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INSTITUTE OF ENGINEERING

KATHMANDU ENGINEERING COLLEGE

KALIMATI, KATHMANDU

Major Project Proposal Report on

GARUD-UAV: A Deep Learning Approach to Image Upscaling for Land Use Classification

BY

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Abstract

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List of Abbreviation

AI Artificial Intelligence

GPIO General Purpose Input Output

IoT Internet of Things

ML Machine Learning

RAM Random Access Memory

OS Operating System

BRNN Bidirectional Recurrent Neural Networks

GRU Gated Recurrent Units

MIMO Multiple Input Multiple Output

SoC System-on-Chip

USB Universal Serial Bus

Wi-Fi Wireless Fidelity

NLP Natural Language Processing

TTS Text-To-Speech

API Application Programming Interface

ARM Advanced RISC Machine

RISC Reduced Instruction Set Computer

IP Internet Protocol

MCU Micro-Controller Unit

Chapter 1: Introduction

1.1 Background Theory

The rapid advancement of Unmanned Aerial Vehicles (UAVs) has transformed applications in environmental monitoring, agriculture, and urban planning by providing cost-effective and high-resolution data collection capabilities [1], [2]. Fixed-wing UAVs, in particular, offer significant advantages for land use image classification due to their extended range, longer endurance, and ability to cover large areas efficiently, making them ideal for wide-areass surveillance and mapping tasks [2]. These vehicles can capture high-resolution aerial imagery, enabling precise analysis of land use patterns critical for precision agriculture, urban development, and disaster management [1], [4]. However, challenges such as limited payload capacity, regulatory constraints, and the need for advanced image processing to achieve high-quality outputs persist, necessitating innovative design and algorithmic solutions [1], [2].

A key component of this project is the integration of Enhanced Super-Resolution Generative Adversarial Network (ESRGAN), a state-of-the-art deep learning model for single image super-resolution (SISR) introduced by Wang et al. in 2018 [5]. ESRGAN employs a Generative Adversarial Network (GAN) framework, comprising a generator that creates high-resolution images from low-resolution inputs and a discriminator that ensures realism. Noted for its ability to reconstruct realistic textures and fine details, ESRGAN is ideal for enhancing images captured by UAV-mounted cameras, such as those using Raspberry Pi modules, typically upscaling images by a factor of 4x [5]. This capability is particularly valuable for land use classification, where high-resolution imagery is essential for identifying intricate land features.

This research project aims to design and develop a fixed-wing UAV tailored for land use image classification, leveraging lightweight materials, advanced sensors, and ESRGAN for enhanced image processing to improve data accuracy and operational efficiency. By addressing design considerations such as aerodynamic efficiency, flight stability, and integration of high-resolution imaging systems, this project seeks to create a UAV capable of collecting and processing aerial imagery for accurate land use analysis [2]. Drawing on prior research, including deep learning applications for UAV systems and their use in precision agriculture [1], [4], this project will optimize UAV performance for environmental monitoring tasks. The outcome is expected to contribute to UAV-based remote sensing, offering a scalable solution for land use analysis in diverse geographical contexts.

1.2 Problem Statement

Land use and land cover (LULC) classification is critical for effective environmental management, agricultural monitoring, urban planning, and disaster response. Traditionally, satellite imagery has been the primary source for such analysis; however, limitations such as low spatial resolution, infrequent data updates, atmospheric disturbances, and high operational costs restrict its applicability for high-precision, real-time monitoring [1]. In contrast, UAVs offer a flexible, cost-effective, and scalable solution for high-resolution remote sensing. Among UAV types, fixed-wing aircraft present superior advantages for surveying large geographical areas due to their extended flight duration, aerodynamic efficiency, and higher operational altitudes [2].

Despite their potential, existing UAV platforms used for LULC classification are often either commercially expensive, overly complex for academic research and field adaptation, or designed around rotary-wing systems that lack the range and endurance needed for broad-area coverage [3]. Moreover, there is a lack of integrated, low-cost fixed-wing UAV solutions that combine autonomous navigation, high-resolution image acquisition, and onboard or post-processed land classification capability tailored to specific regional or environmental needs.

Therefore, there exists a critical need to develop a custom-built, fixed-wing UAV system optimized for land use image classification—one that is affordable, reliable, and capable of autonomous operation in varied field conditions. This research project addresses that need by designing and implementing a fixed-wing UAV equipped with geo-referenced imaging systems and an image-processing pipeline to enable accurate and efficient land use classification.

Chapter 2: Literature Review

The rapid development of Unmanned Aerial Vehicles (UAVs) has significantly impacted remote sensing, particularly in Land Use and Land Cover (LULC) classification. UAVs can capture high-resolution imagery, which is ideal for extracting fine-grained spatial details. However, challenges such as varying resolution, atmospheric distortion, and inconsistent lighting can affect the quality of the images. The application of deep learning techniques, particularly convolutional neural networks (CNNs), in enhancing UAV imagery via image upscaling is a promising direction, as seen in the proposed Gaurad-UAV model.

High-resolution data is crucial for accurate land use classification. Traditional satellite-based imagery often suffers from resolution constraints and longer revisit times. UAVs overcome these issues by offering greater spatial resolution and flexible data acquisition. Studies such as [6] and [7] have successfully demonstrated the use of UAV imagery for detailed classification of urban and agricultural landscapes. In [6], Bui et al. employed a CNN model combined with UAV images and digital surface models (DSMs) to achieve a high overall classification accuracy of over 91

Deep learning models, especially transfer learning-based CNNs, have proven highly effective for LULC classification. Naushad et al. [7] used models like VGG16 and Wide Residual Networks (WRNs) to classify complex land use categories with an accuracy exceeding 98

Image upscaling, or single-image super-resolution (SISR), has emerged as a key pre-processing step to improve classification performance. Tuna et al. [8] applied CNN-based super-resolution methods to remote sensing images, showing improved visual quality and feature detectability, which in turn enhanced classification outcomes. This process helps generate higher-resolution approximations of low-resolution images, mitigating the effects of noise and data sparsity in UAV captures.

The Gaurad-UAV framework is proposed as a comprehensive approach that leverages deep CNNs for image upscaling before land use classification. While specific architectural and experimental details are yet to be broadly published, the conceptual foundation aligns well with existing literature. By enhancing image resolution, Gaurad-UAV aims to improve the feature quality available to classification models, thereby increasing accuracy and robustness in heterogeneous environments.

In summary, the integration of UAV imagery with deep learning and image super-resolution techniques presents a strong foundation for enhanced LULC classification. Gaurad-UAV, as a deep learning-powered image enhancement pipeline, contributes meaningfully to this domain by addressing the challenge of limited image resolution in high-precision mapping applications.

Chapter 3: Related Theory

3.1 Hardware

3.1.1 FLYSKY Receiver

The FLYSKY receiver is a compact wireless communication module used in remote-controlled systems to receive control signals from a FLYSKY transmitter. It operates on a 2.4GHz frequency band and supports multiple channels, allowing it to control various actuators such as motors and servos. This receiver is widely used in drones, RC planes, and robots due to its reliable range, low latency, and compatibility with many FLYSKY models. It typically connects directly to a flight controller or electronic speed controller (ESC) for signal routing.

3.1.2 30A ESC Skywalker

The 30A Skywalker ESC (Electronic Speed Controller) is a device designed to control the speed, direction, and braking of a brushless motor. Rated for a maximum continuous current of 30 amps, it is ideal for medium-sized electric drones and RC aircraft. It takes signals from the receiver or flight controller and converts them into three-phase power for the motor, allowing smooth acceleration and precise speed control. The ESC also includes safety features like overheating and overcurrent protection.

3.1.3 Flight Stabilizer (NXE4 EVO)

The NXE4 EVO Flight Stabilizer is an advanced control system used in RC aircraft and drones to maintain stability during flight. It uses onboard sensors such as gyroscopes and accelerometers to detect orientation and movement, and then automatically adjusts control surfaces or motor speeds to correct any deviations. This improves flight performance, especially in windy or unstable conditions, and enables smoother operation for both beginners and experienced pilots. It’s essential for autonomous or semi-autonomous flight control.

3.1.4 1000KV Brushless Motor

A 1000KV brushless motor is a high-efficiency electric motor that rotates at 1000 revolutions per minute per volt applied. It is commonly used in drones, RC aircraft, and electric vehicles due to its power-to-weight ratio, reliability, and minimal maintenance needs. Unlike brushed motors, brushless motors have no internal contact between the rotor and stator, reducing wear and increasing lifespan. The motor typically has three wires for connection to an ESC and is paired with a propeller or gear mechanism for motion output.

3.1.5 MG996 Metal Gear Servo

The MG996 is a high-torque, metal gear servo motor used for precise angular movement in robotics, RC vehicles, and automation systems. Its durable metal gear construction offers increased torque and strength compared to plastic gear servos, making it suitable for demanding applications. Controlled by a PWM signal, it can rotate to specific angles between 0° and 180°, making it ideal for steering mechanisms, robotic arms, or flaps in RC aircraft. It comes with a standard 3-wire connector for power, ground, and signal.

3.1.6 2200mAh 3S LiPo Battery

The 2200mAh 3S LiPo (Lithium Polymer) battery is a high-capacity, lightweight power source commonly used in RC models, drones, and portable electronics. With three cells in series, it delivers a nominal voltage of 11.1V and a high discharge rate to support power-hungry components like motors and servos. Its 2200mAh capacity provides moderate runtime, making it ideal for short to medium-duration flights or robotic operations. The battery typically features a discharge plug (like XT60) and a balance connector for safe charging.

3.1.7 Buck Module Voltage Regulator

A buck module voltage regulator is a DC-DC converter that steps down higher input voltage to a lower, stable output voltage. It is commonly used in embedded electronics to power microcontrollers, sensors, and other 5V or 3.3V devices from higher-voltage sources like LiPo batteries. The module includes components such as an inductor, capacitor, and adjustable potentiometer to maintain a consistent output. Its compact size and efficiency make it essential for battery-powered projects to protect components from over-voltage.

3.1.8 Raspberry Pi with USB Camera and HDMI Cable

The Raspberry Pi is a credit card-sized single-board computer capable of running a full Linux OS and performing various computing tasks. When paired with a USB camera, it can capture images and video for applications like computer vision, surveillance, and robotics. The HDMI cable allows video output to a monitor or display, enabling real-time viewing or debugging.

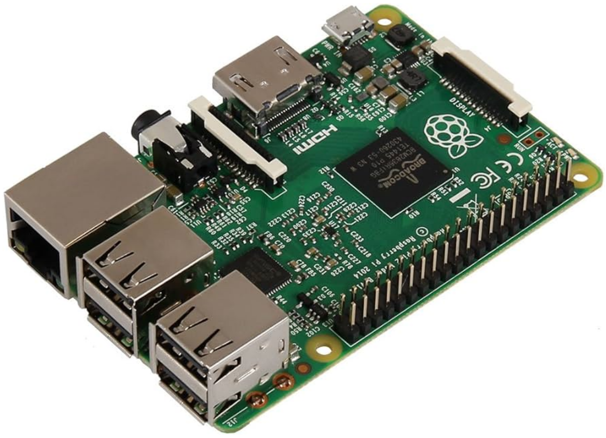

Figure 3.1: Raspberry Pi 4 Model B

This setup is ideal for lightweight, portable embedded systems where processing power, camera input, and display output are all required.

3.2 Software

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3.3 Dataset

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Chapter 4: Feasibility Study

4.1 Technical Feasibility

Table 4.1: Hardware Specification Table

Column 1	Column 2	Column 3
Item 1	Item 2	Item 3
Item 4	Item 5	Item 6
Item 7	Item 8	Item 9

4.2 Economic Feasibility

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Chapter 5: Methodology

5.1 System Block Diagram

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5.2 Algorithm

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5.3 Flow Chart

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Chapter 6: Result And Analysis

6.1 Expected Output

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Gantt Chart

Cost Estimation

Electronics & Core Components

Table 6.1: Electronics and Core Components for Fixed-Wing UAV

Item	Quantity	Cost (NRs)
FLYSKY Receiver	1	8000
30A ESC Skywalker	1	2000
Flight Stabilizer (NXE4 EVO)	1	4500
1000KV Brushless Motor	1	800
MG996 Metal Gear Servo	4	3040
2200mAh 3S LiPo Battery	1	3150
Buck Module Voltage Regulator	1	550
Raspberry Pi with USB Camera and HDMI Cable	1	TBD
Raspberry Pi USB Camera and HDMI Cable	1	TBD

Frame & Construction Materials

Table 6.2: Frame and Construction Materials for Fixed-Wing UAV

Item	Quantity	Cost (NRs)
Depron Sheet	4	10000
Aluminum Motor Mount (L-shape)	1	150
Push Rod (1m)	2	400

Miscellaneous Accessories

Table 6.3: Miscellaneous Accessories for Fixed-Wing UAV

Item	Quantity	Cost (NRs)
Hot Glue Gun Stick	10	200
Duct/Binding Tape	3 rolls	300
XT60 Connector Pair	2	500
3-Pin Orange Connector Pair	4	60
Servo Wire Cable (5m)	1	75
Propeller (7x5 inch)	4	300
Bullet Propeller Holder Adapter	1	170
Jumper Wire (MM, MF, FF, each 5)	15	30