A Systematic Review on Applying Machine Learning and Deep Learning on SBCs

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Abstract: -This research introduces a comprehensive study of the most robust Single-Board Computers (SBCs) implemented recently, where most of them are built on the system-on-chip architecture. This study also presents the main characteristics of each of these SBCs, as well as their prices and applications. Additionally, the study reviews some machine learning (ML) and deep learning (DL) techniques, exploring their implementation on SBCs. Finally, it displays some software tools on how to implement DL and ML projects on SBCs.

Key-Words: - Artificial Intelligence, Machine Learning, Deep Learning, Single Board Computers, Raspberry Pi SBC, NVIDIA Jetson Nano, Google Coral Dev Board.

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1 Introduction

A single-board computer (SBC) is a new type of computer system built on a single-circuit board. The main components of an SBC include: a central processing unit (CPU) to execute processes, a graphical processing unit (GPU) to accelerate graph processing, the Input/Output (I/O) general purpose ports, and a memory (program and data). Moreover, we can find image coding and different types of serial communications systems. These features are integrated into a tiny circuit board System-on-a-Chip (SoC). These physical characteristics of a SBC describe it as extensive. A user of an SBC can improve its usefulness by linking it with other devices through the given I/O ports, mainly: I2c, SPI, UART, USB RG-45, and GPIO pins, [1].

Based on the aforementioned criteria, the Arduino and Raspberry Pi SBCs emerge as the most prominent and widely used SBCs. However, upon the separate examination and review of the Arduino boards in this article, it appears to lack sufficient qualifications. It nonetheless proves to be a valuable contributor to artificial intelligence (AI), [2], machine learning (ML), and deep learning (DL) projects, especially when they are combined with high-performing single-board computers dedicated to AI and DL technologies.

The prevailing global discourse on AI and DL does not exclusively present Arduino and Raspberry Pi SBCs as the sole capable contenders. Additional single-board computers (SBCs) are now matching the criteria for structured edge computing within the domains of AI and DL.

A set of single-board computers (SBCs), deemed proficient in AI and DL within this article, are presented without a specific order. The primary goal of this research article is to offer comprehensive insights into implementing embedded AI and DL solutions, avoiding confinement to particular SBCs that may not have achieved the necessary functional maturity, [1]. The rest of the paper is arranged as follows: Section 2 gives an overview of AI, ML, and DL. Section 3 reviews the main features of the electronic hardware and the libraries of AI and DL. Section 4 introduces the best AI and DL single-board computers. Section 5 demonstrates the main tools and libraries for ML and DL. Finally, Section 6 presents a discussion and a conclusion of the paper.

2 An Overview of AI, ML, and DL

When it comes to AI, the focus is on mastering the automation of tasks related to humans, while ML and DL are concerned with enhancing this automation process. In this context, the ongoing AI process can demonstrate decision-making, language translation, natural language processing (NLP), speech recognition, object detection, and the Internet of things, [2], [3], [4], [5], [6], [7]. Meanwhile, DL operates without direct human supervision and can analyze both unlabeled and labeled data independently, without requiring third-party support. DL finds applications in object tracking and classification, image recognition, face recognition, robot navigation, and large language modeling tasks such as language translation and text generation, [4], [7]. Even more with DL —a transformation from text to image or image to voice or sound — it is generative AI.

AI holds significance for its capability to transform our lifestyles, work environments, and recreational activities. It has proven to be a valuable tool in the business sector, streamlining and automating the tasks traditionally carried out by humans, such as customer service operations, lead generation, quality control, and fraud detection. In various domains, AI has demonstrated the ability to outperform humans in the execution of some specific tasks.

Machine learning has become a prevalent term in today's technology landscape, experiencing rapid growth. It is widely used in many important applications, such as Google Maps, Google Translate, Google Assistant, and Alexa. Many real-world applications of machine learning are now trending and developing, including computer vision (CV) and image identification. This important application detects objects, persons, places, and digital images, showing the usefulness and effect of machine learning in numerous important domains.

Image identification and face recognition have wide usages, such as automatic tagging suggestions for friends on social media sites. The speech recognition process is based on converting spoken words into written text. Presently, many applications of speech recognition use machine learning algorithms. For instance, virtual assistants such as Siri, Google Assistant, Cortana, and Alexa apply speech recognition technology to understand, interpret, and reply to voice commands.

Moreover, machine learning has a great effect in improving the security of online transactions by discovering fraudulent activities, that are based on different fraudulent methods, such as detecting unauthorized money transfers or using fake accounts or IDs. To address this, the Feed Forward Neural Networks machine learning method comes to our aid by examining transactions and determining whether they are legitimate or potentially fraudulent, contributing to a safer online financial environment.

Deep learning, a subset of machine learning based on neural networks, is centered on enabling machines to emulate a fundamental human capability: learning through experience. In the realm of deep learning (DL), machines acquire the ability to learn from datasets. DL algorithms influence artificial neural networks (ANNs) to analyze and process data, akin to the independent learning process of the human brain. While humans provide machines with substantial knowledge bases, training data, and pattern recognition techniques, DL enables machines to operate autonomously thereafter. This approach has significantly increased the accuracy levels. Tasks such as driving cars, printing, text recognition, and natural language processing exhibit enhanced precision with deep learning. Notably, deep learning has surpassed human capabilities in computer vision, excelling in the classification of objects within images, [6].

3 Electronic Hardware Features and Libraries of AI and DL

Electronic hardware features and libraries play a vital role in enabling AI and DL applications, providing the required computational power, flexibility, and connectivity for the construction of intelligent systems in a wide range of domains. The performance of a SBC is measured based on its architecture and main specifications, including the processor's, connectivity options, and processing power.

An SBC board is considered efficient for artificial intelligence and deep learning applications if it consists of CPUs, CPU ports, a good RAM capacity, I/O ports, a graphical processing unit (GPU) processor, Gigabit Ethernet, Wi-Fi, and

Bluetooth. Moreover, it must have a tensor processing unit (TPU) (an integrated circuit developed by Google for AI and machine learning tasks) and a neural processing unit (NPU) (a processor used for deep learning tasks).

All SBCs developed for AI workloads are supported with machine learning and deep learning libraries.

Some remarkable AI and DL libraries are Sci-kit-learn, TensorFlow, PyTorch, OpenCV, GPU4Vision, and OpenVIDIA. For generating 3D computer-generated objects on a SBC, the open-source OpenGL graphics library stands out as a significant tool, [8]. This graphics library controls graphic accelerators, which facilitate the processing of Swift scenes. When engaging in parallel computing with the SBCs covered in this article, it is noteworthy to introduce the open-source OpenCL library. Widely endorsed as a parallel computing standard, OpenCL is particularly relevant in heterogeneous computing environments, encompassing the utilization of specialized accelerator devices like GPUs, TPUs, and FPGAs. Additionally, a key open-source library to consider for SBC projects is OpenCV, [9], [10].

OpenCV has been revealed to be extremely efficient in processing images and videos, utilizing library tools such as DirectX, OpenCL, CUDA, and OpenGL. Its interfaces, including Python, C++, and C, contribute to its platform adaptability and versatility. It also offers a comprehensive aid for interacting with sensors and analyzing sensor data in AI and DL applications. The incorporation of the OpenCL library within OpenCV provides the fulfillment of multi-core processing requirements, addressing the demand for efficient parallel processing on various computing platforms, [11].

4 Best AI and DL Single-Board Computers

The previous section described the main features of SBCs, their architecture, their hardware qualifications, their optimal operation specifications, and a list of libraries to integrate. The best of SBC solutions, [8], are presented in this section. Figure 1 presents the board of the Raspberry Pi 4

4.1 Raspberry Pi 4 (RPi 4)

Fig. 1: Raspberry Pi 4 and Applications

RPI4 was introduced a few years ago, it is widely used as a single board because of its price/performance ratio (around 30 dollars) with RAM OF 2GB.

Because of its well-clear clear user manual, and its HW specifications; the RPI4 board is preferable for use in many applications of AI and ML, [12].

The processing power of the Raspberry Pi 4 exceeds that of its predecessors, such as the Pi 3B or Pi 3B+, with distinguished enhancements such as USB 3.0 ports.

RPI4 is supplemented by AI-supported third-party equipment. For instance, it can be connected to the Intel Neural Compute Stick 2 through USB. This third-party addition is perfect for enabling the provision of an AI framework. Coral Edge TPU USB accelerator is another alternative third-party accessory. It is a perfect pairing gadget for the Raspberry Pi board. Google's AIY Vision and Voice kit is a hardware kit that includes the Raspberry Pi board, cables, and software.

The pairing, RPI4, and Al-accessory hardware is well-suited for home-based projects involving autonomous vehicles, automobile HMI applications, and object identification systems that enhance the design prospects of home security systems.

The specification of RPI4(compact size, compatibility with different OS, price/performance ratio…) makes it preferable to be used in educational settings in the UK.

4.2 Raspberry Pi 5 (RPI5)

Recently, after almost 4 years, we have the new version of the Raspberry Pi-5, which is better performing than the R-Pi 4, in speed 2 to 2.5 times faster than the precedent. It was released in October 2023. It costs $60 for the 4GB variant and $80 for its 8GB sibling (plus the local purchase taxes of the country). Its platform, performance, and features have been improved. The Raspberry Pi 5 has been developed with new features. It is much faster than its predecessors, and it's the first Raspberry Pi computer to feature silicon designed in-house in Cambridge, UK. It is probable that the Raspberry Pi 5 will have a processor that is more powerful in performance than its predecessors. It ensures low power consumption for applications that range from IoT projects to desktop computing.

The main characteristics of the Raspberry Pi 5 include, [13]: a 64-bit Arm Cortex-A76, with 512KB L2 cache and a 2MB shared L3 cache, a CPU with 2.4GHz quad-core, a RAM of LPDDR4X-4267 SDRAM (4GB or 8GB), a GPU 800MHz Video Core VII GPU supporting OpenGL ES 3.1, Vulkan 1.2, and a Micro SD card slot, with support for high-speed SDR104 mode for storage. For communication, it has Dual band WiFi (2.4 GHz) and 5.0 GHz 802.11ac Wi-Fi. Bluetooth: Bluetooth 5.0/Bluetooth Low Energy (BLE), Ethernet Gigabit Ethernet, with PoE+ support (requires PoE+ HAT), Real-Time Clock (RTC), powered by an external battery, and On/Off Switch: On-board power button. Header communication: 2 x micro-HDMI ports (up to 4Kp60 supported) HEVC decoder and HDR support, 2 × 4 lane MIPI camera/display transceivers (3x bandwidth improvement), PCIe 2.0 x1 interface for quick peripherals (it needs a different M.2 HAT or another adapter), and a standard 40-pin Raspberry Pi header.

The enhanced BMC2712 processor in the Raspberry Pi 5, equipped with 4 ARM cores and running at 2.4 GHz, is considered an important increase in processing power. The transition from the Cortex-A72 to the Cortex-A76 structure improves its performance capability to manage more commands at the same time. The processing efficiency of RPI5 was enhanced by using a larger CPU cache, with 512KB L2 caches and a 2MB shared L3 cache.

The Soc of BMC2712 joins four ARM cores running at 2.4 GHz rather than 1.8 GHz. The architecture upgraded from Cortex-A72 to Cortex-A76, which allowed the processing more commands simultaneously and is an actual performance supporter. Particularly when connecting with a 4 times larger and faster CPU cache (512KB L2 cache and 2MB shared L3 cache) and the LPDDR4X-4267 SDRAM storage. According to the RAM size, we can have either 4GB or 8GB.

RPI5 operates on the Raspberry Pi OS, the Bookworm edition, which represents the newest version of the in-house developed operating system (OS). The previous Pi OS versions are not compatible with this version. Other operating systems such as Ubuntu and Android for the Raspberry Pi will be introduced in the coming paragraphs.

The RPI5 identifies the Raspberry Pi experience. It has a robust structure and new characteristics like PCIe, RTC, and a CPU frequency of 2.4 GHz. Implementation of retrained DL models can be done using this SBC with 8 GB RAM. Figure 2 shows the resemblance of RPI5 to RPI4 in component disposal. Moreover, RPI5 will be supported by the Android OS to increase its capacity to construct effective projects.

Fig. 2: Raspberry Pi 5 development board

4.3 NVIDIA Jetson Nano

Nvidia Jetson Nano SBC is considered a sibling to the Nvidia Jetson Xavier NX (presented in subsection 4.4). With a budget-friendly estimated cost of $59, the Nvidia Jetson Nano SBC offers a decent cost-to-execution ratio, [14], making it accessible to a wide range of users interested in AI applications. The mentioned AI processes, including image classification, speech processing, segmentation, and object localization, demonstrate the versatility of this hardware for various neural-related AI tasks. It supports many operating systems, such as the Linux-based OS.

Indeed, the main difference between the two variations of the Jetson Nano SBC lies in their RAM capacity. The options available are the 2GB RAM version and the 4GB RAM version. As you rightly pointed out, the key impact of this difference is in performance. Generally, a 4GB RAM configuration provides more memory space for applications and processes to run simultaneously compared to the 2GB variant.

The Nvidia Jetson Nano indeed boasts some key specifications that make it a versatile and capable single-board computer (SBC) for AI and machine learning applications. The following represents the main features of the Nvidia Jetson Nano: CPU: A quad-core ARM Cortex-A57 CPU running at 1.43 GHz, offering a balance of performance and efficiency for AI and ML tasks, GPU: 128-core NVIDIA Maxwell GPU, providing significant parallel processing power for AI workloads and graphics processing, Memory: Two memory configurations are available: 2GB or 4GB of 64-bit

LPDDR4 RAM, providing the necessary memory for AI processing tasks. The integrated microSD, HDMI, DLA, and NVIDIA on this SBC results in quick and accurate processing of AI. Figure 3 presents the Nvidia Jetson Nano SBC and its application.

Fig. 3: Nvidia Jetson Nano SBC and its application

4.4 NVIDIA Jetson Xavier NX

The Nvidia Jetson Xavier NX, [15] and [16] are indeed remarkable single-board computers (SBCs) renowned for their exceptional performance in the fields of AI and deep learning. The main characteristics of the Nvidia Jetson Xavier NX are Power and size; with twenty-one TOPS and a size up 75 mm. the system manages to do top performance.

GPU and TPU cores: the inclusion of a 384-core NVIDIA Volta GPU and 48 tensor cores underscores its capabilities in handling complex AI workloads, particularly those involving deep learning and neural networks. The performance of this SBC is improved, as its CPU comes with a 6-core NVIDIA ARMv8.2 at 64 bits. Figure 4 shows the NVIDIA Jetson Xavier NX SBC.

Fig. 4: NVIDIA Jetson Xavier NX

The NVIDIA Jetson Xavier NX 16GB represents a powerful system-on-module (SOM) that has these main specifications:

Supercomputer Performance: The Jetson Xavier NX 16GB provides server-class performance, which can deliver up to 14 TOPS at 10W, 21 TOPS at 15W, or 20W.

Energy Efficiency: The NVIDIA Jetson Xavier NX is implemented to be energy-saving during power consumption, which makes it suitable for edge computing applications. **Versatility:** It can be applied in various important applications, such as edge computing, manufacturing, logistics, retail, services, agriculture, smart cities, and medical instruments.

The following points summarize the key benefits of the NVIDIA Jetson Xavier NX 16GB SBC:

- The Xavier NX is well-designed for AI applications and projects, including natural language processing and machine learning.
- It has the capabilities to be applied in robotics projects due to its powerful and high-performance computing for complicated tasks and navigation.
- The inclusion of 4K video output in its design makes it a good tool to be applied in applications that need high-resolution displays.
- It has high computing power, with 21 TOPS computing power, which is suitable for AI workloads.
- It is supported by an HDMI/Display Port, GPIO, USB 3.1, Bluetooth, Wi-Fi, and I/O ports.

On the other hand, the drawback of the Jetson Xavier NX 16GB is its large size compared to other SBCs like the Raspberry Pi 4/5. This issue might be taken into consideration by those projects with space restrictions. Furthermore, its high price is considered another drawback that influences user decisions due to budget constraints.

4.5 NVIDIA Jetson AGX Xavier

The NVIDIA Jetson AGX Xavier is the most expensive SBC within the NVIDIA family, where its an estimated cost is around $694.91. Although its price is considered high, it can handle many functions and workloads.

The Nvidia Jetson AGX Xavier SBC is highlighted for its flexibility, making it adaptable to various business and industrial circumstances. Specific mentions include applications related to horticulture, production, automobile upgrades and manufacturing, and retailing. The versatility of the Jetson AGX Xavier extends beyond these examples, as it can be applied in many other business and industrial scenarios, [17]. Figure 5 displays the NVIDIA Jetson AGX Xavier SBC.

Fig. 5: NVIDIA Jetson AGX Xavier

The high price tag and the advanced design and functional power of the Nvidia Jetson AGX Xavier suggest that it may not be the best fit for beginners or those exploring the field. Its capabilities are geared toward more experienced individuals or professionals. It is ideal for top-level edge and figure execution projects. It is deemed a good choice for organizations, companies, or businesses that are looking for effective software and hardware application adaptability. Nvidia Jetson AGX Xavier is designed specifically for AI, ML, and DL applications. Its computational power is exceptional. Compared to traditional computing solutions, it consumes only a fraction of the power to deliver up to 32 TOPS of AI performance. Additionally, it provides more memory space, which suits the AI and DL workloads. This SBC provides many connectivity options, such as Gigabit Ethernet, PCIe, HDMI, USB 3.1, and PCIe, [18].

The major specifications of this SBC include a tensor cores-supported 512-core Volta GPU, a 7-way VLIW Vision Processor Vision Accelerator, a 2x NVDLA Engines DL Accelerator, and a 64-bit 8-core ARM v8.2 CPU. Moreover, a powerful GPU with a 512-core Volta GPU and tensor core support contributes to high-performance parallel processing in ML and DL workloads. In addition, there is an HDMI 2.0 display, 32GB of eMMC 5.1 storage, and an extra storage extension, the UFS/uSD Card Socket.

4.6 Google Coral Dev Board

Coral Dev Board Micro is a microcontroller board that can run TensorFlow Lite models with acceleration on the Coral Edge TPU. With its onboard camera and microphone, this module provides a complete system for embedded machine learning (ML) applications. Even if we have no experience with microcontrollers, the provided documents on the web page explain everything we need to know about running applications on the Dev Board Micro.

The Google Coral Dev Board SBC is highlighted for its functional design and implementation, making it well-suited for deep learning through AI. If your AI projects require fast, easy, and edge computing prototyping functionality, the Google Coral Dev Board SBC is recommended. The main remarks of this SBC include its removable system-on-module and its ideal Tera Operations Per Second (TOPS) standing at 9 TOPS, [19] and [20]. The Google Coral Dev Board runs Mendel Linux, a Debian-based Linux distribution that has been optimized for it. It is efficient for AI and DL projects.

Its key features include **NXP i.MX 8M SoC (System-on-a-Chip):** The central processing unit of the SBC is built around the NXP i.MX 8M SoC, providing the computational power required for AI and DL tasks. **GC7000 Lite GPU:** Integration of the GC7000 Lite GPU enhances the graphical processing capabilities of the SBC, contributing to its suitability for AI applications. **Google Edge TPU Co-Processor:** This important feature makes the Google Coral Dev Board SBC more useful for edge processing and AI duties. **8GB eMMC Flash Storage:** This storage capacity represents a good option for many AI applications. **Connectivity, WiFi,** and **Bluetooth Hardware:** It supports different connectivity choices, such as Gigabit Ethernet, WiFi, and Bluetooth hardware. **1GB LPDDR4 RAM:** This SBC provides the essential memory for AI tasks.

Furthermore, the Coral Dev Board is considered underqualified as a desktop computer, so it may not be appropriate for common computing tasks. Figure 6 shows the Google Coral Dev Board.

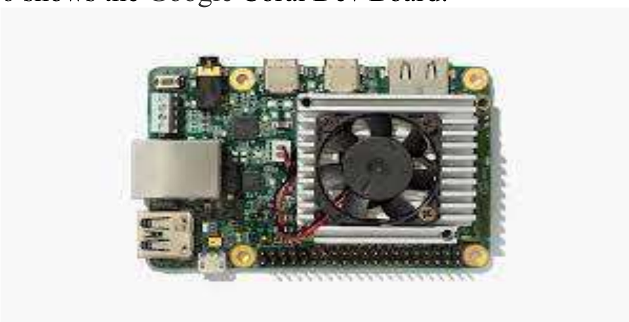

Fig. 6: Google Coral Dev Board

4.7 Google Coral Dev Board Mini

It is a smaller, more flexible, and cheaper SBC that is used for many on-device ML projects to accomplish high-speed machine learning inferencing. It integrates the new Coral Accelerator Module with a MediaTek 8167s SoC. It has an integrated GPU and is extremely useful in computer vision applications. This SBC has an edge-tensor processing unit that can perform 4 trillion operations per second. Figure 7 shows the Google Coral Dev Board mini.

Fig. 7: Google Coral Dev Board Minin

4.8 Rock Pi N10

This SBC has been specially created to be applied to artificial intelligence and deep learning applications. It is built on a robust system-on-chip architecture. It supports different capacities of RAM and provides sufficient storage for processing and storing data. This flexible SBC serves several operating systems, like Android and Linux, [21]. Figure 8 presents the Rock Pi N10 SBC.

Fig. 8: Rock Pi N10

4.9 HiKey 970

This SBC is manufactured especially for working with artificial intelligence and deep learning applications using the Android and Linux operating systems. It is supported with a random-access memory, a graphical processing unit, a CPU, and a neural processing unit. It has WiFi, GPS, and Bluetooth. Figure 9 presents the HiKey 970 SBC.

Fig. 9: HiKey 970

4.10 BeagleBone AI SBC

This open-source SBC is effective in many artificial intelligence and deep learning applications. Moreover, the BeagleBone AI SBC is capable of applying different ML processes, as it was developed using the OpenCL library.

It runs the Linux operating system, and it is affordable since it costs $127.43. In addition, it has reliable and fast network access due to its dual-band WiFi and Gigabit Ethernet connectivity. Moreover, its processing power is ideal for machine learning tasks. However, the only negative point of this SBC is that the computational power of the other SBCs available on the market is greater than the one in the BeagleBone AI. Figure 10 displays the BeagleBone AI SBC.

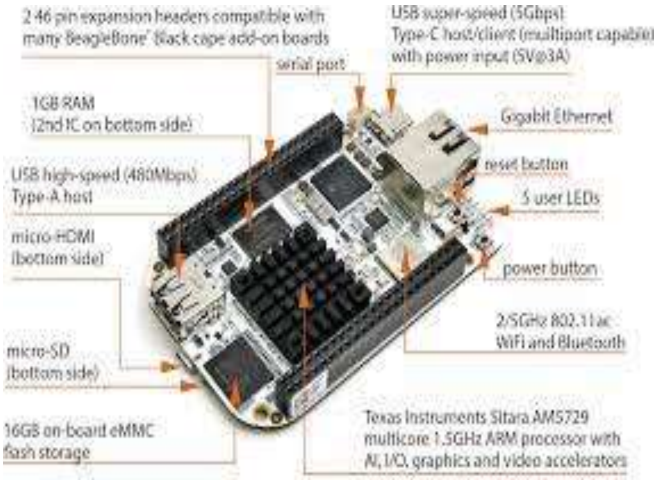

Fig. 10: BeagleBone AI SBC

4.11 Beagle V

The Beagle V is a new competitor in the SBC landscape as it focuses on AI applications. This SBC offers coherent support for Linux-based operating system distributions. BeagleV is applied to edge computing and many AI and DL projects. Two versions of the BeagleV offer different memory configuration options. These two versions are: the 4GB model costs $119, while the 8GB model costs $149. The BeagleV has many key characteristics that improve its applicability in AI and edge computing applications. Some of these features include the Neural Network Engine (NPU), NVDLA Engine 1-core DL accelerator, Vision DSP Tensilica-VP6, a microSD slot for storage expansion, an HDMI 1.4 display interface for video output, and a choice between 4GB or 8GB LPDDR4 SDRAM. The CPU is powered by a RISC-V U74, containing 2 cores running at 1.0 GHz. Figure 11 displays the Beagle V development board, [22].

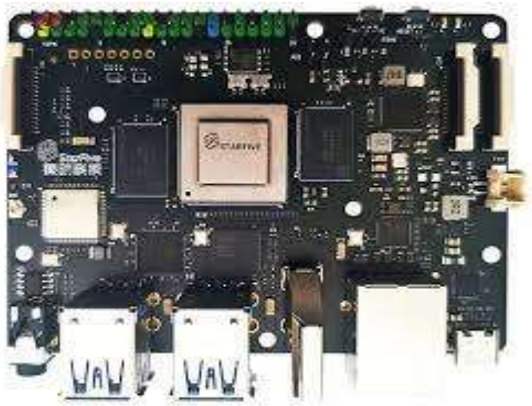

Fig. 11: Beagle V development board

In Table 1, we present the most powerful SBCs, where we can implement ML algorithms such as gradient descent, SVM, K-nn, and K-means or DL algorithms such as CNN for prediction and classification.

Table 1. A Comparative Study of the Main SBCs

SBC Model	CPU	RAM	GPU	Power and cost
Raspberry Pi 4	Quad-core ARM Cortex-A72	2GB, 4GB, 8GB	VideoCore VI	~2.7W (4GB model) 45-60$ 10W
RPI 5	Arm Cortex-A76	2GB, 4GB, 8GB		80-90$
Nvidia Jetson Nano and Xavier	Quad-core ARM Cortex-A57 64-bit 8-core ARM v8.2	4GB LPDDR 4	128-core Maxwell Volta GPU,	~5-10W 140$ 15-20W 200$
Google Coral Dev Board	Quad-core ARM Cortex-A53	1GB LPDDR 4	Edge TPU	~5W 150$
Odroid XU4	Exynos5422 (Octa-core, big.LITTLE)	GB LPDDR 3	ARM Mali-T628 MP6	~5-10W 80$
Asus Tinker Board	Quad-core ARM Cortex-A17	2GB LPDDR 3	Mali-T764 GPU	~5W 85$

5 Languages, Tools, and Libraries for ML and DL

Certainly, the following paragraphs present an overview of some of the most effective and widely used libraries and languages for ML and DL solutions, known for their comprehensive features essential for project development, [9]:

- Python is used in ML and DL, because it is a programming language that has an organized syntax and powerful tools to solve any task. Moreover, it is very close to simple math thinking. Python is chosen as the primary programming language for freshmen at most of the leading universities. Writing code in Python is easy; it is like Pascal programming from the old generation. In addition, Python excels in this aspect with robust support for multi-threading, devoid of memory-related issues. At present, virtually all contemporary ML or DL libraries offer a Python API, simplifying decision-making processes. Opting for Python is advantageous as it is straightforward to use and learn, characterized by its simplicity. Engaging in ML experimentation and algorithm creation does not require proficiency in Python [23] or [24].
- The R language is widely used for statistical computing, data preprocessing, and graphics, making it ideal for data analysis and visualization in ML projects. The main libraries that are available for R include Caret, Random Forest, Keras, and MXNet. Furthermore, R faces challenges related to scalability due to its single-threaded nature, operating in RAM, and being limited by memory constraints. -The Jupyter Notebook is an effective tool for data analysis, offering a combination of simplicity and power. It allows writing codes in different programming languages, such as Python and R. Moreover, it enables the direct inclusion of text descriptions, charts, and graphs into web pages.
- The Scikit-learn library represents the main library used for machine learning tasks. Using this library, we can apply different supervised and unsupervised machine learning techniques, like logistic regression, Naive Bayes, decision trees, random forest, k-nearest neighbor, support vector machine, and k-means clustering. Additionally, this library can be used for data processing. It also supports standard machine learning approaches, but it cannot handle deep learning jobs.
- The Pandas library is applied to data processing and analysis. Using this library, we can read, prepare, transform, clean, and analyze the data.
- The NumPy library is applied for multi-dimensional arrays and metrices. It also supports some mathematical functions and operations.
- The TensorFlow and Keras libraries are extensively used for deep learning tasks such as object detection, image classification, and natural language processing. Google's deep learning library called TensorFlow supports computations on the CPU, GPU, and Google tensor processors (TPU), [25].

- Keras works as an extension to TensorFlow to handle many concerns and improve the general experience. It is capable of building neural network architectures by employing a Python domain-specific language (DSL). This approach facilitates the process of constructing neural networks to be more user-friendly and accessible for users.

6 Discussion and Conclusion

Single-board computers (SBCs) have shown up as vital models for many applications, such as industrial AI and businesses. This research presented a comparative study of the current and most powerful SBCs, including their features and prices. The study also demonstrated the implementation of ML and DL on SBCs. AI development has been made more accessible by these compact, powerful SBCs. Moreover, SBCs presented effective and high-performance computing solutions and ideal platforms for AI workloads. The availability of different operating systems, such as Android, and Linux distributions, and custom-built environments, improves the versatility and flexibility of SBCs for AI development.

In conclusion, our findings showed that SBCs that are advised to be used in AI and DL projects and workloads fall into two groups: they are either extremely capable or powerful but expensive or affordable yet less powerful. The selection of a suitable SBC depends on our knowledge and experience in the ML or DL fields. For instance, development SBCs like the Google Coral Dev Board and NVIDIA Jetson Xavier are prepared for immediate AI implementation right after purchasing them. In contrast, additional development SBCs, like the Raspberry Pi 4 or the most up-to-date Pi 5, may require add-ons and extra components such as the Google Coral TPU Accelerator Intel or the Neural Compute Stick to perform machine learning or deep learning tasks efficiently, especially for complicated projects that request extra computational power.

For trainees, we recommend acquiring an initial understanding of AI and DL notions. Once they become familiar with these concepts, the Raspberry Pi SBC, together with the add-on devices such as the Google Coral TPU Accelerator or Intel Neural Compute Stick, will be a good choice for their initial AI projects. Advanced SBCs, such as BeagleBone AI and HiKey 970, are recommended for expert users in AI.

In future works, it is recommended to apply the deep learning algorithm called convolutional neural networks (CNNs) to SBCs, especially in AI domains like robotics, the Internet of things, and computer vision. Besides, it is recommended to develop more advanced SBCs that have high performance with more memory capacity and less processing power consumption.

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