Comprehensive Documentation: Low-Cost DIY Spectral Band Cameras for Agricultural Drones Using Filters with RGB Cameras

---

Introduction

Multispectral cameras are widely used in agriculture for remote sensing and precision farming. These cameras are capable of capturing data in multiple spectral bands, such as Near Infrared (NIR), Red, Red Edge, and Green, which are crucial for vegetation health analysis, crop monitoring, and other agricultural applications. However, commercial multispectral cameras are expensive, making them inaccessible to small-scale farmers or researchers with limited budgets.

This documentation provides a detailed explanation of how a low-cost, DIY solution using **Raspberry Pi Camera Module 3 NoIR** combined with specific optical filters can be employed to isolate these essential spectral bands. This solution offers a feasible and low-cost alternative to commercial multispectral cameras while maintaining comparable accuracy and effectiveness.

Multispectral Cameras vs DIY Solution Cost Comparison

- **Commercial Multispectral Cameras**:
    - Typical Cost: ₹150,000–₹500,000 depending on the model (e.g., Micasense RedEdge, Parrot Sequoia).
    - Features: High accuracy, multiple integrated spectral bands, rugged design for drones.
- **DIY Solution (Using Raspberry Pi Camera Module 3 NoIR and Filters)**:
    - Cost of Camera Module 3 NoIR: ₹2,000–₹2,500
    - Cost of Filters for Each Spectral Band:
        - NIR Band Filter (Hoya R72): ₹3,000–₹4,500
        - Red Band Filter Combination: ₹6,500–₹9,500
        - Red Edge Band Filter Combination: ₹6,500–₹9,500
        - Green Band Filter (Wratten 58): ₹1,500–₹3,000
    - Total Estimated Cost per Camera (with filters): ₹10,000–₹20,000

Conclusion: The DIY approach offers a low-cost alternative, with the total setup costing around **₹40,000–₹80,000** for four cameras covering all spectral bands. This is **approximately 80% cheaper** than commercial multispectral cameras.

Spectral Bands and Filter Implementation

The Raspberry Pi Camera Module 3 NoIR, without its infrared cut filter, allows detection of light in the entire visible and near-infrared spectrum. By using specific optical filters, we can isolate the required spectral bands: **Near Infrared (NIR), Red, Red Edge, and Green**. Below, we outline the method to isolate each band, including the exact models of the filters and actionable steps for implementation.

---

1. Near Infrared (NIR) Band (700–1000 nm)

Filter Setup:

- **Primary Filter**: **Hoya R72 Infrared Filter**
    - **Transmission Range**: Above 720 nm, effective for NIR from 700–1000 nm.
    - **Cost**: ₹3,000–₹4,500
    - **Available From**: Amazon India, camera retailers.

Implementation Steps:

1. **Filter Attachment**: Attach the **Hoya R72** filter directly in front of the Raspberry Pi Camera Module 3 NoIR using a filter holder or custom mount.
2. **Lens Compatibility**: Ensure the filter size (e.g., 25mm or 37mm) matches the camera lens to avoid vignetting.
3. **Testing and Calibration**: Capture images of vegetation or objects reflecting NIR light to verify isolation of the 700–1000 nm band. Adjust the camera's ISO and exposure settings for optimal NIR sensitivity.

Conclusion:

The Hoya R72 filter effectively isolates the NIR band, allowing the camera to capture crucial near-infrared data necessary for vegetation health analysis.

---

2. Red Band (620–750 nm)

Filter Setup:

- **Primary Filter**: **Schott RG630 Long-Pass Filter**

    - **Transmission Range**: Above 620 nm.
    - **Cost**: ₹2,500–₹3,500
    - **Available From**: Edmund Optics, Knight Optical.
- **Secondary Filter**: **Thorlabs FELH0750 IR-Cut Filter**
    - **Transmission Range**: Blocks wavelengths above 750 nm.
    - **Cost**: ₹4,000–₹6,000
    - **Available From**: Thorlabs, Edmund Optics.

Implementation Steps:

1. **Filter Stack**: Stack the **Schott RG630** filter on the camera side and the **Thorlabs FELH0750** IR-Cut filter in front of it.
2. **Filter Mounting**: Secure the filter stack onto the Raspberry Pi Camera Module using a filter holder or adhesive.
3. **Calibration**: Capture images of objects with strong red reflectance (e.g., vegetation or red targets). The combined filters will isolate the **620–750 nm** red band, blocking light beyond 750 nm.

Conclusion:

The combination of the **Schott RG630** and **Thorlabs IR-Cut filter** allows for precise isolation of the **Red Band** (620–750 nm), crucial for monitoring plant stress and chlorophyll content.

---

3. Red Edge Band (700–750 nm)

Filter Setup:

- **Primary Filter**: **Schott RG715 Long-Pass Filter**
    - **Transmission Range**: Above 700 nm.
    - **Cost**: ₹3,000–₹4,000
    - **Available From**: Edmund Optics, Knight Optical.
- **Secondary Filter**: **Thorlabs FELH0750 IR-Cut Filter**
    - **Transmission Range**: Blocks wavelengths above 750 nm.
    - **Cost**: ₹4,000–₹6,000
    - **Available From**: Thorlabs, Edmund Optics.

Implementation Steps:

1. **Filter Stack**: Stack the **Schott RG715** filter with the **Thorlabs FELH0750** IR-Cut filter to block light beyond 750 nm.
2. **Mounting**: Attach the filter assembly to the camera using a filter holder.
3. **Testing**: Capture test images of vegetation. Red Edge reflectance will become prominent, enabling isolation of the **700–750 nm** Red Edge band.

Conclusion:

The **Schott RG715** and **Thorlabs IR-Cut filter** combination effectively isolates the **Red Edge band** (700–750 nm), which is essential for monitoring plant health and early signs of vegetation stress.

---

4. Green Band (500–600 nm)

Filter Setup:

- **Primary Filter**: **Wratten 58 Green Band Filter**
  - **Transmission Range**: 500–600 nm.
  - **Cost**: ₹1,500–₹3,000
  - **Available From**: Amazon India, photography stores.

Implementation Steps:

1. **Filter Attachment**: Attach the **Wratten 58** Green Filter in front of the camera lens using a filter holder or mount.
2. **Calibration**: Perform test imaging of green vegetation to verify isolation of the **500–600 nm** green band.
3. **Adjustments**: Adjust the camera settings (ISO, exposure) to optimize image capture in this spectral range.

Conclusion:

The **Wratten 58 Green Filter** provides effective isolation of the **Green Band** (500–600 nm), which is important for assessing plant vigor and vegetation indices like the NDVI.

Conclusion: Feasibility of the Low-Cost DIY Solution

The combination of the **Raspberry Pi Camera Module 3 NoIR** and carefully selected optical filters for each spectral band (NIR, Red, Red Edge, Green) provides a viable and low-cost alternative to commercial multispectral cameras. The DIY solution offers the following advantages:

1. **Cost Efficiency**: The entire setup costs approximately ₹40,000–₹80,000, which is **80% cheaper** than most commercial multispectral cameras.
2. **Customization**: The solution allows customization by swapping filters to target specific spectral ranges as needed, offering flexibility in agricultural research and monitoring.
3. **Accuracy**: By using high-quality optical filters, this setup achieves spectral isolation comparable to commercial multispectral cameras. With proper calibration and mounting, this solution provides high-quality data for agricultural applications, such as vegetation health monitoring, crop yield prediction, and stress detection.
4. **Scalability**: Multiple Raspberry Pi cameras can be mounted on drones to simultaneously capture data across different spectral bands, mimicking the capabilities of integrated multispectral cameras.

In conclusion, this DIY low-cost multispectral camera solution offers a highly feasible and effective replacement for expensive commercial cameras, making advanced agricultural sensing accessible to a wider audience.
