People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

University of KASDI MERBAH OUARGLA

Faculty of New Technologies of Information and Communication

Electronic and Telecommunications Department

ACADEMIC MASTER THESIS in :

Electronic

Specialty :

instrumrntation and systems

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Theme thesis :

Smart Home security system using Raspberry Pi and YOLOv8

In front of jury composed of :

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ACADEMIC YEAR : 2023/2024

Acknowledgement :

The team members would like to express our deep appreciation and gratitude to Kasdi Merbah University and all those who support and provide us to complete our project "smart home security system".

Special gratitude to our supervisor Dr. Rouabah Boubakeur and our co-supervisor Dr. Achbi Mohamed Said for their contribution, help and encouragement to coordinate our project .

A special thanks to gentlemen Hedadi Belkacem ; Harrouz Salah for helping us on software and hardware development

Dedication :

I thank God for the blessings, strength and courage He granted me to have achieved this milestone in my academic career.

I would like to express a fond feeling of gratitude to dear loving parents whose wholesome words of appreciation and acts of support have been crucially helpful and continue to resonate with me.

Not to mention my dear brothers who hold a special place in my heart. They have always been cheering me up and never left my side.

I must extend my gratitude to my grandparents, aunts and uncles for their appreciated encouragement, as well as their continuous prayers at all times..

I want to express my heartfelt thanks to my friends who have stood by me throughout my university career

ملخص:

في المداخل غير الرئيسية للمنزل ، يلجأ العديد من الأشخاص إلى استعمال كاميرات المراقبة و أنظمة الحماية تجنبا للسرقة إلا أن هذه الأخيرة قد تتضمن بعض الأخطاء في عملية الكشف إضافة إلى التكلفة المرتفعة وهذا ما دفعنا الى البحث عن جهاز يتضمن حلولا للمشاكل المذكورة ,في اطار مفهوم المنزل الذكي تقدم هذه الاطروحة دراسة حول تطوير و انجاز نظام حماية و امان شامل للمنازل باستخدام تقنيات التعلم العميق و الراسبري باي بحيث انه يستفيد هذا النظام من تكلفته المنخفضة و دقته العالية في الكشف عن الاشياء .

الكلمات المفتاحية: انظمة الحماية , منزل ذكي , تكلفة, التعلم العميق , راسبري باي, الكشف عن الاشياء

Abstract :

In non-main etrances to the house , many people use surveillance cameras and security systems to avoid theft ;but the latter may incluse some issues in the detection process and the high cost , this is what prompte us to search for a device that includes solutions to the previous problems montioned

This thesis presents the development and implimentation of a home security system using Raspberry Pi and deep learning techniques ; this system benefits from its low costs and high accuracy in the detection process

Keywords : security system , smart home , cost, deep learning , Rasberry Pi ,object detection

Résumé:

Dans les entrées non principals de la maison , de nombreuses personnes ont recours à des cameras de surveillance et des systems de sécurités our éviter le vol mais ces derniers peuvent inclure des erreurs dans le processus de detection et le cout élevé.ça nous permettant de chercher un dispositive inclut des solutions aux problemes montionnés

Dans le cadre du concept de maison intelligente cette dissertation presente le développement et la mise en oeuvre d'un system de sécurité à la base du raspberry pi et l'aprentissage en profondeur afin que ce système benefice la haute precision et le cout faible

Mots clés: systems de sécurités , maison intelligente , cout , aprentissage en profondeur, Raspberry pi

Table of content :

List of Acronyms :

***AI** : Artificial Intelligence*

***DL**: Deep Learning*

***ML**: Machine Learning*

***CNN:** Convolution Neural Network*

***ConvNets**: Convolutional Networks*

***YOLO:** You Only Look Once….*

***Fast R-CNN:** Fast Region-based Convolutional Neural Network*

***Faster R-CNN**: Faster Region-based Convolutional Neural Network…*

***GPU**: Graphic Processor Unit*

***IOU**: Intersection over Union*

***MAP:** Mean Average Precession*

***RPN:** Region Proposal Network*

***R-CNN:** Regions-Based Convolutional Neural Network*

***SSD:** Single Shot Detector*

***RAM :** Random Access Memory*

***USB** : Universal Serial Bus*

***HDMI** : Hight-definition Multimedia Interface*

***OpenCv** : Open Source computer vision library*

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General introduction :

The first thing you desire when you look at your family and your home is their safety. And thus the idea of advanced home security system comes into picture. The concept of home automation and its safety has been around since late 1970s. But during the course of time with the advancement of technology, our expectation from home has changed a lot and so have the idea of home automation and its security systems. The main role of home automation systems over time is to provide efficient, convenient and safe ways for home inhabitants. Therefore, home security is crucial for following reasons: -it provides peace of mind, -belongings are protected, -it deters burglars and intruders, -reducing the risk of theft or vandalism.

Motivation The biggest motivation for working on this thesis is the importance of protecting houses from theft and burglaries with effectively and low costs by using latest technologies and AI .

Problematic Overall, investing in home security is an essential measure to safeguard your home. Many people are hesitant to get home security systems because *of different issues related to these systems. A three* most common problems *are exist*:

- **False alarms:**

A large number of security system activations are false alarms. This usually happens when the system was not installed properly and almost any sound, from an open window to falling branches, can trigger it.

- **Incorrect programming :**

Even if panels were properly installed and programmed, if the building's layout changes, the system won't function as expected.

- **Issues of security cameras:**

Issues of security cameras are: Cost, setting up a comprehensive security camera system can be expensive, especially for large properties or businesses:

Maintenance and monitoring: cameras require regular maintenance and monitoring to assure well operating.

Legal issues: depending on the jurisdiction there may be legal restrictions on where cameras can be placed and footage can be used.

Limited coverage : cameras have blind spots and limitations in coverage , meaning ther may still be areas where incidents occur whitout being captured on cameras

So the existing security systems have some malfunctions that can be solved ;through the security system that we developed which intended as a resolution to existing issues , we will be able to solve security systems issues.

Contribution: in this work, A smart security system was developed for homeowners to assist in real time detection and recognition process of persons. Deep learning and Raspberry Pi are used to develop an efficient AI algorithm allowing for real time data processing and dicision-making for home automation security. In addition, this system offer cost-effectiveness and easy to install.

Thesis organisation:

This work is organized as follow: **In chapter one**, smart home definition and latest statistics about exciting home security systems. **In chapter two,** a brief presentation of the Raspberry Pi and it caracteristics next a definition of the artificial intelligence, machine learning and deep learning also an overview about object detection method

In chapter three, a general description and implimentation of the system Besides, a brief presentation of the used components and programming environment of the system, also the details of the proposed approaches for object detection and data set next a test and a discussion of the results

Finally, conclusion section summarize the main findings and persperctive of this dessertation

Chapter I :

Overview of home security systems

I.1. Introduction:

Home security has undoubtedly come a long way in recent years with the introduction of new technologies and innovations. From smart home automation to facial recognition technology, these advancements are changing how we use home security systems. In 2023, we can expect to see even more growth in the industry, with a particular focus on improving the user experience, artificial intelligence, and robust protection technologies. As we dive into the latest home security statistics for 2023, we'll explore how these new technologies are shaping the industry and what homeowners can expect in years to come.

I.2. Smart Home definition :

There exist several definitions of Smart Home. Some of them overlap very well but, others seem to have nothing in. Thus some existing definition and possible aliases are presented and afterwards our definition is generated. The Smart Home Energy web page mentioned:

"A smart home, or smart house, is a home that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and control over the building's functions. For example a smart home may control lighting, temperature, multi-media, security, window and door operations, as well as many other functions" as in this figure

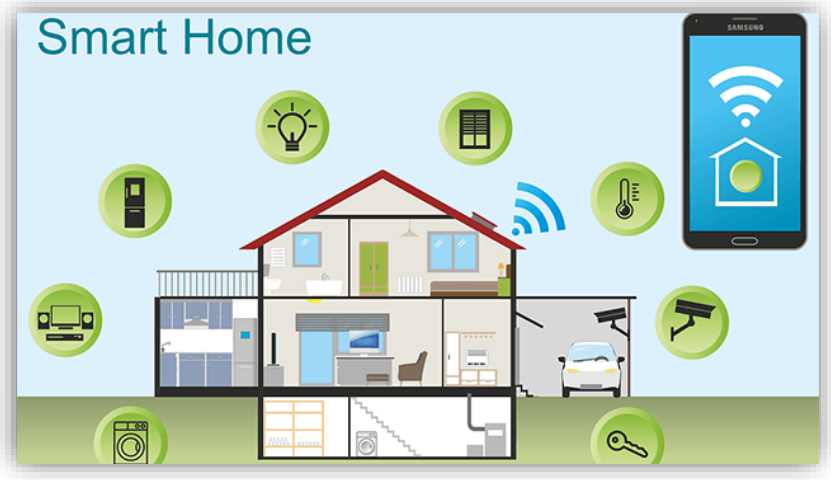


Figure I. 1 Smart home

I.3. History of home security :

A security system consists of means or methods with which something is protected from being damaged or taken away unwillingly. Home security system are networks of electronic devices put together with a central processor to defend residents against burglars and thieves. This is the definition that we see nowadays.

However, home security is not something new that appeared in the modern time. It appeared long time ago. Some information of home security in the past is as follows:

Humans initially used branches, rocks, and weapons to protect wild animals, later rescued abandoned wolf cubs, raised guard dogs, and dug trenches around ancient Egypt to protect people from intruders

During first World War, crime rates increased significantly, leading Americans to implement measures to protect their property and themselves. Homeowners subscribed to door shakers, where night watchmen would shake doors to ensure lockdowns. Wealthier individuals used electromagnetic contacts on doors and windows to set off alarms when windows were opened, sending a central station to send a guard to the residence. These measures aimed to protect property and individuals during this time.

In the 1940s, video surveillance technology was developed, but it only gained attention in the 1970s when Marie Van Brittan Brown and her husband Albert Brown invented the first video home security system with remotely controlled doors. The system consisted of four peepholes on a front door and a motorized camera that could move up and down. The control panel had features like an intercom, a switch to lock the door, and an alarm button. Although initially intended for domestic use, the system's effectiveness attracted businesses to install it.

With technology ever evolving, home automation system is also in constant development. Being one of the system’s most important parts, the field of security system has never been left outdated or unwanted. For such reasons, home security system is an extremely potential field that may still be one of the main focuses of every automation system in the future.

I.4. Review of existing literature on home security systems, technologies, and trends :

I.4.1. Current Home Security Market Size and Projected Growth :

The global home security market is expected to grow from $40.7 billion in 2020 to $84.4 billion in 2027, with a compound annual growth rate (CAGR) of 8.2 percent. Factors such as increasing home security awareness, rising crime rates, and technological advancements are driving this growth According to our latest research, at least 39 million U.S. households are protected by alarm systems.

Young adults 18-29 being the most likely to have some type of home security devices. As many as 13 million more households may install new alarm systems in the next 12 months. *[2]*

I.4.2.Examples of exicting home security systems :

There are several different types of home security systems, including :

- Burglar alarms
- Fire alarms and smoke detectors
- Carbon monoxide detectors
- Video surveillance
- Environmental sensors

I.4.3.How Many Homes Have Home Security Systems?

According to the 2023 Home Security Market Report by SafeHome, most households (72%) have at least one home security device. Here is a breakdown of the types of devices homeowners prefer to protect their homes .

The most popular types of home security technologies include alarms, cameras, and access control systems. Video surveillance tools are the most widely used home security technology, followed by video doorbells and alarm systems.

Our recent research revealed that home security systems are becoming increasingly popular among US homeowners u can see it in figure I

Among these home decision-makers,

42 percent used video surveillance

37 percent used video doorbells

32 percent had alarm systems installed

11 percent had access control systems

43 percent of system owners had their systems professionally installed *[3]*

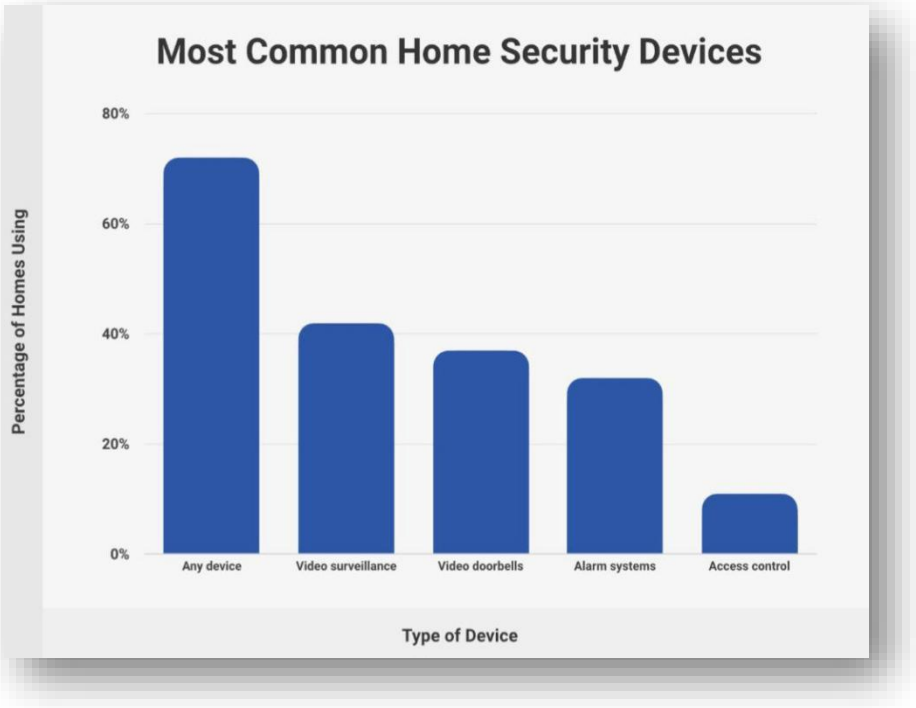


Figure I. 2 Most common home security devices

I.5.Reasons For Installing Home Security Systems :

A recent study reveals that people are increasingly installing home security systems in 2023 to enhance their safety, protect their children, and guard their homes while frequently away :

About 74 percent of respondents reported installing a security system to improve their overall sense of safety, making it the most common reason.

Protecting children was the second most common reason, with 27 percent of respondents choosing it. Meanwhile, 26 percent of people installed a security system because they frequently spend time away from home, and 18 percent did so because they own many valuable items.

Home security systems provide several benefits, including deterring burglars, alerting homeowners of potential threats, and providing evidence in case of a break-in. *[2]*

➡ ***Homes without security systems are 300 percent more likely to experience a burglary***

I.6.What to Look for in a Security System :

As you're selecting a home security system, you should consider what will offer the best protection for your family. Here are some factors to consider:

Affordability: A custom security system ensures home safety while maintaining budget, allowing you to select the options that protect your living space.

Power accessibility: Most security systems are battery-operated and connected to WiFi, and can be solar-powered for added security during power outages.

Ease of installation: If you choose a wireless option, your home security system will be easy to install. You could even order the technology and install the devices yourself.

I .7.How Much Do Home Security Systems Cost?

Home security systems cost 25000 DA to install on average. Of course, costs can vary depending on the extent and type of the system ; we take few examples : (without the cost of installation)

Equipement	***Cost average***
Security camera	*15000 DA for one camera*
Smart Doorbell	*21000 DA*

Tab I. 1 some exicting security systems costs in Algeria

I.8.Conclusion :

As conclusion, with the rise of theft and burglaries on homeowners, this chapter has provide an overview about the meaning of smart home and its history, also a statistics have been presented on existing literature on home security systems and their technologies in 2023, and what homeowners look for to choose a security system in order to guaranty safety and security.

Chapter Ⅱ :

Raspberry Pi and YOLOv8

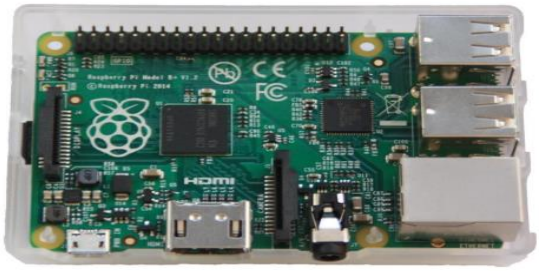
II.1.Introduction :

In recent years, the integration of artificial intelligence and small-scale computing has opened new frontiers in technology, one of the most promising being object detection using devices like the Raspberry Pi. The Raspberry Pi, has become a powerful tool for hobbyists and professionals alike, enabling a wide range of innovative projects. Object detection, a subset of computer vision, involves identifying and locating objects within an image or video feed. This chapter explores the joint work between the Raspberry Pi and object detection technologies, highlighting You Only Look Once (YOLO V8) algorithm .

II.2.Raspberry Pi :

Raspberry Pi, (figureI 1) an efficient and powerful minicomputer having the dimension approximately equal to the size of a credit/debit card. It was invented by the United Kingdom Raspberry Pi foundation with the hope of enlightening and empowering the generation of learners to be more creative and efficient.

The Raspberry Pi is a smaller version of a modern-day computer capable of performing task effectively. The module utilizes various kinds of the processor; therefore, it can only install open source operating systems and apps on it. Pi also enables the user to browse the internet, send emails, write documents using a word processor, and much more. Raspberry Pi support various programming languages such as Python, C, C++, the first Raspberry Pi, model B was launched back in 2012 by the United Kingdom Raspberry Pi foundation [11]



FigureII. 1 Raspberry Pi

II.2.1.Available versions of Raspberry Pi :

Models & specifications			
Model	**Raspberry Pi 2 B**	**Raspberry Pi B+**	**Raspberry Pi A+**
Processor	BCM2836 ARMv7	BCM2835 ARMv6	BCM2835 ARMv6
CPU frequency	900 MHz	700 MHz	700 MHz
RAM	1 GB SDRAM	512 MB SDRAM	256 MB SDRAM
Storage	MicroSD	MicroSD	MicroSD
Power Draw & Voltage Voltage	600mA - 1.8A @5V	600mA - 1.8A @5V	600mA - 1.8A @5V
GPIO	40 pin	40 pin	40 pin
HDMI	Yes	Yes	Yes
USB 2.0	4 Ports	4 Ports	1 Port
Ethernet Port	Yes	Yes	No
Audio	3.5mm audio jack and composite video	3.5mm audio jack and composite video	3.5mm audio jack and composite video

Tab I. 2 Raspberry Pi versions

II.2.2.TECHNICAL SPECIFICATIONS :

The below Specifications are of the latest Raspberry Pi 4 Model B [18]

Processor: Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz [18]

RAM: 4GB LPDDR4-3200 SDRAM [18]

Bluetooth: Bluetooth 5.0, BLE [18]

Wi-Fi: 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless [18]

USB: 2 USB 3.0 ports; 2 USB 2.0 ports [18]

Ethernet: Gigabit Ethernet [18]

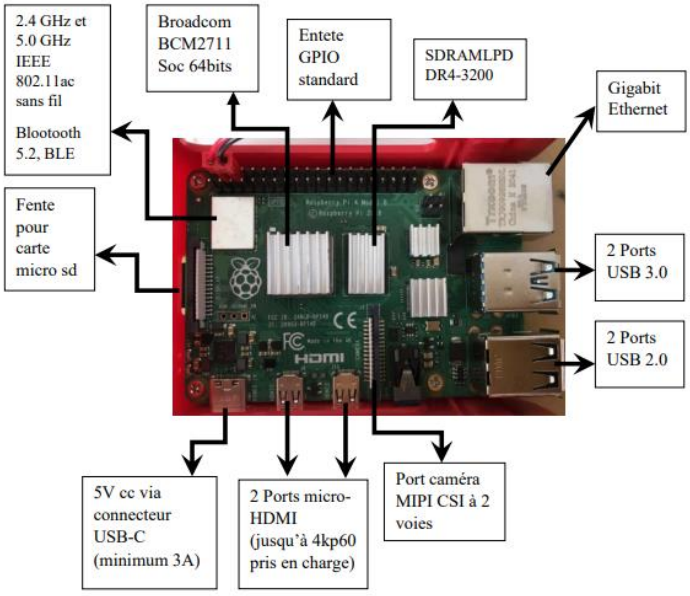
HDMI: 2 × micro-HDMI ports (up to 4kp60 supported) [18]

Storage: MicroSD Card Slot [18]

Power Supply: 5.1V 3A USB Type C Power(Recommended) [18]

Dimensions: 85.6mm × 56.5mm [18]

Raspberry Pi initially has its own operating system previously called Raspbian based on Linux. In the emerging software world, there are few non-Linux based OS options available in the market [18]



FigureII. 2 TECHNICAL CARACTIRISTICS

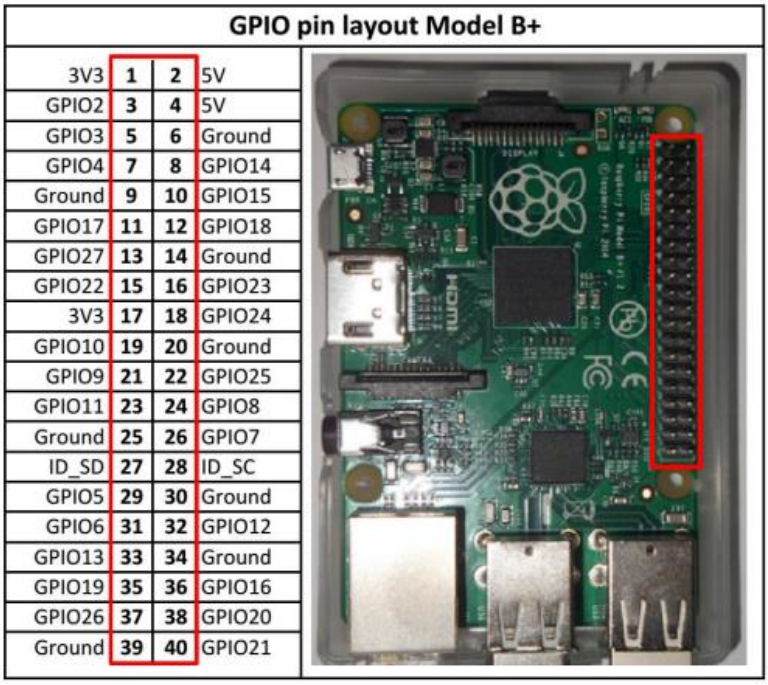
II.2.3.Raspbian Wheezy :

Raspbian Wheezy is a free operating system based on Debian distribution Raspbian is optimized for the Raspberry Pi's hardware and it comes with over 35 000 packages and pre-compiled software. Raspbian is still under active development and it aims to improve the stability and performance of the Debian packages. [17]

Raspbian Wheezy is one of the fastest ways to setup and get the RasPi running [23]

II.2.4.General Purpose Input Output (GPIO) :

Raspberry Pi has two rows of pins on one side of it. These pins are called GPIO connector. The GPIO connector allows attachment of electronic hardware to the Raspberry Pi. In the model B+ the GPIO consists of 40-pin connector where the first 26 pins are same as in the earlier versions. *[23]*



FigureII. 3 GPIO pins

II.2.5.differences between Arduino and Raspberry Pi:

Table

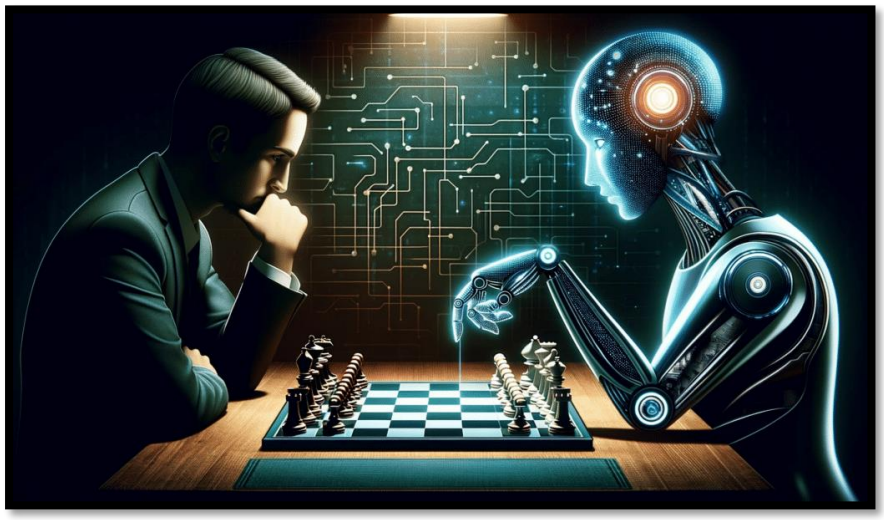
Aspect	Arduino	Raspberry Pi
Purpose and Design	Microcontroller for hardware control	Single-board computer with OS
Hardware Architecture	ATmega-based, 8-bit CPU	ARM-based, 64-bit CPU
RAM	Minimal (2 kB)	More (1 GB)
Clock Speed	16 MHz	1.4 GHz
Operating System	None	Yes
I/O Capability	Strong	Weaker (requires transistors)
Cost	Generally cheaper	More expensive
Power Consumption	About 200 mW	About 700 mW
Applications	Simpler projects (e.g., traffic lights)	Diverse (robot controllers, servers)

Tab I. 3 differences between arduino and raspberry Pi

II.3.artificial intelligence :

II.3.1.Definition:

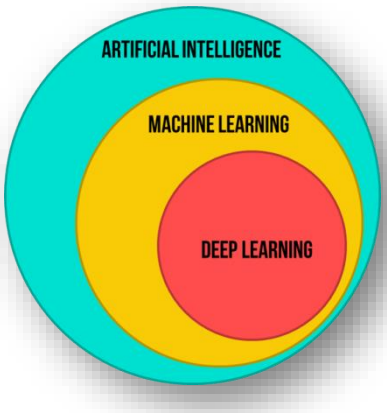
John McCarthy, the father of artificial intelligence, described artificial intelligence this way: “Artificial intelligence is just thatScience and technology, especially the production of intelligent machines intelligent computer program. "Artificial intelligence (AI) is the ability of a robot or computer program to perform operations that typically require human intelligence, such as learning, problem solving, and decision-making .John McCarthy coined the term in 1956, defining it as "the science and engineering of building intelligent machines." Artificial intelligence is the science of using computers to imitate human intelligence[1] and it show in this picture figure II 4



FigureII. 4 Artificial Intelligence

II . 3.2.Principle of artificial intelligence (AI) :

Simply put ; intelligent iterative processing algorithms and systems Artificial intelligence technologies work together to deliver useful results. AI can learn patternsand the characteristics of the data examined using this combination. artificial intelligence system Test and evaluate its performance after each data processing cycle usendata to gain new knowledge. [20]



FigureII. 5 Principle of artificial intelligence

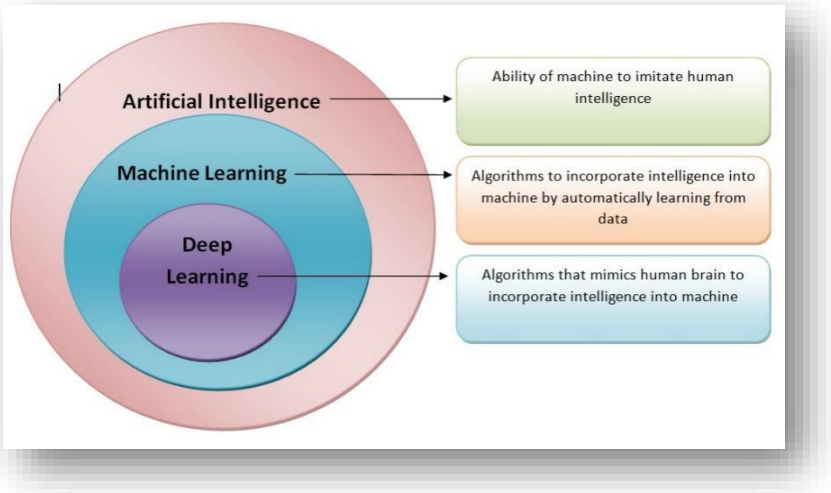
Artificial Intelligence is frequently used as a catchall term for Machine Learning and Deep Learning, but they are not interchangeable terms, where :

II.3.2.A.Machine learning (ML) :

Is a subset of artificial intelligence Statistical techniques are used to enable machines to learn from data without having to do so explicitly program. In other words, it is a method of teaching machines to recognize patterns and make predictions data-based results [13].

Ⅱ. 3. 2. B. Deep learning (DL):

is a subset of ML and includes the following Learn from data using multilayer artificial neural networks. Deep learning algorithms can do this.Analyze massive amounts of data and automatically learn to identify patterns andfeatures people cannot identify themselves [13]



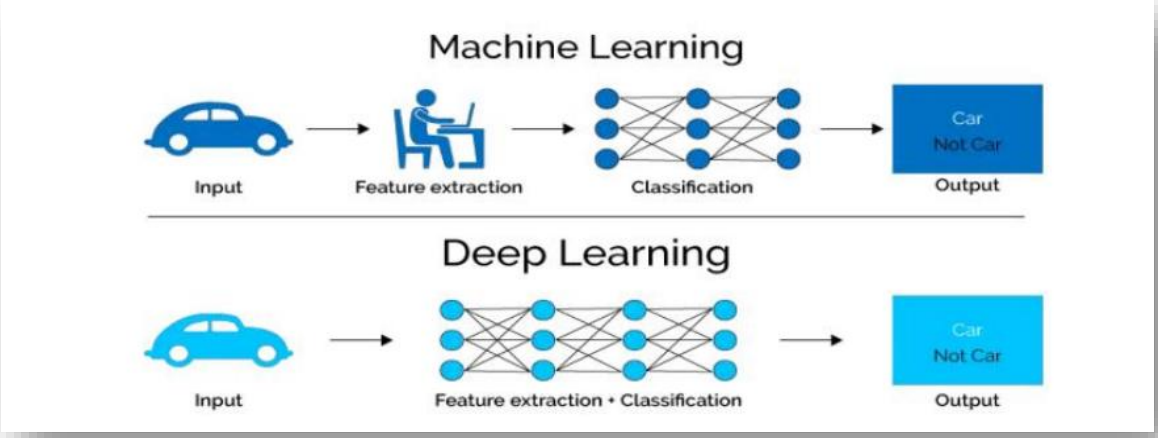
FigureII. 6 Relationship between AI, ML and DL**.**

II. 3. 3. Choosing between Machine Learning and Deep Learning :

Dependson your application, the amount of data you process, and the nature of the problem trying to solve these problems, machine learning and deep learning offer a variety of methods and models Choose from.

- For deep learning to be effective, thousands of models must be trained images require high-performance GPUs to process data quickly. When deciding between the two Machine learning and deep learning consider GPU performance and the amount of annotation data available.

- Machine learning is more beneficial than deep learning find out if you are missing any of these resources. To gain accurate insights through deep learning it needs at least a few thousand images. If this is the case, the model will process all these images faster High performance GPU [8] the figure II 7 shows the difference



FigureII. 7 Deep learning VS Machine learning

II. 3. 4. Domain of artificial intelligence :

A-Learning and adaptation : Artificial intelligence has the ability to acquire knowledge from data, evolve over time and improve with time. Intelligent models are capable of interpreting and analyzing data, find patterns and discover new information. [20]

B-Automation and improved efficiency : Automation by artificial intelligence can improve procedures and systems. It increases work efficiency and saves time and effort because it can complete tasks more quickly and correctly than people. [20]

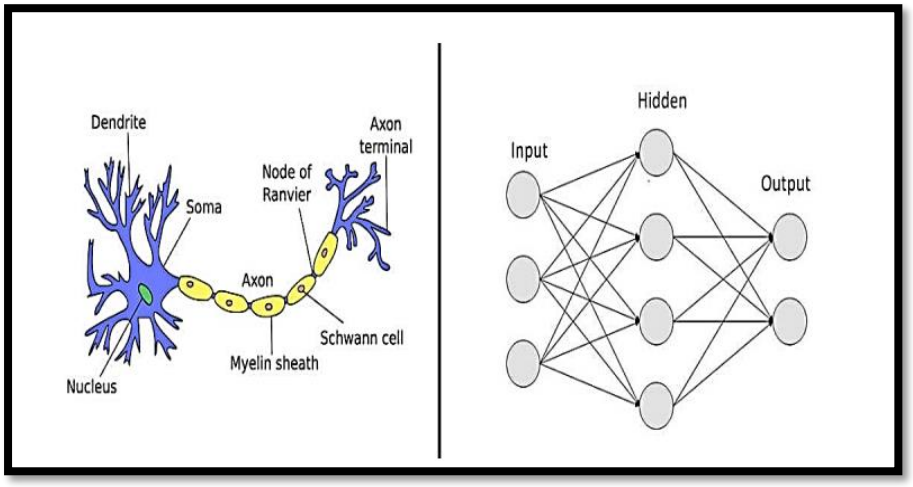
C-Prévision et anticipation : Artificial intelligence analyzes data and extrapolates the future using forecasting methods. Intelligent models can predict future events, identify trends and patterns and make judgments. [20]

D-Natural language processing: artificial intelligence is capable of understand and manage natural language in the same way as humans. It is used in the creation of programs for automated management of conversations, information extraction and language translation [20]

E-Reasoning and decision making : Complex problems can be solved by artificial intelligence using reasoning and decision-making it is able to analyze several options, to weigh the advantages and disadvantages and make wise choices [20]

Ⅱ.4.Neural networks:

neural network is a computational model that mimics the way biological neurons work together to make decisions. It consists of interconnected units called neurons that send signals to one another. These neurons can be either biological cells or mathematical models. While individual neurons are simple, when combined in a network, they can perform complex tasks , neurons are fully connected between different layers. Layers that sit between the input layer and output layer are called hidden layers. Each hidden layer contains several neurons that are fully connected to all neurons in the previous layer. the issue with this densely-connected network architecture is that it is not suitable for processing large images. To handle large images, the most preferred approach is to use a convolutional neural network (CNN) as it montioned in the figure II 8



FigureII. 8 The biological neurons VS the Artificial Neural Network

Ⅱ.4.1Neural network parameters and hyper-parameters :

Weights : Neural network variables determine neuron connections strength, which are learned and adjusted during training to minimize cost function, typically seeded random and updated iteratively. [6]

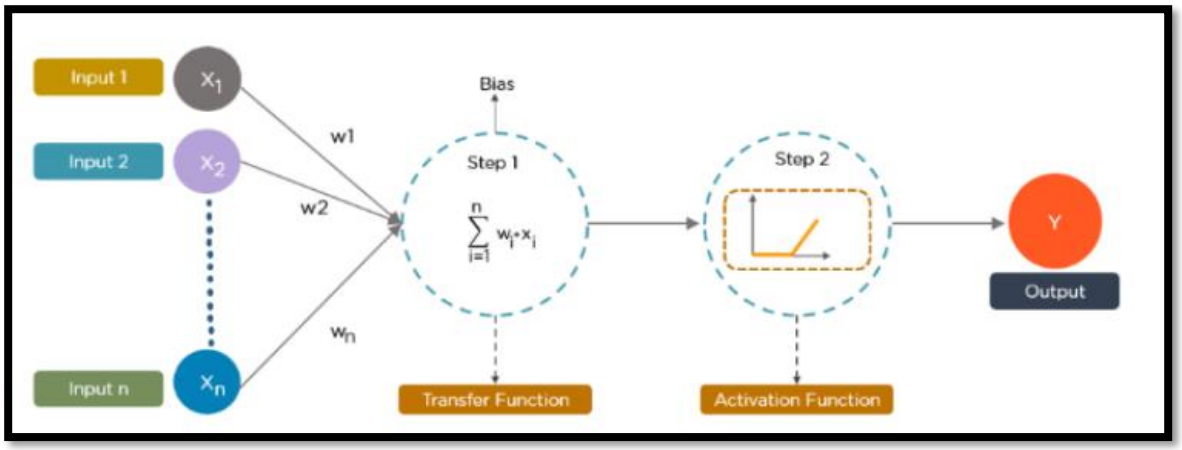
Bias: A bias parameter is added to each neuron in the network to learn complex relationships between input and output variables, which is also learned and updated during training[6]

The cost function: The model's training aims to minimize the cost function by adjusting the weights and biases of the network's neurons. [6]

Epoch: An epoch is a single training iteration of all batches in forward and backpropagation, requiring a certain number of epochs based on task complexity and dataset size. [6]

Batch size: The batch size is a hyper-parameter in gradient descent algorithms that determines the number of training examples used in each iteration, with small batch sizes promoting faster convergence and less memory use. [6]

Learning rate: The learning rate is a hyper-parameter in the gradient descent algorithm, regulating the step size and affecting the neural network's weights, typically set to a minor value like 0.1 or 0.01[6]. *all in figure II 9*



FigureII. 9 hyper-parameters

II.5.Convolutional Neural Network (ConvNet/CNN) :

is one of the most popular deep learning architectures that consists of multiple number of layers. The main concept of Conv-Nets is to obtain local features from input (usually an image) at higher layers and combine them into more complex features at the lower layers. However, because of its complex architecture, training such networks on large datasets can take several days, and it is computationally expensive. As a result, deep networks are frequently trained on GPUs [22]

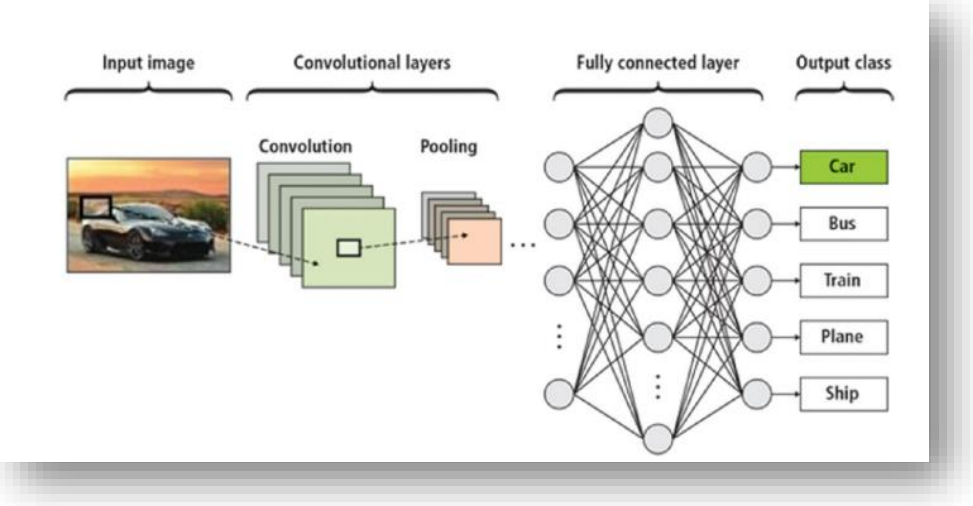
ConvNet consists of a sequence of different types of layers to achieve different tasks. A typical Convolutional neural network consists of the following layers:

• Convolutional layer

• Activation Function Layer (ReLu)

• Pooling layer

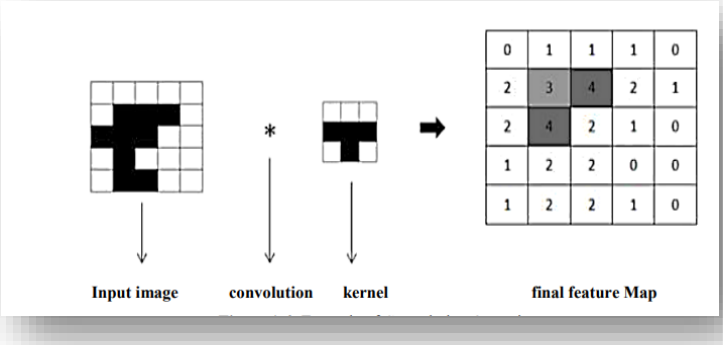
•Fully-connected layer



FigureII. 10 Convolutional Neural Network

Ⅱ.5 .1.Convolution layer:

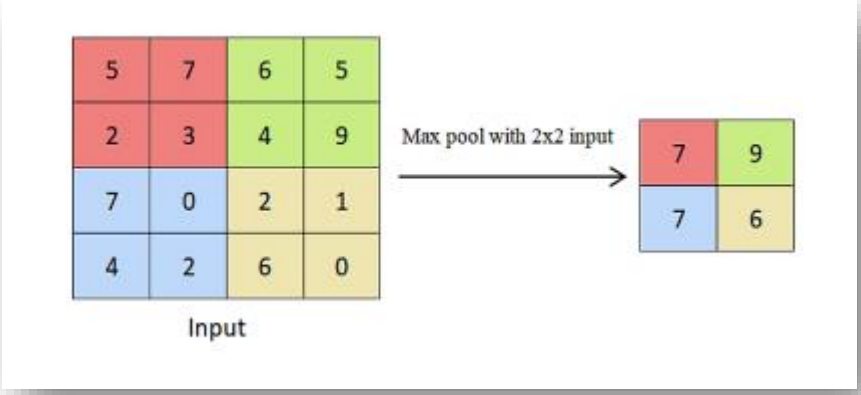
Convolution layer is the core building block of a Convolutional Neural Network which uses convolution operation (represented by *) in place of general matrix multiplication. Its parameters consist of a set of learnable filters also known as kernels(Figure II. 11) below shows how a filter is convolved with the input to get the feature MAP. Feature MAP is obtained after adding a bias term and then applying a non-linear function to the output of the convolution operation. The purpose of non-linearity function is to introduce non- linearity in the ConvNet model [22]



FigureII. 12 Example of Convolution Operation

Ⅱ.5.2.Pooling layers:

A pooling layer follows a convolution layer in CNNs. It takes the feature map and shrinks it down to a smaller size. During the shrinkage, the most dominant feature or data is preserved in each step of the pooling. The pooling operation performs a similar operation as in the convolution layer. The dominant data is extracted by determining the pooling size and how much it steps through the map. This pooling method is called max pooling [19]



FigureII. 13 max pooling

Ⅱ.5.3.Fully connected layer :

They are the last layers in a CNN architecture. In such a layer, each neuron of the layer is connected to each neuron from the previous layers. This layer takes in the last feature map, which is a matrix, and flattens it to a vector by scanning it in a predetermined way. This vector is then fed into the fully connected layer, to generate the final output for CNN [19]

Ⅱ.6.Object detection :

Object detection is the field of computer vision that deals with the localization and classification of objects contained in an image or video.

An object detection system can detect, locate and trace the object (determine where objects are in a given image) and identify the object category (person, table, chair, etc.) [4]

The goal of object detection is to develop computational models and techniques that provide one of the most basic pieces of knowledge needed by computer vision applications

Object localization, involves detecting one or more objects in an image and drawing a bounding box around them, Bounding boxes are used to indicate the location of objects within an image it represented by four integers

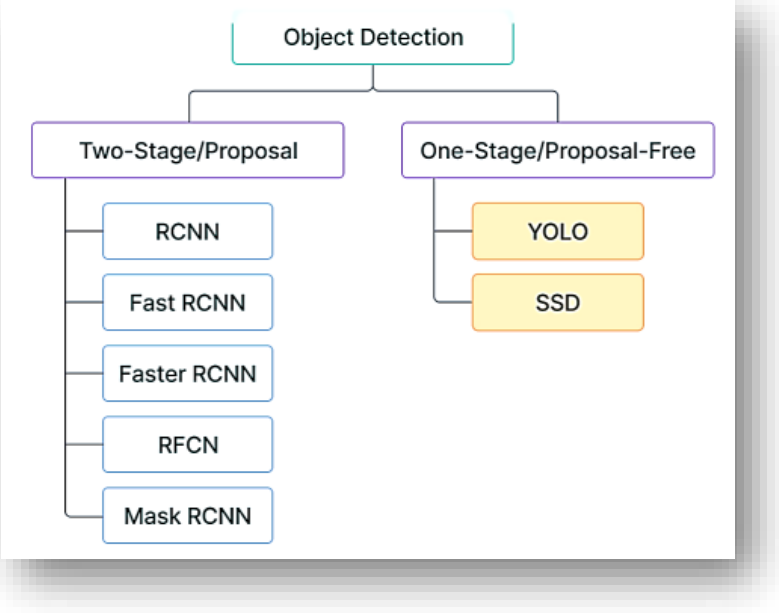
FigureII. 14 localizing object

Localizing an object in a picture means predicting a bounding box around the object and can be expressed as a regression problem. On the other hand, Image classification includes identifying an object's class (such as humans, animals, or cars) from an image. Once an object is localized, the object detector model predicts the class or category that the object belongs to. This is done by considering the pixels within the region of the localized object. The model outputs probabilities for each class it is trained to identify. For example, if the model is trained to detect men and women, it will provide probabilities for both categories . An example of this is shown in(figure II. 16)

FigureII. 15 classifying object

II.6.1 .Object detection Algorithms :

In general, there are two types of object detection algorithms: single stage and two stage



FigureII. 16 object detection types

In our thesis we will deal with single stage detection

Object detection in images and videos is performed using single-stage object detection algorithms, also referred to as one-stage detectors In a single forward pass, these algorithms use a single neural network to forecast the bounding boxes and class probabilities for every object in the input image

In general the method used by single-stage object detection algorithms is to divide the incoming image into a grid of cells and forecast the bounding boxes and class probabilities for each cell. The network generates a collection of bounding boxes, each of which includes a confidence value and a probability distribution over object classes. Then duplicate bounding boxes are removed, leaving only the most probable ones, using non-maximum suppression.

• **Single shot detector SSD :** it uses the RPN of Faster R-CNN. In Faster R-CNN, RPN is used to give object confidence score but here it directly uses the RPN to classify object inside the prior box.

• **YOLO :** In 2015 Joseph Redmon published a paper "You Only Look Once" Unified, Real-Time Object Detection (YOLO). YOLO is a development of multi-box which is a CNN based region proposal solution. It Convert multi-box from a region proposal system to object recognition system by adding soft-max layer parallel to the box regressor and box classifier layer, to directly predicts the object class. It gives great result as well as high speed. [10]

We take a look about some of two stage detection algorithmes :

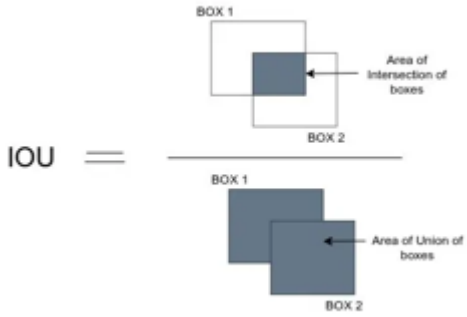
• **Region-based convolutional neural network (R-CNN) :** The R-CNN method is a combination of heuristic region proposal method and CNN feature extractor, extracting objects from images, cropping, and warping, and training a support vector machine model for classification.

• **Fast R-CNN** : is similar to R-CNN ,Fast R-CNN uses selective search for feature extraction, applying CNN to the entire image and Region of Interest pooling for classification and regression. However, it still relies on selective search for region proposals.

• **Faster R-CNN :** is a Fast R-CNN ; it replaces selective search with Region Proposal Network (RPN) for region proposal, inspired by multibox, ensuring end-to-end trainability.- • Mask R-CNN : It is a modified Faster R-CNN for segmentation. Here a Branch is added for predicting class specific object mask. Mask R-CNN replace ROI Pooling with ROI Align since the previous technique was not designed for pixel to pixel alignment.

Ⅱ.6.2.Important Object Detection Concepts :

A-Intersection over Union (IOU) : it's a widely used metric for evaluating the performance of object detection it measures a degree of overlap between two bounding boxes It simply determines whether a detection is valid (True Positive) or not (False Positive) and is given by the overlapping area between the predicted bounding-box and the ground truth bounding-box divided by the area of union between them.



$$IOU = \frac{Area\ of\ Intersection\ of\ two\ boxes}{Area\ of\ Union\ of\ two\ boxes}$$

B- Non-Maxium Suppression (NMS) : is a greedy algorithm used in most modern object detectors to merge overlapping bounding boxes (or region proposals). It sorts detections by their object confidence scores, takes the highest scoring detection and re- moves lower-scoring detections which have an IOU greater than a pre-defined threshold. [4]

C- Bounding-box regression (bounding-box refinement) : Bounding-box regression is a method used in modern object detectors to predict the offset between an input region and the ground truth box. It is often accompanied by a bounding-box classifier to estimate object existence confidence. [4]

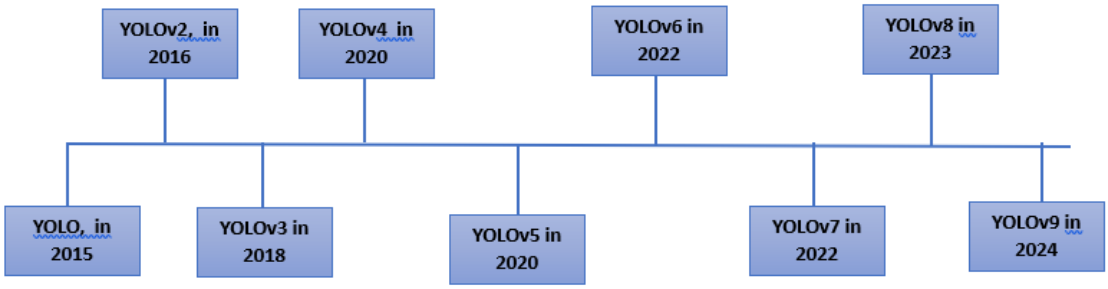
D- Region of Interest (ROI) : A region of interest, or more colloquially known as region proposal or bounding-box proposal, is a rectangular region in an input image that potentially contains an object. These proposals can be generated by some external algorithms such as Selective Search , Edge Box detection or by a Region Proposal Network (RPN). A bounding-box is represented as a 41 vector containing its center location, width, and height (x, y, w, h). Each bounding-box in an image is

accompanied by an abjectness or confidence score of how likely the box contains an object. The difference between two bounding-boxes is usually measured by the L2 distance of their vector representations as montioned in figure II.17

FigureII. 17 Region of Interest

Ⅱ.7.You Only Look Once (YOLO) :

is an algorithm that uses convolutional neural networks for object detection, it has gained significant popularity among researchers worldwide as one of the most prevalent techniques for object detection. It is a very good choice when we need real-time detection, without loss of too much accuracy.



FigureII. 18 YOLO's version

•YOLOv2, released in 2016, improved the original model by incorporating batch normalization, anchor boxes, and dimension clusters.

•YOLOv3, launched in 2018, further enhanced the model's performance using a more efficient backbone network, multiple anchors and spatial pyramid pooling.

•YOLOv4 was released in 2020, introducing innovations like Mosaic data augmentation, a new anchor-free detection head, and a new loss function.

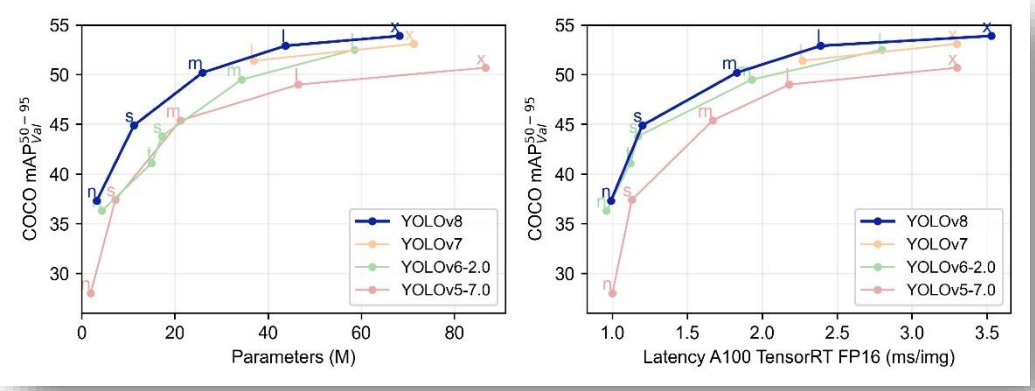
•YOLOv5 further improved the model's performance and added new features such as hyperparameter optimization, integrated experiment tracking and automatic export to popular export formats.

•YOLOv6 was open-sourced by Meituan in 2022 and is in use in many of the company's autonomous delivery robots.

•YOLOv7 added additional tasks such as pose estimation on the COCO keypoints dataset.

•YOLOv8 is the latest version of YOLO by Ultralytics. As a cutting-edge, state-of-the-art (SOTA) model, YOLOv8 builds on the success of previous versions, introducing new features and improvements for enhanced performance, flexibility, and efficiency. YOLOv8 supports a full range of vision AI tasks, including detection, segmentation, pose estimation, tracking, and classification. This versatility allows users to leverage YOLOv8's capabilities across diverse applications and domains.

•YOLOv9 Introduces innovative methods like Programmable Gradient Information (PGI) and the Generalized Efficient Layer Aggregation Network (GELAN).



FigureII. 19 mAP of YOLO's version

Ⅱ.7.1 Loss function :

The main objectives of the research of loss function is to design a function which leads to a model with superior discriminative abilities [4]How well the model discriminates can be measured by the compactness of clusters (intra-class variance) and the distance between them (intra-class variance),the goal is for the clusters to be as compact as possible while maximizing the istance in-between them

Ⅱ.7.1 Softmax Loss :

Is a popular choice in deep learning classification tasks ; the difinition of the loss is as follows :

$$\mathcal{L}_S = -\frac{1}{N}\sum_{i=1}^{N}\log\frac{e^{W_{y_i}^T x_i + b_{y_i}}}{\sum_{j-1}^{n} e^{W_j^T x_i + b_j}}$$

where xi ∈ R^{d} denotes the feature vector of the i-th sample belonging to the yi-th class. Wj ∈ $R^{d}$is the j-th column of the weight matrix W ∈ $R^{dn}$and b is the corresponding bias term. N is the batch size and n is the class number.

Ⅱ.8.Main evaluation metrics :

is the most common metric used to measure the accuracy of the detections among different annotated datasets used by object detection challenges and the scientific community, Before examining the variations of it, we should review some concepts that are shared among them. The most basic are the ones defined below:

• **True positive (TP):** A correct detection of a ground-truth bounding box.

• **False positive (FP):** An incorrect detection of a nonexistent object or a misplaced detection of an existing object.

• **False negative (FN):** An undetected ground-truth bounding box; It is important to note that, in the object detection context,

•**true negative (TN) :** result does not apply, as there are infinite number of bounding boxes that should not be detected within any given image.

. The above definitions require the establishment of what a “correct detection” and an “incorrect detection” are. A common way to do so is using the intersection over union (IOU)

Mean Average Precision (MAP) : is a performance indicator that is frequently used to rate object detection systems. It is an indicator of how effectively the algorithm can locate and identify things in an image

Recall : is the percentage of true positive detections out of all ground truth objects

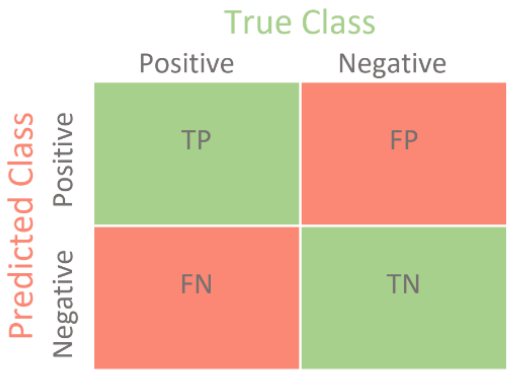
Precision : is the percentage of true positive detections out of all detections

Precision and recall values are obtained for each class of object in the dataset in order to determine the MAP for object detection

the MAP is determined by averaging the AP (Average Precision) scores obtained from all classes. The area under the precision-recall curve is used to calculate each class's AP score. In conclusion, MAP is a measure of an object identification algorithm's performance across all classes, accounting for both recall and precision. Better performance is indicated by a greater MAP

MAP = 1 / N ∑ Api

Where APi being the AP in the ith class and N is the total number of classes being evaluated.



FigureII. 20 confusion metrix

II.9.YOLO V8 Key Features :

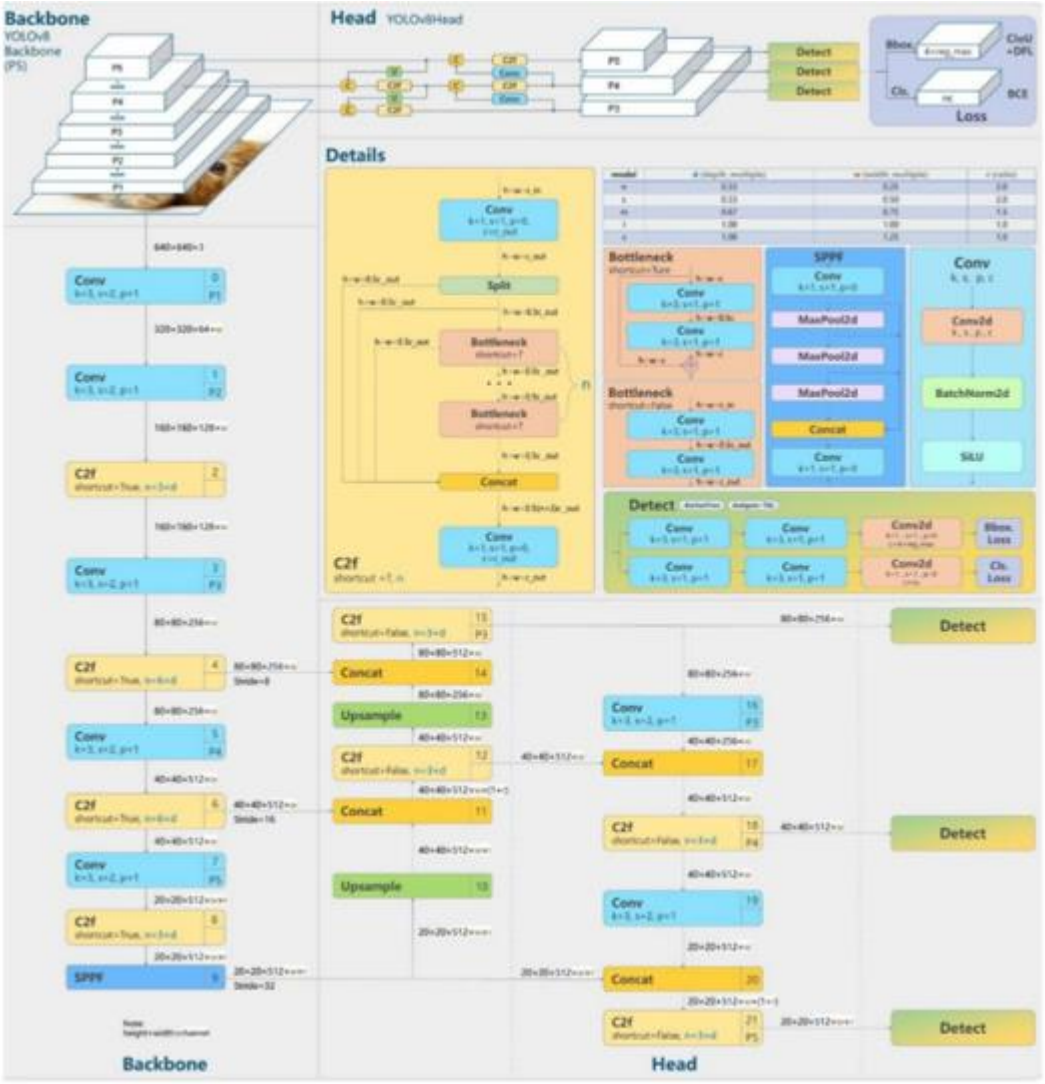
YOLOv8's main improvement is: [21]

- **Advanced Backbone and Neck Architectures:** YOLOv8 employs state-of-the-art backbone and neck architectures, resulting in improved feature extraction and object detection performance. [21]
- **Anchor-free Split Ultralytics Head:** YOLOv8 adopts an anchor-free split Ultralytics head, which contributes to better accuracy and a more efficient detection process compared to anchor-based approaches. [21]
- **Optimized Accuracy-Speed Tradeoff:** With a focus on maintaining an optimal balance between accuracy and speed, YOLOv8 is suitable for real-time object detection tasks in diverse application areas. [21]
- **Variety of Pre-trained Models:** YOLOv8 offers a range of pre-trained models to cater to various tasks and performance requirements, making it easier to find the right model for your specific use case. [21]

II.9.1 .YOLOv8 Overview :

YOLOv8 is the latest version of the YOLO object detection model. This latest version has the same architecture as its predecessors but it introduces numerous improvements compared to the earlier versions of YOLO such as a new neural network architecture that utilizes both Feature Pyramid Network (FPN) and Path Aggregation Network (PAN) and a new labeling tool that simplifies the annotation process. This labeling tool contains several useful features like auto labeling, labeling shortcuts, and customizable hotkeys. The combination of these features makes it easier to annotate images for training the model. The FPN works by gradually reducing the spatial resolution of the input image while increasing the number of feature channels. This results in the creation of feature maps that are capable of detecting objects at different scales and resolutions. The PAN architecture, on the other hand, aggregates features from different levels of the network through skip connections. By

doing so, the network can better capture features at multiple scales and resolutions, which is crucial for accurately detecting objects of different sizes and shapes. [5] as you see *architecture in figure II 21*



FigureII. 21 YOLO v8 architecture

Ⅱ. 10.Coclusion :

In conclusion, the fusion of Raspberry Pi and object detection technology represents a significant advancement in making AI-driven solutions more accessible and cost-effective. The Raspberry Pi's affordability, versatility, and ease of use make it an ideal platform for deploying object detection systems in our home security system. This synergy not only democratizes technology but also fosters innovation, enabling enthusiasts and professionals to explore and implement sophisticated AI applications. As the capabilities of both hardware and software continue to evolve, the potential for

Raspberry Pi-based object detection using YOLOV8 will expand, further cementing their role in the future of smart systems.

ChapterIII : *Implimentation of the system and test results*

III.1 Introduction :

This chapter introduce the implimention of our innovative system that leverages the power of raspeberry Pi and YOLO v8 to acheive cutting-edge object detection capabilities also present a discription of softeware and hardware components and finalize by testing , examing system results

III.2 General Description of the System:

an embodiment of the concept of smart home ; this system is a small sized device installed in the non-main entrances of the house works with object detection

this system is aimed to guaranteed safety for people from burglary with low cost and easy installation

to provide this, we employed a Raspberry Pi , Camera and YOLOv8

when camera captured a person ; we receive a notification in telegram

Figure III. 1 system operation diagram

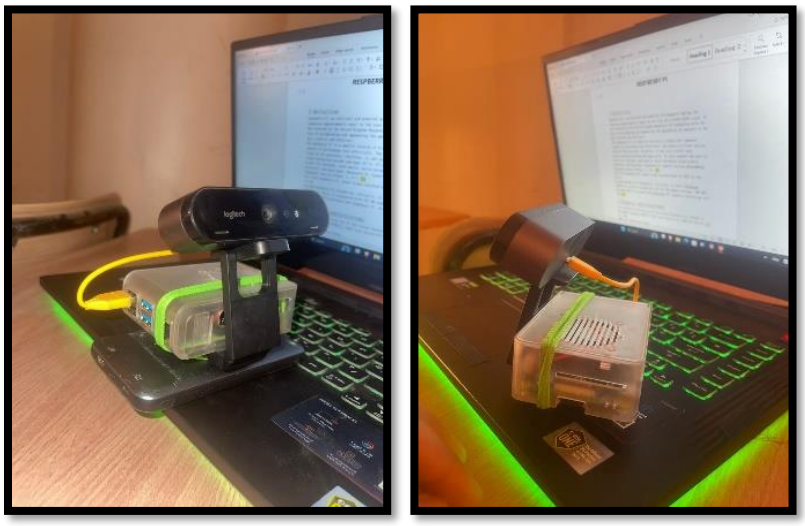


Figure III. 2 prototype of the system

III .3 . software and hardware compenents :

III.3.1 Hardware :

1. **Display :** like a computer or a tv in order to show the operating system of the PI and python program of YOLO and also what camera captures
2. **Raspberry Pi :** for programming the system
3. **Keyboard**
4. **mouse**
5. **Webcam :** is used for capturing the user's environment and has the following charact :
6. **Phone** : to receive the notification on telegram application

III.3.2 Software :

1. -Rasbian operating system
2. -Programming Environment:–Python3 , Visual Studio , YOLOv8
3. -Libraries – PyTorch, OpenCV, ultralitycs , telegram bot
4. -telegram application
5. -talegram bot
6. -Visualstudio

III .4 Implimentation of the system :

III .4 .1 setting up the raspberry pi :

Installing the Operating system the raspi **:**

As part of this project on the Raspberry Pi, we chose Raspbian as the system GNU/Linux operating system. Raspbian is specifically designed and optimized for devices single board like the Raspberry Pi To recap the process of installing and configuring Raspbian on the Raspberry Pi4, we followed the following steps :-a computer you can use to image the storage device into a boot device a way to plug your storage device into that computer [17]

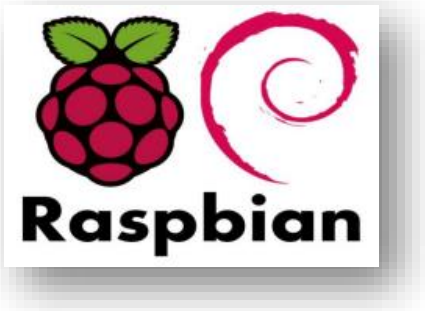


Figure III. 3 Logo Rasbian

-Most Raspberry Pi users choose microSD cards as their boot device [17]

- We recommend installing an operating system using Raspberry Pi Imager. [17]

-Raspberry Pi Imager is a tool that helps you download and write images on macOS, Windows, and Linux [17]

-You can install Imager in the following ways: Download the latest version from raspberrypi.com/software and run the installer [17]

-Once you've installed Imager, launch the application by clicking the Raspberry Pi Imager icon or running rpi-imager [17] as montioned in Figure III. 4

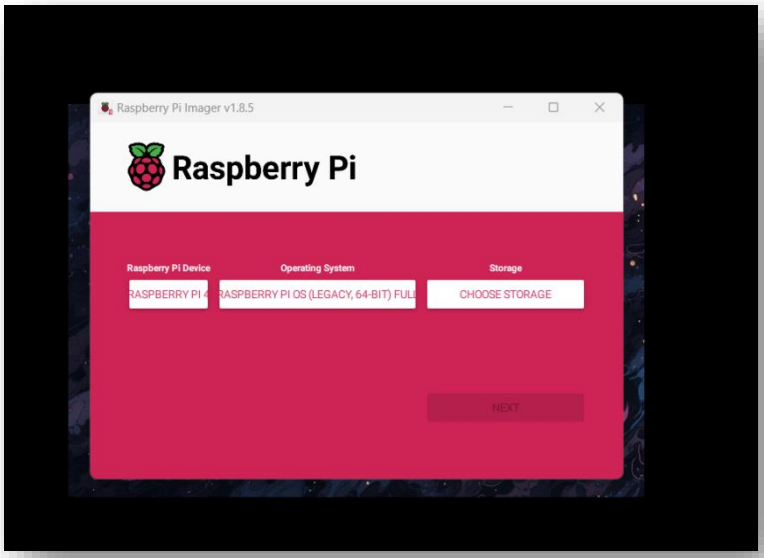


Figure III. 4 installing OS

-Click **Choose device** and select your Raspberry Pi model from the list as you see

In figure III 5

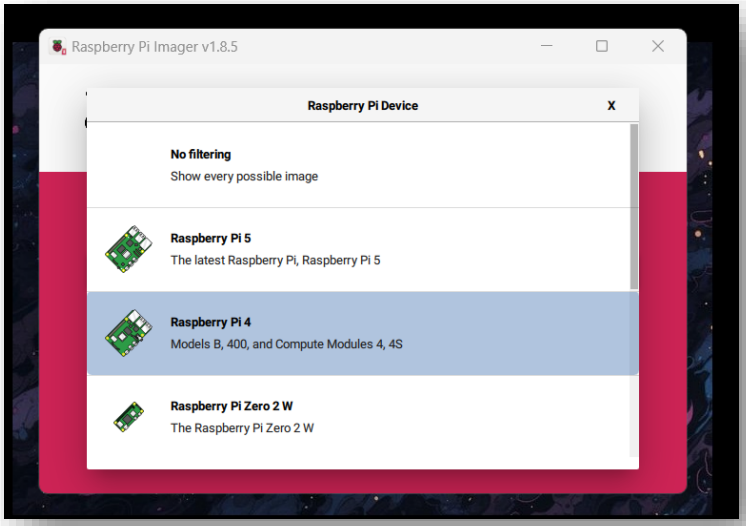


Figure III. 5 installing Os

-an operating system to install Imager always shows the recommended version of Raspberry Pi OS for your model at the top of the list as montioned in Figure III. 6

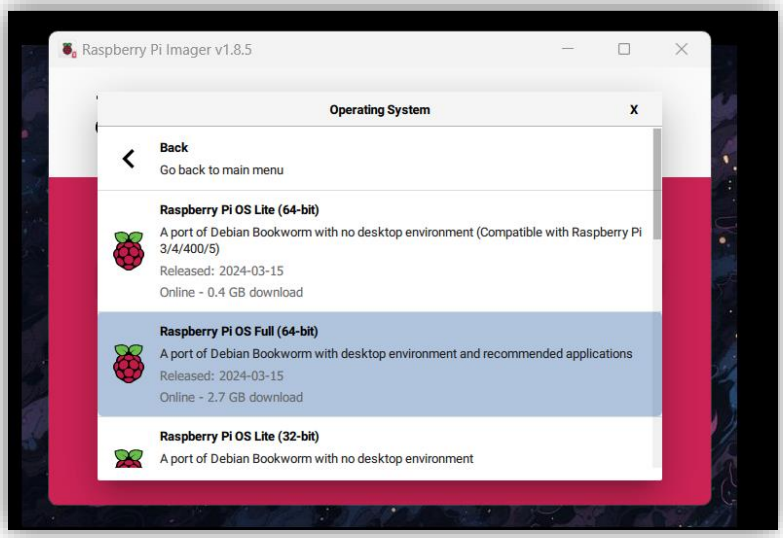


Figure III. 6 installing OS

Connect your preferred storage device to your computer. For example, plug a microSD card in using an external or built-in SD card reader. Then, click **Choose storage** and select your storage device. [17]

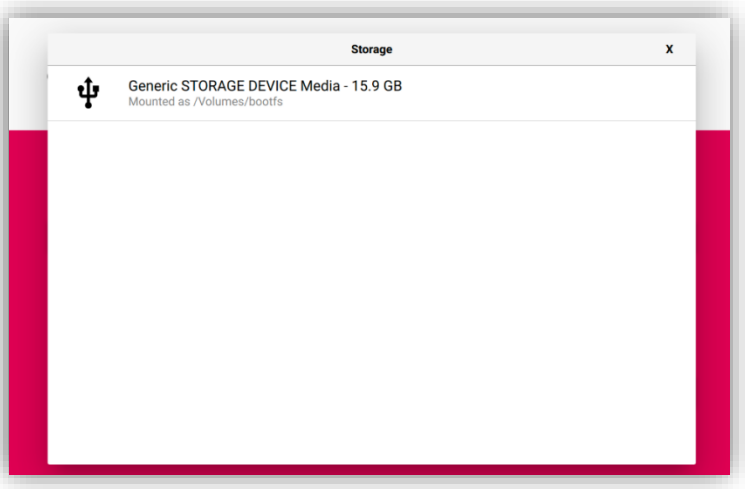


Figure III. 7 installing OS

When you see the "Write Successful" popup, your image has been completely written and verified. You're now ready to boot a Raspberry Pi from the storage device

Finally, connect the power supply to your Raspberry Pi. You should see the status LED light up when your Pi powers on. If your Pi is connected to a display, you should see the boot screen within minutes. When you see a popup indicating that your system is up to date, click **OK** to proceed to the next step after next okey

At the end of the configuration wizard, click **Restart** to reboot your Raspberry Pi. Your Raspberry Pi will apply your configuration and boot to the desktop [17]

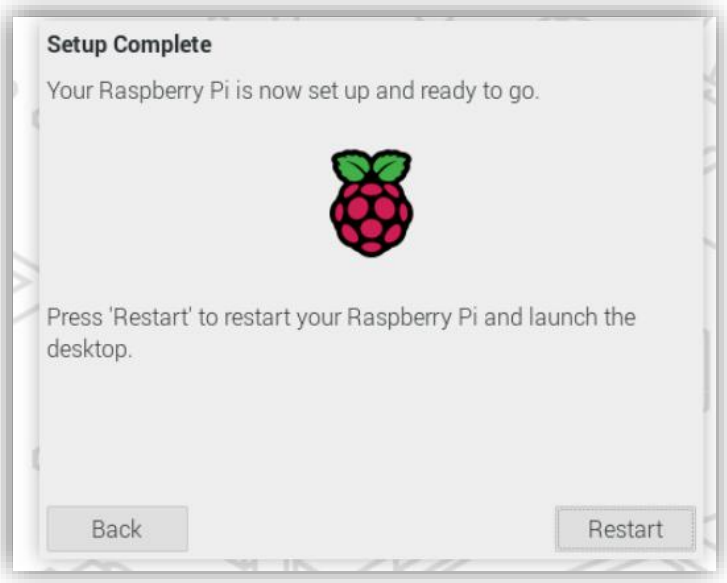


Figure III. 8 installing OS

Now that your Raspberry Pi is set up and ready to go

Initial setup and startup:
After preparing the SD card with Raspbian OS by following the previous steps, we have performed the initial configuration and started the Raspberry Pi 4. Here are the steps we followed:

-Inserting the SD card into the Raspberry Pi:

Once the SD card was prepared, we removed it from our computer and inserted it into the dedicated slot on our Raspberry Pi 4.

-Connecting the necessary peripherals:

We connected the essential peripherals to the Raspberry Pi, such as a keyboard, mouse, display, and power supply. These components are necessary for the initial configuration of the Raspberry Pi and to be able to use it independently.

- Using the complete kit:photo

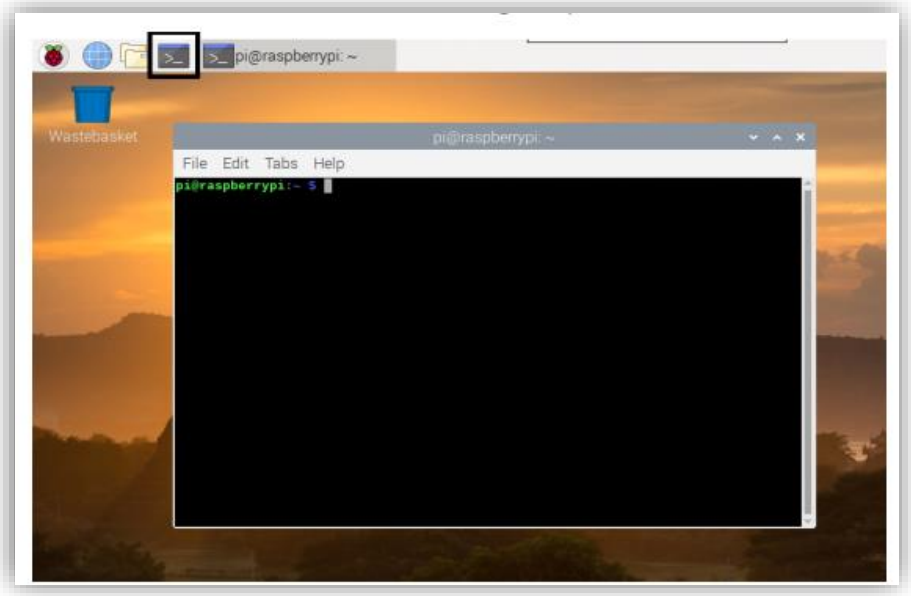


Figure III. 5 Raspberry Pi terminal

-Once the Raspberry Pi was powered, the operating system automatically launched. Figure 19 illustrates the system boot process, confirming that the Raspberry Pi is working properly with Raspbian installed.

III .4 .2 .Programming Environment:

In order to prepare the programming environment on Raspberry Pi 4, we performed the following operations :

Figure III. 6 programming environnement of PI

We updating the system by running this commande on the terminal :

```
Sudo apt update
Sudo apt upgrade
```

Visualstudio:

is a powerful developer tool developed by Microsoft that you can use to complete the entire development cycle in one place. It is a comprehensive integrated development environment (IDE) that provides the necessary infrastructure for developers to write and edit, debug and build code, and then deploy their app. Beyond code editing and debugging, Visual Studio includes compilers, code completion tools, source control, extensions, and many more features to enhance every stage of the software development process. [12]

Python:

is a computer programming language often used to build websites and software, automate tasks,and conduct data analysis and it is a general-purpose language, meaning it can be used to create a variety of different programs [15]

```
Python3 –version
```

If it isn't installed we run the commande:

```
sudoaptinstall python3
```

III .4 .3 Instalisation of YOLOv8 model:

YOLOv8 can be installed in two ways: pip install and from the source on GitHub.

We use this last in order to train our model from scratch:

• From pip (recommended).

• From source : install the model from the source on GitHub

III .4 .4 installing required labraries :

Open cv : is an open source computer vision library contains over 2500 algorithms used for tasks like image processing ; machine learning … , supports a wide variety of programming languages like python , C++ , etc [14]

On our system we installed this library by running :

```
Pip install opencv-python
```

Ultralytics YOLO: is a cutting-edge, state-of-the-art (SOTA) model that builds upon the success of previous YOLO versions

ultralytics YOLOv8 is designed for various computer vision tasks like object detection and image classification

we install this library by running the command*:*

Pip install ultralytics

PyTorch library: is a python-based machine learning library that offers a rich ecosystem for deep learning tasks

We install it by running *:*

Pip3 install torch torchvision torchchaudio

Telegram bot library : This library provides a pure python asynchrounous interface for the telegram bot API it's compatible with python versions 3.8+ [16]

To install the library we run the commande :

Pip install python-telegram-bot--upgrade

III .5. Used data-bases and processing :

In our home security system we need a data set with only one class because the aim of the system is to detect only prosons that's why we have choosed one class (person) ; this project contain a data set whith this following caracteristics :

Images : 2554

Size :640* 640

Annotations : 6029

Most of the images were obtained from (unsplash.com, 2024)and google images. We don't own most of the images in this dataset, all of them were obtained for free and will be used only with academic purposes. This dataset contains images of people labeled as Person.

Figure III. 7 annotated images

Figure III. 8 no annotated images

Object Data set processing:

We start by dividing the Dataset, to 80% for the training set around 4407 images and 20% for the Validation set around 1071 images. And 0% for the test set around 5 imagesThe dat

a set was recognized as an RGB images.

III .6. Discussion the results of training model :

We recognize object from one object classe which is : person we will study the learning phase of our model using 500 epochs, to see the improvement of our model after each epoch. We present the confusion metrix and representative plot of the precision, the recall,

and the loss functions of the model of each epoch

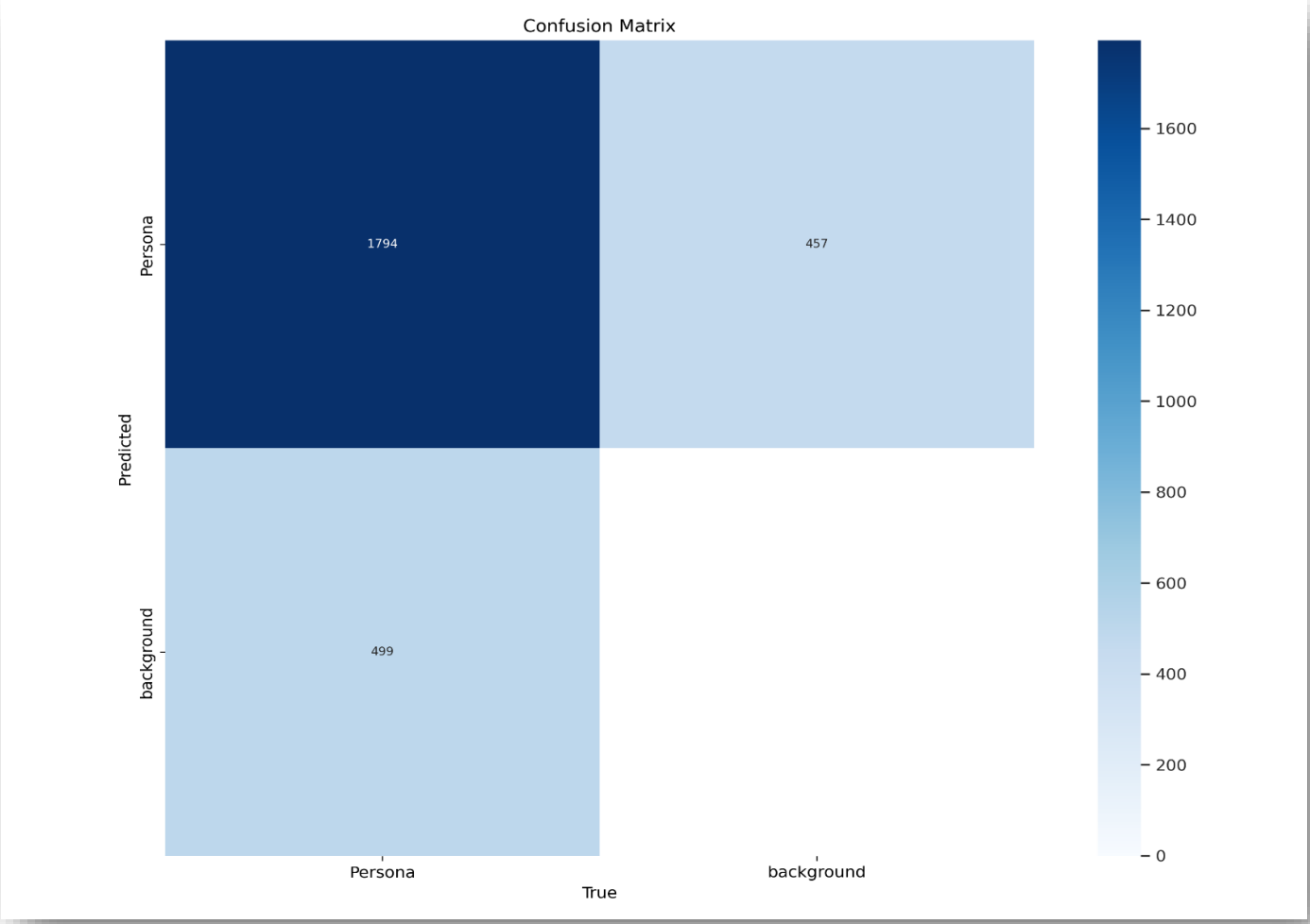


Figure III. 9 confusion metrix of our project

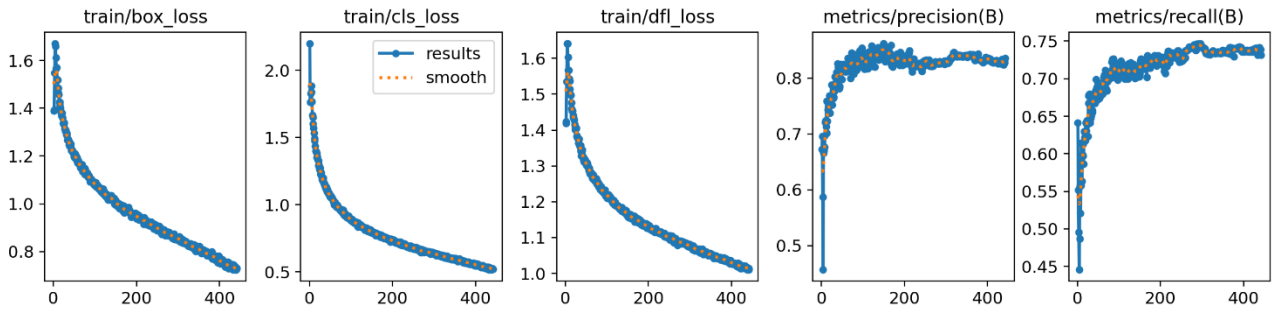


Figure III. 10 Plots of recall and precision and f box loss, cls loss and dfl loss over the training epochs for data set

from this figure we observe that :

the curves (box loss, cls loss, dfl loss) decrease rapidly despite the curves (precision, recall, mAP) increase rapidly, : and this because the model is at the beginning of the learning process,

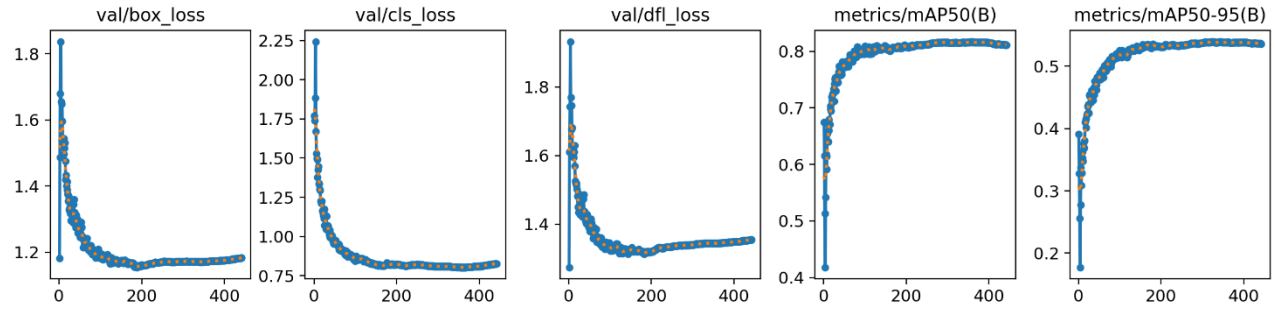


Figure III. 11 Plots of box loss, cls loss and dfl loss mean Average Precision over the validation epochs of data-set

the decrement of (loss functions) and the increment of the precision curves (precision, recall, mAP) will be slow because of the saturation of the model with information and then stabilizes despite of the increment of the number of epochs.

- For the best results, it was necessary to use 100% of the database, the more the model learns on a large number of samples, the better the results we get

From the previous analyse we can evaluate our model gives a satisfied results ; precision (85%) recall (75%) and accuracy (85%)

III. 6 .1 Test part :

After the training phase of our model ; the test on another object (another class)according to the following steps :

- Water bottle class :

-Choosing a water bottle as a testing object and put it in front of the camera

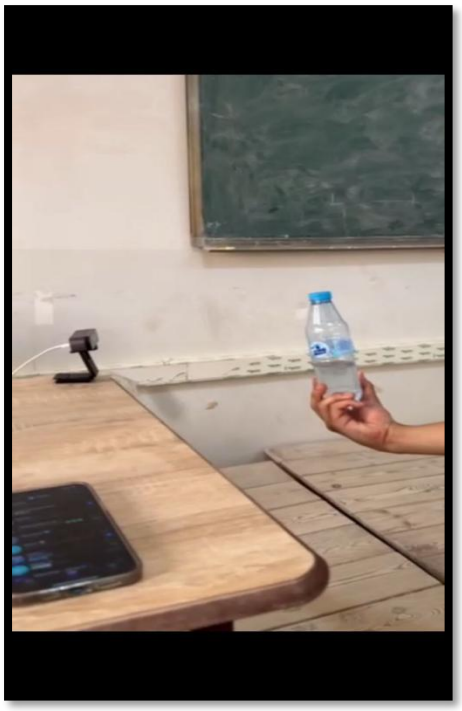


Figure III. 12 a bottle in front of camera

-We chek the program if it appears any bounding box

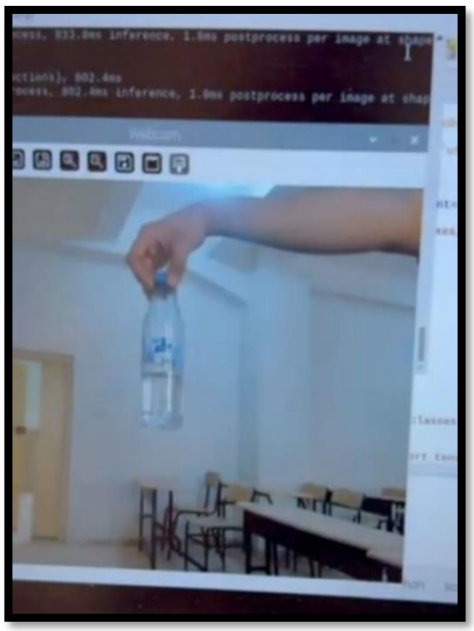


Figure III. 13 no bounding box

-after cheking the telegram both there is no message

- Person class:
  -we make a person in front of the camera

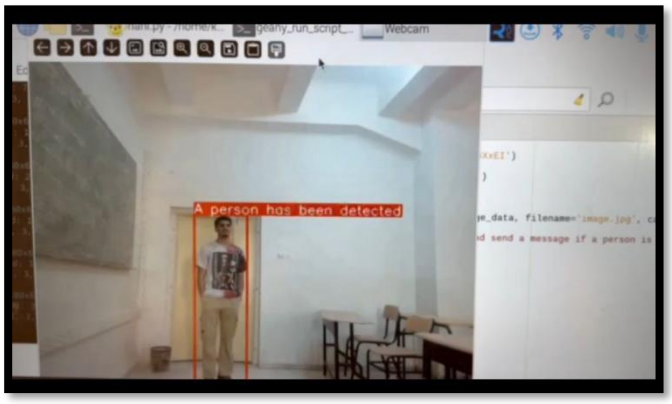


Figure III.14 bounding box around the person

- we observe a bounding box appeared on the display
- a notification telegram appeared

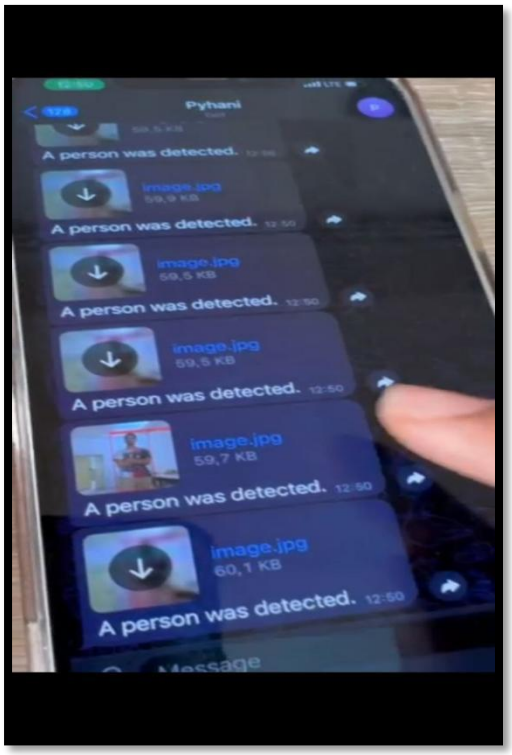


Figure III. 15 message contain the picture of the person

III .6 .2 Discussion of test results :

In order to evaluating the performance of the system we have performed a test using another class not montioned in the data base , the system has succeeded to make the difference between the two classes and that's the target is to create an alarm system detect only persons or human

Although the execution time was a little bit long (7 seconds)

III .7.Conclusion:

In conclusion, the implementation of our system has been highly successful and cost-effective becausevof the few number of components ;We strategically managed resources and optimized processes to minimize costs without compromising on quality.

The results of the testing phase were exceptionally positive, confirming that the system performs reliably and meets all our functional requirements because of the using of YOLOv8 and the Raspberry Pi This achievement highlights our ability to deliver high-quality solutions while maintaining budgetary constraints.

As we move forward, the successful deployment of this system stands as a testament to our commitment to innovation, efficiency,

General conclusion:

In this thesis, we explored the design and implementation of an advanced home security system leveraging the capabilities of Raspberry Pi and YOLOv8 for real-time human detection. The integration of artificial intelligence techniques, specifically YOLOv8 offers a cost-effective, efficient, and reliable solution to enhance home security against theft. The Raspberry Pi serves as a versatile and affordable platform, capable of handling the computational requirements for deploying the YOLOv8 model. YOLOv8, renowned for its superior accuracy and speed in object detection, significantly improves the system's ability to identify and track human with high precision. Throughout our implementation, we demonstrated the system's capability to detect unauthorized human presence, and send alerts in real-time. This proactive approach not only helps in deterring potential thefts but also provides homeowners with timely notifications, allowing for swift action. Future enhancements could include integrating additional sensors, improving the model's robustness under varying lighting conditions, and extending the system's functionality to include facial recognition for even more precise identification. In conclusion, the developed home security system proves to be an effective solution for modern security needs, combining the flexibility of Raspberry Pi with the advanced human detection capabilities of YOLOv8. This project lays a solid foundation for further research and development in the realm of intelligent home security systems. This project has introduced us to a vast world, which is artificial intelligence, we have learned new things such as python as programing language, and the fundamental principle of Deep Learning.

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