Automated Insect Classification and Pest Control Recommendation System

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GitHub repository link

Problem Statement

- Agricultural crops are highly prone to insect pest infestations, leading to significant yield losses.
- Manual pest identification is time-consuming, error-prone, and requires expert knowledge.
- Many insect species look visually similar, making accurate identification difficult.
- There is a lack of automated systems that both classify insect species and recommend pest control solutions.
- This project aims to develop a computer vision-based system for automated insect classification and pest control recommendations.

Objectives

- Develop a deep learning-based pipeline for automated insect classification and detection.
- Use the IP102 dataset with 102 insect species for training and evaluation.
- Implement and compare **VGG-16** and **YOLOv5s** models.
- Evaluate using accuracy, precision, recall, F1-score, mAP, and speed.
- Address class imbalance using data augmentation in VGG-16 pipeline.
- Map identified insects to suitable chemical and organic pesticides.
- Use trusted data sources: USDA and EPA pesticide databases.
- Deliver a scalable and trustable decision-support tool for pest control.

Methodology: Data Collection & Preprocessing

- **Dataset:** IP102 (Insect Pest Dataset)
  - 75,000+ images across 102 insect classes
  - Highly imbalanced dataset
- **For VGG-16 (Image Classification):**
  - Images resized to 150×150 pixels
  - Normalization using rescaling (1/255)
  - Manual data augmentation (rotation, flipping, cropping, etc.) to balance classes
  - Dataset split into 80% training, 10% validation, 10% test
- **For YOLOv5s (Image Classification & Object Detection):**
  - Annotations converted from Pascal VOC XML to YOLO format
  - Folder structure organized as per YOLO requirements: `images/train`, `labels/train`, `images/val`, `labels/val`
  - Dataset split into 80% training, 20% validation

Methodology: Model Selection & Training

- **YOLOv5s**
  - Lightweight real-time object detection model
  - Initialized with pretrained weights (yolov5s.pt)
  - Trained for 100 epochs with SGD and cosine learning rate decay
  - Loss functions: Box Loss, Classification Loss, Distribution Focal Loss (DFL)
- **VGG-16**
  - Pretrained on ImageNet, fine-tuned for 102 insect classes
  - Dropout added to prevent overfitting
  - Trained for 7 epochs using categorical cross-entropy
  - Call backs: EarlyStopping and ReduceLROnPlateau for adaptive training

Methodology: Model Evaluation & Comparison

- **Evaluation Metrics:**
  - Accuracy (Top-1)
  - Precision, Recall, F1-score
  - Inference Speed
  - Mean Average Precision (mAP)
- **Model Selection Criterion:**
  YOLOv5s selected for final deployment based on a trade-off between accuracy and inference speed.

Metric	**VGG-16**	**YOLOv5s**
Accuracy	0.6048	0.4495
Precision	0.5033	0.5219
Recall	0.4668	0.5609
F1-Score	0.4657	0.5400
Inference Speed	25.45 img/sec	80 img/sec
mAP@0.5	0.5253	0.5548

Table: Comparison of VGG-16 and YOLOv5s Performance

Methodology: Insect-to-Pesticide Mapping

- Data Sources:
  - USDA National Insect & Disease Risk Mapping
  - EPA Pesticide Use Limitation Database
- Mapping Steps:
  - Extract pesticide data for 102 insect species
  - Create insect-to-pesticide lookup table
  - Ensure compliance with regulations
- Final Output: Pesticide recommendation based on detected insect

Mapping screenshot(first few classes):

```
pesticide_mapping = {
    0:  ("Rice leaf roller", "Chlorantraniliprole", "Neem oil"),
    1:  ("Rice leaf caterpillar", "Lambda-cyhalothrin", "Bacillus thuringiensis (Bt)"),
    2:  ("Paddy stem maggot", "Fipronil", "Spinosad"),
    3:  ("Asiatic rice borer", "Cartap hydrochloride", "Beauveria bassiana"),
    4:  ("Yellow rice borer", "Bifenthrin", "Garlic-pepper spray"),
    5:  ("Rice gall midge", "Imidacloprid", "Diatomaceous earth"),
```

Pipeline

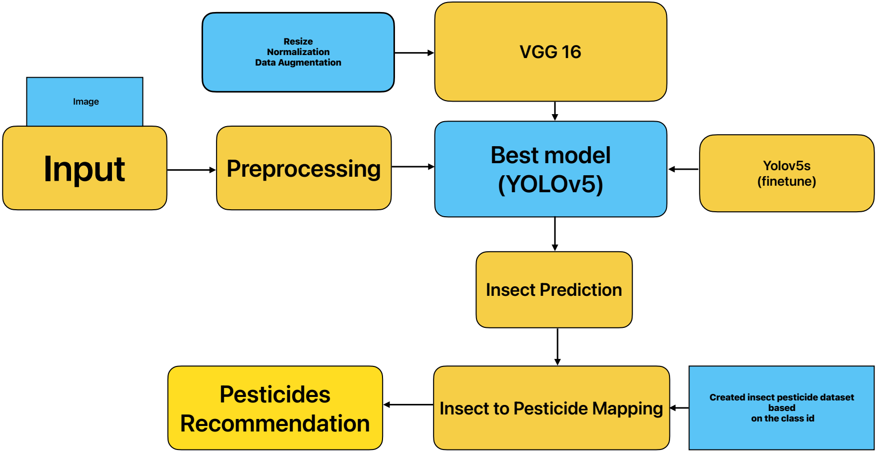


Figure: Flowchart of Methodology

Input and Output Example

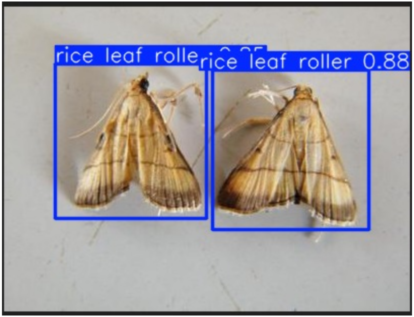
Input:

VGG's Output:

```
Predicted class index: 0
Predicted insect: rice leaf roller
Recommended chemical pesticide: Chlorantraniliprole
Recommended organic pesticide: Neem oil
```

Input and Output Example

Yolo's predicted bounding box:



Yolo's Output:

```
image 1/1 C:\Coding\Pythonworkspace\DLCV_Project\detection\Detection\VOC2007\JPEGImages\JPEGImages\IP000000002.jpg: 480x640 2 rice leaf rollers, 140.4ms
Speed: 8.8ms preprocess, 140.4ms inference, 242.1ms postprocess per image at shape (1, 3, 480, 640)
Detected classes in image: {'rice leaf roller'}
```

Conclusion

- Developed an integrated system for automated insect classification and pesticide recommendation using deep learning.
- Leveraged the IP102 dataset with 102 insect categories for training and evaluation.
- Compared two models:
  - **VGG-16:** Higher classification accuracy (60.48% Top-1).
  - **YOLOv5s:** Faster inference and higher detection performance (mAP: 0.5548).
- **YOLOv5s selected** as final model due to real-time performance and practical deployment suitability.
- On image input, system classifies insect species and recommends chemical and organic pesticides.
- Recommendations backed by USDA and EPA data ensuring scientific reliability and regulatory compliance.
- Provides a scalable AI-based tool for precise, sustainable pest management in modern agriculture.

References

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