REPORT OF SUMMER TRAINING

UNDERTAKEN AT

INSTRUMENTS RESEARCH & DEVELOPMENT ESTABLISHMENT

DEHRADUN – 248001

In partial fulfilment of the degree

Bachelor of Technology in

COMPUTER SCIENCE & ENGINEERING

MADAN MOHAN MALAVIYA UNIVERSITY OF TECHNOLOGY

GORAKHPUR – 273010

BY

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CSE, 3rd YEAR

2022021169

ACKNOWLEDGEMENT

I am thankful to the whole team of **Instruments Research And Development(IRDE)** for providing me with a wonderful opportunity and learning **AI/ML** during my **forty five days** summer training period.

I am highly grateful to **Dr. Vaibhav Gupta, Technical Officer-'C'**, for allowing me to work in the group.

I would like to express my sincere gratitude towards our guide Dr.Vaibhav Gupta for his kind co-operation, and encouragement which helped me in completion of this training and mini project.

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INSTRUMENTS RESEARCH AND DEVELOPMENT ESTABLISHMENT

GOVERNMENT OF INDIA, MINISTRY OF DEFENCE

DEHRADUN-248001

COMPLETION CERTIFICATE

This is to certify that **YASH SRIVASTAVA** (B.Tech. 3rd year, COMPUTER SCIENCE AND ENGINEERING) from **MADAN MOHAN MALAVIYA UNIVERSITY OF TECHNOLOGY, GORAKHPUR**, **UTTAR PRADESH** has successfully completed his training on **"Servo controlled AI based Drone mounted Payload drop mechanism using Arduino in Python"** as a summer trainee at Instruments Research and Development Establishment(IRDE), Dehradun during period **19-May-2025 to 30-June-2025**.

The training has been completed under the supervision of **Dr.Vaibhav Gupta**, Technical Officer-'C', IRDE,DRDO.

He has excellent job and was sincere during the training period.

DATE: 30th JUNE 2025

Dr.Vaibhav Gupta

Technical Officer-'C'

IRDE, DRDO, Dehradun

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ABSTRACT

This training program focuses on the design, integration, and deployment of multi-payload drone drop mechanisms for precision aerial delivery applications. Participants are introduced to the foundational principles of UAV (Unmanned Aerial Vehicle) payload engineering, including structural design, servo-actuated release systems, control logic, and flight synchronization. Through a combination of theoretical sessions and hands-on implementation, trainees develop and test modular mechanisms capable of independent or sequenced payload release during flight. The course emphasizes practical use cases such as disaster relief, defense, smart agriculture, and autonomous logistics, preparing learners to contribute to cutting-edge aerial delivery technologies. Upon completion, participants gain a deep understanding of multi-payload control systems and are equipped to innovate within the rapidly evolving UAV domain.

INTRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have transformed the landscape of modern technology across multiple industries including logistics, agriculture, disaster management, and defense. Among the many emerging applications, aerial payload delivery has become increasingly critical for tasks that require speed, precision, and access to remote or hazardous environments.

Traditional drone delivery systems are typically limited to single payload deployments, restricting their efficiency and scalability in real-world missions. To overcome these limitations, the development of multi-payload drop mechanisms enables UAVs to deliver multiple items to different locations in a single flight. This capability significantly enhances the operational flexibility and mission range of drones, especially in emergency supply drops, agricultural seed/fertilizer distribution, and strategic military operations.

This training program was designed to provide participants with both theoretical knowledge and practical experience in designing, building, and testing a modular, servo-controlled multi-payload release system for drones. The project involved understanding UAV dynamics, mechanical payload design, control system integration using microcontrollers, and software logic for precise drop sequencing.

By the end of the training, participants gained hands-on expertise in integrating hardware and software for real-time deployment scenarios, and learned how such systems can be adapted for various innovative applications in the rapidly growing drone technology ecosystem.

BACKGROUND

The evolution of Unmanned Aerial Vehicles (UAVs) has significantly expanded the possibilities for remote sensing, surveillance, and delivery operations. Initially developed for military use, drones have now penetrated diverse sectors including logistics, agriculture, healthcare, disaster management, and e-commerce. A major area of focus in drone research and innovation is the development of efficient and reliable payload delivery systems.

Conventional drone delivery systems are generally limited to single payload drops, which means the drone must return to base after each delivery. This not only reduces operational efficiency but also increases energy consumption, time, and cost. In response to these limitations, researchers and engineers have begun exploring multi-payload drop mechanisms, which allow UAVs to carry and drop multiple payloads in a single mission. Such systems can be manually or autonomously controlled, and are especially beneficial in situations requiring sequential deliveries across geographically distributed points.

While mechanical and control innovations are vital to achieving this, **Artificial Intelligence (AI)** and **Machine Learning (ML)** are increasingly playing a critical role in enhancing these systems. AI/ML can be applied in several areas, including:

- **Smart target detection and localization** using computer vision models (e.g., YOLO, CNNs) for object/person recognition in real-time
- **Payload prioritization** based on mission-critical factors using predictive analytics
- **Autonomous decision-making** for dynamic drop sequencing in unpredictable environments (e.g., changing weather, blocked drop zones)
- **Anomaly detection and self-correction** in flight behavior using pattern recognition

This training aimed to bridge the gap between theoretical understanding and real-world implementation of such technologies.

SMART VISION INTEGRATION

Image Processing

Image processing plays a pivotal role in enhancing the intelligence and autonomy of Unmanned Aerial Vehicles (UAVs). By equipping drones with cameras and vision-based systems, it becomes possible to analyze visual data in real-time for a wide range of applications such as object detection, target tracking, obstacle avoidance, and precision payload delivery.

Key steps invovled in the image processing:

1.Image acquisition – It involves the capturing images or videos frames using onboard UAV cameras.

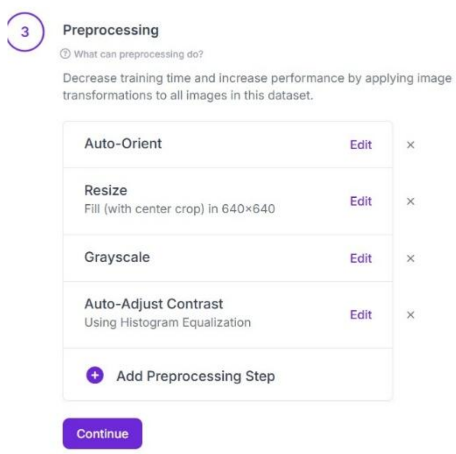
2.Preprocessing – Enhances image quality and prepare it for further analysis. It involves resizing, grayscale conversion, noise removal and histogram equalization.

3.Image Enhancement – Improves visibility of features or objects. It involves edge enhancement, contrast ajustment and sharpening filters.

4.Segmentation – divides the image into meaningful regions, useful for isolating the targets. It involves thresholding, contour detection and clustering.

5.Feature Extraction – Identifies important visual features like edges, shapes and color patterns.

6.Object Detection – uses AI models to detect specific objects and produces bounding boxes, class labels and confidence scores.



YOLO

YOLO (You Only Look Once) is a state-of-the-art, real-time object detection algorithm widely used in computer vision tasks, especially where speed and accuracy are critical — such as in **drone-based visual systems**.

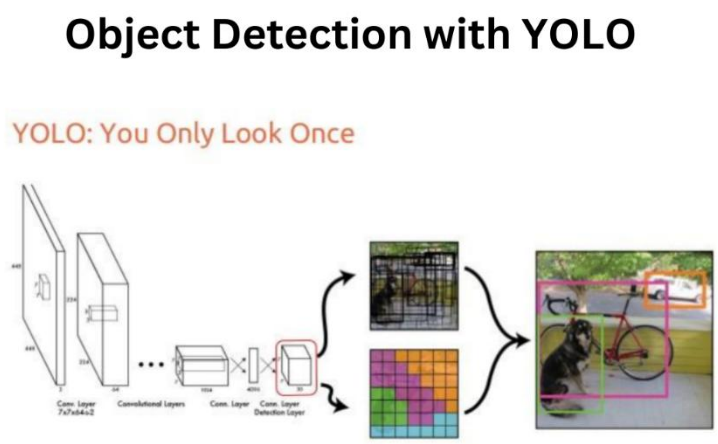
Unlike traditional object detection algorithms that perform **region proposal followed by classification** (e.g., R-CNN), YOLO treats object detection as a **single regression problem**, directly predicting bounding boxes and class probabilities from the input image in **one forward pass** of the network. This makes it **extremely fast and efficient**, ideal for **real-time UAV applications**.

1. Image is divided into a grid (e.g., 13×13).

2. Each grid cell predicts:

- **One or more bounding boxes (location of object)**
- **Confidence score (probability that an object exists)**
- **Class probabilities (e.g., person, vehicle, marker)**

3. Predictions are processed using Non-Maximum Suppression (NMS) to remove overlapping boxes and refine results.



SYSTEM DESIGN

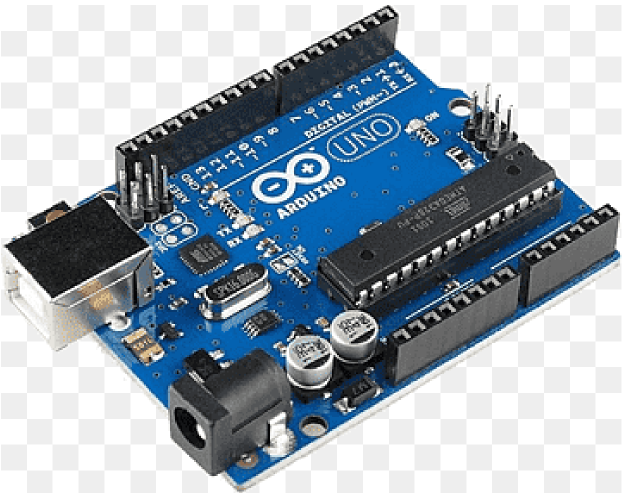
The multi-payload drone drop mechanism was designed to be lightweight, modular, and capable of **autonomous or semi-autonomous operation**. The system integrates electronic, mechanical, and vision components to identify drop zones and release payloads in a controlled manner.

1.CONTROL UNIT: ARDINO UNO

The core control logic was implemented on an **Arduino Uno** microcontroller. Its simplicity, low power consumption, and support for PWM (Pulse Width Modulation) made it ideal for controlling servo motors with precise angle adjustments.

Responsibilities:

- Control the rotation of each servo motor
- Execute the payload release sequence
- Interface with the host (e.g., computer or ground station) for commands or signals
- Respond to input triggers from image processing models or manually (via serial/bluetooth)



2.ACTUATION: SERVO MOTOR

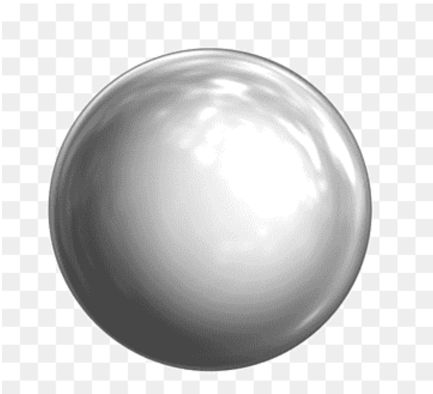
SG90 servo motors were used, attached to a specific payload compartment. Servo motors rotate their shaft to a specific angle when commanded by the Arduino, thereby releasing the payload through: A **rotating latch** that unlocks the payload slot.

3.VISION SYSTEM: WEB CAM

An external **USB webcam** was used as the drone's visual sensor, mounted in a forward -facing orientation. The webcam streamed real-time video frames to a **host computer or onboard edge device**, where **image processing and object detection** algorithms (like YOLO) were executed.

4.PAYLOAD: BALL BEARINGS

For the purpose of this training and prototype demonstration, metal ball bearings were used as simulated payloads. Each ball bearing was placed in a dedicated payload chamber or slot, aligned with a servo-controlled drop mechanism. When the target was detected and the corresponding servo was activated, the compartment released the bearing, simulating a precision strike or supply drop.



CONTROL MECHANISM

The control mechanism of the multi-payload drone drop system is designed to **coordinate sensor input, visual detection, and actuation** to execute precise and selective payload releases. It involves the integration of **manual control logic** through an Arduino microcontroller and **automated decision-making** via image processing on a host computer.

1.DECISION UNIT

The onboard or externally connected **webcam** continuously captures frames during flight.These frames are analyzed in real-time using an **AI-based object detection model** such as **YOLO**.When the model identifies a valid **target zone**, such as a person, symbol, or drop marker:

- A **signal is sent from the host system** to the **Arduino** via serial communication.
- This signal contains the **payload index or compartment number** to be released.

2.EXECUTION UNIT

The **Arduino Uno** serves as the core control hub for executing drop commands.It receives serial data from the image processing unit and matches it to a corresponding servo motor.Using **PWM (Pulse Width Modulation)** signals, the Arduino:

- **Rotates the assigned servo motor**
- **Releases the payload** (ball bearing) from its slot
- Returns the servo to its initial position after the drop

SOFTWARE IMPLEMENTATION

1.OBJECT DETECTION with YOLO (pyhton)

2.ARDUINO FIRMWARE(C/C++)

sketch_jun20a.ino

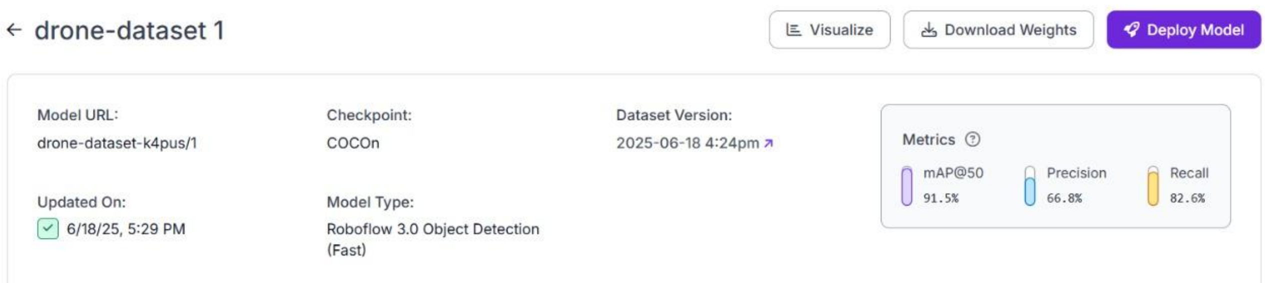
```
#include <Servo.h>

Servo myservo;
int target_angle = 0;
int current_angle = 0;

void setup() {
  Serial.begin(9600);
  myservo.attach(9);
  myservo.write(current_angle);
  delay(1000);
}

void loop() {
  if (Serial.available() > 0) {
    target_angle = Serial.parseInt();


    if (target_angle != current_angle && target_angle >= 0 && target_angle <= 180) {
      myservo.write(target_angle);
      delay(2000);
      current_angle = target_angle;
    }

    while (Serial.available() > 0) {
      Serial.read();
    }
  }
}
```

TESTING & RESULTS

a. **SETUP** – The drone system was mounted on a test rig or held stationary at a height of ~1.5 to 2 meters (initially, without flight).Webcam oriented downward for visual target acquisition.Drop zones were marked with printed **target symbols**, colored markers, or QR codes.Ball bearings were loaded into multiple servo-controlled compartments.

b. **TARGET DETECTION TEST** – YOLOv5 model was tested for vehicles and humans.Accuracy of object detection was recorded across different background conditions.

c. **PAYLOAD DROP TEST** – upon detection, serial signals were sent to the Arduino.Each payload was triggered sequentially to test independent control of servos and repeatable release mechanism.



APPLICATIONS

1.Defence and Tactical missions: **Surveillance-Based Payload Deployment**: Drones can detect enemy positions or markers and drop countermeasures. **Miniature Precision**: Controlled drop of small payloads based on visual identification of targets.

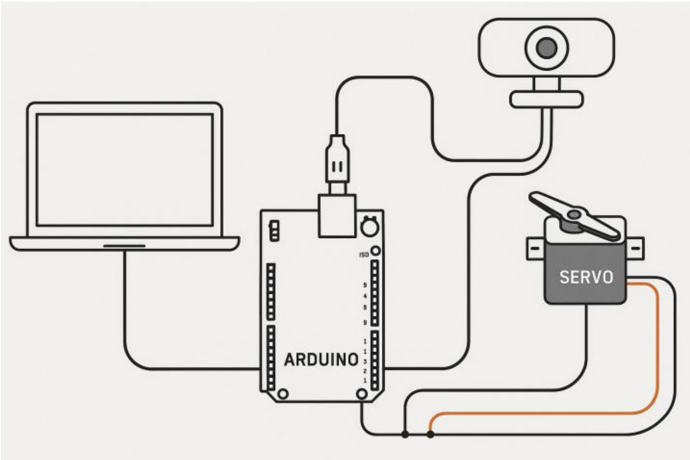
2.Disaster Relief: Medical Supply Delivery: Drones can deliver life-saving items like first-aid kits, insulin, or water bottles to victims based on visual recognition. **Marker-Based Targeting**: Aid workers can place visual markers for drone detection, triggering automated payload drops.

3.Agriculture Application: **Precision Seeding or Fertilizer Drops**: Drop seeds or nutrients based on visual conditions detected.
Autonomous Spot Treatment: Use YOLO to detect weeds or diseases and drop targeted treatments or traps.

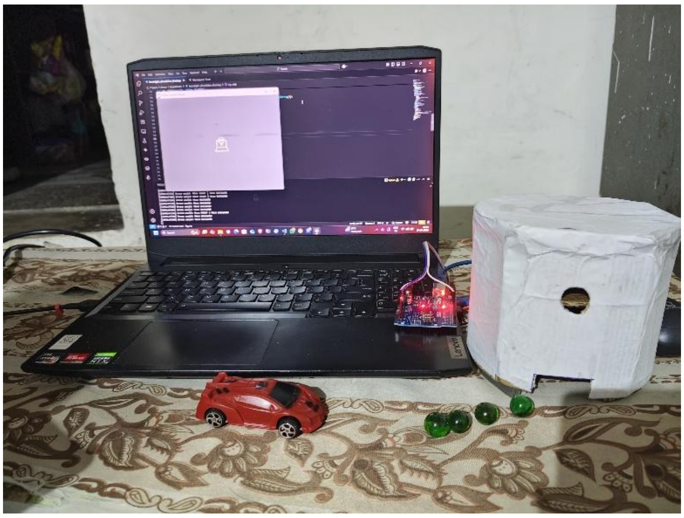
4.Commercial and Research Applications: **Autonomous Delivery Drones**: Support multi-address deliveries from a single flight path.
In large warehouses or open storage yards, drones can drop specific items to required spots.

APPENDIX

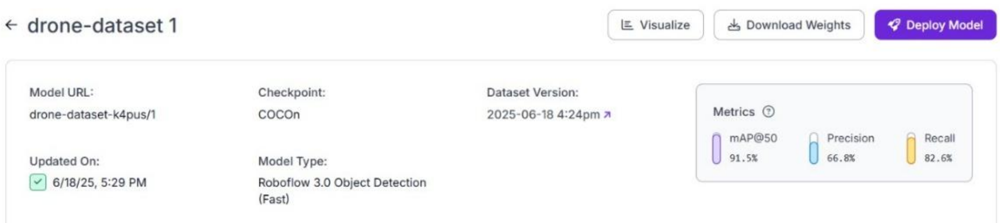
- CIRCUIT DIAGRAM



- RESEMBLING MODEL



- DATASET



FUTURE SCOPE

1.Add GPS and inertial measurement units (IMUs) for **fully autonomous flight** and navigation.

2.Combine object detection with **path planning algorithms** to dynamically decide where and when to drop.

3. Enhance YOLO with **temporal awareness** across frames to improve stability in predictions.

4.Payload optimization and scaling

5.Swarm Coordination - Enable **multi-drone collaboration** where a group of drones communicates and divides tasks.

6.Cloud and IoT Integration - Implement remote monitoring and mission control using **IoT platforms**

CONCLUSION

The design and operation of a drone-based multi-payload deployment mechanism represent a significant advancement in autonomous aerial systems, offering enhanced versatility and efficiency for a wide range of applications. This project successfully integrated robust mechanical design, precise control systems, and innovative payload handling solutions to enable the reliable deployment of multiple payloads in diverse operational scenarios.

The integration of advanced computational platforms, enabled efficient management of complex algorithms for autonomous navigation, object detection, and environmental recognition, further elevating system performance and mission reliability. The successful deployment of multiple payloads, including sensors and delivery packages, underscores the system's adaptability for applications in surveillance, delivery, inspection, and emergency response.

In summary, the drone-based multi-payload deployment mechanism offers a scalable and cost-effective solution for modern aerial operations, paving the way for future innovations in unmanned systems and expanding the potential for autonomous missions in both commercial and industrial sectors.

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