Data-Efficient Strategies for Object Detection

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Tutorial Goals

01

Train an Object Detection model on custom data

02

Use **Active Learning** to reduce annotation workload

03

Understand how **annotation quality** affects model performance

04

Apply **Transfer Learning** to boost performance and reduce training time

Agenda

- Case Study
- Data collection and Annotation
- State of the Art in Object Detection
- Application of Active Learning
- Impact of Data Quality
- Transfer Learning

Case Study

Motivation

- Pests destroy up to 40% of crops globally
- Traditional pest control is costly, chemical-heavy, and often reactive

- Feeding the world sustainably requires smarter farming : more precise and proactive
- Early detection can save billions and reduce pesticide use, which means healthier crops, safer food, and a greener plane

Data-driven farming is the future

Case Study

The whitefly pest

Whiteflies are small, sap-sucking insects that pose a significant threat to agriculture worldwide

- Feed on plant sap, weakening crops and reducing yields
- Reproduce rapidly
- Vectors of many plant viruses
- Spread worldwide and affect a multiple range of crops — including cotton, tomato, soybean and cassava

- One the **most significant agricultural pests** globally
- Lead to **billions of dollars in economic losses annually**

Case Study

Conventional methods

Conventional methods include:

- **Yellow sticky traps** to monitor populations, manually checked
- **Manual removal** of heavily infested leaves in small-scale farming.

  - Time consuming as it is totally **human-based**
  - Heavy reliance on insecticides that leads to **resistance development**
  - **Costly**

Case Study

Smart farming methods

Scoutboxes combine sticky traps with **IoT sensors, cameras, and connectivity**.

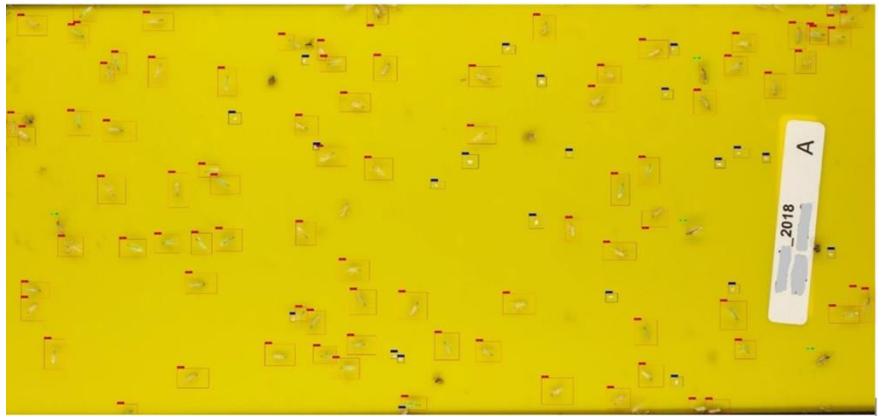
- Capture images of trapped insects automatically
- Can use onboard or cloud-based to **identify, count, and report pest populations** in real-time

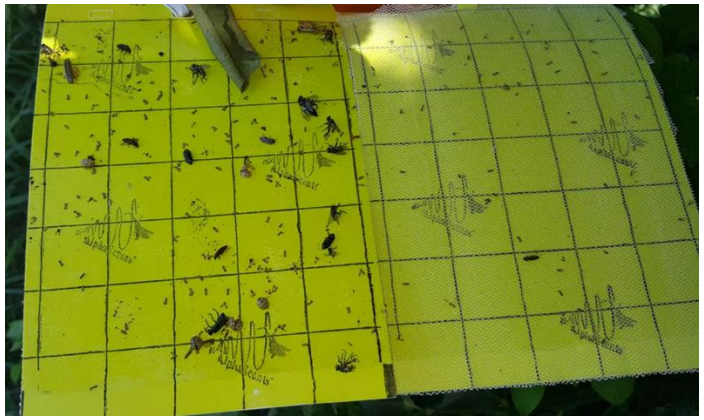
Benefits include:

- ✓ **Early detection:** enabling rapid intervention before outbreaks spread.
- ✓ **Reduced labor:** eliminating manual scouting rounds.
- ✓ **Data-driven decisions:** providing precise pest population trends over time.
- ✓ **Sustainability:** allowing targeted treatment and reducing unnecessary pesticide use.

Case Study

Challenges





- **Species identification:**
  - differentiating similar insect species remains difficult
  - insects captured in traps are usually degraded
    - ➢ **Object Detection with few high-quality annotated data**
- **Image quality & environmental conditions:** dust, rain, humidity, or sunlight glare
    - ➢ **Noisy environment**
- **Cost & scalability:** Initial investment and maintenance costs can be high, especially for small-scale farmers.
    - ➢ **Low-cost equipment**

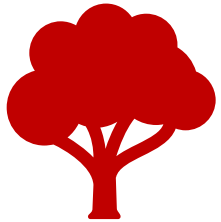
Object Detection with few high-quality annotated data in noisy environment with low-cost equipment

Case Study

Goal

Pest detection

Whitefly Pest



Detections in Natural Environments

Goal is to detect and count whiteflies in an image

Data Collection and Annotation

Goal

DIVERSITY IS CRITICAL

REPRESENT THE REAL-WORLD

BALANCE THE DATASET

Background in Object Detection

One Stage vs Two Stage Model

- 1-Stage Detectors
  - Use Cases:
    - **Real-time applications** (e.g., drones, robotics, video surveillance)
    - **Edge devices** (e.g., Jetson Nano, Raspberry Pi)
    - Scenarios where **speed is more critical** than slight accuracy gains
  - Examples:
    - **YOLO** (v1 → v11)
    - SSD (Single Shot Multibox Detector)
    - DETR (transformer-based, one-stage-style)

- 2-Stage Detectors
  - Use Cases:
    - **High-accuracy applications** (e.g., medical imaging, autonomous vehicles)
    - **Offline processing** (speed not critical)
    - **Complex scenes** with small or overlapping objects
  - Examples:
    - RCNN
    - Fast RCNN
    - **Faster RCNN**

Hands on

URL: bit.ly/ibpria25tutorial