would extend its usability in more challenging environments. Expanding the capabilities of the robotic arm to handle a broader range of objects and perform more intricate tasks would also make the drone more versatile and effective in diverse operational scenarios.

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