Design and Development of Autonomous Drone with Pick and Place Mechanism

Suraj Gavade[1], Sahil Zunjarrao[2], Rohan Waghmare[3], Sarthak Thete[4]

[1]Asst. Professor, Mechanical Department, SKNCOE,Pune, Maharashtra, India

[2,3,4,]UG Students, Mechanical Department, SKNCOE,Pune, Maharashtra, India

Abstract — The integration of autonomous drones with pick-and-place mechanisms has garnered significant attention in recent times. This research project focuses on the design and development of such drones, with a view to their application in sectors such as logistics, agriculture, manufacturing, and healthcare. The core objectives of this study involve designing and optimizing the mechanical structure, propulsion system, and control algorithms of the drone. This meticulous approach ensures precise and efficient execution of pick-and-place operations. The drone incorporates computer vision and machine learning techniques to identify and manipulate objects with a high degree of accuracy. This level of intelligence is crucial for successful task completion. The research methodology adopted an iterative process of prototyping, testing, and refinement, culminating in a fully functional autonomous drone capable of navigating complex environments, detecting objects, and performing versatile pick-and-place tasks. This research contributes significantly to the field of autonomous robotics by presenting a comprehensive approach to designing and developing a versatile drone with a pick-and-place mechanism. It paves the way for groundbreaking solutions across a range of industries.

Keywords—**Drone, UAV Automation, Pick and place mechanism, Unmanned aircraft system.**

1. Introduction-

The field of robotics, particularly unmanned aerial vehicles (UAVs), is witnessing significant advancements. One area of interest is the integration of autonomous drones with pick and place mechanisms, which has immense potential for revolutionizing logistics, agriculture, manufacturing, and healthcare sectors. This research will focus on three crucial aspects: Mechanical Structure, Propulsion System, and Control Algorithms. The physical framework of the drone will be meticulously crafted to ensure robustness and maneuverability. Factors such as weight distribution, material selection, and overall design will be carefully considered to optimize the drone's ability to carry and manipulate objects while navigating complex environments.

The selection and optimization of the propulsion system are paramount for achieving precise flight control and efficient energy consumption. This may involve exploring alternative power sources or innovative propeller designs tailored to the specific weight and payload requirements of the pick-and-place operations. Finally, the development of control algorithms will play a vital role in ensuring the drone's autonomy and ability to perform complex tasks. By combining these three crucial aspects, this research aims to develop an advanced pick and place drone that can revolutionize various industries and address complex challenges. The true power of drones lies within their sophisticated control algorithms. These algorithms are expertly crafted to facilitate autonomous flight, object recognition, precise pick and place movements, and real-time obstacle avoidance. We explore advanced control systems that incorporate cutting-edge techniques like machine learning and computer vision to ensure a seamless and adaptable operation.

The ability to accurately identify, grasp, and manipulate objects is essential for successful pick-and-place tasks. This research aims to explore the integration of cutting-edge technologies. A robust computer vision system will be installed on the drone to enable it to recognize and identify objects accurately. The system will be trained on a vast

dataset of objects, allowing the drone to differentiate between target objects and their surroundings with high precision. In addition, machine learning algorithms will be employed to refine the drone's grasping capabilities. By analyzing past successes and failures, the algorithms will learn to adapt grasping strategies in real time, thereby ensuring a high degree of accuracy and minimizing object damage.

The successful deployment of autonomous drones with pick-and-place mechanisms requires addressing several challenges, such as obstacle avoidance, real-time decision-making, and robust object manipulation. The drone should be equipped with robust obstacle detection and avoidance mechanisms that may involve using LiDAR sensors, vision systems, or both to navigate complex environments and ensure safe operation. The dynamic nature of real-world scenarios demands real-time decision-making capabilities for the drone, and advanced algorithms will be developed to enable the drone to adapt its actions and flight path in response to unforeseen obstacles or changes in the environment. To grasp and manipulate objects securely, the pick-and-place mechanism must be robust and adaptable. The design of the mechanism will be carefully considered to ensure successful object handling across diverse shapes, sizes, and weights.

This research project aims to make significant contributions to the development of autonomous drones capable of pick-and-place operations. The Drone Design Optimization will provide valuable data and methodologies for optimizing the design and performance of drones for such tasks. The Advanced Control Algorithms will play a crucial role in the development of sophisticated control algorithms that can enable precise drone movements This research project aims to make significant contributions to the development of autonomous drones capable of pick-and-place operations. The Drone Design Optimization will provide valuable data and methodologies for optimizing the design and performance of drones for such tasks. The Advanced Control Algorithms will play a crucial role in the development of sophisticated control algorithms that can enable precise drone movements.

This technology has the potential to transform numerous industries, paving the way for exciting research opportunities. We will investigate industry-specific applications to enhance the drone's capabilities for tasks such as warehouse automation, precision agriculture, search and rescue operations, and medical supply delivery. Our goal is to unlock the immense potential of autonomous drones equipped with pick-and-place mechanisms, ushering in a new era of automation and efficiency across a wide range of fields. Join us on this journey as we explore the possibilities.

1.1. Problem Statement

- Current drone designs often struggle to integrate robust pick and place mechanisms without compromising flight performance due to weight and power limitations.
- Existing gripper technologies lack the dexterity and adaptability required to handle objects of diverse shapes, sizes, and textures, leading to potential manipulation challenges
- Effectively combining sensor data from LiDAR, cameras, and other sources remains a challenge, hindering the drone's ability to fully comprehend its environment and make real-time decisions for safe and efficient object manipulation.
- The additional power demands of operating pick and place mechanisms significantly limit current drone flight times, restricting operational range and mission duration.
- Developing cost-effective and scalable pick and place mechanisms suitable for the mass production of autonomous drones is crucial for widespread adoption across various industries.

1.2. Aim:

To Design Autonomous drone aim to revolutionize aerial operations by eliminating the need for direct human control during flight. By leveraging artificial intelligence, sensors, and advanced navigation systems, the aim is to enable drones to perform tasks independently, efficiently, and accurately.

1.3. Objectives:

2. To design 3D model & Develop sophisticated navigation algorithms and systems to enable drones to autonomously plan routes.
3. Improve energy efficiency and flight endurance to maximize the operational range.

4. Optimize the drone's energy consumption and flight efficiency for extended mission durations.
5. Ensure the drone can handle a variety of object types, sizes, and weights in diverse environments.

2. Proposed Work:-

The project started by looking through research papers to find ones that were helpful. From this, we learned about Drone. Following 3-D model and drafting were completed using SolidWorks software we manufactured the drone arms and hub plates, integrating chosen components and design elements to create a functional prototype.

Fig. 1 Proposed Model Setup

2.1.Design

In our research work, we are creating Drone capable of navigating rough and uneven terrain. To achieve this, we're integrating a PID controller. This mechanism enables the Drone to control and maintain its altitude.

2.2.Calculation for Motor:

It is usually measured in RPM. Higher is the speed, more the current it draws. It also depends on KV ratings as RPM is directly proportional to volts supplied. KV is defined as revolutions per volt. Below is the details of motor and battery which we have used in our drone.

2.2.1. Motor specification:

Current: 12A
Battery: 2 or 3S ESC: 18A (30A suggested)
Thrust: 3S with 1045 propeller 800gm approx.
Weight: 50gm approx.
Input voltage: 16V (Max)

2.2.2. Battery specification:

5200mAh LiPo 3S
C-rating: 40C
Burst rating: 80CDimension: 137x28x44(mm)
Weight-360gm
Balance plug: JST XH
Discharge plug: XT-60 (60A)
Voltage: 11.1V

RPM= KV x Volts
  Max voltage= 3.7x 3   (3S is the No. of cells in a battery and each cell carry 3.7V)

= 11.1V

Total estimated weight = 9.32*9.081 = 91.433 N = 100 N (Approximately).

RPM=1000 x 11.1

= 11000rpm (single motor)

Since we are using quad copter there are four motors.

Therefore,

Total RPM= 4 x111000 = 44400rpm

We have to attain RPM in range of 25-35000, hence our RPM is sufficient for stable flight

2.2.3. Calculation of Weight Drone:

It is one of the most important parameters in designing of drone as many other factors like torque, power etc. directly or indirectly depends upon it. Below is the list of all parts and components weight

Arms- 50gm=50 x 4= 200gm

Upper base plate- 47gm

Bushing-3.1gm=3.1 x 4= 12.4gm

Lower base plate-47gm

Landing gear=230gm

Nuts, bolts, washers-60gm

Robotic Arm = 200gm

Frame weight= 796.4~800gm

Electronic components-918gm

Hence, total weight will be frame weight plus weight of electronic components. Total weight= 1718gm (approx).

2.2.4. Calculation of Motor Torque:

The amount of thrust the motor are generating to lift the drone is known as torque. It depends upon the size of motors lesser is KV rating, greater is the torque. Since our drone is freestyle and its aim is for pick and place goods. We can assume that equipment's up to 200g can mounted on it for transporting.

Self-weight of drone= 1718gm

Weight of payload= 200gm

Actual/ Takeoff weight= 1713+200= 1918gm

Using 2212, 1000KV motors with 1045 propellers

Max. Continuous current discharge = C-rating x Capacity

= 40 x 5.2

= 208 Ahr

Max. Continuous current = It is the maximum amount of current that battery could deliver before depleting.

Burst current discharge = 80 x 5.2 = 416Ahr

Burst current discharge = It is a current which a battery can discharge for a short period (say 10 sec)

Now, determining the current consumed by motors at full throttle. Current consumption of single motor = 12Ahr (full throttle).

Therefore, current consumed by four motors = 12 x 4 = 48Ahr

The motors together must produce thrust greater than the takeoff weight to hover the drone in air. Total weight that must be overcome is 1713g. Hence, each motor has to produce at least 600g of thrust to surpass takeoff weight

To produce 600g of thrust current consumed by one motor is= 1.5 x 600/100 = 9Ahr

Current consumed by four motors = 4 x 9 = 36Ahr

Current consumption of one motor to produce 100g of thrust is

Amps (A)	Load (g)
12	800
X	100

x = 1.5

Above is the current which is drawn by motors from battery to effective flying. Next is the flight time, one may find out the flight time if current consumption of motors is derived. Flight time is the actual time that the pilot can control or fly the drone. It is determined by using a formula, i.e

Flight time = (battery capacity x battery discharge/ Avg. Amp draw) x 60minutes

Avg. Amp draw = current consumed by motors + current consumed by other electronic components

$$= 36Ahr + 5Ahr$$
$$= 41Ahr$$

Therefore,

Flight time = (5.2 x 80%/41) x 60

$$= 6.08 \text{ minutes}$$

(Note: We cannot drain the battery below 20% voltage as it will permanently damage it so effective capacity is only 80% is available for flight time)

Henceforth, we can say that the thrust produce by motors is 3200g and load which the drone has to handle is 1713g including extra 200g for placing of good.

3. Components Description

After determining the necessary components, we proceeded to finalize our component selection. The components were manufactured and subsequently assembled.

3.1. BLDC Motor

The Readytosky 2212 920KV brushless motor is a metal motor with a voltage of 12 volts and a speed of 920 RPM. It weighs 191 grams and is compatible.

3.2. Propellers

The 1045 propeller is a 10 inch long propeller with a 4.5 inch pitch per revolution. It has wide and thin blades that make it flexible in crash conditions and less likely to break. The 1045 propeller has a 15 degree angle at the end to avoid whirlpool when the multi-copter is flying. It weighs 14 grams, has a shaft diameter of 6 mm, and is designed for multi-copters.

3.3. Battery

The 5200mAh is in reference to the battery capacity- meaning 5200 milla-Amp-hours. The amp-hour can be misleading though. Basically the 5.2 amp hours means it can last 5.2 hours with a load of 1 amp or 1 hour with a load of 5.2 amps.

3.4. ESC

An ESC 40A is an electronic speed controller that can drive motors that use up to 40A of current. ESCs control the speed and direction of a motor by adjusting the battery's power feed based on signals from the receiver. The ESC raises or lowers the voltage to the motor based on a signal from the flight controller, which changes the propeller's speed.

3.5. Flight controller

The KK 2.1.5 is a flight controller board for multi-rotor drones. 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, and calibrate your ESCs.

3.6. Transmitter And Receiver

The Transmitter is an electronic device that uses radio signals to transmit commands wirelessly via a set radio frequency over to the Radio Receiver, which is connected to an aircraft or multirotor being remotely controlled

3.7.GPS module

A GPS drone is broadly defined as a drone that uses GPS positioning to hold its spot in its airspace in all three dimensions. Many of these drones also have the ability to return to their launch point when the signal is lost between the operator and the drone or when the battery level becomes critically low.

3.8.LiDar

LiDAR is a ranging device, which measures the distance to a target. The distance is measured by sending a short laser pulse and recording the time lapse between outgoing light pulse and the detection of the reflected (back-scattered) light pulse.

3.9.Camera

Drones now have many functions, ranging from monitoring climate change to carrying out search operations after natural disasters, photography, filming, and delivering goods.

Fig.2 Circuit Connection

4. Results and Outcomes

In our research work, we proposed a fast and simple deep learning model for recognizing diseases in potato leaves. This model used multi-level deep learning techniques to classify diseases like early blight and late blight. Initially, it extracted features from potato leaf images and then developed a convolutional neural network for disease detection. We also considered the impact of environmental factors on potato leaf diseases. We evaluated the performance of our CNN techniques on another dataset, where they outperformed other methods. We compared our technique's performance with existing studies in potato leaf disease detection. Our method was trained on the PLD dataset with and without data augmentation techniques, achieving high accuracy, precision, recall, F1-score, and ROC curve. It had fewer parameters and was simpler compared to state-of-the-art methods, resulting in significant savings in computational cost and speed.

5. Conclusion

Every year, more than 20% of crop production is lost due to various plant diseases. Detecting diseases early is crucial for improving productivity and product quality. Deep learning techniques, such as CNN models, play a vital role in this process. In our study, we employed a fast and customized CNN model to detect and classify diseases in potato plant leaves. The accuracy of our CNN method was determined to be 96 %. Our research involved identifying the infected areas on the plant leaves across the entire leaf surface. The paper presents a novel autonomous vehicle employing a rocker-bogie mechanism, featuring an active six-wheel configuration. Basic movements were validated by implementing resolved velocity control on this autonomous vehicle prototype. The experiments confirmed the

vehicle's successful navigation of various terrain surfaces.

References

[1] V. Sathiesh Kumar, Gogul I., Deepan Raj M., Pragadesh S.K., Sarathkumar Sebastin J. (2016). "Smart Autonomous Gardening Rover with Plant Recognition using Neural Networks." Procedia Computer Science, Volume 93, Pages 975-981.

[2] Pandey, A., Kumar, A., Diwan, T. D., Hasan, M. E., Mohanty, R. L., & Gour, S. S. (2022). New Concept-Based Six-Wheel Rocker-Bogie Robot: Design and Analysis. Vol-56, part-2, 726-734.

[3] Toha, S. F. and Zakariya Zainol. "System Modelling of Rocker-Bogie Mechanism for Disaster Relief." Procedia Computer Science, Volume 76, 2021, Pages 243-249.

[4] Gupta, M. Satyanarayana, V. Shravan Koundinya, Venkata Phani Babu Vemuri, A. Sai Kumar, G. Venkata Rambabu, and M. Ganesh. "Field study of remote controlled Agrobot." Volume 64, Part 1, 2022, Pages 865-869.

[5] Sharma, R., Jaiswal, R., Yadav, A., & Roy, S. (2020). "Design and Fabrication of Rocker Bogie Mechanism Automated Combat Rover." International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 8 , Sep 2020, Pages 257-262.

[6] Honrao, D. V., & Awadhani, L. V. (2023). "Design and development of agricultural spraying system." Volume 77, Part 3, 734-738.

[7] Ghafar, A. S. Abdul, Hajjaj, S. S. H., Gsangaya, K. R., Sultan, M. T. H., Mail, M. F., & Hua, L. S. (2023). "Design and development of a robot for spraying fertilizers and pesticides for agriculture." Volume 81, Part 2, 242-248.

[8] Lu, R., Gao, H., Liu, Z., Yuan, R., & Deng, Z. (2023). "Design and analysis of a high-speed planetary rover with an adaptive suspension and spring damper." Acta Astronautica, Volume 211, October 2023, Pages 827-843.

[9] R.S. Sravya, S. Sreeja, "Design and Simulation of Interplanetary Lunar Rover," In Press, Corrected Proof, Available online 27 March 2023.

[10] Marinoudi, V., Sørensen, C. G., Pearson, S., Bochtis, D. (2019). "Robotics and Labour in Agriculture: A Context Consideration." Biosystems Engineering, Volume 184, June 2019, Pages 111-121.

[11] Gai, J., Xiang, L., & Tang, L. (2021). "Utilizing a depth camera for crop row detection and mapping for under-canopy navigation of agricultural robotic vehicles." Computers and Electronics in Agriculture, Volume 188, July 2021, Pages 106-301.

[12] Dey, Manash; Bisht, Harshit; Kumar, Rishab; Kumar, Abhinav; Arora, Aman. (2019). "Rocker Rover And Its Implementation In The Field Of Agriculture: A Review." Journal of Emerging Technologies and Innovative Research (JETIR), Volume 6, June 2019, Pages 900-903.

[13] Chakraborty, K. K., Mukherjee, R., Chakraborty, C., & Bora, K. (2022). "Automated recognition of optical image-based potato leaf blight diseases using deep learning." Physiological and Molecular Plant Pathology, Volume 117, January 2022.

[14] Arshad, F., Mateen, M., Hayat, S., Wardah, M., Al-Huda, Z., Gu, Y. H., Al-antari, M. A. (2023). "End-to-end hybrid deep learning framework for potato leaf disease prediction." Alexandria Engineering Journal, Volume 78, Pages 406–418, 1 August 2023.

[15] Wang, M., Fu, B., Fan, J., Wang, Y., Zhang, L., & Xia, C. (2023). "Sweet potato leaf detection in a natural scene based on faster R-CNN with a visual attention mechanism and DIoU-NMS." Ecological Informatics, Volume 73, Pages 1-14, 23 November 2022.

[16] Falaschetti, L., Manoni, L., Di Leo, D., Pau, D., Tomaselli, V., & Turchetti, C. (2022). "A CNN-based image detector for plant leaf diseases classification." HardwareX, Volume 12.

[17] Verma, S., Kumar, P., & Singh, J. P. (2023). "A meta-learning framework for recommending CNN models for plant disease identification tasks." Computers and Electronics in Agriculture, Volume 207, April 2023.

[18] Nishad, M. A. R., Mitua, M. A., & Nusrat Jahan. (2022). "Predicting and Classifying Potato Leaf Disease using K-means Segmentation Techniques and Deep Learning Networks." Procedia Computer Science, Volume 212, 2022, Pages 220-229.

[19] Md. Marjanul Islam Tarik, Sadia Akter, Abdus Sattar, Abdullah Al Mamun. (2021). "Potato Disease Detection Using Machine Learning." Conference Paper, February 2021.

[20] Shi W., Zhang S., Wang M., Zheng W., "Design and Performance Analysis of Soil Temperature and Humidity Sensor," IFAC PapersOnLine, Vol. 51, 2018, pages 586-590.

[21]　　Sharma, G., Tiwary, S., Kumar, A., Suresha Kumar, H. N., & Keshava Murthy, K. A. (2018). "Systematic design and development of a flexible wheel for low mass lunar rover." Journal of Terramechanics, 2017.

[22]　　H. Inotsume, S. Moreland, K. Skonieczny, D. Wettergreen, "Parametric study and design guidelines for rigid wheels for planetary rovers," Journal of Terramechanics, Volume 85, 2019, Pages 39-57.

[23]　　Jackulin, C., Murugavalli, S. "A comprehensive review on detection of plant disease using machine learning and deep learning approaches." Measurement: Sensors 24 (2022) , 5 September 2022.

[24]　　Nevavuori, P., Narra, N., & Lipping, T. "Crop yield prediction with deep convolutional neural networks." Computers and Electronics in Agriculture, 2019, Pages 64-87.

[25]　　Doshi, J., Patel, T., Bharti, S. K., "Smart Farming using IoT, a solution for optimally monitoring farming conditions." Procedia Computer Science, 2019, Pages 746–751.