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Smart Surveillance Drone – Warehouse Operations

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Abstract: *Drones have recently gained in popularity and are now frequently used for a variety of purposes. The majority of commercially available drones are generally non-self-governing and require the assistance of a human operator. However, advances in computer vision and artificial intelligence in general have drastically altered the situation. The growing scale of warehouses, as well as the difficulty in hiring trained workers, rising demand for customer services, and the rise of e-commerce, have heightened the need for warehouse operations to be more efficient through automation. In warehouses, drones may be a feasible alternative to manual inspections and surveillance activities. They can also be used for intralogistics, such as transferring parts from warehouses to assembly lines in factories. Multiple organizations throughout the world have been doing product delivery studies, but the focus of this article will be on the use of drones in warehouses for inventory management, which is gaining traction every day. Inventory management, stock inspection, and visual feedback will be the project's main applications. Manually inspecting the condition of things or confirming the contents of a product is common. The system makes it possible to do so fast and efficiently. The method allows still photographs to be collected for subsequent processing or a live video feed for FPV viewing because the drones are equipped with cameras. The report contains a thorough examination of the done systems and their application in warehouse management.*

Keywords: Drones, Logistics, Warehouse, Stock Inspection, Inventory Management, Visual Feedback, Cameras Drones, Logistics, Warehouse, Stock Inspection, Inventory Management, Visual Feedback, Cameras

I. INTRODUCTION

Drones have particularly found applications in warehousing operations. Recent technological advances in drones such as visual-based navigation and sensors enable indoor applications of drones. In addition to the advancement of drone technology, the main reason is that the scale of warehouses is increasing due to the growth of global e-commerce. For instance, drones can be used for automated inventory checks and intralogistics. Using drones for such applications can help warehouse managers to remove tedious and dangerous tasks. The use of drones in warehouses has been increasing over the past years. Large warehouses are aiming to increase efficiency by investing more in automation and robotics. This is not without precedence since the cost of warehousing operations account for 30% of the total costs in logistics. Furthermore, the difficulty of attracting skilled laborers, increasing demand for customer services, and the rise of e-commerce have intensified the need to further increase efficiency in warehouse operations.

1.1 Objectives

- To design a quadcopter-based system, which would be able to successfully percept a designated object in its surrounding and be able to track it after developing unique identifications for each of initial detections.
- To build an in-built barcode scanning system for product management and inventory inspection.
- To build a drone which will help in warehouse management with respect to location of the product and provide live feedback to the manager.

1.2 Scope

Due to sophisticated navigation and obstacle avoidance sensors, warehouse drones play an important role in smart warehouses. Drones are one of the most significant warehouse automation trends, with the goal of reducing non-value-added tasks. Warehouse drones carry out tasks such as inventory auditing, cycle counting, stock finding, and so on. They fly autonomously, identifying and counting the material in the warehouse and comparing it to the data stored "virtually," allowing for safe and cost-effective inventory operations. It entails a significant amount of work and costs that not all businesses can afford.

II. MATERIAL SELECTION AND CONFIGURATION

It's critical to pick the right material for the drone frame if one wants it to fly steadily and last for a long time. The material with low weight, cost and high strength is an ideal one. Some of the most popular materials used to construct a drone frame are described below.

Table 1: Difference Between H, Y and X Frames.

Comparison aspect	**H-Frames**	**Y-frames**	**X-frames**
Design:	H-frames have a frame that forms an "H" shape	Y-frames have a frame that forms a "Y" shape.	X-frames have a frame that forms an "X" shape
Flight performance:	H-frames are not as agile and maneuverable as X-Frames	Y-Frames are not as agile and maneuverable as X-Frames	X-frames are generally more agile and maneuverable
Payload capacity:	H-frames are typically better suited for carrying larger payloads due to their stable platform and strong frame.	Y-Frames have the least payload carrying capacity	X-Frames can carry more payload than Y-Frames, but not as much as H-frames, for longer distances.
Camera and sensor positioning:	H-frames may have a few limitations on camera and sensor positioning due to their closed design.	Y-frames may have most limitations on camera and sensor positioning due to their closed design.	X-frames are generally better for carrying cameras and sensors on the underside of the drone due to their open design

- Wood: Wood is cheap and easy to work with, so it would be a good choice for the frame. In addition, if the quadcopter crashes, the wooden pieces would be simple to repair. However, using wood would not be aesthetically appealing.
- b. Foam: Foam is most commonly employed as a skeleton for the drone frame and is seldom used on its own. It's commonly utilized for propeller guards, landing gear, and dampening applications.
- Plastic: Most commercial mid-sized quadcopters are made of plastic. This is due to the fact that plastic can be 3D printed as a complete structure. However, this is only done in small-sized frames. Furthermore, by employing plastic for the drone frame, the strength of the drone is slightly compromised.
- Aluminum: In most cases, aluminum is not used throughout the quadcopter. Aluminum is generally used to build arms or landing gear of the quadcopter. Fabrication of an aluminum frame, on the other hand, is difficult. Furthermore, despite its modest weight, aluminum is still heavier than CFRP or GFRP.
- CFRP: Drone frames are commonly made of CFRP, or carbon fiber reinforced plastic. It is very light in weight yet has high strength. In most cases, CFRP sheets are employed to construct the drone frame. CFRP sheets and tubes can be used, however, complex designs cannot be made.

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- GFRP: Drone frames are also made of GFRP, or glass fiber reinforced polymer. It is lighter than aluminum, but a bit heavier than CFRP. Despite this, it has a remarkable strength-to-weight ratio. Although GFRP and CFRP are almost equivalent, CFRP is more expensive than GFRP. In most cases, GFRP sheets are utilized.

Table 2: Comparison of Material Properties for Drone.

Properties	Aluminum	Carbon Fiber	ABS plastic
Young's Modulus(GPa)	68	228	1.2
Density(kg/m3)	2700	1750	1010
Ultimate Tensile Strength (MPa)	180	1500	27

A quadcopter frame is chosen based on the information about the drone frame arrangement and material described above. The chosen frame is based on the F450 model. The F450 frame has its arms made of Polyamide-Nylon, which are strong and have high thickness. This would help prevent breakage at the motor mount in case of a hard landing. There are support ridges on the arms, which increase stability and allow for quicker forward flight. The center frame is made up of Glass fiber.

III. DESIGN CALCULATIONS

3.1. Analysis of Frame Arms

Minimum thickness of rod = 4mm (Manufacturing Constraint)

Assuming that Arm behaves as a cantilever beam;

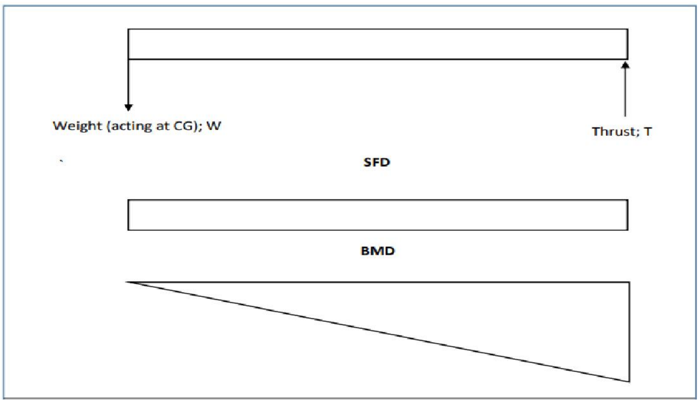

Fig 1- Analysis of Frame Arms

$\sigma = M/Z$

Where Z= Moment of Inertia (I)/Distance of Centre from Neutral Axis(y)

M= Load (P) * Length of Arm (L)

In order to minimize Bending stresses, " σ " should be minimum. This can be achieved when Section Modulus(Z) is as low as possible.

Assuming Hollow Cylinder with Outer diameter, D=50 mm Inner Diameter, d= 45 mm;

∴ Z= 4220.2879 mm3

Now, we consider total weight of the drone as 1.5 kg rounded off (Frame=300grams + Payload = 1200 grams)

Thus, P = 1500*9.81 = 14.715 N

For Length of Arm, the propeller is of 10" x 4.5 Model. Thus the minimum distance from propeller center to Drone center should be more than 5" i.e. 127mm. Thus considering the clearances, we assume the length of arm to be 225mm.

Thus, M = 14.715*225 = 3310.875 N-mm

Thus we have,

∴ σ =35.96 MPa

Now, For Safe Operation;

σ * FOS < Ultimate Tensile Strength

Aluminum:

σ * FOS = 71.92 < 180

Carbon Fiber:

σ * FOS = 71.92 < 1500

ABS Plastic:

σ * FOS = 71.92 > 27

Thus, ABS Plastic Can't Be Used.

Thus, we select Carbon Fiber, as it has maximum ultimate tensile strength amongst other Materials.

3.2. Wheelbase Calculations

Length of arm, l = 225mm

Wheelbase= Distance between 2 diagonal frame arms

= 225 * 2 = 450 mm = XY (in Figure 2)

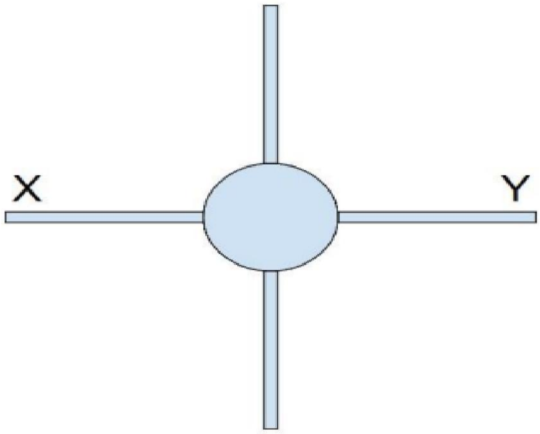

Fig 2- Wheelbase Understanding

The wheelbase is taken as 450 mm the reason being the propeller diameter is 10 inch that is 254 mm the innermost point from the center of the propeller towards the center of the frame of the propeller will be of 5 inch that is 127 mm. We are assuming the mountings to be at the center with a distance or rather a maximum diameter of 150 mm.

3.3 Thrust Calculations

Frame weight= 280gm

Payload = 1200 gm

Rounding up the final weight = 1500 gm= 1.5 kg

Velocity, v = 15 m/s

Thrust is to weight ratio for our quad rotor is 2:1

[For other cases where drone might be used in outdoor condition or at high altitude places or where they need Swift speeds to perform aerial manures, this thrust is to weight ratio is taken as 5:1 or even 10:1]

Thrust on each rotor = Total thrust / 4

The diameter of the blade is 10 inches, i.e., 0.254 meters

Therefore, the area of cross section will be= $\pi (d)^2 / 4$

$= \pi (0.254^2 / 4)$

Thus, the area A will be, A $= 0.05069\ m^2$

The value of C_d, i.e., the coefficient of drag, is equal to 1.12 for a circular flat disc.

For hover condition of quad rotor

Total thrust =Weight of quad rotor= 9.81*1.5= 14.715 N

Considering the density of air as 1.225 kg per meter cube, We have, for airborne condition

Total thrust needed > The total weight + The drag force

$> 14.715 + (½)\ \rho\ A\ V^2\ C_d$

$> 14.715 + ((½) * 1.225 * 0.05069$

Total Thrust > 22.539 N

Thus, Thrust per propeller = 22.539/4 = 5.634 N

3.4. Arduino and Gyroscope

We have included two libraries; one which allows the communication between I2C/TWI devices and the second which includes mathematical functions.

Now we have to find some 16 bit integers as well as some calibration variables. The correction values are individual for acceleration for temperature and for gyroscope as well. This depends on the usage of gyroscope and might be needed to reset after sometime duration for more accurate readings. There are total four connections made between the Arduino UNO and the gyroscope, which are the VCC that is input voltage, which we connect to 3.3 volts or 5 volts depending on the availability, then we have GND which is connected to ground. After that SCL and SDA of the gyroscope are connected to A5 and A4 respectively of the Arduino UNO. We read acceleration data as well as Gyroscope data in x, y and z directions. We read the temperature output as well, from the same device.

After reading the values we first make the temperature calculations from the data sheet for output in degree Celsius then we get the pitch role angle by using the mathematical function getAngle, for which we have mention the formulas in the bottom part of the code.

Then we print outputs for angle, pitch and role. Then again we print the output for accelerometers in individual X, Y and Z directions and gyroscopic readings in individual X, Y and Z directions, then we print out the temperature in degree Celsius.

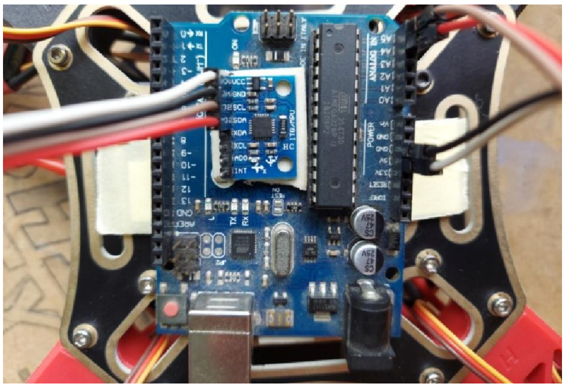

Fig 3- Arduino Top View

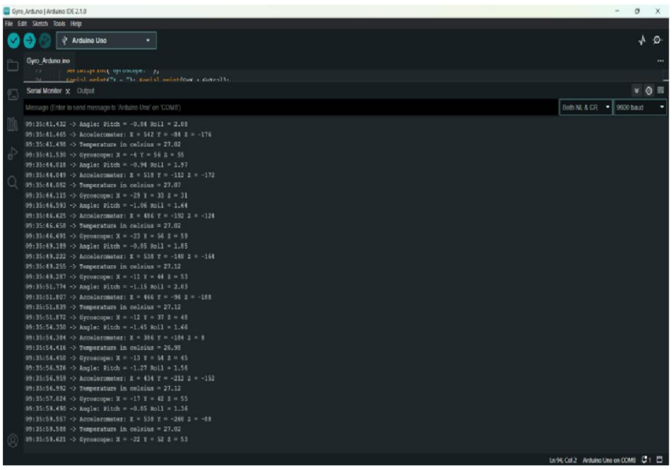

Fig 4- Arduino Gyroscope Readings Output.

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3.5. Barcode System

A high-visibility on-drone visual display is mounted at an ergonomic angle on the drone to allow for operator feedback during scanning and is easily seen from the ground while the drone is in flight. The primary feedback information shown on the drone is an incremental SCAN number as well as feedback such as:

- Warehouse name
- Shelf Number
- Barcode number

Information received will contain current position of the package and destination of the package in the given format.

Fig 5- Barcode and Corresponding Output

IV. CONCLUSION

Using Solidworks , we designed the frame and it was 3D printed. Some of the components from the payload were Procured from the vendors. Depending on the Preliminary Calculations and carrying out Analysis on ANSYS, we were able to find suitable models for propeller and the battery packs. Moreover, the barcode system was primarily tested using Webcam available on the laptop and then a dedicated Camera was procured for the Barcode scanning.

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