Object detection applied to the problem of robotic controlled pollination

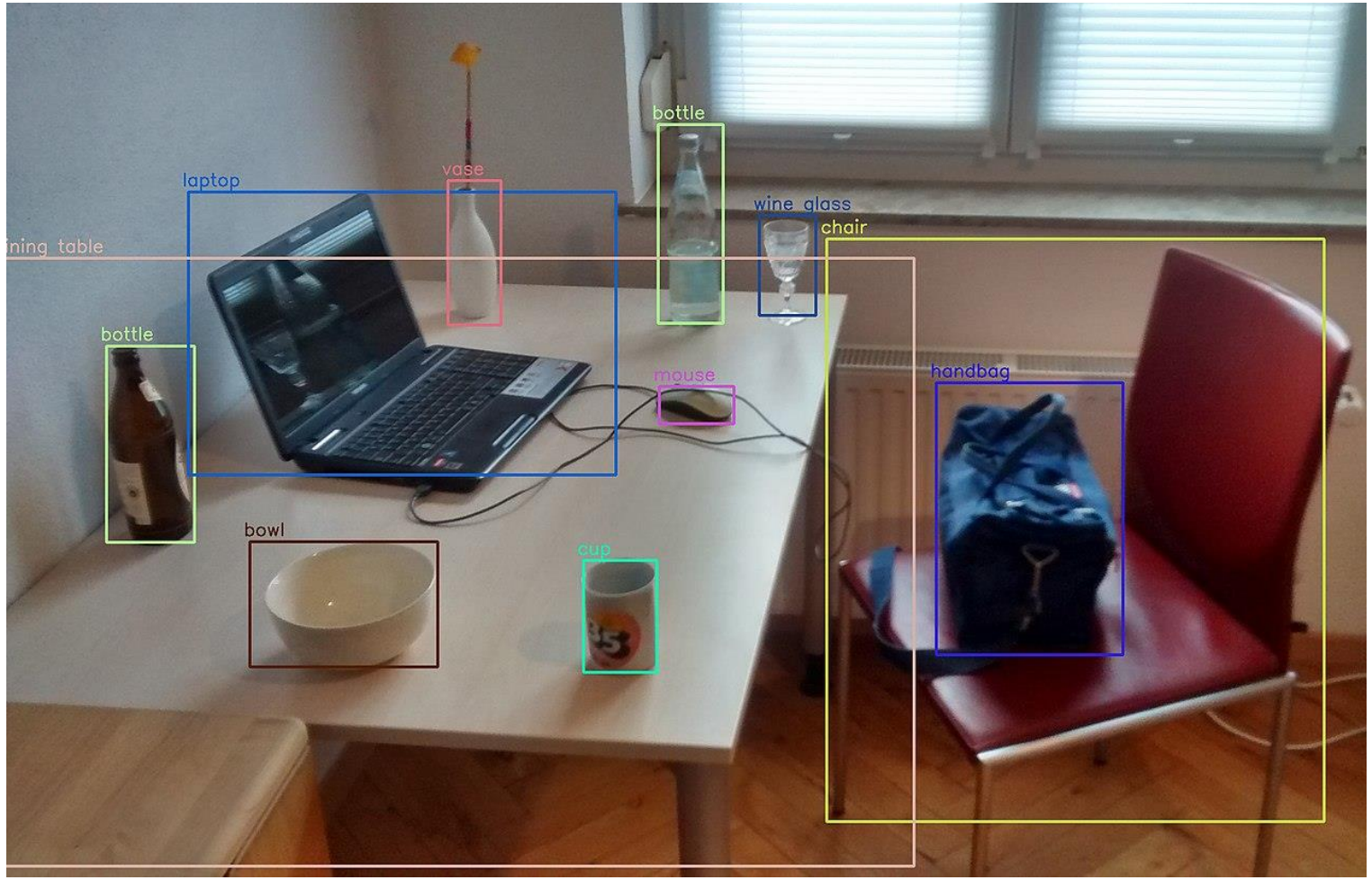
Piyush Pandey

2024/04/19

Overview

1. Object detection
2. Controlled pollination and the need for bag detection
3. Model architecture and workflow
4. Code implementation (Google Colab)

Object detection

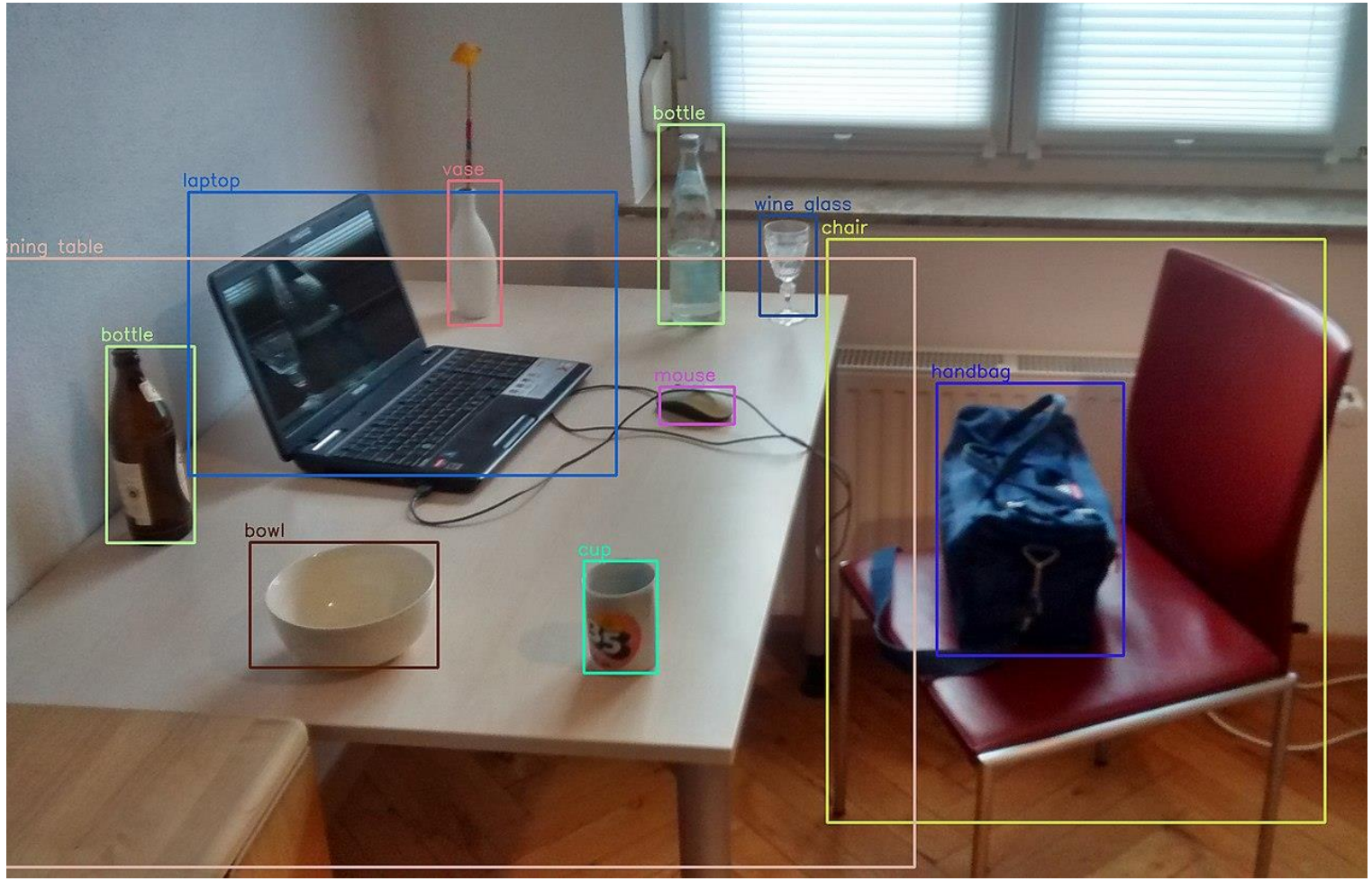


- Object detection includes the localization and classification of objects in the image

- Localization : bounding box
- Classification: box labels

https://upload.wikimedia.org/wikipedia/commons/thumb/3/38/Detected-with-YOLO--Schreibtisch-mit-Objekten.jpg/1280px-Detected-with-YOLO--Schreibtisch-mit-Objekten.jpg

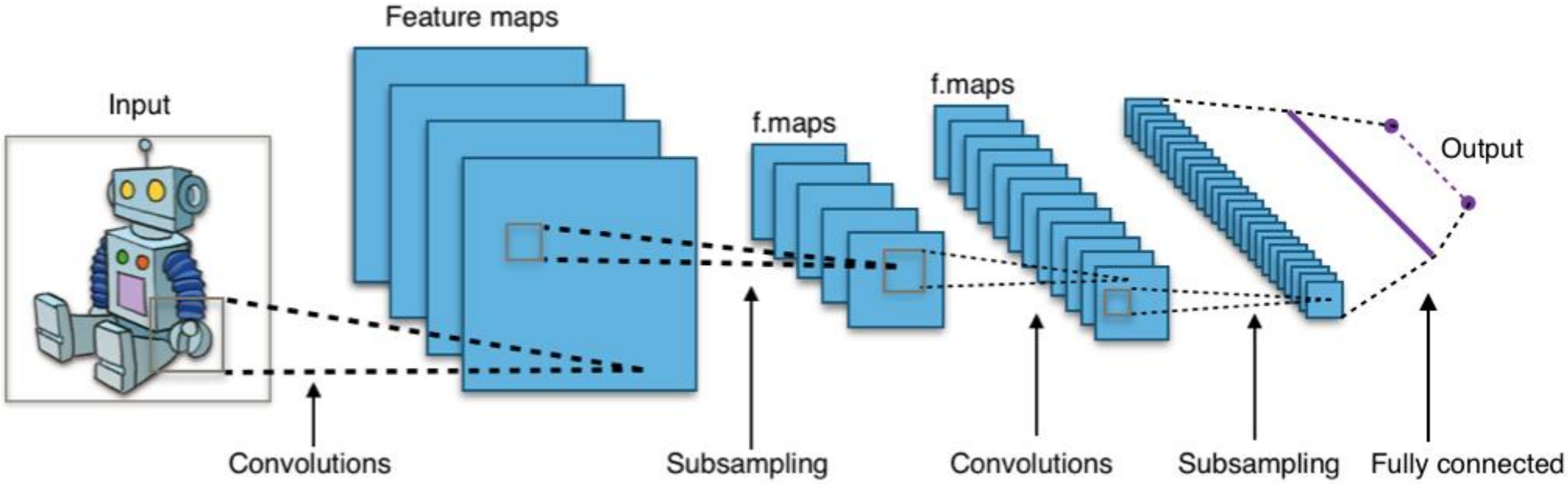
Image classification



- Classification requires the assignment of a single label to the entire image
- A possible label for this image?

https://upload.wikimedia.org/wikipedia/commons/thumb/3/38/Detected-with-YOLO--Schreibtisch-mit-Objekten.jpg/1280px-Detected-with-YOLO--Schreibtisch-mit-Objekten.jpg

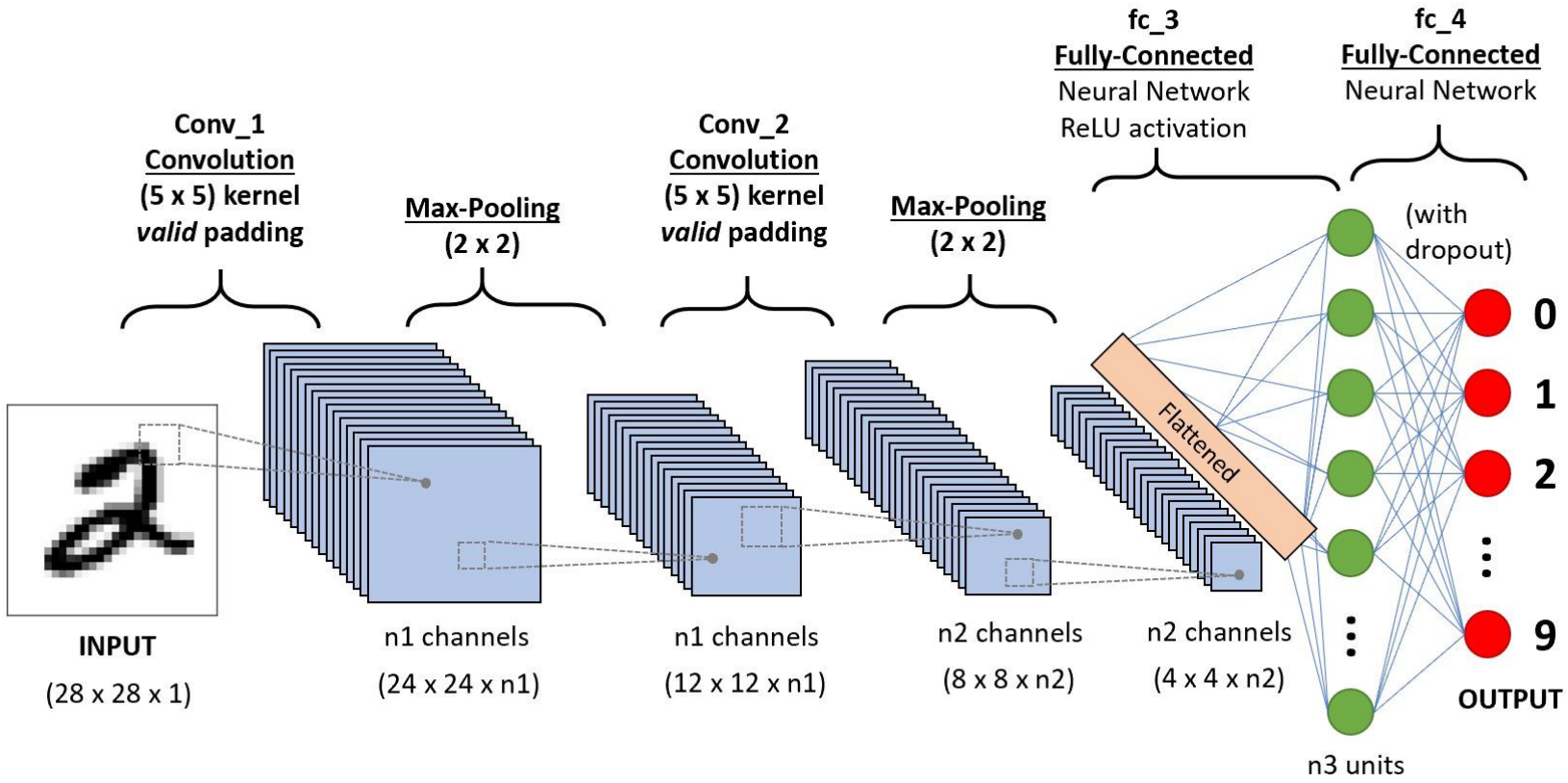
Image classification with CNNs



Typical CNN model with convolutional and subsampling (pooling) layers followed by fully connected layers

https://upload.wikimedia.org/wikipedia/commons/6/63/Typical_cnn.png

Image classification with CNNs



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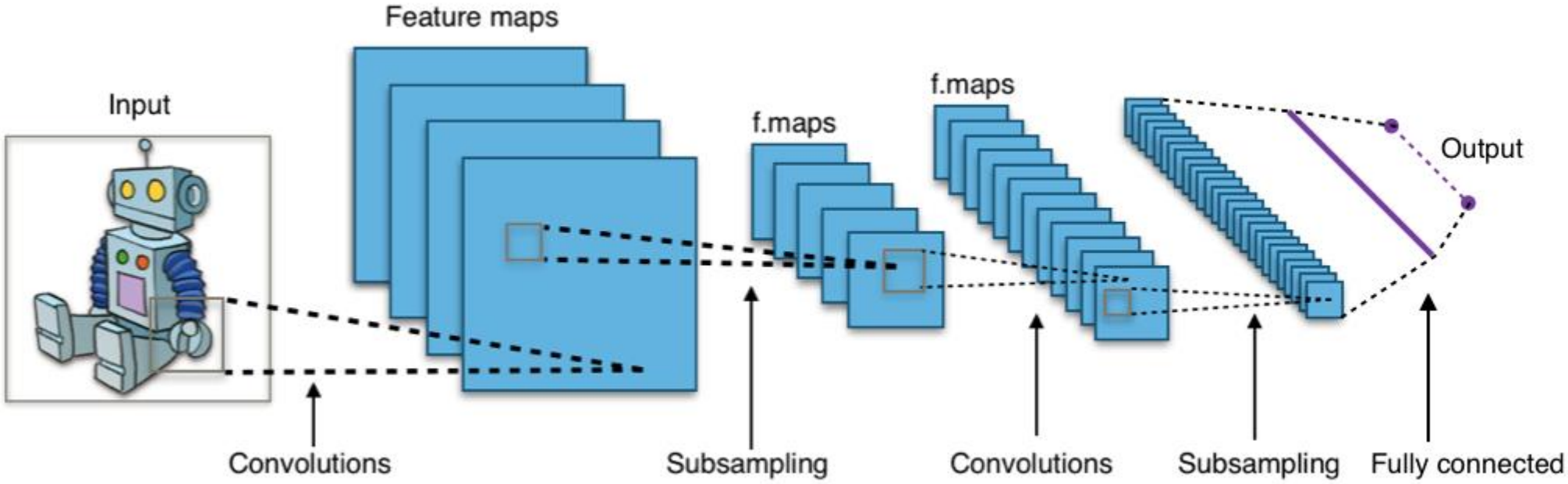
https://machine-learning.paperspace.com/wiki/convolutional-neural-network-cnn

Object detection with CNNs



Object detection can be understood as the problem of operating this typical CNN model on an image patch

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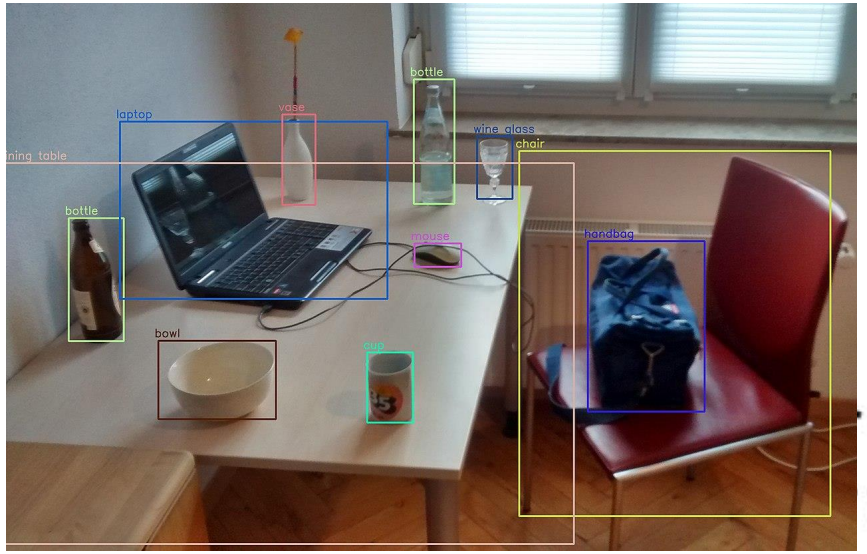

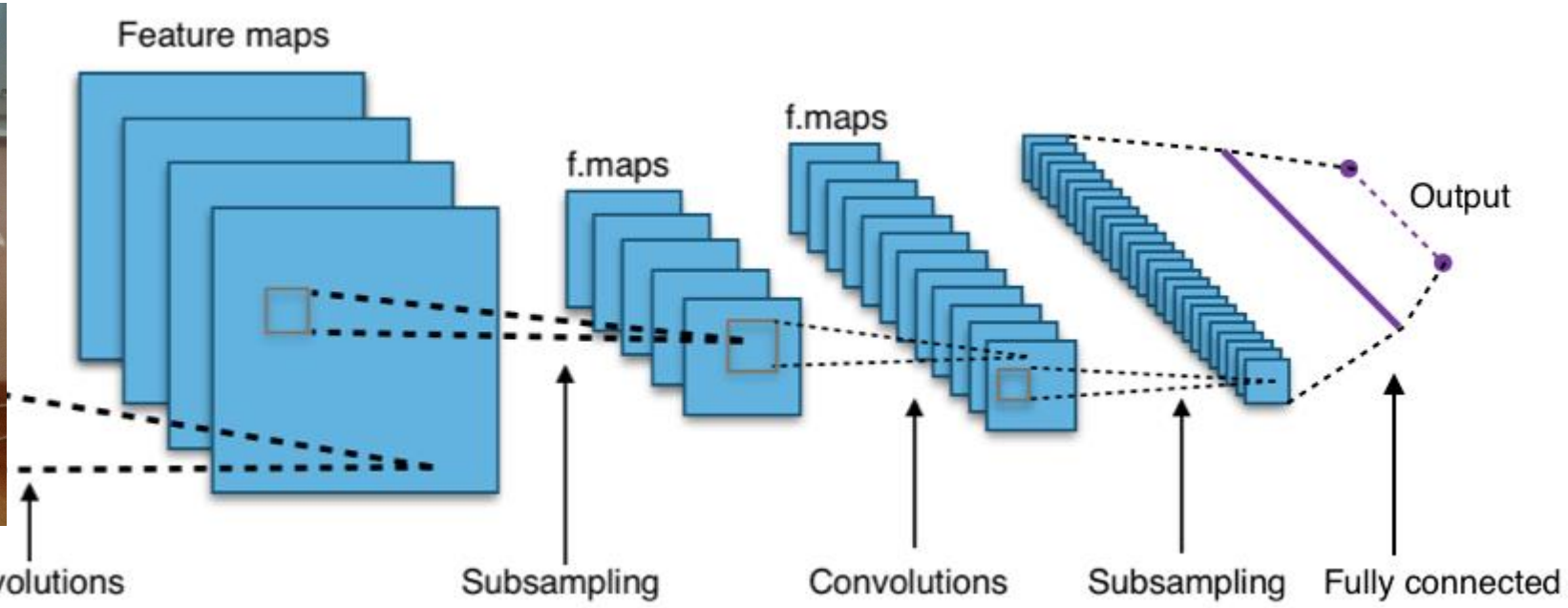

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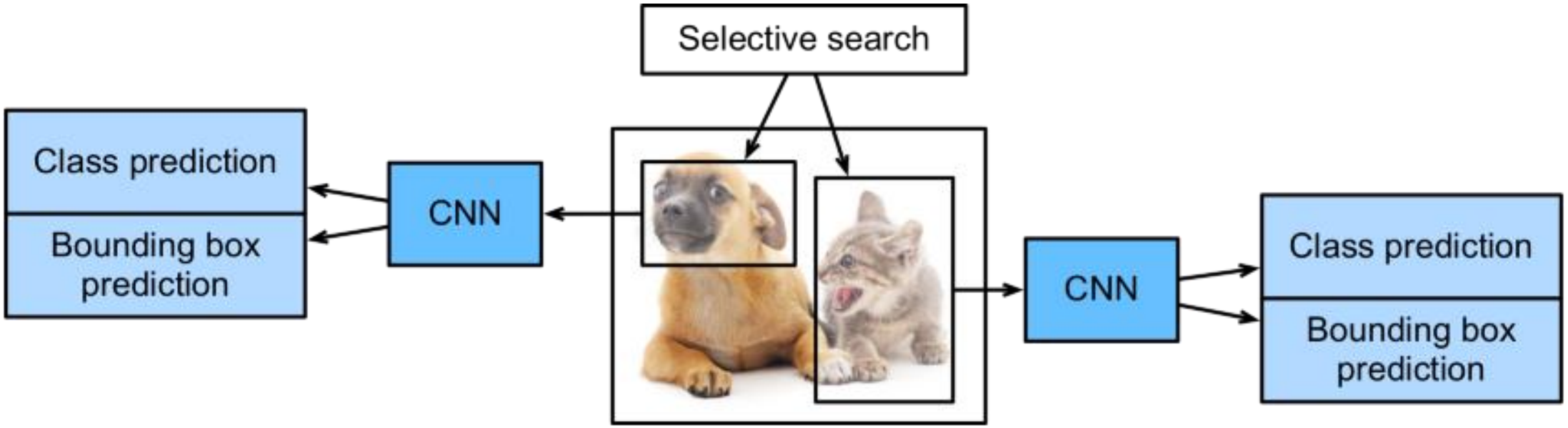
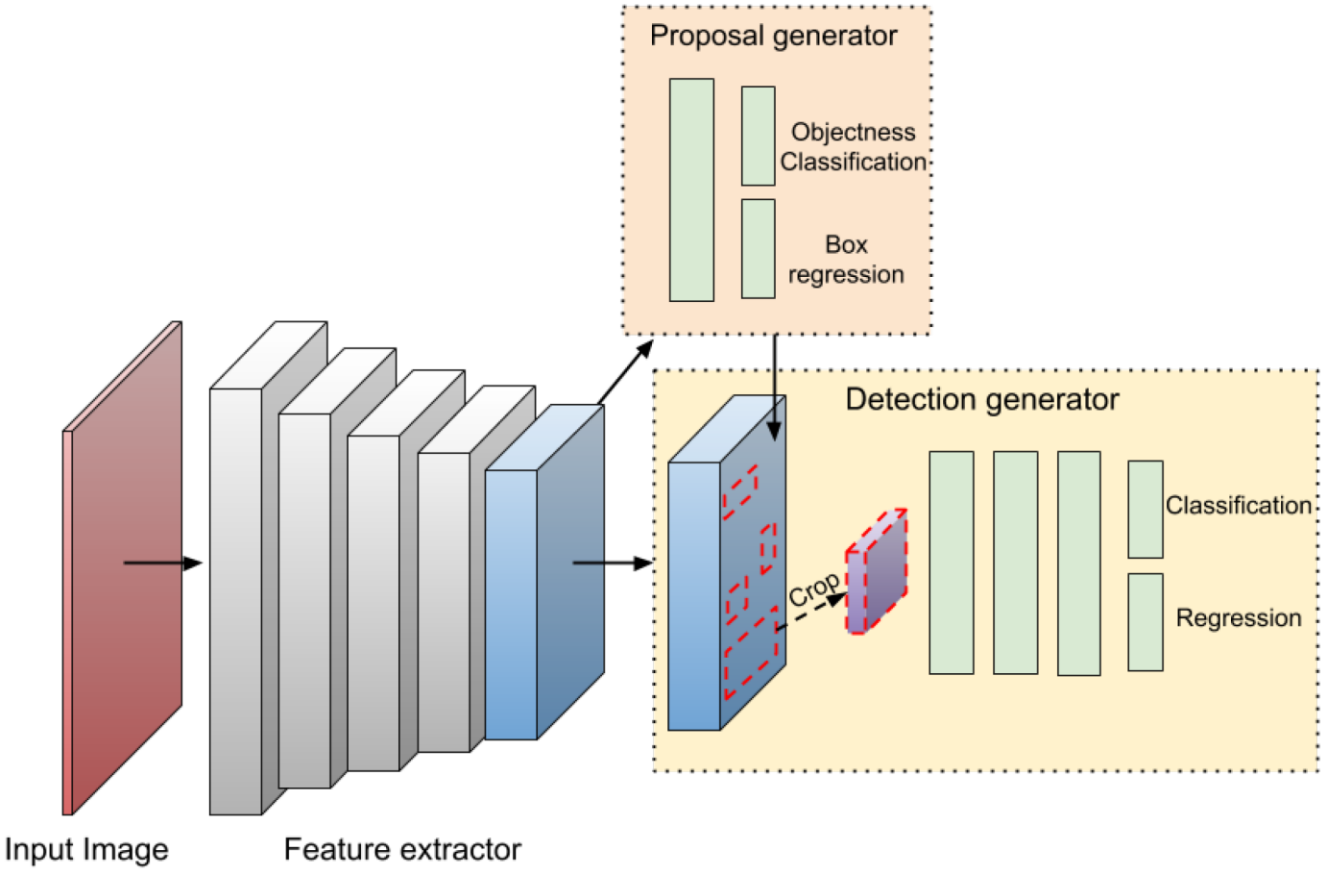
Object detection with CNNs



https://d2l.ai/_images/r-cnn.svg

Two-stage object detectors



(a) Two-stage Faster R-CNN

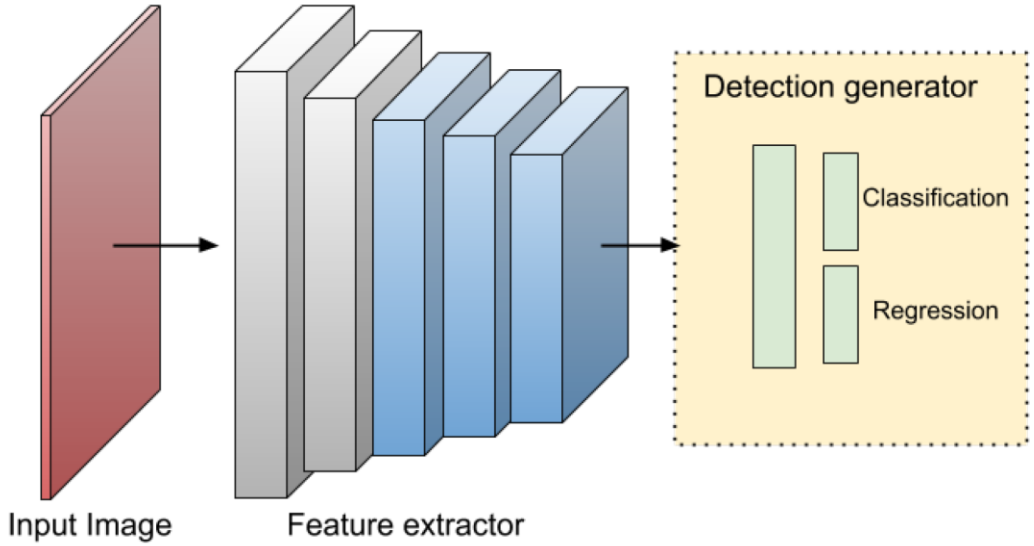
In a two-stage object detector, possible patches of object location are first identified followed by the classification of these patches and the refinement of the location

Carranza-García, M., Torres-Mateo, J., Lara-Benítez, P., & García-Gutiérrez, J. (2020). On the performance of one-stage and two-stage object detectors in autonomous vehicles using camera data. *Remote Sensing*, *13*(1), 89.

Two-stage object detectors

In a one-stage object detection model, bounding box location and label are simultaneously predicted by the model

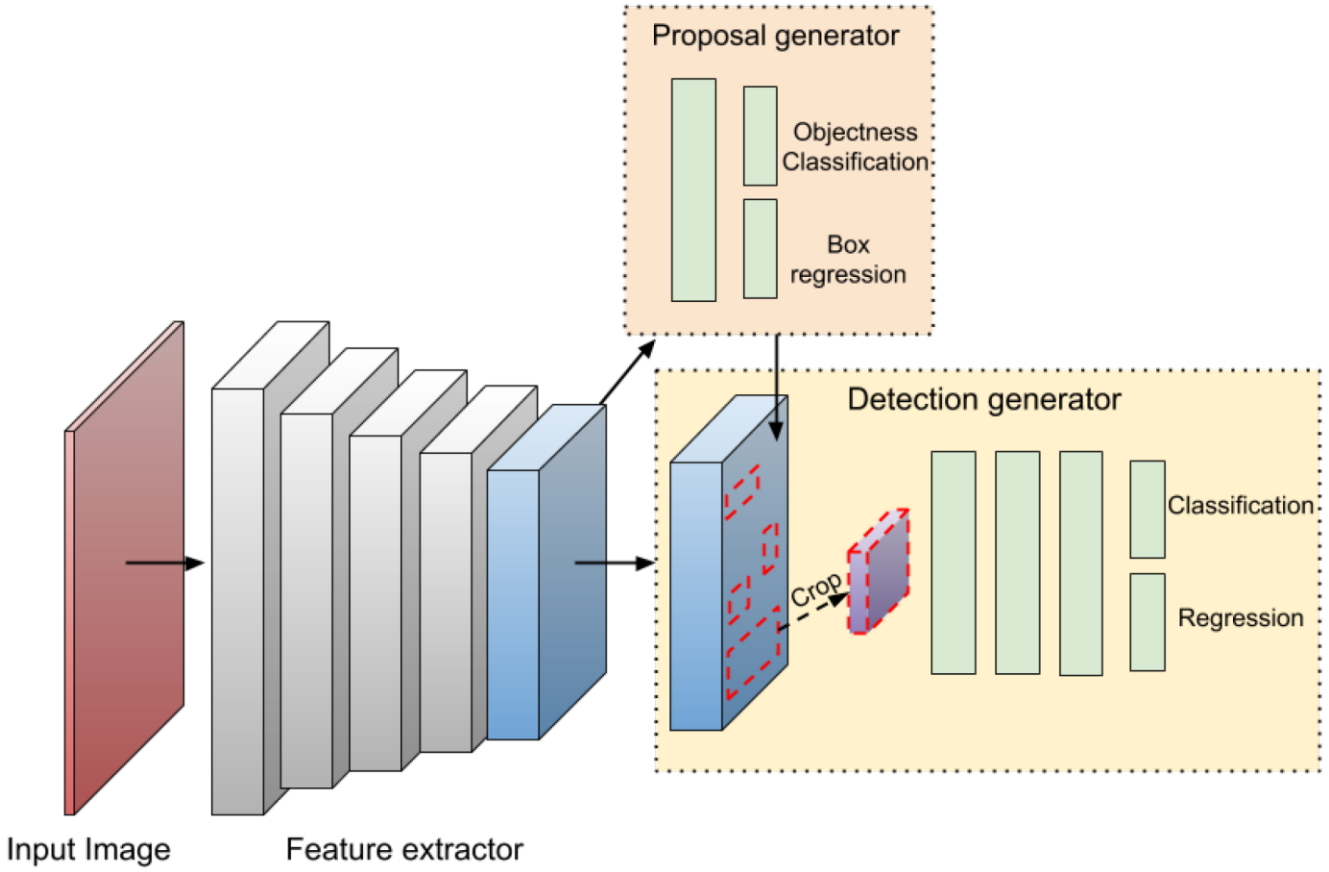
The recognition of the patch with possible object is included in the model architecture



(**b**) One-stage RetinaNet

Carranza-García, M., Torres-Mateo, J., Lara-Benítez, P., & García-Gutiérrez, J. (2020). On the performance of one-stage and two-stage object detectors in autonomous vehicles using camera data. *Remote Sensing*, *13*(1), 89.

Two-stage object detectors



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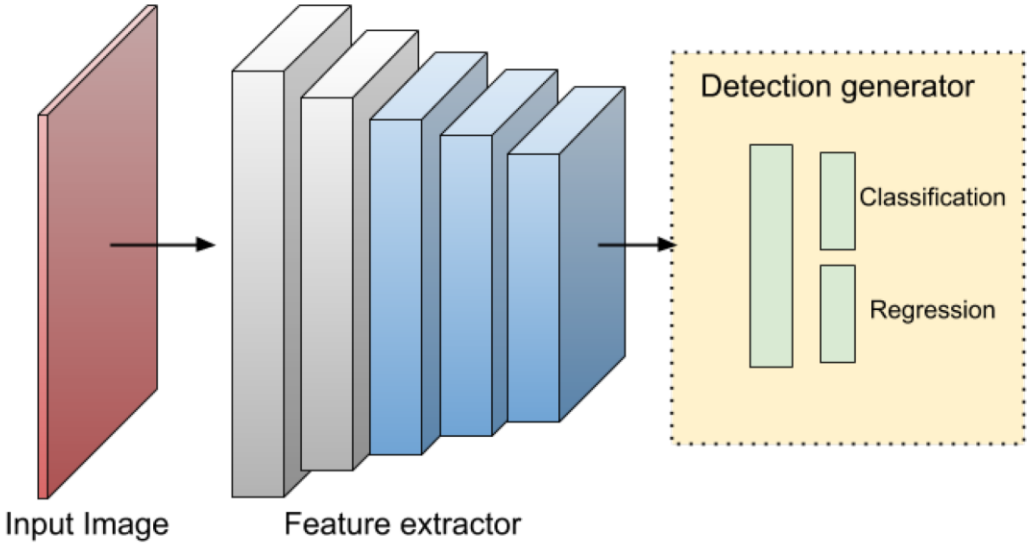

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Robotic controlled pollination in loblolly pine

- Timber tree used for pulp, plywood, general construction
- Dominant tree species in NC and the southeast
- In 2019, forest sector generated $21.6 billion in industry output[1]

[1] Parajuli, R.et al. (2020). *Economic Contribution of the Forest Sector in North Carolina, 2019*. NC State Extension, NC State University, College of Natural Resources.

Robotic controlled pollination in loblolly pine

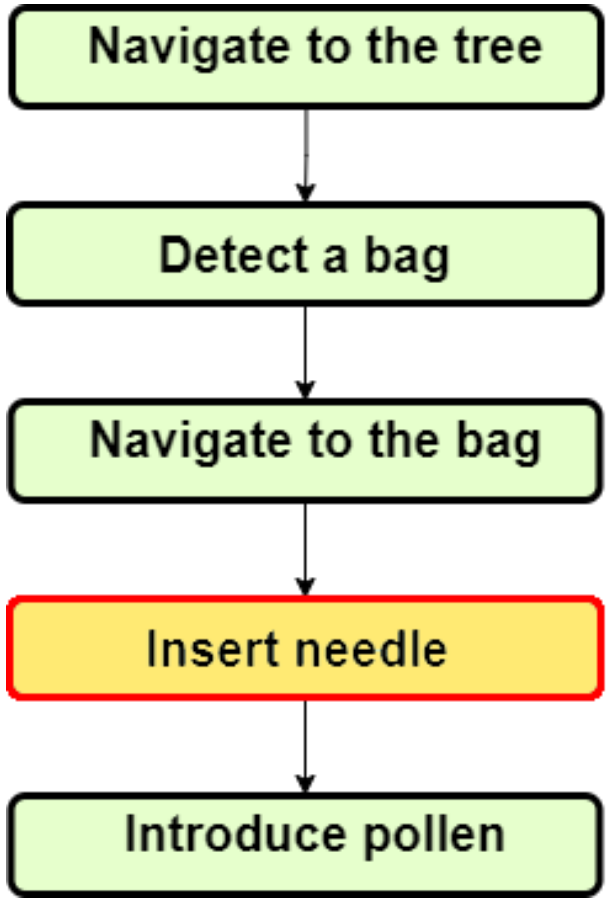
Robotic controlled pollination in loblolly pine

Pneumatic injectors

Robotic controlled pollination in loblolly pine

- More than a million bags placed annually
- Narrow time-window for pollination
- Challenges due to weather
- Safety
- Soil compaction

Robotic controlled pollination in loblolly pine



Robotic controlled pollination in loblolly pine

DUO MLX
Stereo camera

Robotic controlled pollination in loblolly pine

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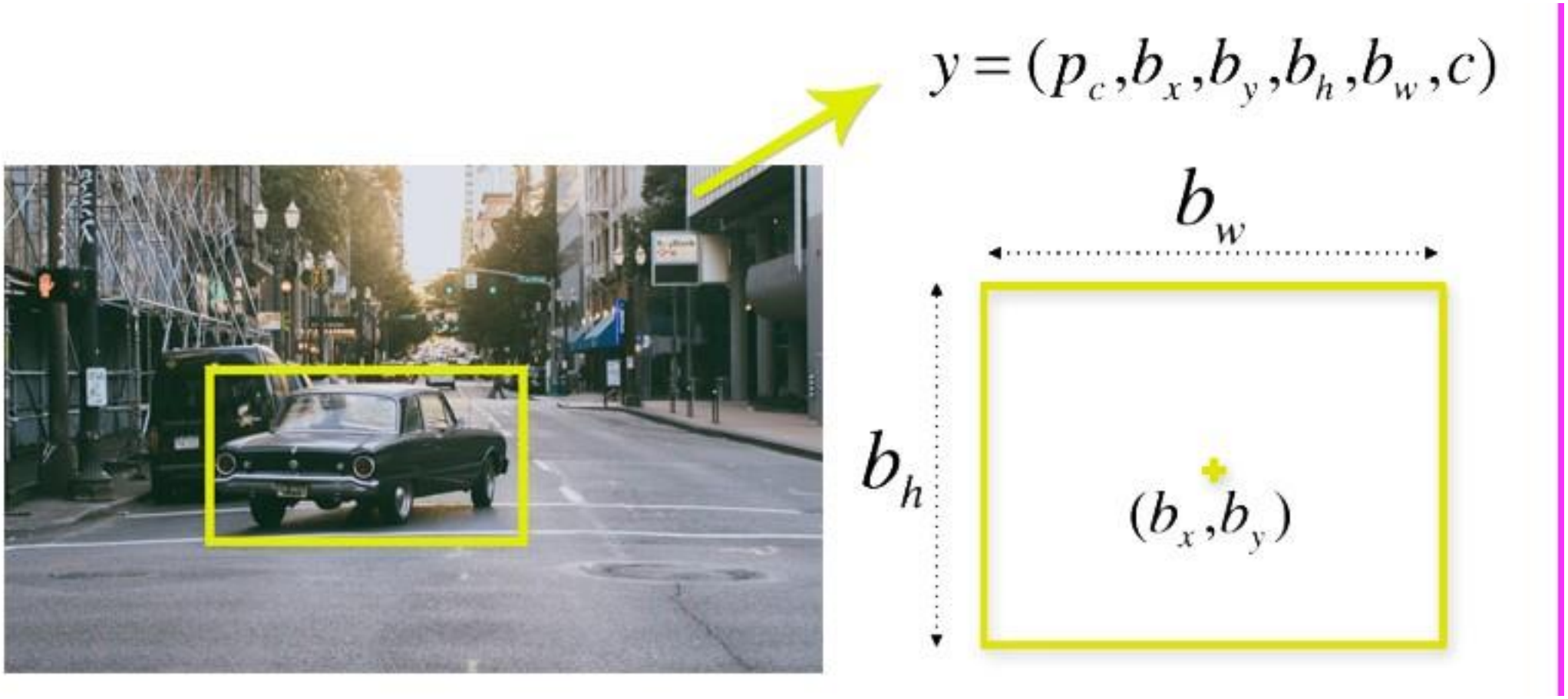
Stereo camera

Classification or detection?

One-stage object detection model or a two-stage model?

What about segmentation?

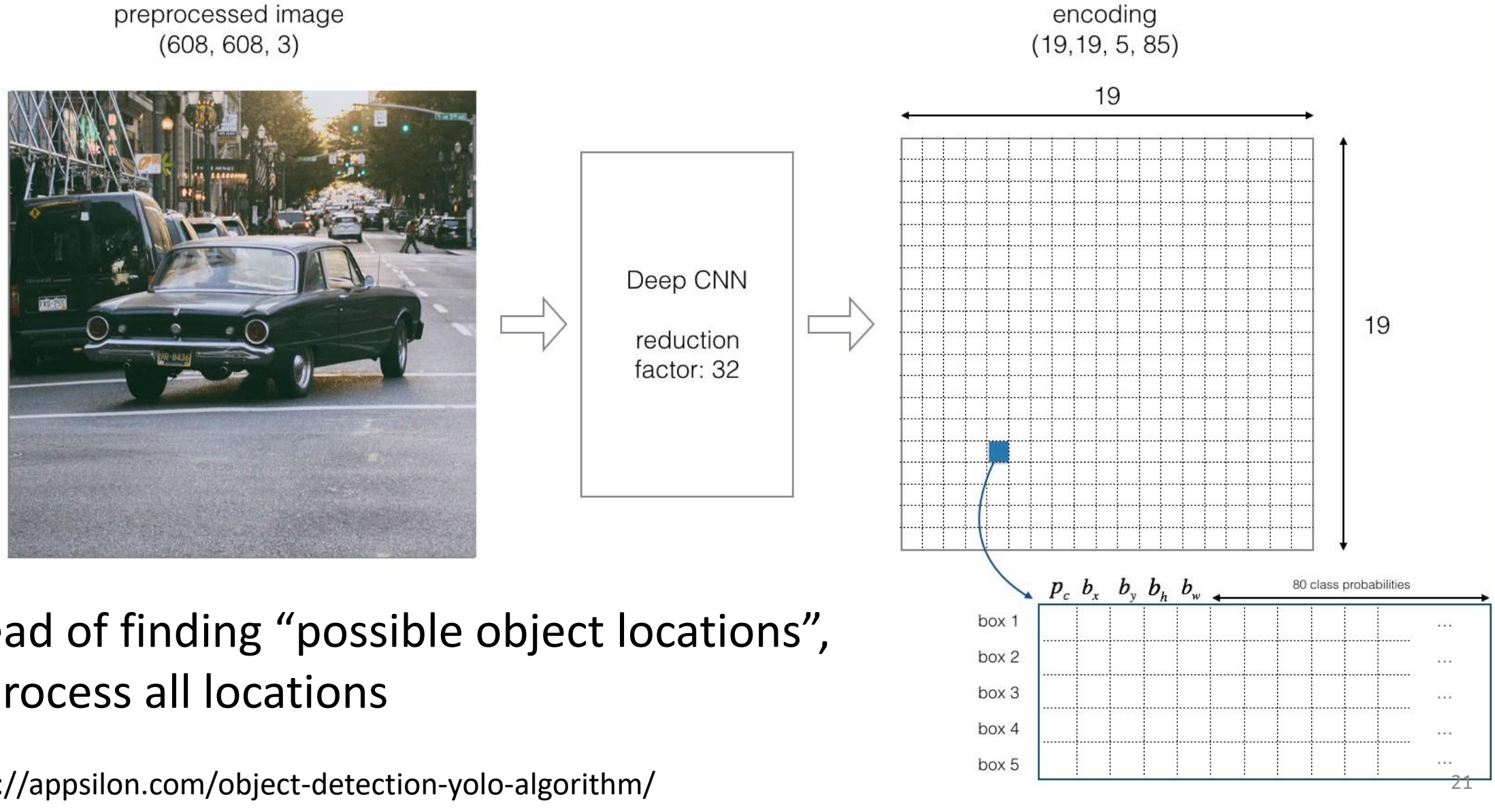
You Only Look Once (YOLO)



https://appsilon.com/object-detection-yolo-algorithm/

We predict bounding box location (b_x, b_y, b_h, b_w), probability of objectness (p_c) and the object class label (c).

You Only Look Once (YOLO)

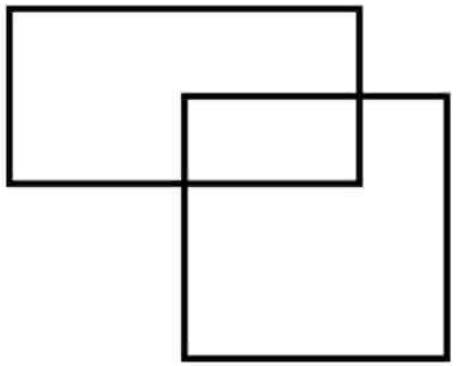


Instead of finding “possible object locations”, we process all locations

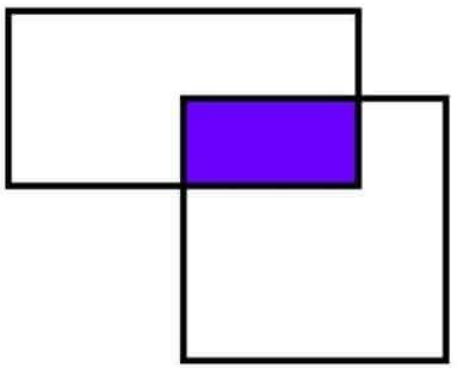
https://appsilon.com/object-detection-yolo-algorithm/

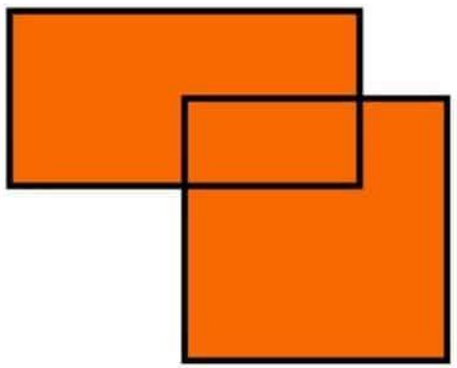
YOLO Idea 1: NMS

YOLO Idea 2: IoU



For a set of bounding boxes like the given one



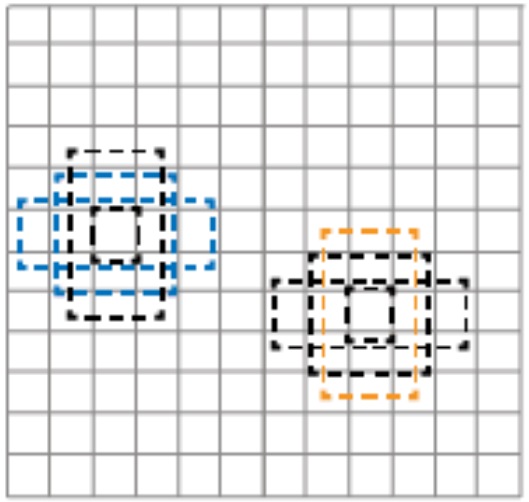


The purple area is Intersection

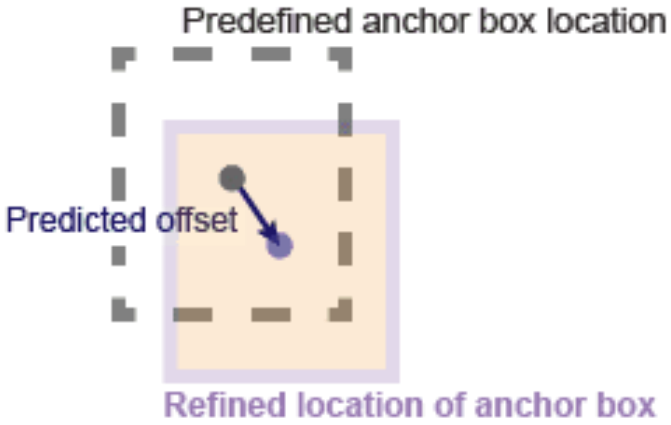
The orange area is Union

YOLO Idea 3: Anchor boxes

Ground truth image and bounding boxes



Anchor boxes at each predefined location in each feature map



Two anchor boxes
Class: airplane
Class: sailboat

Filter by class scores, perform non-max suppression and intersection over union

https://ww2.mathworks.cn/help/vision/ug/anchor-boxes-for-object-detection.html

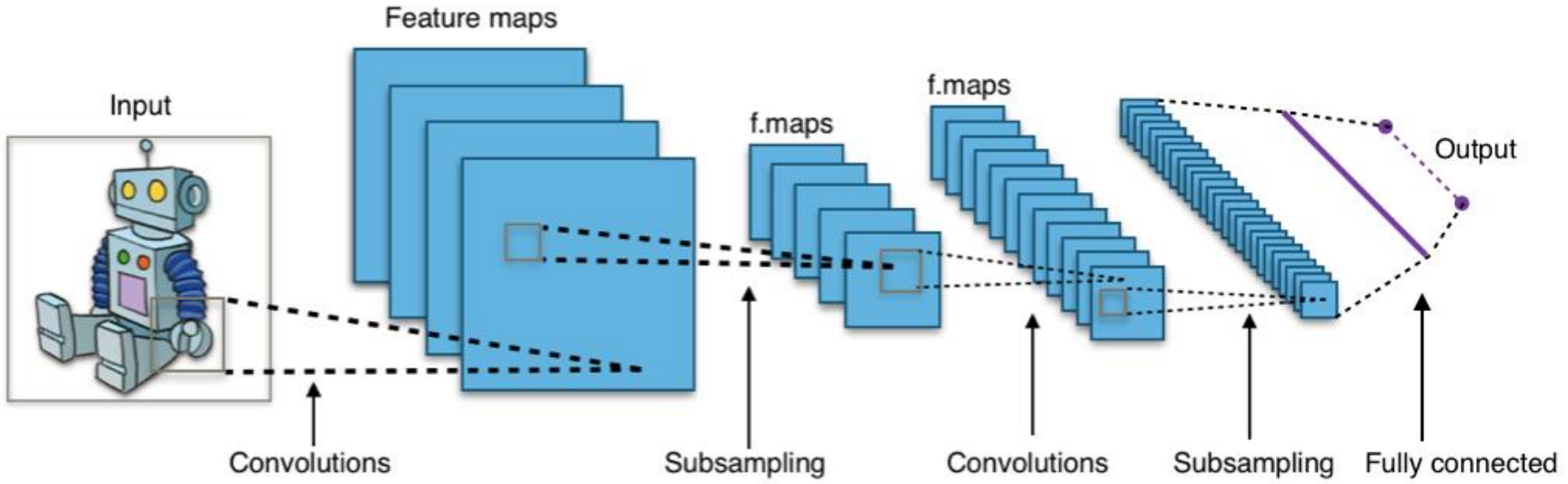
Model training pipeline

1. Select model architecture
2. Decide training process (Training from scratch? Transfer learning?)
3. Label images
4. Split data into train-validation-testing
5. Train the model and iterate

Transfer learning

The initial layers are frozen

Existing model architecture, pre-trained on large dataset…



But not trained on paper bags put on tree branches.

Freezing parts of the pretrained model (keeping the trained parameters unchanged) leads to faster training on the novel dataset.

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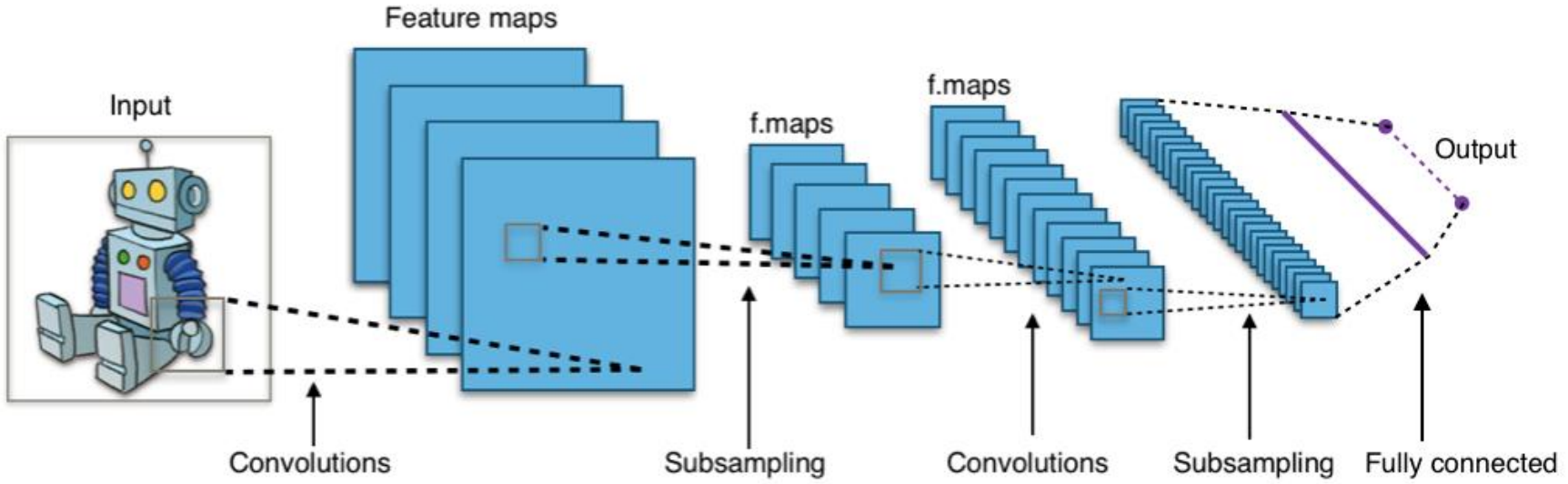

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Model training pipeline

1. Select model architecture: **one-stage detector (YOLOv5)**
2. Decide training process: **Transfer learning**
3. Label images
4. Split data into train-validation-testing
5. Train the model and iterate

Labeling tools

Labeling for object detection is simply drawing a rectangle and assigning a class label

1. MATLAB image labeler: Computer vision toolbox
   Stable, intuitive, and reliable, not free

2. LabelImg: https://github.com/heartexlabs/labelImg (Transitioned to a new tool (Label Studio))
   Intuitive and free, limited functionality

3. VGG Image Annotator: https://www.robots.ox.ac.uk/~vgg/software/via/
   Simple and free but not user friendly

Larger/ advanced applications: CVAT, LabelStudio

Image Labeler

LABEL

New Session
Open Session
Save Session
Import
FILE

Show ROI Labels
On Hover
ROI Color
By Label
VIEW

Label Opacity
Polygon
Pixel
LABEL OPACITY

Algorithm:
Select Algorithm
Automate
AUTOMATE LABELING

View Shortcuts
RESOURCES

View Label Summary
SUMMARY

Layout
LAYOUT

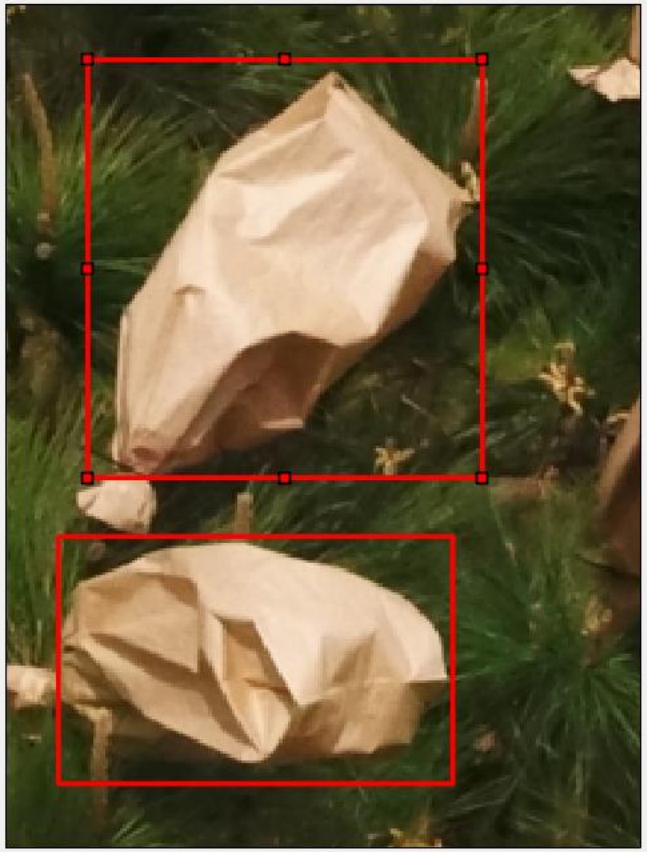
Export
EXPORT

ROI Labels
Scene Labels

Label
Sublabel
Attribute

bag

9



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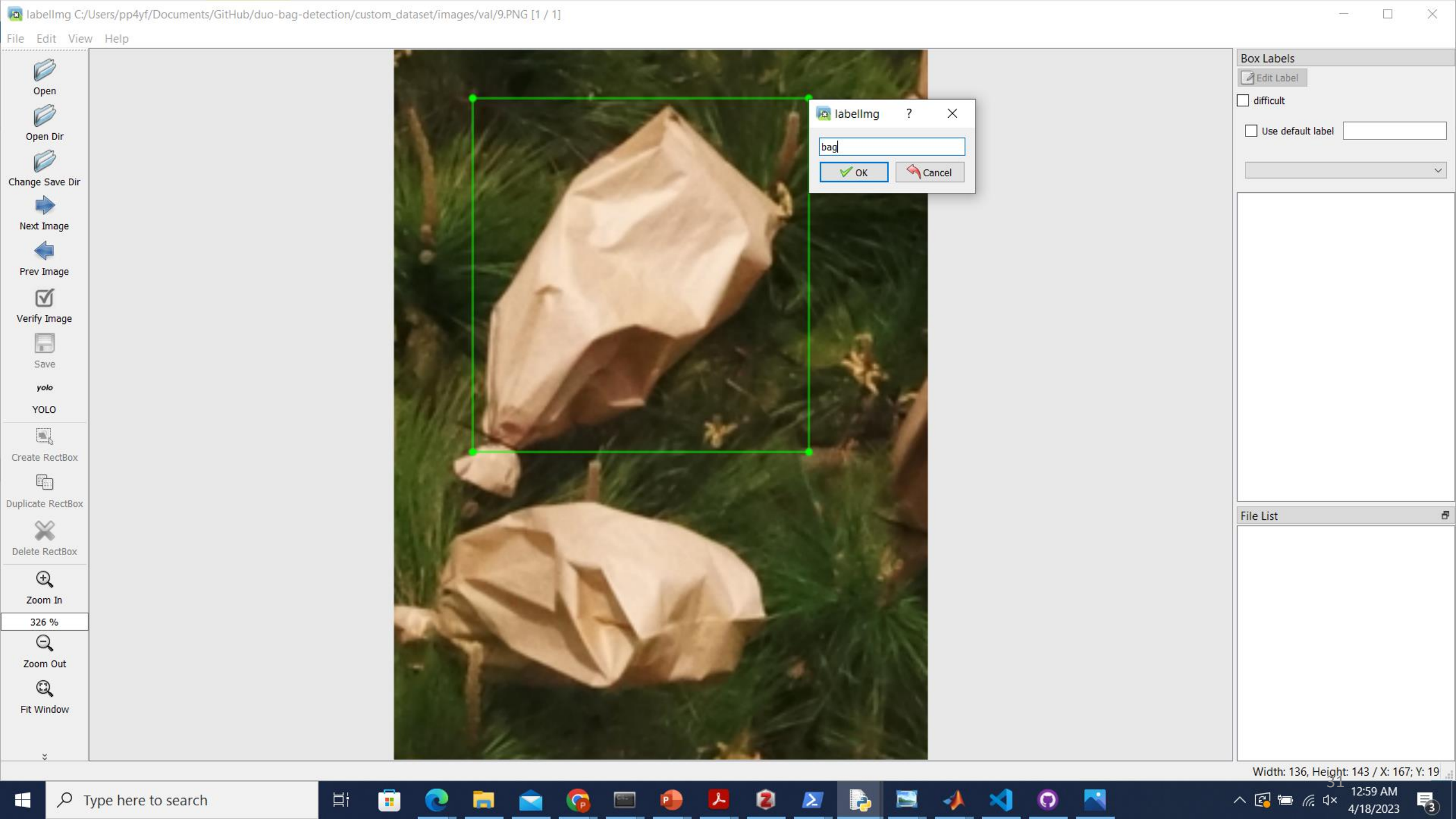
labelImg C:/Users/pp4yf/Documents/GitHub/duo-bag-detection/custom_dataset/images/val/9.PNG [1 / 1]
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Model training pipeline

1. Select model architecture: **one-stage detector (YOLOv5)**

2. Decide training process: **Transfer learning**

3. Label images
4. Split data into train-validation-testing
5. Train the model and iterate

For steps 4 and 5, visit https://github.com/piyuss/bag-detection, click on Exclusion_bag_detection_demo_YOLOv5.ipynb, click on 

You will need a Google account and will need to log in to your account to run the code.