MACHINE VISION

Agenda

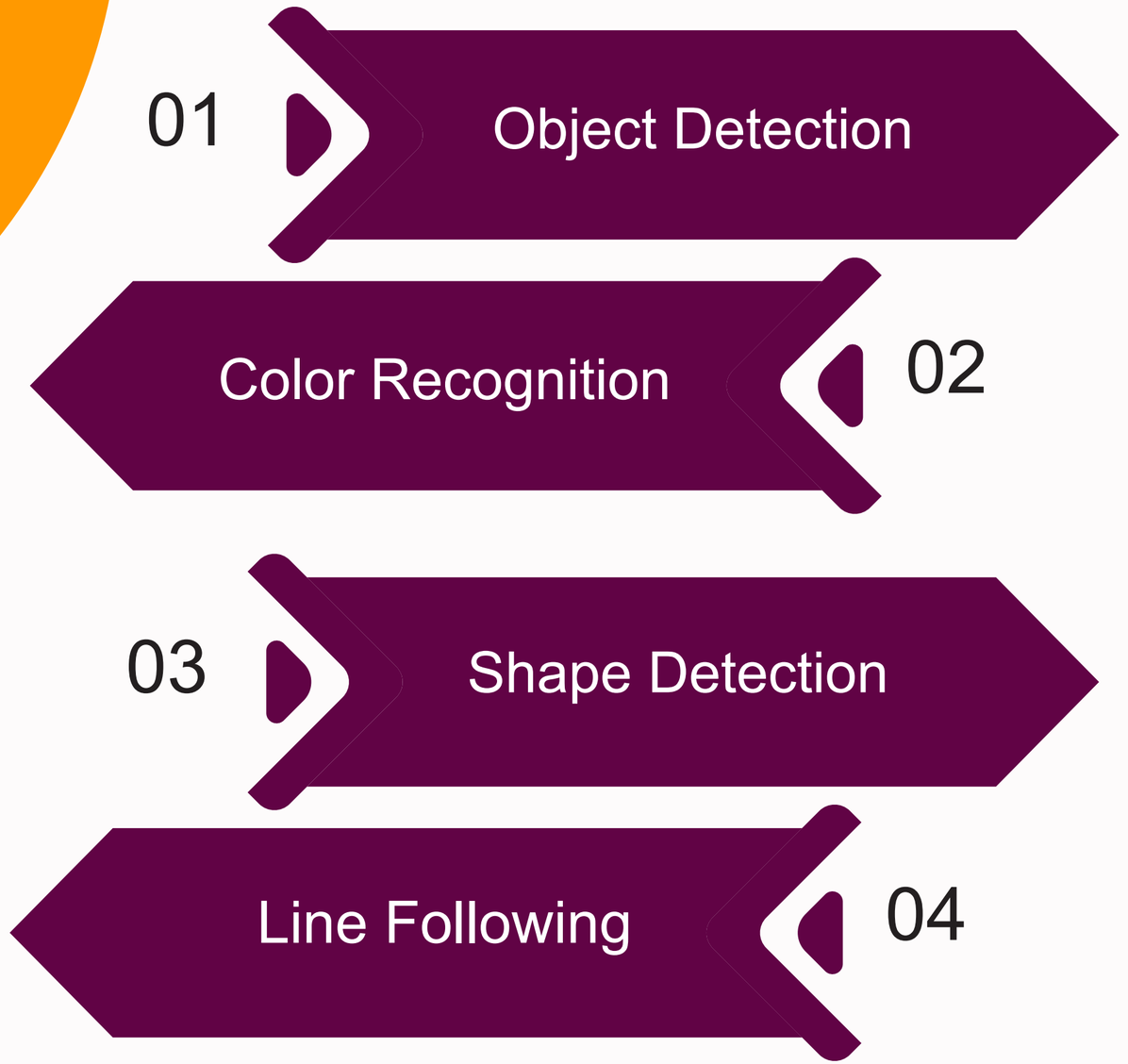
01 Overview

02 Vision Basics

03 Vision Applications (ArUco)

04 Machine Learning Overview

Overview


01
Object Detection
Color Recognition
02
03
Shape Detection
Line Following
04

Cameras

Raspberry Pi Camera

ESP32 Camera

Depth Camera

Cameras

Tracking Camera

USB Webcam

OV7640

VISION BASICS

Seeing isn't easy

Categories

04 Instance Segmentation

03 Object Detection

02 Image Classification

01 Raspberry Pi Camera Setup

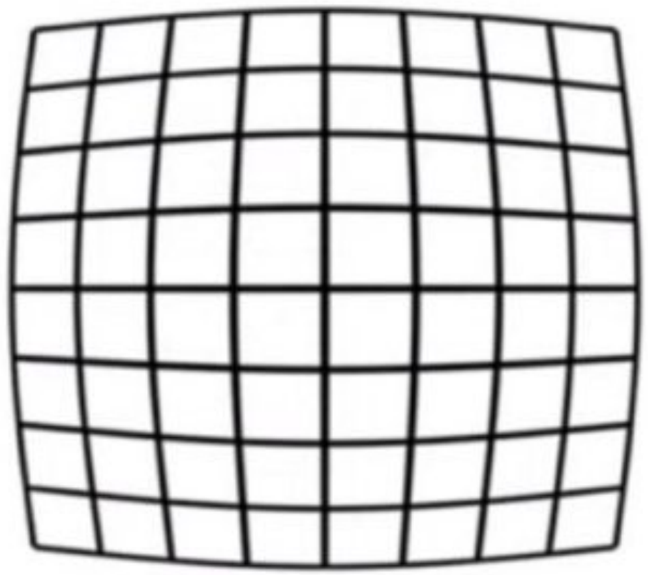
PI CAMERA SETUP

HARDWARE

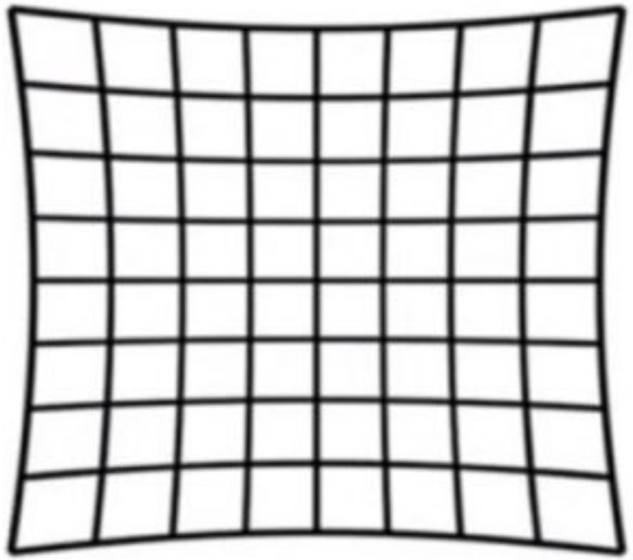
SOFTWARE

- **Operating System**
  - Raspberry Pi OS (Raspbian)
  - **Ubuntu 22.04**
- **Language:**
  - **Python**
  - **C++**
- **Framework:**
  - OpenCV
  - **ROS**

PI CAMERA CALIBRATION



Barrel Distortion

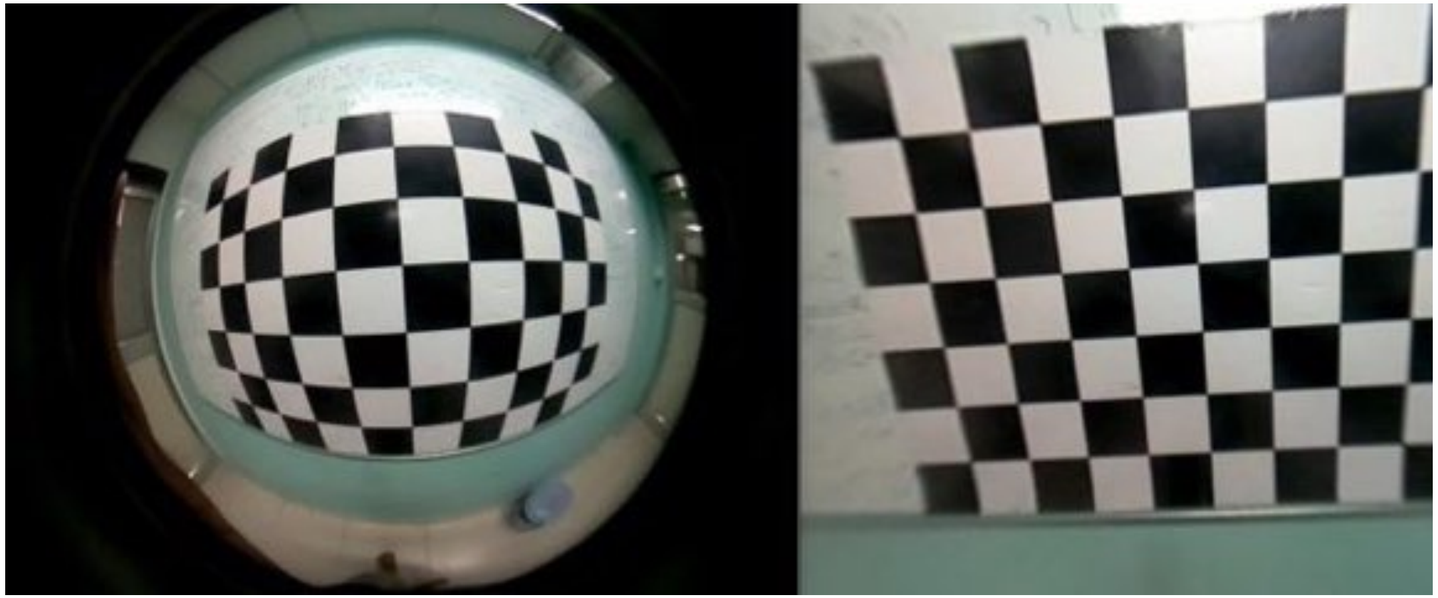


Pincushion Distortion

PURPOSE

- **Remove Distortion**
  - Geometric Distortion
    - Barrel
    - Pincushion
- **Get Camera Matrix**
  - Useful in depth estimation

PI CAMERA CALIBRATION



METHODS

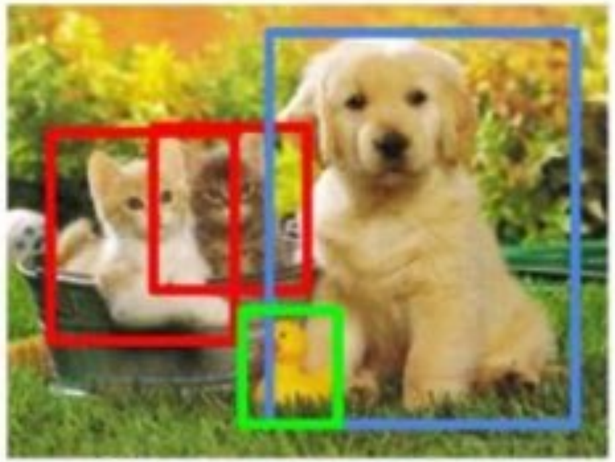
- **Zhang's Method**
- Record Video of Chessboard
- Use the video2calibration library
- The library generates the Camera Matrix

IMAGE CLASSIFICATION

Classification

CAT

Object Detection



CAT, DOG, DUCK

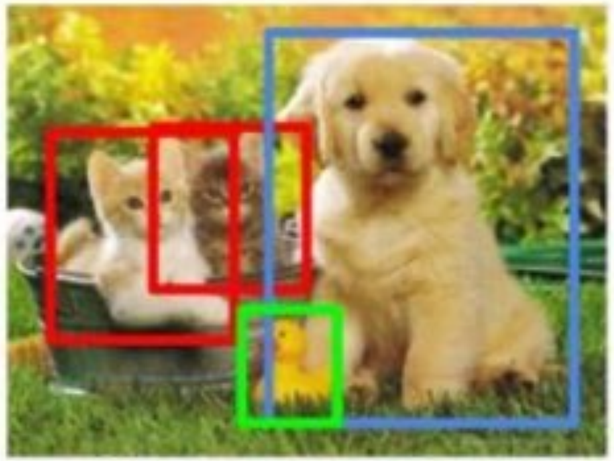
- Tells us **what's in the image**
- Doesn't give us positional info
- Example: Mask Detector

OBJECT DETECTION

Classification

CAT

Object Detection



CAT, DOG, DUCK

- Involves **classification** & **localization**
- Gives us positional info for every object detected
- Example: People Counter

OBJECT DETECTION

TRADITIONAL METHODS

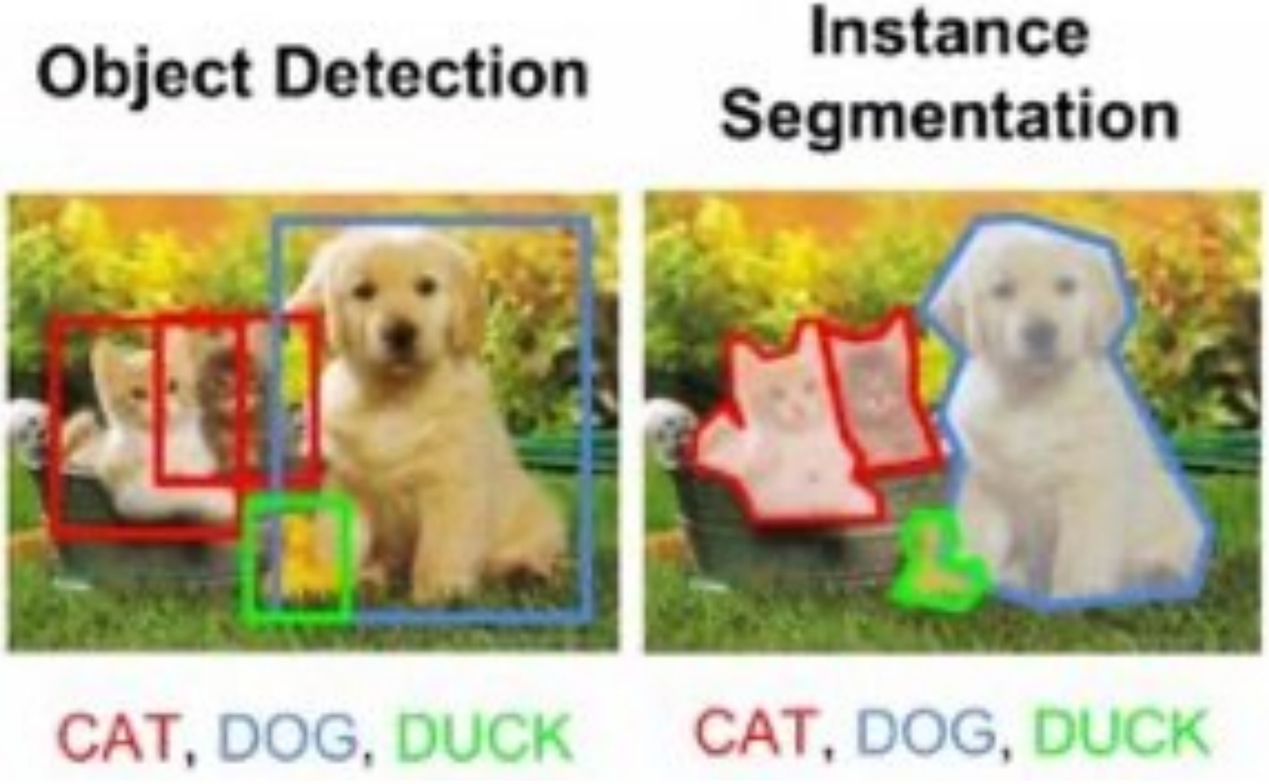
- Classical Algorithms
  - Haar Cascades
  - HOG Detector

MODERN METHODS

- Deep Learning:
  - R-CNN
  - Faster R-CNN
  - Single Shot Detectors (SSDs)
  - **YOLO (You Only Look Once)**

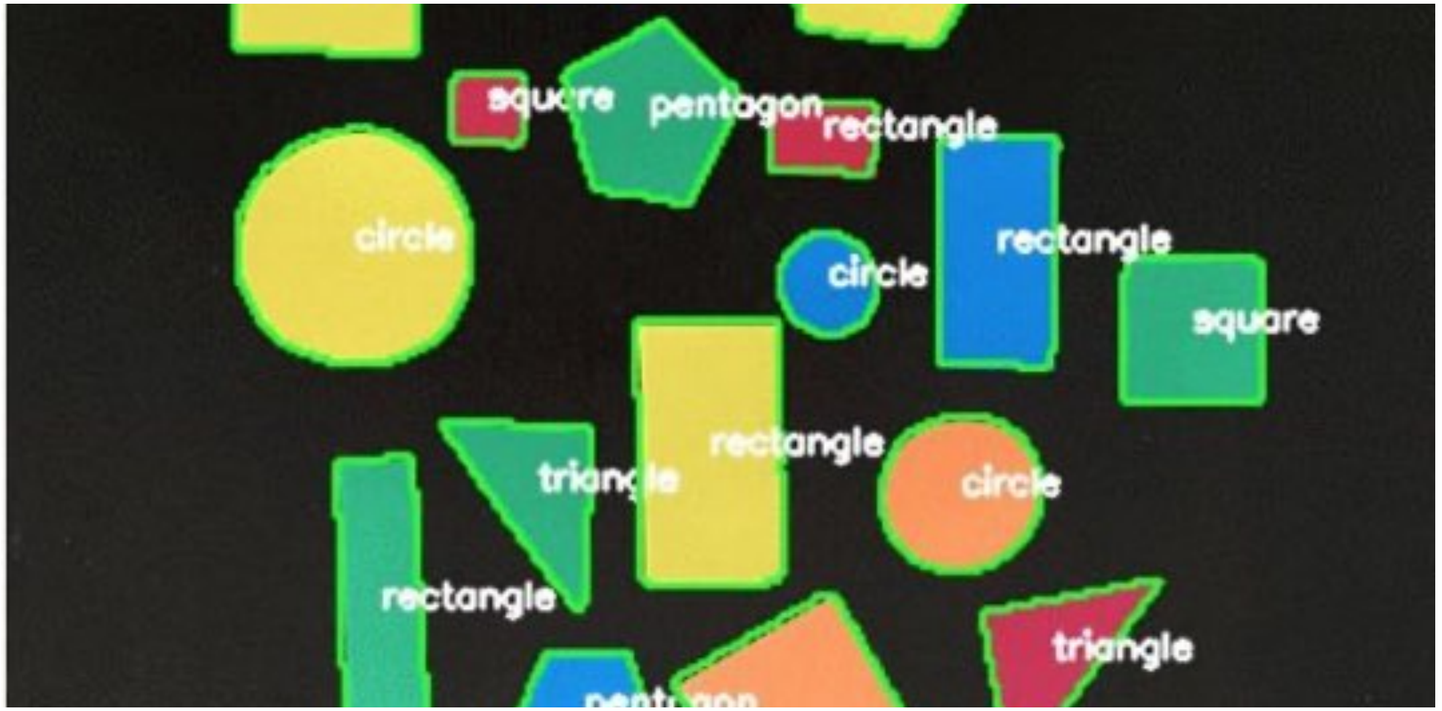
OBJECT DETECTION

INSTANCE SEGMENTATION



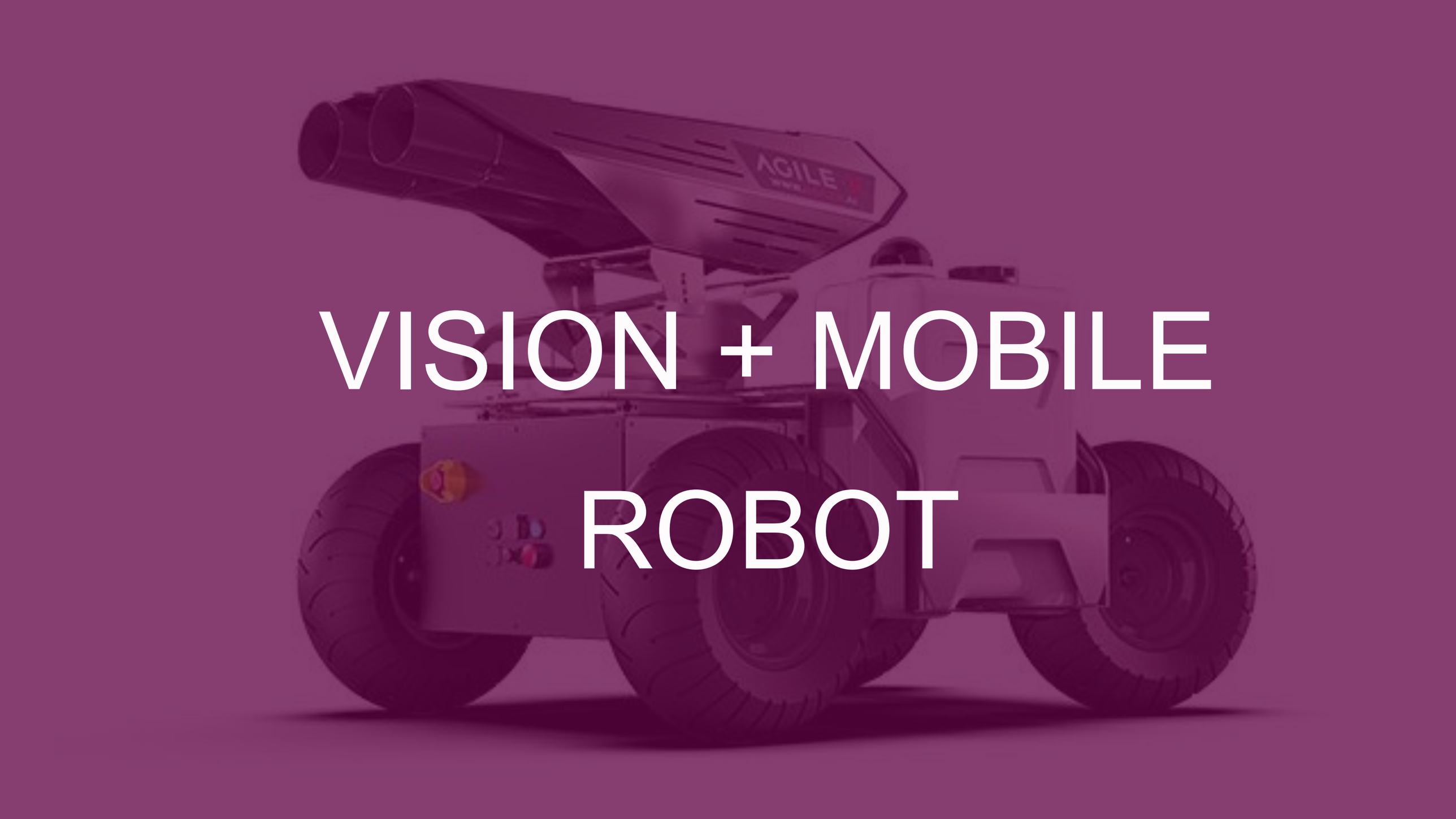
- Even more detail - **Distinguishes objects** from other objects / background
- Example: Localizing Cancer Cells

SHAPE DETECTION



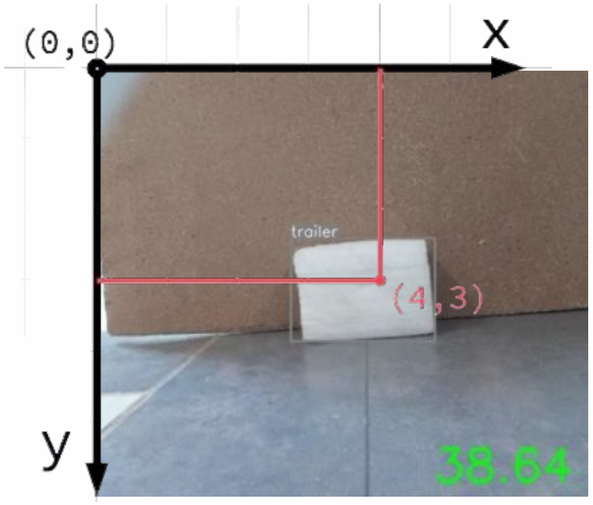
- Instance Segmentation can be complicated
- OpenCV can be used to detect shapes

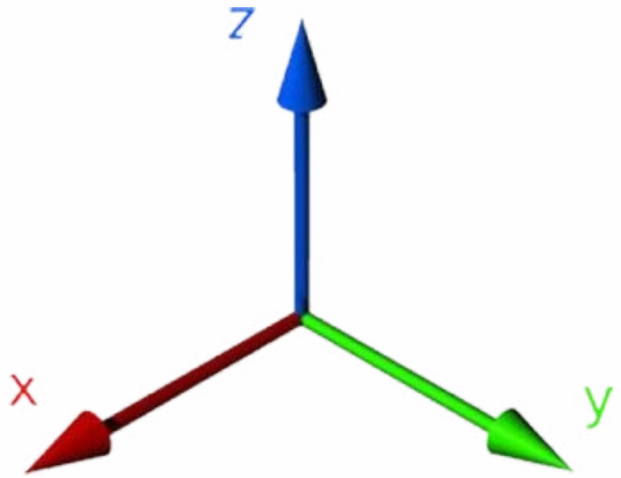
A FEW CHALLENGES



VISION + MOBILE ROBOT

COORDINATE TRANSFORMATION

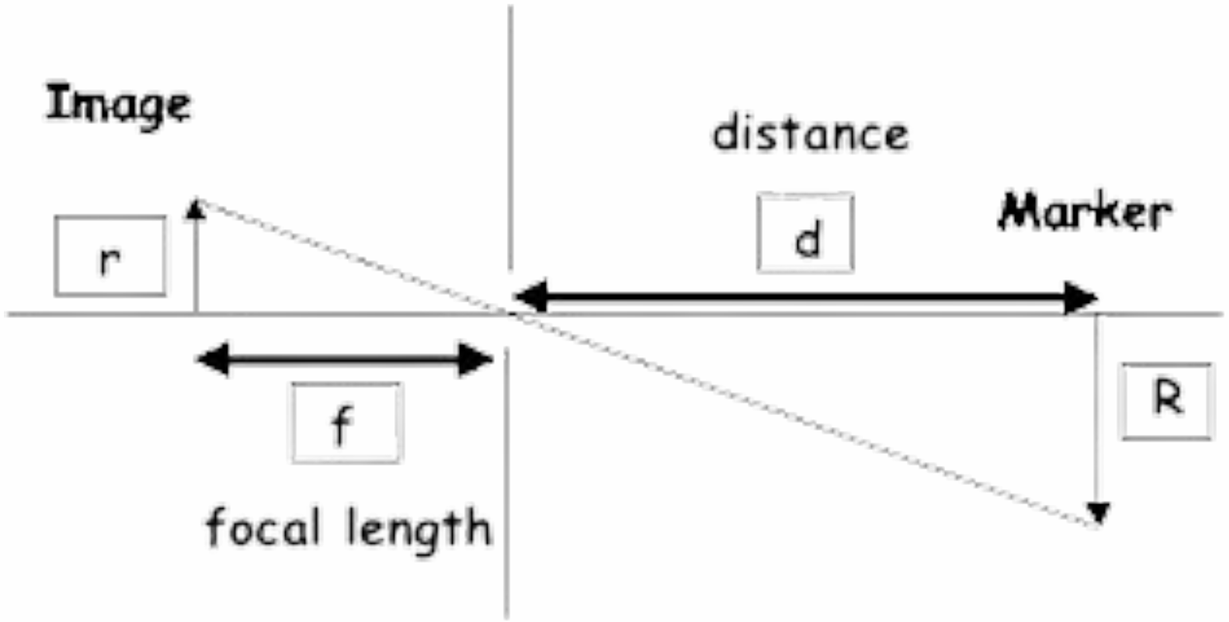




- Converting **camera** coordinates to **robot** coordinates
- Camera coordinates in 2D to **robot** coordinates in 3D

- One Axis Missing

DEPTH ESTIMATION



METHODS

- Use a **Depth Camera**
- **Stereo Vision**
- Ultrasonic Sensor
- Train a Deep Learning Model
- Homogeneous Matrix
- Triangle Similarity

TRIANGLE SIMILARITY

$$F = (P \times D) / W$$

- F = Camera Focal Length
- P = Apparent Width
- D = Distance from Camera
- W = Known width

$$D = (W \times F) / P$$

HOMOGENEOUS MATRIX

$$\boldsymbol{x} = \mathbf{PX}$$

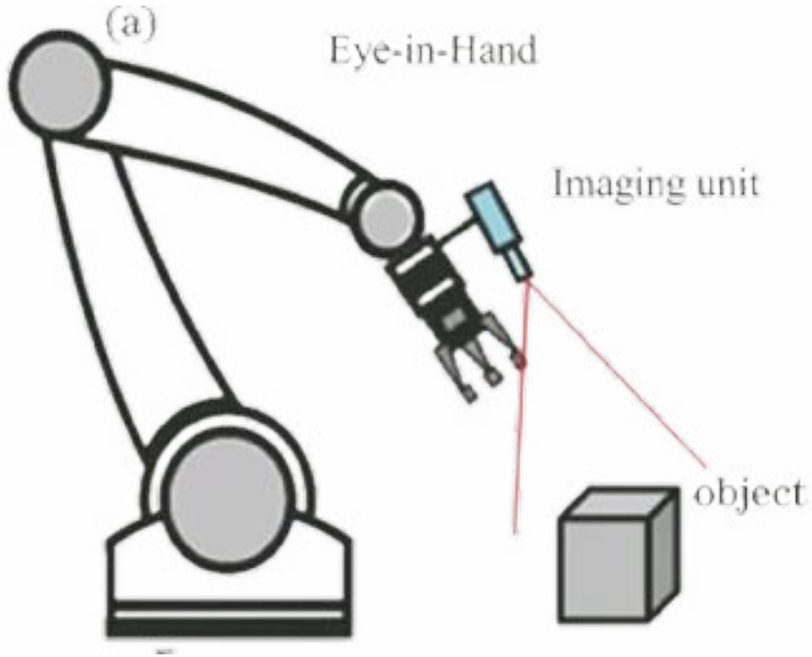
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} p_1 & p_2 & p_3 & p_4 \\ p_5 & p_6 & p_7 & p_8 \\ p_9 & p_{10} & p_{11} & p_{12} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

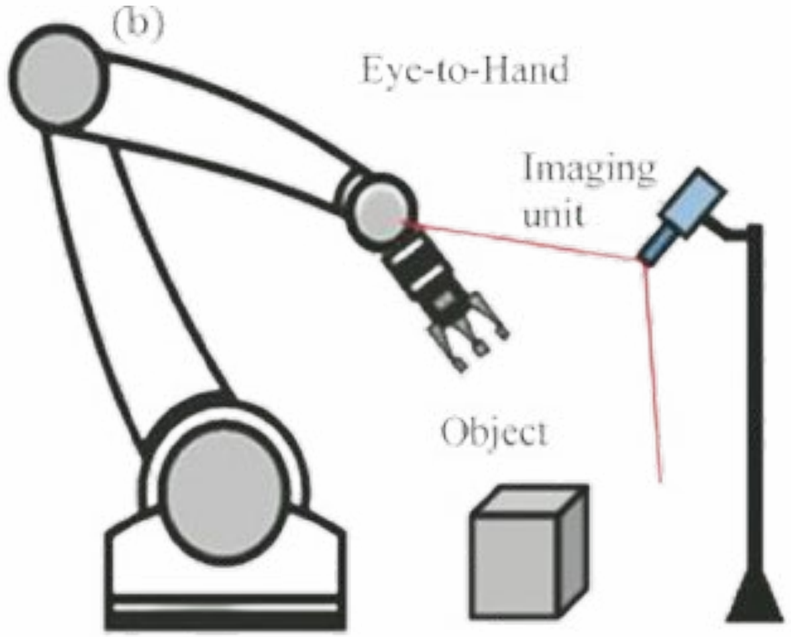
homogeneous image 3 x 1

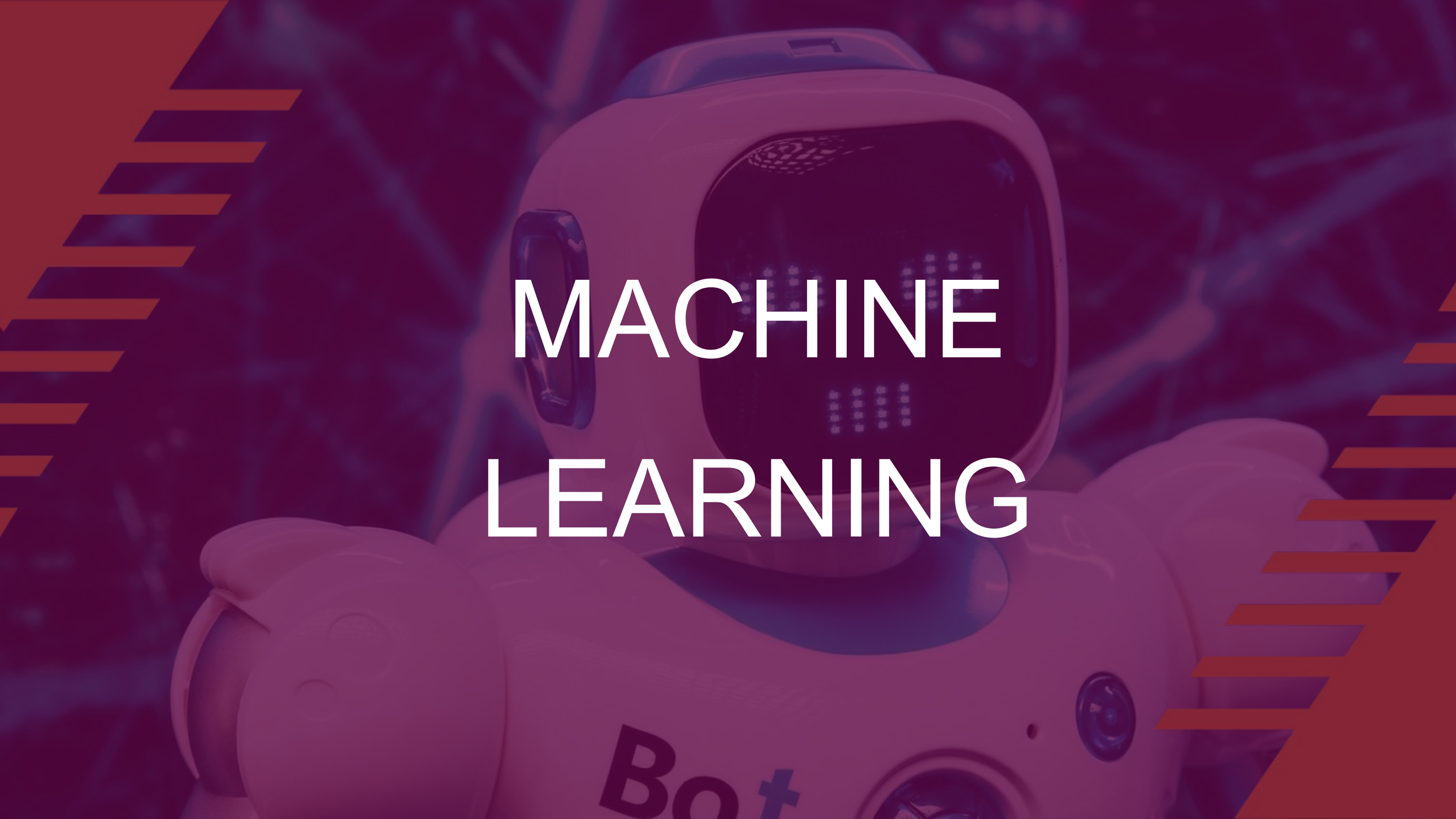
Camera matrix 3 x 4

homogeneous world point 4 x 1

CAMERA POSITIONING

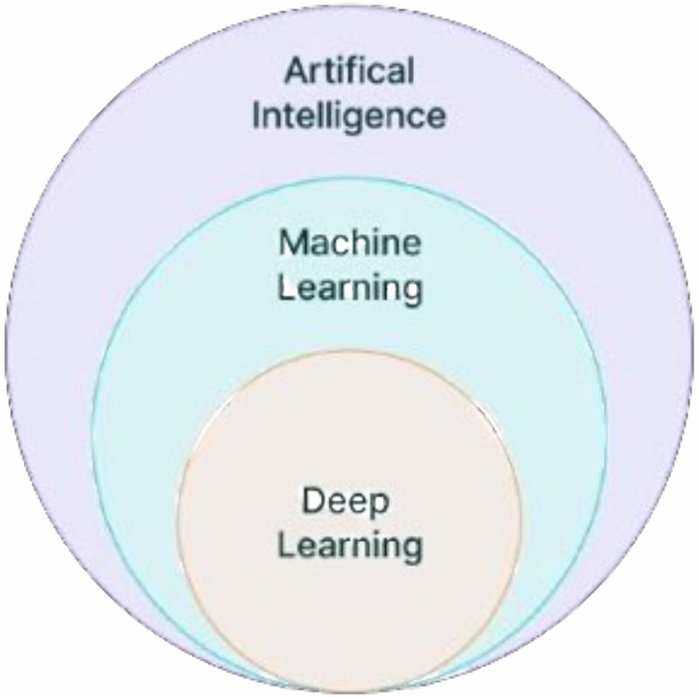





MACHINE
LEARNING

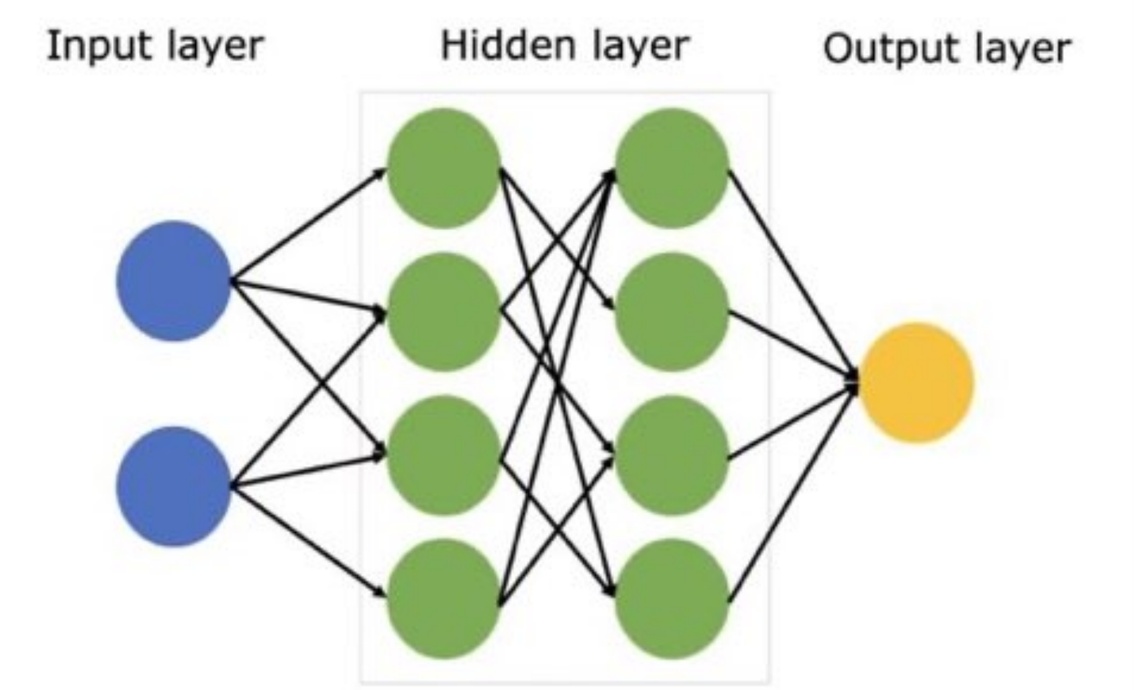

*Machine Learning
*Algorithms
*Maths
What the hell is this?

ARTIFICIAL INTELLIGENCE



- **Artificial Intelligence (AI)**
  - Computer Vision
  - Natural Language Processing
- **Machine Learning (ML)**
  - Statistical Models
- **Deep Learning (DL)**
  - Artificial Neural Networks
- **Large Language Models (LLMs)**
  - Vision Language Models

DEEP LEARNING MODELS



- R-CNN
- Mask R-CNN
- Fast R-CNN
- Faster R-CNN
- YOLO

YOU ONLY LOOK ONCE (YOLO)

TRADITIONAL METHODS

- YOLO v3
- YOLO v5
- YOLO v7
- YOLO v8
- YOLO NAS

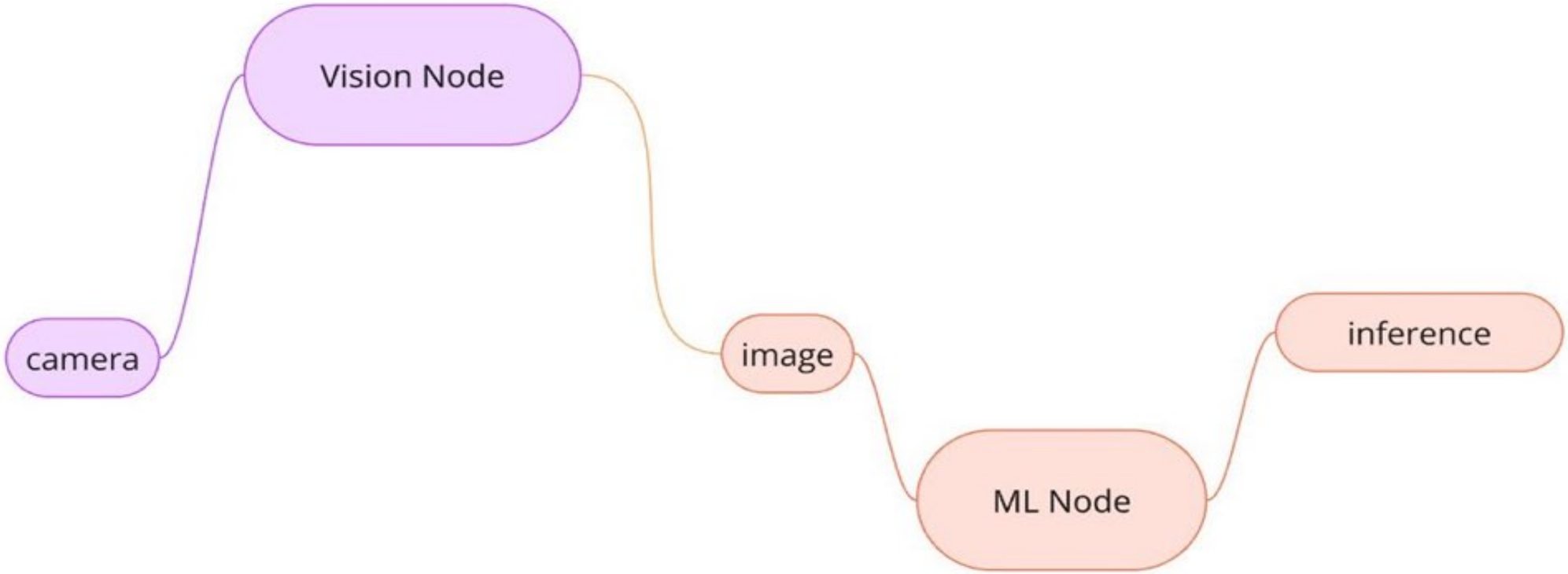
CAPABILITES

- Image Classification
- Object Detection
- Instance Segmentation
- Pose Estimation
- Motion Tracking

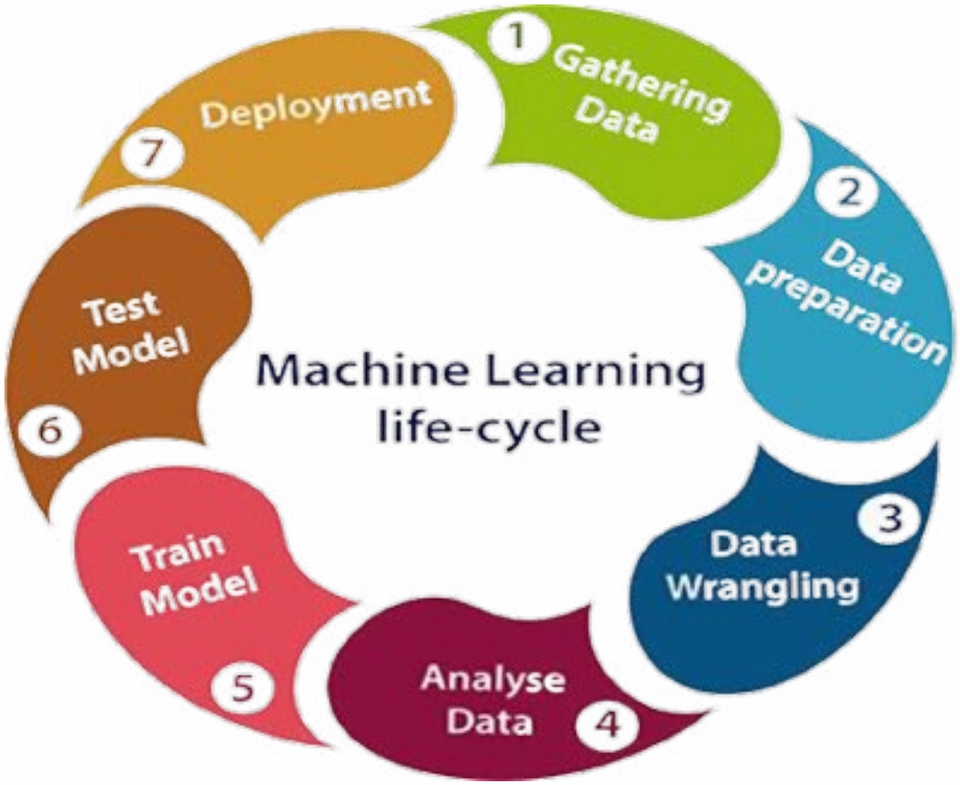
FRAMEWORKS

- Ultralytics
- PyTorch
- Tensorflow
- ML.Net

MODEL INTEGRATION



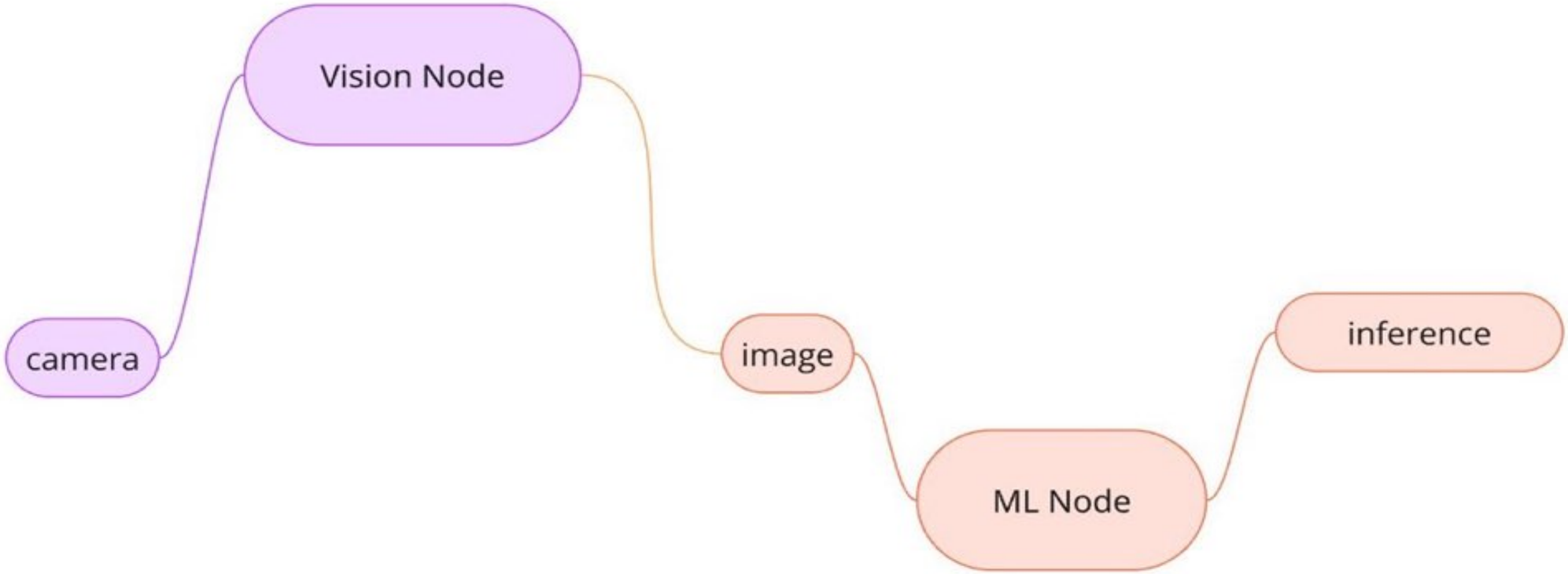
CUSTOM TRAINING



PLATFORMS

- Roboflow
- Google Colab
- Local Machine
- **Cloud Services**
  - Amazon Web Services (AWS)
  - Microsoft Azure

MODEL INTEGRATION



THANK YOU

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