ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)

Volume 11 Issue 09 September 2024

Hexacopter with Gripper for Aerial Transportation

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Abstract*— Robotic grippers have become an emerging trend due to their boundless applications in industrial automation. A gripper is a mechanism that allows you to manipulate the holding of an object. A gripper can grab, tighten, handle, and release an object. Deploying unmanned aerial vehicles, especially Hexacopter for last-mile delivery is the aim of this project. The Proposed work has the ability to autonomously carry a payload minimum of 10 kg. In this project, a robotic gripper with the ability to grab objects is attached to the drone to carry the load autonomously. With the increasing capabilities of robotic systems, their applications have been promoted from industrial areas with simple and repetitive tasks to more unknown areas with more complicated applications. The robotic gripper arm is controlled by the Digital servo motors which are used to grab the load. The gripper is configured using the Arduino boards. The hardware part of Arduino comprises Arduino boards, input and output devices (including digital and analog pins, and sensor actuators), shields, breadboards, jumper wires, and so on. The software consists of the development tools needed to write, debug, compile, and upload code to Arduino boards. Most of the software tools are available in the Arduino IDE (Integrated Development Environment). Arduino boards are programmed in C.

***Index Terms*— Arduino, Hexacopter, Robotic Gripper**

I. INTRODUCTION

Multi-rotor aircraft are typically small unmanned aerial vehicles (UAVs) used for aerial photography, Traffic Monitoring, Aerial Measurements, Fire Detection, Monitoring, and Extinguishing, [13] surveillance, and recreational flying. Multi-rotor aircraft are popular due to their simplicity, agility, and ease of control. Dynamic aerial grasping [1] is a recent research challenge that bears much potential to enable many new applications in automation and hard to reach places. Multi-copters and soft robotic grippers are a natural match for aerial manipulation as they are easy to maneuver and provide much versatility as a research platform. These properties have been beneficial for multi-copter in a wide range of applications such as point-to-point deliveries [2] and aerial manipulation [3]. While there is extensive previous work on normal flights, recent approaches continue to incorporate new features of Rotorcraft platforms [4],[5],[6]. The arm-like structure of an industrial robot is known as a robot manipulator. An end-of-arm tooling (EOAT) device is an attachment that enables a robotic arm to manipulate things. End of arm tooling devices, like grippers allows the drone used in machine automation to manipulate and move an object. Mechanical grippers can be either two-fingered or three-fingered, depending on the gripping requirements.Mechanical grippers find applications in industries such as automotive manufacturing, where they are used for material handling , pick and place operations.

II. RELATED WORK

Combining robotic grippers with flying platforms opens a new dimension for aerial object transfer. Hiranmayee Panchangam[10] developed a mini controller arm which picks and places things as desired,the control the Robotic arm not only by using the wired controls, but with the aid of the Internet of Things which introduces automation in the system. J. Fishman, S. Ubellacker, N. Hughes, and L. Carlone [1] creates soft drone - a quadrotor where traditional landing gears are replaced with a soft tendon-actuated gripper to enable aggressive grasping.Tae-Yoon Kim and Jae-Hyun Kim [4] designed an unmanned aerial system (UAS) in a surveillance environment that includes a relay system.System provides the drone communication from Ground Control Station(GCS) to the long-distance areas that want to observe through wireless communication enhancement in dangerous situations. Surveillance drone records video, and it is used to find specific people in dangerous areas. Viral Kumar Goyal , Abhishek Kamal , Adarsh , Pratapbhan Singh , Vernika Singh [6] Quadcopter of plastic fame and polycarbonate propellers with "TS832 transmitter" used to transmit and "RC832S receiver" to receive signal from the Remote Controller. An arduino module is attached to the digicam which sends the data in the form of video and images to the control center. Haar cascade classifier to detect human face and LBPH algorithm that recognize human. Ron Oommen Thomas and Prof. K. Rajasekaran [11] designed a robotic arm controlled by using the raspberry pi module .It monitors the movements and actions of robotic arm.

III. PROPOSED WORK

This project aims at introducing a multi-rotor that can fly to the accident spot with the required medical aid like Automated External Defibrillator (AED), Cardio Pulmonary

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Resuscitation (CPR) and can be used to transport blood products ,mini oxygen cylinders and even human organs. The main purpose of this project is to develop a drone which can carry the load from one place and drop it in the another place. This project uses a 6-motor drone which is called Hexacopter which increases the stability during the flight and also increases the load-carrying capacity. The Drone lifts the carrier box using the gripper which is attached to the base of the Hexacopter. The Tower Pro MG995 Servo Motors, each attached to a mechanical arm metal claw are the foundation of the Gripper's design. A gripper module, which consists of four arms each driven by a high-speed servomotor. An Arduino Nano microcontroller controls each of the four arms of the gripper module, which is fastened to the drone's underside. The drone's flight controller and Arduino are connected. The Mission Planner software used in this project controls the drone's location and allows it to function autonomously.The Drone returns to its original location using the one-touch return mechanism once the task is completed.

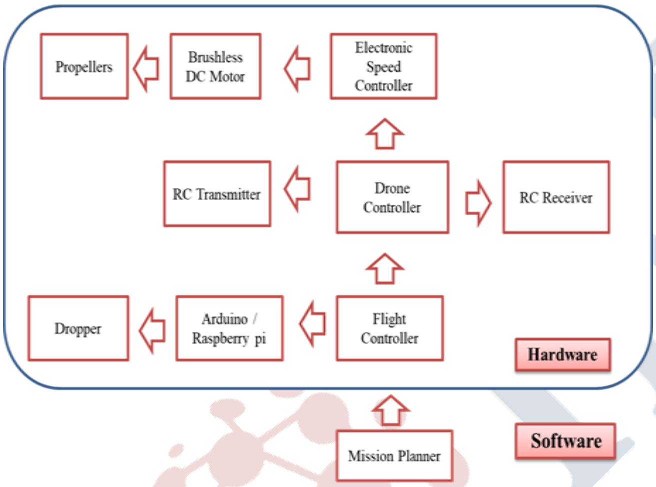

Fig 1: Block Diagram of the Proposed system

IV. SYSTEM ARCHITECTURE

A. System Components

For structures just like the drone, there exist already off-the shelf components that allow us to compose our systems reducing the need for specialized development. This permits us to focus on creating a strong gripping system. Our system consists of three subsystems: the drone, the gripper module, offboard components, and Middlewares.

1) Drone Body:

Hexacopters are very similar to the quadcopters, but they provide more lifting capacity with the extra motors. The hexacopter [12] has 6 motors mounted typically 60 degree apart on a symmetric frame, with three sets of CW and CCW motors/propellers. We placed the different components to provide easy access to the various functional units. We modified the EFT E610 platform to achieve our objective of a lightweight design .The drone's body is comprised of industrial materials such as cardon fibre, making it extremely sturdy and smooth.The foldable propellers make it simple to transport.

- To keep the weight of the drone as low as possible EFT E610 carbon fiber frame is used
- Carbon fiber is used in the drone’s structure or frame because of its high strength and light weight.
- **Frame weight -** 5 kg approx
- **Wheel base** - 1404mm
- **Arm diameter** – 30 mm (6 axis)
- **Opening size -** 1495 X 1308 X 500mm
- **Folding size -** 945 X 848 X 500mm
- **Landing Gear** – 304 mm height
- **Supports take off weight** – 35 kg

2) Motor and Propeller :

Weight of drone = Mass (Frame weight + batteries + Equipment weight) x gravity
Weight = 35(approx) x 9.81
Total thrust= 343.35 N or 35 kgf
(1kgf = 9.8 N)
Since we are using hexacopter i.e 6 propellers
Thrust per motor = Total Thrust/number of motors
Thrust per motor= 35 / 6
Each propeller Thrust = 11.667 kg

Here we use Hobbywing XRotor X6 Plus Motor with the following specification:

- Motor KV Rating -180 kV
- Have inbuilt ESC – No ESC needed
- Fibre Tube Propeller -2480
- Max Thrust: 11.8 kg
- Recommended Weight - 3-5 kg
- Battery – 12 S

Fig 2: Hobbywing XRotor X6 Plus Motor

To determine the propeller size we have to follow certain parameters:

- Drone frame size determines the diameter of the propeller
- Calculate the straight line distance between 2 adjacent axes and the angle between them, the distance is the max of the propeller

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- To find the distance between the axes, we use cosine formula,

$$c^2 = a^2 + b^2 - 2ab\cos(\gamma)$$

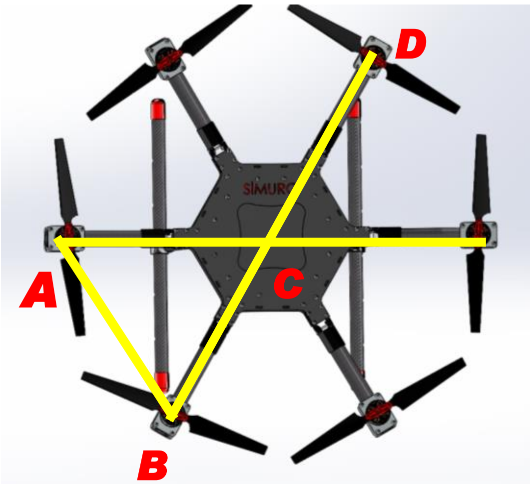

Fig 3: Angle of Hexacopter Frame

We used the frame of Wheelbase - 862mm

$AB^2 = AC^2 + BC^2 - 2AC \cdot BC \cdot COS(\beta)$

$= 431^2 + 431^2 - 2(431)(431)(COS\ 0)$

$= 185761 + 185761 - 2(431)(431)(0)$

$AB^2 = 371522mm$

1 inch = 25.4mm

AB =609.53/25.4

AB =23.99 ~ 24 inch

Hence we use 23-24 inch propeller.

3) *Flight Controller*

The flight controller is the brain of the hexacopter drone, responsible for interpreting pilot inputs and sensor data to maintain stability and control during flight. It utilizes various sensors, Several flight controller options are available in the market,we choose Jiyi K++ Version 2 Flight Controller.

Electronic Speed Controller is an electronic circuit which is used to change the speed and direction of brushless motor. Basically, an ESC converts DC battery power into 3-phase AC for driving Hobbywing X6 BLDC Motors. Here we use Hobbywing Skywalker- 80A UBEC which comes with the BEC, battery eliminator circuit, which delivers the electric power to other circuitry without the need for multiple batteries.

Specification of the Flight controller

- Supported frame types:
  Quadcopter (+, X)
  Hexacopter (+, X, IY and YI coaxial twins)
  Octocopter (+ type, X type, V type)
- Supports ESC control: up to 1000Hz
- Supported receiver types: PPM, S-BUS receiver
- Supported ESC type: 490HZ or less PWM ESC
- Power consumption: less than 5W
- SBUS receiver Maximum vertical speed: 6 m / s
- Hardware specification

The Jiyi K ++ V2 flight controller comes with two Power Management Unit (PMU's), GPS,FC,LED. Jiyi K ++ V2 flight controller is configured by the Jiyi K ++ V2 flight controller software

Fig 4: Jiyi K ++ V2 flight controller

4) *Remote Controller*

Drone controllers serve as the primary interface between the pilot and the drone, allowing for seamless control over its flight and movements. They consist of a transmitter, responsible for sending signals to the drone, and a receiver, which receives signals from the drone. Communicating through radio frequencies, typically in the 2.4 GHz range, drone controllers enable pilots to command their drones with precision and accuracy.A drone transmitter uses many frequencies like 27MHz, 72MHz – older frequencies ,433Mhz, 900Mhz, and 1.3GHz – long range FPV and RC system ,2.4Ghz – Provides Frequency Hoping . Most transmitters work on 2.4GHz for accuracy.

The range of a drone's controller depends on factors such as frequency, power, and interference.

We can determine the range of a RF by using the equation,

$$R = (10^{(Pt + Gt + Gr - Pr - Lf + 60)/20}) / 41.88 * F$$

Where,
Pt = Transmission Power
Gt = Transmitting Antenna Gain
Gr = Receiver Antenna Gain
Pr = Receiver Sensitivity
Lf = Loss factor
F = frequency of the signal

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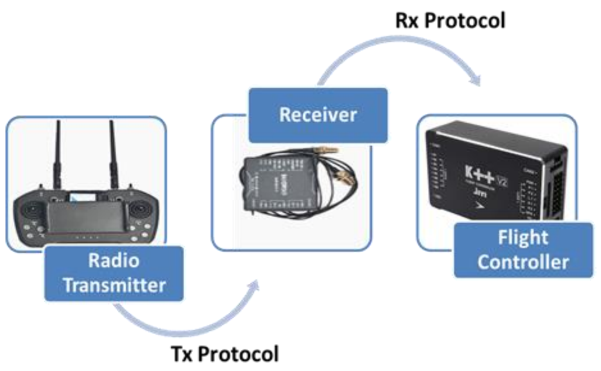

Fig 5: Tx & Rx Protocol

Here we use Skydroid T12 Remote Controller with specification:

- **Frequency:** 2.400-2.4833GHz
- **Duration:** 25 hours
- Uses the latest FHSS technology (Frequency hopping Spread Spectrum)
- up to **20 KM** transmission

Fig 6: Skydroid T12 Remote Controller

5) Gripper Architecture

An end-of-arm tooling (EOAT) device is an attachment that enables a robotic arm to manipulate things. EOAT provides a "hand" that can perform a variety of functions. There are numerous end-of-arm tooling devices available. One of the most prevalent kinds of end of arm tooling is the gripper, which can grasp and release parts in an automation project. Most grippers or pick-and-place units have precise mounting surfaces for specific attachments. The Gripper is designed with four Tower Pro MG995 Servo Motor each connected with Mechanical Arm Metal Claws. The Gripper arm's Claw is made up of aluminum alloy material with the Degree of Freedom (DOF) two. The Servo motors are used to perform "twist" and "grasp" movements to manipulate objects with the gripper. The Arduino is used to to optimize robotic control. The servos can control the gripper to open upto 55mm from closed state.

Determining the griping force and torque required to Pick an object

Grip Force = Part Weight x (1+Part Gs) x Jaw Style factor
Grip Force Required = 10 kg x 3 x 1 = 30 kg
Jaw Torque = Jaw Length x Grip Force
Jaw Torque = 4" x 30 pounds = 120 kg
Part Torque= Jaw Length x Part weight x Acceleration
Part Torque = 4" x 10 kg x 2 = 80 kg
Total Torque = Jaw Torque + Part Torque
Total Torque: 120 kg + 80 = 200 kg
Specifications: 10 kg of grip force, 200 kg of torque

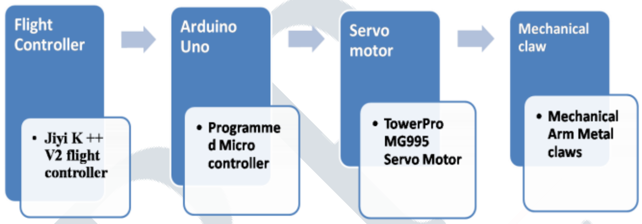

Fig: 7 Flow diagram of Gripper model

B. Software Components

1) Flight Control Software

Jiyi K ++ V2 flight control software includes four functional interfaces:

- Viewing,
- Basic,
- Advanced and
- Tools

2) ARDUINO UNO

The Arduino Web Editor is a web-based integrated development environment that includes online storage. The Arduino IDE, as it is often known, is an integrated development environment. To program your board, first write a program, then compile it into machine code, and finally deliver the new program to your board. The Arduino IDE makes all of this possible, from the first line of code written to its execution on the Arduino board's microcontroller. It is a program or application that may be downloaded (or used online) to manage your entire code development process.

There are three Arduino IDEs available:

- Arduino IDE 1.8.x (classic)
- Arduino IDE 2 (new)
- Arduino Web Editor (online)

V. EXPERIMENTAL RESULTS

Experiment is carried on with the model to check the loading capacity of the model. The model is subjected to carry the load of different weights.

Below Table shows the success rates to pick up the object for the 15 attempts for weights 1kg, 2kg, 5kg, 7kg and 10kg.The object of each weights is picked from one location and dropped at the distance of 5 meter apart. Both manual and automatic dropping system is tested. One-touch return mechanism is also tested.

Objects/ Weights	No. of Trails	No. of Successful Attempts	Success Rate (Percent)
1 KG	15	15	100
2 KG	115	15	100
5 KG	15	14	93
7 KG	15	14	93
10 KG	15	13	86.66

VI. RESULT AND CONCLUSION

This research presented the design and development of a robotic gripper for a Hexacopter drone, facilitating autonomous last-mile delivery.

The proposed system offers a minimum payload capacity of 10 kg, making it suitable for a wide range of delivery needs. Future work can explore advanced gripper designs, integration with object recognition systems, and enhancing the gripper's autonomy for secure and efficient package delivery.

Fig 8: Proposed Model

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