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Tricopter Based Aerial Transport Maintaining Organ Viability Through Controlled Flight and Temperature

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***Abstract*— Emergency organ transportation demands rapid, reliable, and thermally controlled delivery systems to preserve organ viability. Conventional logistics and existing unmanned aerial vehicle studies are limited by traffic dependency, simulation-only validation, lack of active cooling, and insufficient emergency handling under real-flight conditions. A tricopter-based aerial system integrating precision flight control, a medical payload container, and thermoelectric cooling is presented to address these limitations. The system employs PID-based stabilization, real-time sensor monitoring, and a Peltier module to maintain container temperature during flight. Experimental evaluation demonstrates stable operation with nominal battery voltage of 11.1 V, hover current draw of 4.5 A, maximum motor speed of 8500 RPM, and attitude response times below 0.2 s. Orientation deviation remains within ±2 degrees, achieving a maximum flight duration of 12 minutes. Compared to prior simulation-centric or vision-only studies, the results confirm improved real-world stability, payload safety, and emergency readiness. Overall findings validate the feasibility of tricopter-based emergency organ transport for short-range medical missions.**

Keywords*— *Autonomous Aerial Vehicle, Emergency Medical Transportation, Organ Preservation, Precision Flight Control, Thermoelectric Cooling

I. INTRODUCTION

Transplantation is a very sensitive procedure because organs are sensitive and delay in transportation has a direct effect on the organ life and survival of the patient [1], [2]. The traditional logistic operations such as road ambulance and air helicopter operations are usually limited by the traffic jams, weather conditions, expensive operation, and low accessibility in crowded urban areas [3]. The latest developments in unmanned aerial vehicles have brought about drones as a possible solution to medical logistics, such as blood samples transportation and emergency supply delivery [4]. However, the majority of the current UAV-based medical systems are optimized to lightweight payloads and short-range use, and they do not provide organ-specific features, including thermal stability, vibration isolation, and emergency operation stability [5], [6]. Also, the quadcopter-dominant designs have high power consumption and fault tolerance, which makes them less viable in life-critical missions [7], [8].

New inventions have been made on autonomous navigation, GPS-based routing, and load monitoring in medical drones but there has been little focus on optimization of the drone architecture towards emergency organ transportation [9]. The current literature does not pay much attention to the problem of integrated cooling and real-time thermal control that is necessary to maintain transplant organs. In addition, response facilities like safe landing, compensating motor imbalances and system redundancy are not adequately tackled. The current paper suggests a design of a tricopter-based UAV optimized to emergency medical delivery, that is, incorporating a dedicated organ container and thermoelectric Peltier cooling. The system uses accuracy of flight control, real-time temperature sensors and emergency stabilization systems to enhance quick and dependable delivery of organs in emergency cases.

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A. Problem Statement

Current research on the medical drone delivery is mainly based on general logistics but not on the life-threatening situations of organ transplantation. The majority of UAV platforms do not have active thermoregulation and instead have passive insulation, which does not provide the tight thermal range necessary to preserve organs [10]. Designs with quadcopter offer increased power use and low endurance with medical cargo, and failover systems are scarcely investigated [11]. Moreover, little of the existing studies combines cooling, navigation, and safety control into one concept. These constraints present a major research gap on the development of a lightweight, energy-efficient and thermally controlled UAV system that more specifically target emergency organ transportation, and have strong safety and reliability characteristics.

B. Research Motivation

The growing need to have timely organ transplantation and the constant constraints of traditional means of transport prompt the quest of alternative delivery mechanisms. The development of UAV technology gives a chance to reorganize medical logistics on the basis of energy-efficient structures and built-in cooling. The creation of a dedicated tricopter platform that would maintain the organ quality during the emergency transportation will fill one of the most important gaps between the needs of medical use and the current drone system.

C. Research Significance

The suggested research involves the contribution to the emergency healthcare logistics by presenting a UAV system based on tricopters adapted to the organ transplantation. Combination of thermoelectric cooling, precise flight control and safety backup technologies make transport more reliable and preserve the organs. The results are positive towards the application of UAV-based systems of assisting medical transport in the future, which may lead to a shorter ischemic duration, better effectiveness of transplantation, and more robust healthcare infrastructure of quick response.

D. Key Contributions

- Design of a tricopter UAV architecture optimized for emergency medical organ transportation with reduced power consumption.
- Development of a dedicated medical payload container incorporating active Peltier-based thermoelectric cooling.
- Integration of real-time temperature monitoring and feedback-controlled thermal regulation during flight.
- Implementation of emergency stabilization and safe-landing mechanisms to enhance operational reliability.
- Experimental evaluation of flight performance, thermal stability, and delivery feasibility under medical payload conditions.

The remaining of the study is organized as follows. Section II provide an extensive review of the literature that discusses the existing models and their limitations. Section III, elaborate on the proposed approach. Section IV present the experimental results and interpretation. The conclusion and future research directions, limitations, and recommendations are discussed in Section V.

II. Literature Review

Drones research has already achieved a high level of success in autonomous navigation, visual perception, and flight control each of which has a different impact on the overall performance of unmanned aerial vehicles. Foehn et al. [12] introduce a vision-based drone racing system that is able to navigate at high speed through nonlinear filtering and time-optimal trajectory planners. Though suitable in competitive settings, the research focuses more on speed as opposed to stability, load carrying and real-life medical use. Aydin and Singha [13] present a YOLOv5-based system that can identify drone misuse, which proves to be more accurate in detecting drone misuse with the help of transfer learning and data augmentation. Nonetheless, it is a research that only considers aerial object recognition but does not cover physical drone implementation and flight control. On the same note, Jung and Choi [14] maximize the robustness of visual detections in unfavorable scenarios with an enhanced version of the YOLOv5 architecture, but they do not take into account the propulsion dynamics, sensor fusion, and payload stability. Mariani and Fiori [15] propose an evolutionary neural controller that controls a quadcopter in case of navigation, but confine the validation to a simulation on the control side. Elagib and Karaarslan [16] use dynamic modeling and apply sliding mode control to control the attitude, again restricted to the evaluation being performed on a computer. In general, there is a lack of integrated hardware verification, a real-flight stability test, thermal load control, and emergency response in the currently studied tricopter based emergency organ transportation system which focuses on perception or simulated control.

The shortcomings encountered by the current studies are overcome with a complete hardware and software-validated tricopter system in the present research that is to be used in the field as an emergency medical unit. In contrast to vision-based or simulation-only systems, the suggested system is a physical flight control system that incorporates real-time motor behavior analysis and onboard sensor feedback under real operating conditions. A dedicated medical container with shock isolation and active thermoelectric cooling is provided to ensure stable payload handling, which has not been done in previous works. Reliability is also improved by emergency detection and safe landing mechanisms in addition to simulated control models. Through experimental flight

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testing that proved the stability, thermal regulation, and emergency response of the study, it can be seen that there is feasibility in practice and that the gap between the theoretical UAV research and life-saving medical applications is bridged.

III. Proposed Methodology for Emergency Organ Transportation Using a Tricopter Aerial Platform

The proposed system includes the emergency medical tricopter UAV that is meant to be used in time-sensitive organ transportation. The system combines lightweight tricopter airframe, embedded flight control unit, special medical payload container, and thermoelectric cooling module to make it safe and reliable to deliver. The stability of flights, the integrity of the cargo, and the temperature inside the containers are monitored by sensors in the course of the mission. Compared to traditional quadcopter platforms, the tricopter design has less weight on structure, less power, and higher maneuverability to meet the needs of a fast delivery to a congested city environment. The directional movement and stable hovering during takeoff and landing are made possible by the use of a servo-based mechanism to provide yaw control. All the stages of the work are regulated by an emergency-driven design philosophy, the main priorities of which are system reliability, fault detection, and safe landing protocols. The organ is placed in the cooled container, the tricopter flies automatically along a fixed route and real-time health and temperature monitoring is made to guarantee conservation until the moment of the exact delivery in the destination facility, in a typical hospital-to-hospital setup. Fig. 1 shows the process of the proposed system.

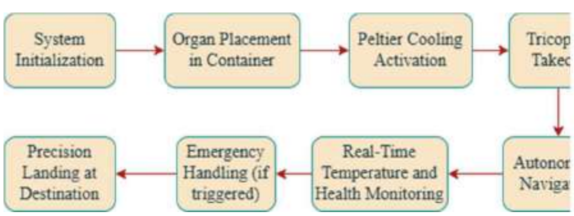

Fig. 1. Workflow of Proposed System

A. *Tricopter Mechanical Design*

The tricopter uses a three-motor design by having two fixed front motors and one rear motor that actuates the yaw. The motors are paired with high efficiency propellers that are optimized to produce thrust and conserve energy. The three-motor design has fewer mechanical parts and consumes less power compared to quadcopter designs and still has adequate lift capabilities to carry medical cargo. To be able to fly stably, the total force of the tricopter should be greater than the total system weight as shown to be:

$$T_{\text{total}} = T_1 + T_2 + T_3 > W \quad (1)$$

Where, T_1, T_2, T_3 represent the thrust produced by individual motors and W denotes the total system weight including payload. This configuration enhances endurance and allows rapid acceleration during emergency deployment scenarios. Yaw control in the tricopter is achieved through a servo-actuated tilting mechanism mounted on the rear motor. Unlike differential thrust-based yaw control used in quadcopters, the tricopter modifies the thrust vector direction of the rear motor to generate a yaw moment. The yaw torque τ_y can be represented as

$$\tau_y = T_3 \cdot L \cdot \sin(\theta) \quad (2)$$

Where T_3 is the rear motor thrust, L is the arm length from the center of mass, and θ is the tilt angle induced by the servo. This mechanism provides precise yaw control with minimal power loss, improving maneuverability during directional changes and precision landings. The servo-based yaw system also enhances fault tolerance, as directional stability can be maintained without aggressive motor speed variations. Overall, the tricopter mechanical design achieves a balance between structural simplicity, aerodynamic efficiency, and control precision, making it suitable for emergency medical missions requiring reliability, agility, and payload safety.

B. *Flight Control Unit*

The flight control unit (FCU) is the heart of the proposed tricopter system and it is capable of holding a balance, precision in navigation and safe flight in an emergency medical mission. The FCU is a real time embedded system that brings sensor data acquisition, control algorithm execution and actuator command generation together. Its main aim is to give it a stable flight under different payload conditions with the ability to give it an exact maneuvering needed to transport hospital-to-hospital organs.

The attitude of the tricopter is stabilized using PID-based techniques in roll, pitch and yaw directions. The Proportional-Integral-Derivative (PID) control is chosen because it is simple, strong and applicable in real-time context in UAVs. The controller constantly calculates the difference between the desired and measured values of attitude and produces corrective control signals to change the motor thrust and the yaw servo position. The law of PID control is written as

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt} \quad (3)$$

Where, $e(t)$ represents the attitude error, K_p, K_i, and K_d denote the proportional, integral, and derivative gains, respectively, and $u(t)$ is the control output. The proportional term ensures immediate response, the integral term minimizes steady-state error, and the derivative term improves damping and reduces oscillations, resulting in smooth and stable flight even during sudden payload-induced disturbances.

The aspect of sensor integration is quite important in facilitating the correct state estimation and control. The IMU is an Inertial Measurement Unit which is a three-axis accelerator and gyroscope that gives high-frequency measurements of the angular velocity and the linear acceleration. Nevertheless, IMU data are prone to noise and drift, hence, sensor fusion methods

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are used to enhance reliability. A complementary or Kalman-based filtering algorithm uses a combination of accelerator and gyroscopes to have steady and reliable orientation values.

The GPS data are integrated to facilitate the navigation, position maintenance, and autonomous flight using way points. GPS has an absolute position and velocity data, which allow the tricopter to track predetermined hospital-to-hospital directions with minimal human intervention. At the time of flight, IMU data provide short-term positional accuracy of the motion, whereas GPS data fixes the long-term drift. The fused position estimate may be expressed as

$$\hat{x} = \alpha x_{\text{IMU}} + (1 - \alpha) x_{\text{GPS}} \quad (4)$$

Where $\hat{x}$ is the estimated state and α is a weighting factor determined by sensor reliability. Through the integration of PID-based stabilization and multi-sensor fusion, the flight control unit ensures precise attitude control, reliable navigation, and robust performance under emergency medical transport conditions.

C. *Medical Payload Container*

An emergency transportation-related medical payload container is a vital subsystem of the suggested tricopter UAV, designed in such a way that the viability of organs is maintained. The container design has been designed to focus on the sterility, mechanical protection and minimum weight to ensure that it is compatible with the flight characteristics and medical needs of organ transplantation. It is firmly fixed on the center of gravity of the tricopter to ensure that it balances and minimizes disturbances of attitudinal dynamics in flight.

D. *Peltier Cooling Module*

The Peltier cooling module is integrated into the proposed medical payload container to maintain the strict thermal conditions required for transplant organ preservation during emergency transport. The thermoelectric principle is based on the Peltier effect, where heat is absorbed or released at the junction of two dissimilar semiconductor materials when an electric current flows through them. When powered, one side of the Peltier device becomes cold while the opposite side dissipates heat. The cooling capacity Q_c of the module can be expressed as

$$Q_c = \alpha I T_c - \frac{1}{2} I^2 R - K(T_h - T_c) \quad (5)$$

Where, α is the Seebeck coefficient, I is the input current, T_c and T_h represent the cold and hot side temperatures, R is the electrical resistance, and K is the thermal conductance. This relationship highlights the dependence of cooling performance on electrical input and temperature difference. A heat sink and forced air dissipation mechanism are attached to the hot side to efficiently remove excess heat and sustain continuous cooling operation.

The temperature control range is maintained between 2 °C and 8 °C, which is the clinically recommended range for preserving organs such as kidneys and hearts during transportation. Temperature sensors placed inside the container provide real-time feedback to the control unit, enabling closed-loop regulation. The cooling system dynamically adjusts the Peltier input current to counteract external temperature variations and heat generated by environmental exposure. The temperature error e_T is defined as

$$e_T = T_{\text{set}} - T_{\text{measured}} \quad (6)$$

Where, T_{set} lies within the desired preservation range. This feedback-driven control ensures minimal temperature deviation and uniform cooling throughout the payload chamber. Power management is a critical aspect of the Peltier module due to its relatively high energy demand compared to passive cooling methods. The cooling system is powered through the UAV's onboard battery via a regulated DC–DC converter to ensure stable voltage supply. The electrical power consumption P of the module is given by

$$P = V \times I \quad (7)$$

Where, V is the supply voltage and I is the operating current. To optimize energy usage, the cooling module operates intermittently based on temperature thresholds rather than continuous full-power operation. Priority-based power allocation ensures that flight stability and navigation systems remain unaffected during peak cooling demand. Through thermoelectric cooling, controlled temperature regulation, and efficient power management, the Peltier module enables reliable organ preservation while maintaining overall system endurance and flight safety, making it well suited for emergency medical UAV applications.

E. *Control and Emergency Mechanism*

Control and emergency mechanism is meant to achieve reliable flight operation and safe mission completion during the normal and abnormal conditions. Since organ transportation is a life-critical activity, the system also emphasizes on stability, responsiveness, and fault tolerance throughout the operations. The control logic combines sensor feedback in real-time with predetermined safety limits to assist in sustaining constant monitoring and quick decision-making.

Algorithm 1: Tricopter emergency organ transport

```
// initialize system
    initialize flight controller
    initialize sensors imu gps temperature
    initialize motors bldc via esc
    initialize peltier module
initialize battery monitor
// load organ into payload container
    load organ
    activate peltier control target temperature five degrees
// preflight checks
    if system check not passed
      abort mission
    end if
// takeoff sequence
    arm motors
takeoff to altitude target altitude
// main flight loop
```


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```
while destination not reached
   read sensors
   compute attitude errors roll pitch yaw
   pid stabilization
   update motor speeds
   adjust yaw servo
   control lateral movement left right
   maintain hover if needed
// monitor emergency conditions
   if battery voltage below minimum or
     temperature above maximum or
     motor speed out of range
      trigger emergency landing
      break
   end if
end while
// landing sequence
   descend safely
   disarm motors
deactivate peltier module
// mission complete
   log mission data
end algorithm
```

The autonomous flight is controlled by Algorithm 1 as well as the organ security and reliability of the mission. It also opens all hardware and sensors, sets on the Peltier cooling system, and conducts pre-flight inspections. It constantly corrects the attitude with PID control during flight, controls lateral movement and hovering, and monitors important parameters, including battery voltage, motor performance, and container temperature. The algorithm will activate safe emergency landing and record mission data in case of anomalies.

The developed approach combines tricopter UAV construction, accurate flight control, and medical cargo to allow transporting organs fast and safely. The system starts with the pre-flight program of the flight controller, sensors, motors and the Peltier cooling system, and then the loading of the organ into a shock-isolated, sterile container. PID-based stabilization ensures the control of the attitude in roll, pitch, and yaw directions and, in addition, the adjustments of the yaw servo enable a perfect lateral maneuvering and hover by using the differential thrust. Real-time sensor data from the IMU, GPS, battery, and temperature module are continuously monitored to detect anomalies. Upon detecting battery depletion, motor malfunction, or temperature deviation, emergency protocols trigger safe landing at the nearest designated zone. The Peltier module maintains organ temperature within 2–8°C during the mission, ensuring viability. Post-flight, system logs are recorded to evaluate performance, cooling efficiency, and operational reliability.

IV. Result and Discussion

The tricopter UAV is shown to be effective in the emergency organ transportation missions as the results of the experiment show. Flight performance check-up established the constant thrust, accurate attitude leveling and lateral maneuvering, thereby ensuring that critical tasks could be performed with proper navigation and hovering. The medical payload container kept the required level of temperature in the necessary clinical range and the Peltier cooling module provided the stability of temperature control throughout the flight. Mechanisms of shock isolation reduced effectively vibrations and mechanical disturbances, which preserved the integrity of organs. Emergency handling procedures were also effective tested, as the system identified irregularities in the battery performance, operation of the motors, and temperature of containers, and triggered controlled emergency landing operation. Even in fault conditions of the landing, preciseness was attained, which implied safe delivery of payload.

A. Flight Performance Analysis

The analysis of the flight performance is aimed at analyzing the stability, maneuverability, and the responsiveness of the tricopter UAV when performing organ delivery missions. Stability of motor thrust and RPM is constantly being controlled to maintain uniform lift production and equal distribution of power among the three rotors which is needed in maintaining flight efficiency and to avoid overloading of the motors. The control of roll, pitch and yaw is used to determine attitude stability and the adjustments made using PID compensate any disturbances in the environment, changes in the payload, and any abrupt change of direction. Lateral maneuver and hover control are examined to confirm the capability of the UAV to work in small corridors, to stay still during precision operations and controlled approach and landing procedures. The recorded performance measures are analyzed to detect the variances of the desired performance, which is used in future refinements of the control algorithms.

Fig. 2. Top view of Tricopter

Fig. 2 shows the entire hardware system including motor arms, propellers and central electronic parts, which are used as a visual guide to the system configuration.

B. Payload Condition and Cooling Efficiency

The payload condition and cooling efficiency analysis aims at keeping the organs alive during transportation emergencies. The medical container kept temperatures at the crucial range of 2-8º C, which kept the organ in clinically safe range during the flight. The assembled Peltier cooling system was shown to have a

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consistent thermal control, with real-time feedback of temperature sensors allowing the automatic correction of the system with the external temperature variations. The performance of the cooling with time was studied to ensure that the deviation is minimal to the set range, which shows the stability of the system. Further, shock isolation was tested to determine the capacity of the container to reduce vibration and unexpected impacts during takeoff, flight, and landing. The thermal and mechanical protection also worked together to make sure that organs were not exposed to changes in temperature and even physical disturbances.

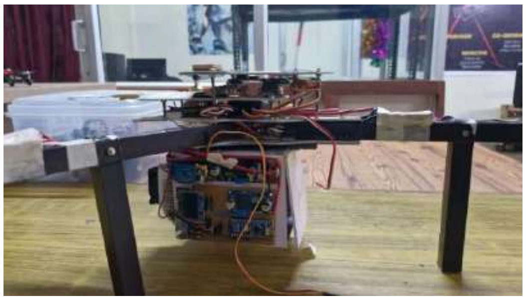

Fig. 3. Side view of drone electronics

Fig. 3 displays the arrangement of the flight controller, ESCs, and sensor modules, showing how the electronics are integrated for signal processing and stability control.

TABLE I. PERFORMANCE PARAMETERS OF THE TRICOPTER UAV

Parameter	Observed Value
Battery Voltage	11.1
Battery Current Draw	4.5
Maximum Motor RPM	8500
Average Motor PWM	60
Hover Thrust per Motor	1.2
Pitch Response Time	0.15
Roll Response Time	0.16
Yaw Response Time	0.18
Maximum Flight Time	12
Orientation Stability Deviation	±2
Peltier Temp Range	2–8

Table I summarizes the observed electrical, mechanical, and flight performance parameters of the tricopter UAV during test flights.

C. Discussion

The flight tests verified the tricopter UAV with the standard performance at the target load and the required working conditions. The battery voltage was 11.1 V and the hover current draw was 4.5 A, which showed that there was enough power to deliver flight sustainably. Motors reached maximum RPM of 8500 and an average PWM duty cycle of 60 and gave the motors a stable hover thrust of 1.2 kg. The attitude responses under PID-controlled conditions were rapid and stabilized within 0.15, 0.16, and 0.18 seconds of pitch, roll, and yaw respectively and orientation deviations stabilized within ± 2 degrees, which can be taken as evidence of precise control. Top flight time was 12 minutes fully loaded in the battery, which proved that it had enough endurance in making short-range hospital-to-hospital delivery.

V. Conclusion and Futurework

This paper is an analysis of a tricopter UAV system, which is specifically targeted at emergency organ transport by combining accurate flight control, a medical payload container, and Peltier cooling module. The results of the experiment show the stability of the thrust, quick attitude control, successful lateral maneuvering, and constant thermal regulation, which guarantees the organ viability in transit. Emergency management protocols were able to ensure safe functioning in the conditions of battery anomalies, motor anomalies, and temperature anomalies. There are however limitations such as low flight endurance capacity because of battery capacity, weight capacity and exclusion to unfavorable weather conditions. The integrated design can cope with such limitations, however it is suitable to meet the specifications of fast, safe, and reliable delivery of organs in short distances offering a promising solution in improving the time-sensitive medical logistics in urban areas.

The next steps in future research can be the extension of the flight duration by the use of the more significant capacity or hybrid power system and an increased optimization of the design of the payload containers used to carry bigger organs. Adding sophisticated navigation algorithms, including AI-based path planning and obstacle avoidance algorithms can be used to improve the performance of autonomous vehicles in busy cities. Several drone coordination and swarm-based delivery solutions can be further used to enhance efficiency and coverage. Constant feedback on the status of organs can be received through integration with real-time networks of hospital communication and monitoring based on IoT. Also, the environmental resilience can be increased by testing the performance in different weather conditions, such as the wind, temperature, and precipitation, to guarantee the operational dependability on emergencies medical operations.

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