Al-Mustaqbal University
College of Sciences
Intelligent Medical System Department

Embedded systems

Lecture 10 :

Microcontroller Types

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جامعة المستقبل
AL MUSTAQBAL UNIVERSITY

Microcontrollers: Hardware for Embedded Computing

- Computers have evolved with time and now we can find them in places that are hard to believe. In our refrigerator, our TV, our WiFi Router, or even in our car. Embedded systems now manage to use computers in many creative and ingenious ways.
- With this evolution, many hardware vendors start to produce mini-computers with limited memory, CPU, and storage resources. They can be embedded in such small machines, and there are many options available in the market such as :

1. **Arduino**
2. **Beagleboard**
3. **Raspberry Pi**
4. **Toradex i.MX**
5. **Nvidia Jetson**
6. **Intel Nuc**

Embedded Hardware: Boards, Development Kits and Operating Systems

- Around forums, chats, or social networks you can hear about systems like Arduino, Raspberry Pi, or Beagleboard. They are micro-computers that come with a CPU or an MCU, and a limited amount of memory and storage capacity. To communicate, these computers usually offer USB ports, an Ethernet port (or WiFi support), Audio Input/Output, and a Video Output.
- You can create all kinds of embedded systems with these boards. They are used within small devices that fulfill a unique purpose. For example, a robot that cleans your house or the computer in charge of reading all the sensors in your car.
- But to create your own device, you need more than a board. You also have to consider which programming language and integrated development environment (IDE) the board supports and what operating system is available for it. This post will show you the options each board offers to create embedded applications.

Examples of Embedded Systems

- A lot of projects use these boards. For example, you can install embedded hardware to rotate an antenna or use embedded computers in drones, robots, or weather stations. As a consumer, you will often see them being used by startups and hobbyists. But of course, you can also find them in aerospace projects, industrial robots or even in your car

BEAGLEBONE DRONE

ARDUINO ANTENNA ROTATOR

RASPBERRY PI WEATHER STATION

TORADEX ROBOT

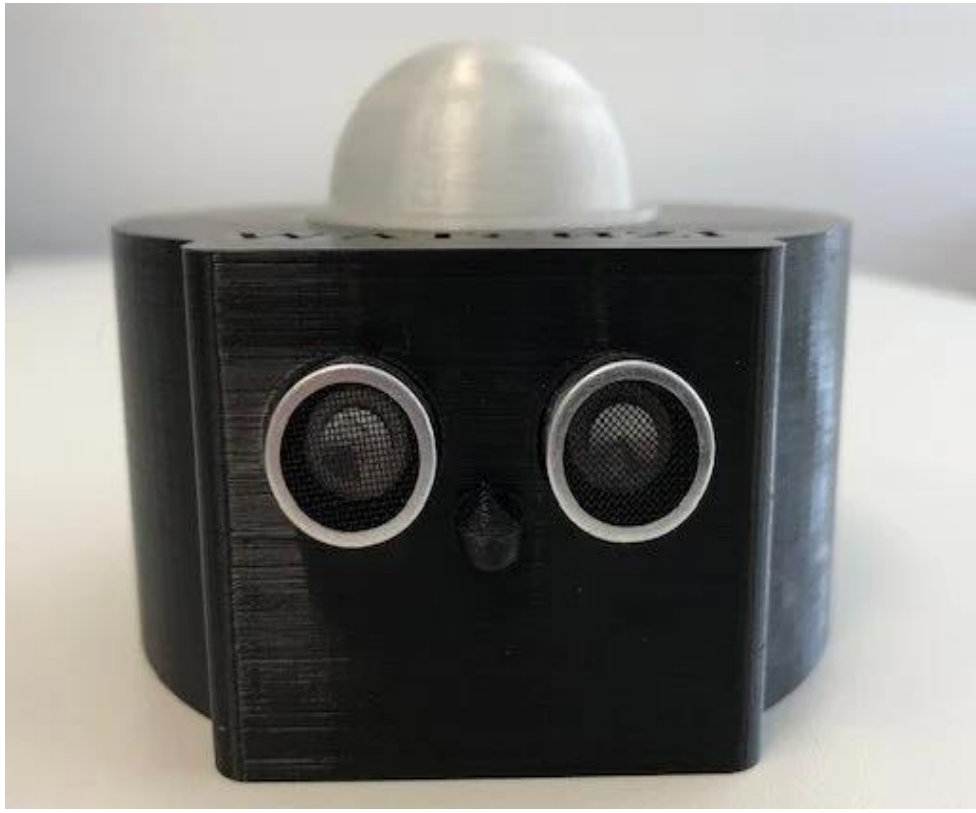
1. Arduino


RESET
AREF
GND
13 12 ~11 ~10 ~9 8 7 ~6 ~5 4 ~3 2 TX→1 RX←0
DIGITAL - PWM~
L
TX
RX
JP2
SMD
UNO
ON
ARDUINO
ICSP
T16.000
RESET EN
CS 47 25V
CS 47 25V
IOREF
RESET
3.3V
5V
GND
Vin
POWER
ANALOG IN
A0 A1 A2 A3 A4 A5
ARDUINO.CC

1. Arduino

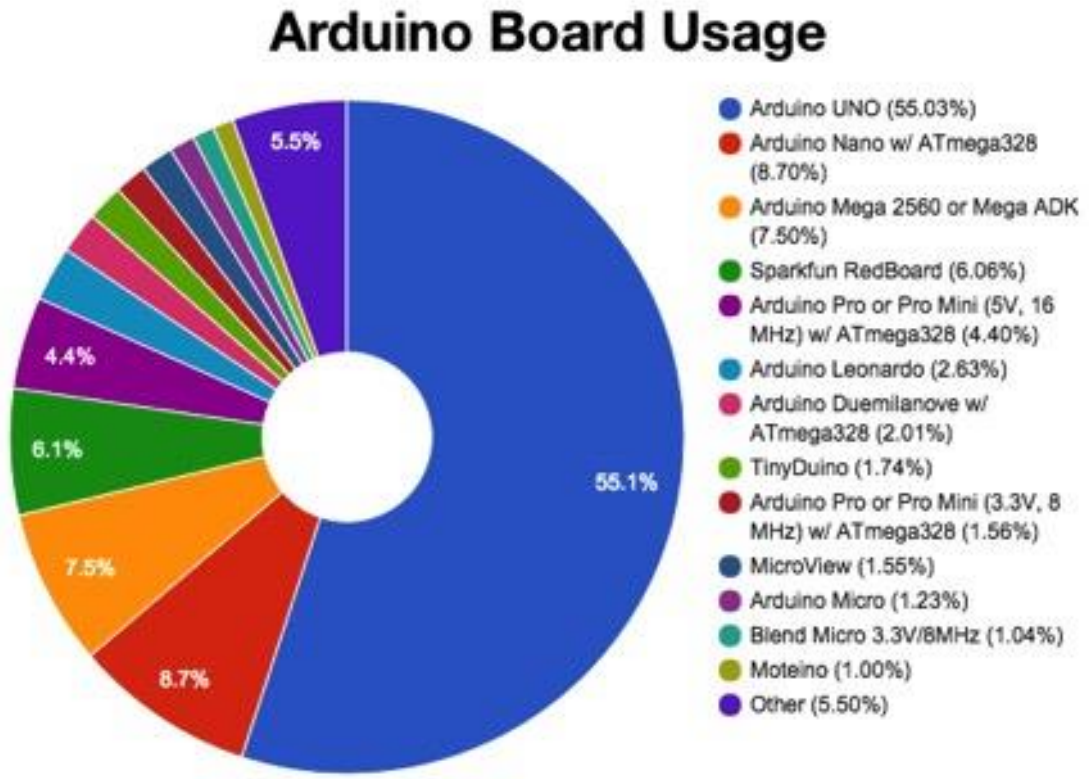
- Arduino is “an open-source hardware and software ecosystem” launched in 2005 in Italy. It is the first open-source hardware project to reach worldwide spread and one of the most used to create embedded projects.
- Arduino includes a group of boards, an IDE, a set of instructions (Arduino language) and a collection of libraries, which makes the control of electronic parts really friendly.
- Arduino is mainly used by hobbyists and professionals around the world for many types of projects: robots, door control systems, instruments, light dimmers, IoT devices, almost anything that requires to control electronics can be done with Arduino.

Embedded Software Examples for Arduino



1. Arduino

- Arduino - Embedded Computer Specifications
- Arduino comes with a whole family of boards: **Arduino UNO.**



Arduino UNO in Embedded Systems

The Arduino UNO is a compact 8-bit board that offers a user-friendly microcontroller solution for various projects. It provides a platform for controlling LEDs, DC motors, servos, and many other digital and analog electronic components that cannot be directly connected to a computer. To achieve this, the Arduino UNO is equipped with digital and analog pins for interfacing with electronics.

The Arduino IDE is used to program the board in C and C++. This development environment includes a wide range of libraries that facilitate the creation of complex applications, such as servo motor control, WiFi connectivity, and radio communication. Additionally, the IDE supports Arduino Shields, which are add-on boards designed to expand the functionality of the Arduino UNO.

It is important to note that the Arduino UNO features an 8-bit ATmega328P microcontroller. This allows the development of electronic control applications without the complexities of programming the microcontroller directly. However, the board has limitations in terms of processing power, storage, and memory. While it does not officially support running an embedded operating system, there are real-time operating systems (RTOS) compatible with the Arduino UNO, such as:

- FreeRTOS
- Simba
- Trampoline
- DuinOS
- OpenWrt

Benefits of Embedded Computers by Arduino

- Arduino makes electronics prototyping, embedded system design, and electronics control very easy for beginners. You need to use C or C++ to program your application but the Arduino libraries make the development a fast and pleasant experience.
- Arduino is perfect for you if you are:
- a beginner looking to start in the embedded board
- a professional who doesn’t want to program the MCU directly and use assembly language or a very low-level C/C++
- Arduino is a low-cost board. You can purchase the Arduino UNO for only $23 in the Arduino store. The IDE is open-source software that you can download for free from the Arduino website.
- Arduino UNO is licensed under the Creative Commons Attribution-Share-Alike license and the Arduino software is licensed under the LGPL and the GPL license.

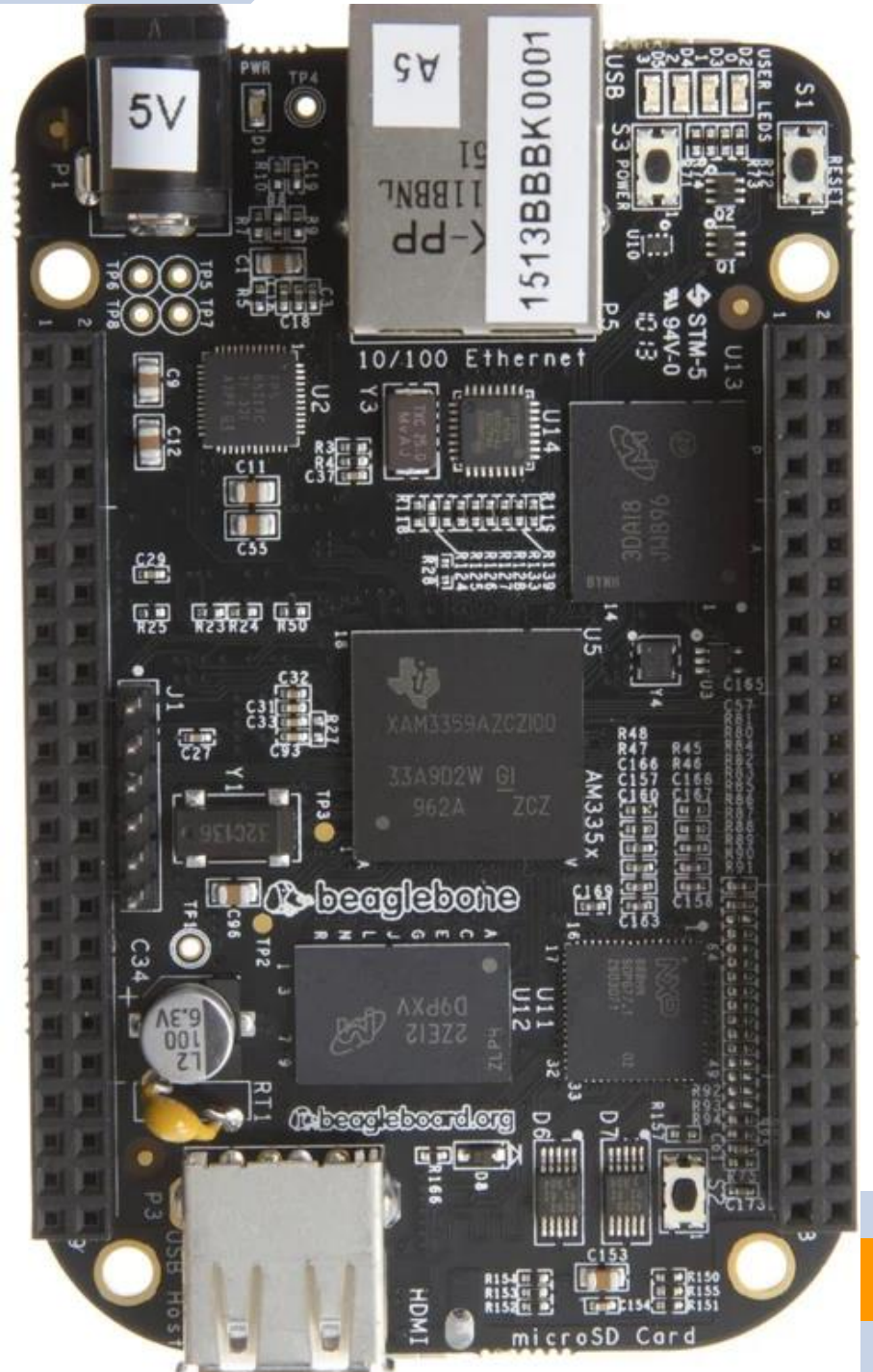
1. Arduino

- **Advantages of the Arduino Board**
- It is open-source
- It provides its own IDE
- It is easy to use
- It provides access to many shields that extends the functionalities
- **Disadvantages of the Arduino Board**
- It has low hardware resources for complex projects
- It doesn't use an OS (Arduino Yun supports Linux based OS)

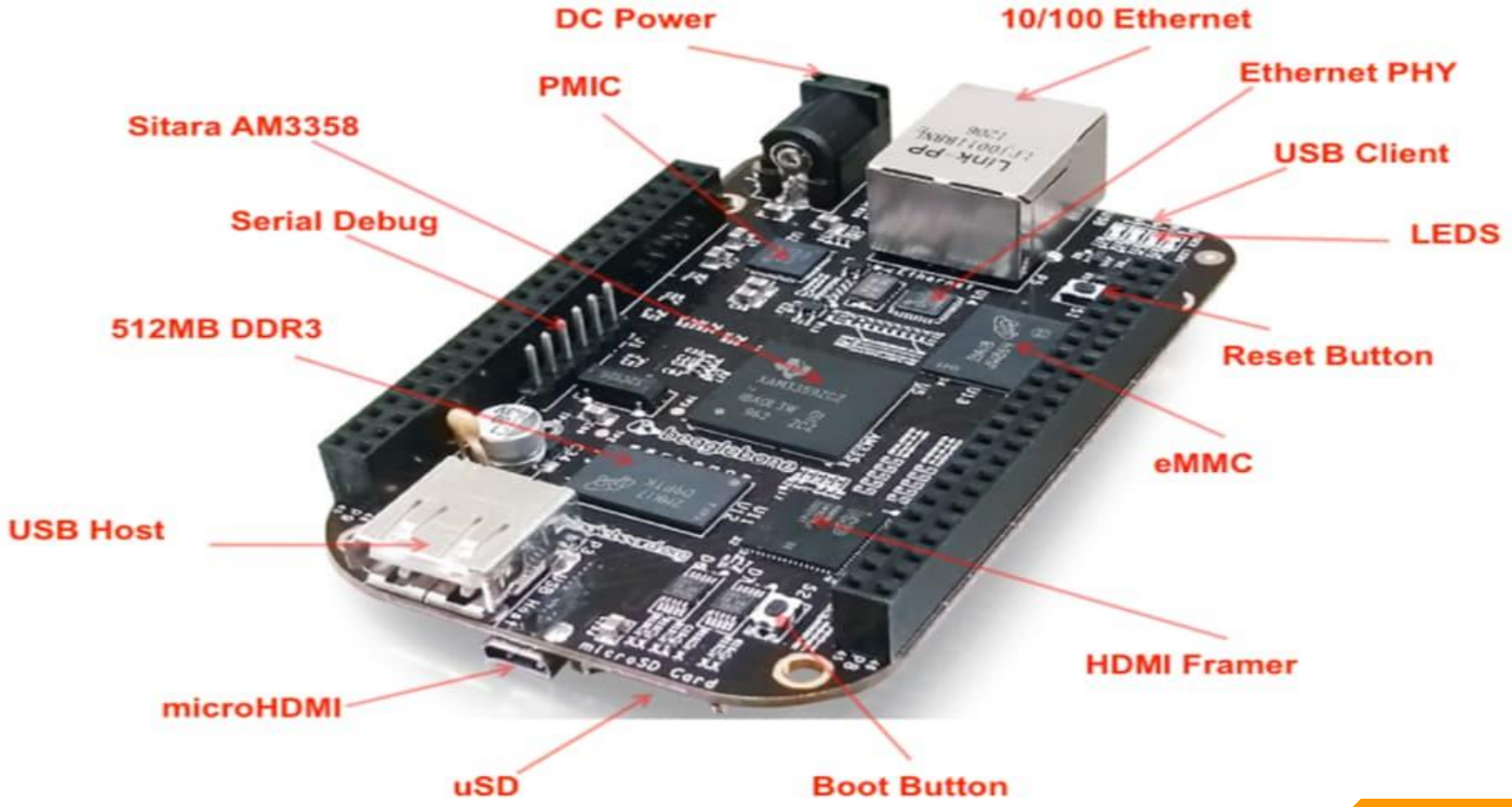
2. Beagleboard

- The BeagleBoard is a low-power, open-source, single-board computer, approximately the size of a credit card. It is manufactured by the BeagleBoard Foundation and was developed by Texas Instruments in collaboration with Digi-Key and Newark element14. First released in the United States in 2008, it operates under the Creative Commons Share-Alike license.

- Designed to showcase the capabilities of Texas Instruments' OMAP system-on-a-chip processors, the BeagleBoard aims to promote open-source software development. It serves both educational purposes and as a versatile platform for developers and hobbyists.



Embedded Devices Examples for Beagleboard



3. Raspberry Pi

- Raspberry Pi is a single board computer (SBC) created by the Raspberry Pi Foundation in the UK. It was first released in 2012. One of the foundation goals is to bring knowledge to the people about how computing works and how to create new things with it. The project has a strong orientation towards the educational field. It is also one of the most used boards to teach programming and embedded systems to children. Hobbyists and professionals also use Raspberry Pi in various embedded projects.

Examples of Embedded Systems with Raspberry Pi

Use Cases:
Raspberry Pi is widely used in educational, hobbyist, and professional projects, including robotics, embedded systems, personal computing, and rapid prototyping. Tutorials, documentation, and DIY projects are available on the Raspberry Pi website.

Raspberry Pi 4 Highlights:

- **Processor:** 64-bit Quad-core Cortex-A72 (ARM v8).
- **Memory:** 2GB to 8GB LPDDR4 RAM.
- **Connectivity:** WiFi, Bluetooth, Ethernet, 40 GPIO pins, 2 USB 3.0, 2 USB 2.0, and 2 HDMI outputs.
- **Expansion:** Supports shields for functionalities like motor control and RF communication.
- **Storage:** Requires a micro SD card for OS and applications.
- **Supported OS:** Raspbian (Linux-based) and others, with options to compile custom Linux distros.

Programming Options:
Supports various programming languages and visual block-based programming with Scratch, making it suitable for beginners and children learning computing.

3. Raspberry Pi

Advantages of Raspberry Pi in Embedded Systems

This board is the easiest to use for beginners and requires no programming or computer knowledge to start. Also, the great amount of shield removes the need to work with electronics to create new devices.

Benefits of the Raspberry Pi

- It's inexpensive
- It's easy to use
- It's open-source
- It offers many shields to extend the board functionalities
- It allows you to use any programming language that is supported by the operating systems

Disadvantages of the Raspberry Pi

- It only supports Linux
- External storage might be needed

4. Toradex i.MX

Toradex Verdin is a family of computers in modules made by Toradex. It is an industrial level solution for embedded systems.

- **Examples of Embedded Applications with Toradex i.MX**
- You can use Toradex boards to create embedded devices for many fields. Right now, Toradex is applied in the following cases: Aerospace , Automotive , Defense Systems , Digital Signage,Entertainment,Edge Computing, Robotics,Medical Devices,Retails and Ticketing.
- Some examples of Toradex in commercial applications are: Interface Box for Medical Infusion Pump, Quilla, or MyTapp.

4. Toradex i.MX

Benefits of Embedded Systems using Toradex i.MX

The Toradex board is not recommended for beginners. Nevertheless, it has a great amount of documentation on their website. It also documents how to create a Linux version for the board and how to configure a toolchain and your IDE.

Advantages of the Toradex Board

- It is industrial proven
- The CPU and memory give you a lot of computation power

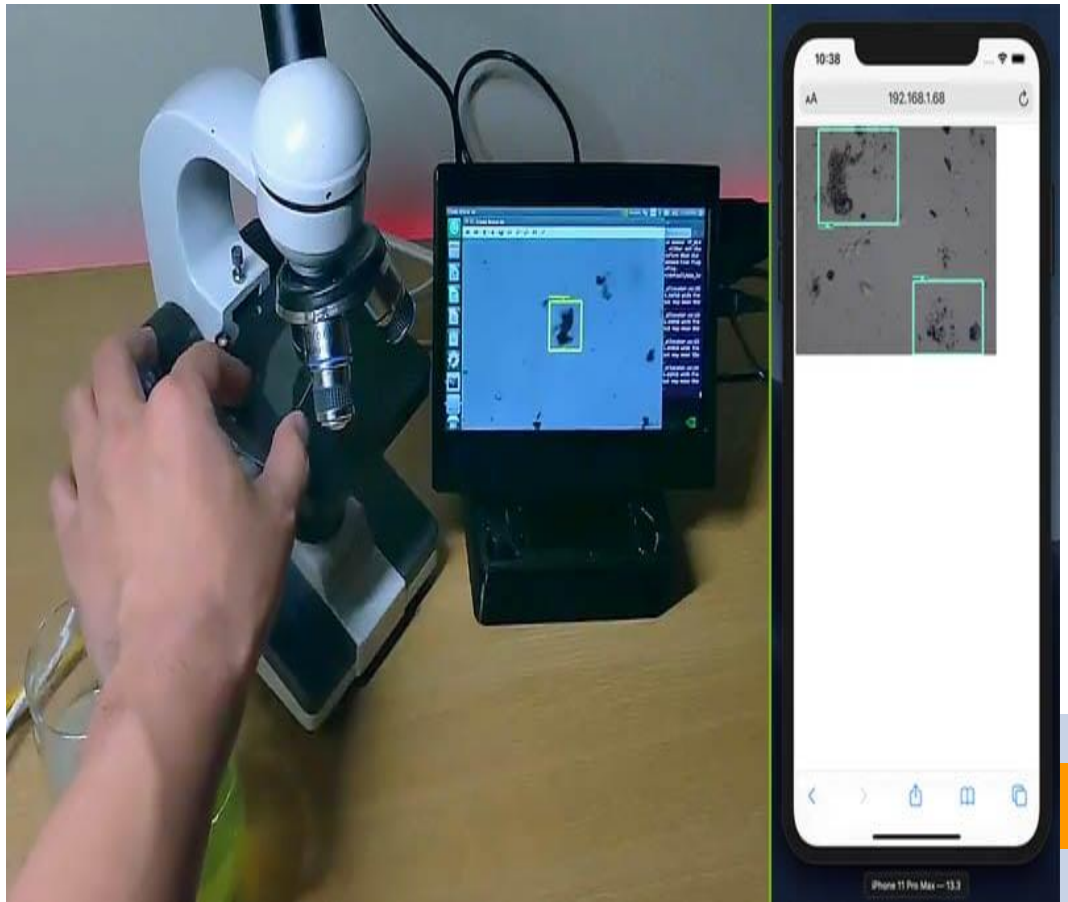
Disadvantages of the Toradex Board

- It is fairly expensive
- It requires additional boards to run
- It is not suited for beginner embedded developers

5. Nvidia Jetson

- Nvidia Jetson is a series of boards developed by Nvidia meant for IA and robotics projects. First released in 2014, Jetson is an embedded development board that takes advantage of the Nvidia GPUs power to enable you to create machine learning based devices.

Embedded Project Examples with Nvidia Jetson



5. Nvidia Jetson

Benefits of Nvidia Jetson for Embedded Applications

If you are a beginner and would like to use this board for embedded systems projects, this might not be the best choice. On the other hand, it comes with an IDE for developing your own application. You can also use some Raspberry Pi Shield to create your own devices.

Advantages of the Nvidia Jetson Board

- It has great processing power
- It includes a GPU
- It provides an SDK
- It is compatible with Raspberry Pi

Disadvantages of the Nvidia Jetson Board

- It sells at a higher price compared to other boards
- It only provides support for one operating system

6. Intel Nuc

- The Intel Next Unit of Computing (NUC) is a compact, high-performance computing platform designed for versatility across various applications, including embedded systems. Equipped with Intel Core processors, NUCs offer capabilities comparable to desktop PCs, making them suitable for both industrial and personal computing needs.

6. Intel Nuc

Benefits of Intel Nuc Embedded Boards

Intel Nuc is simple to use because it is similar to working on your PC.

Advantages of the Intel Nuc Board

- It is easy to use
- It feels like working on your own PC
- It supports Windows and Linux
- It allows you to use any supported programming languages

Disadvantages of the Nvidia Jetson Board

- It sells at a higher price in comparison to the other embedded boards
- It doesn't offer any examples or use cases for the board in embedded system projects

Thank You