Exploring the New Edge AI Computer based on Raspberry Pi CM5

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Abstract: The advent of advanced artificial intelligence (AI) systems is fundamentally reshaping industrial operations, driving a new era of efficiency, automation, and data-driven decision-making. This paper explores the capabilities and industrial applications of the new edge AI computer based on Raspberry PI computer module CM5 called "Alpon X5", a sophisticated AI platform designed for enterprise-level deployment. Leveraging a robust architecture that integrates machine learning, computer vision, natural language processing, and predictive analytics, Alpon X5 serves as a central cognitive engine for complex industrial environments. Its primary applications span critical domains such as predictive maintenance, where it analyzes sensor data to forecast equipment failures, minimizing unplanned downtime and extending asset lifespan. In the realm of manufacturing optimization, the platform utilizes real-time computer vision for quality control, anomaly detection, and process automation, significantly enhancing production yield and consistency. Furthermore, Alpon X5 facilitates smart supply chain management by forecasting demand, optimizing logistics, and managing inventory with unprecedented precision. By integrating seamlessly with existing Industrial Internet of Things (IIoT) infrastructure, Alpon X5 enables the transition towards autonomous factories and data-centric operations. The implementation of this AI system demonstrates a tangible impact on key performance indicators, including operational cost reduction, improved product quality, and enhanced workplace safety. In this work we included tests and discussion, then concluded that Alpon X5 represents a pivotal technology in the fourth industrial revolution and IIoT, offering a scalable and powerful solution for industries seeking to harness the full potential of AI to maintain a competitive edge in the global market.

1. Introduction

In the era of the Internet of Things (IoT) and Artificial Intelligence (AI), there is a growing need to process data and make intelligent decisions right where it's generated—at the "edge." The ALPON X5 is a powerful response to this need. It is not just another single-board computer; it is a robust, industrial-grade platform designed to be the brain for the next generation of smart machines, autonomous systems, and intelligent visual inspection systems.

The upgrading from the Raspberry Pi Compute Module 4 (CM4) to the anticipated Compute Module 5 (CM5) is poised to be a monumental leap, mirroring the architectural shift from the Pi 4 to the Pi 5. Building on the CM4's solid foundation of a custom BCM2711 SoC and flexible PCIe support, the CM5 will fundamentally upgrade the core platform by incorporating the more powerful and modern BCM2712 SoC. This transition promises a significant boost in CPU performance with ARM Cortex-A76 cores, a substantially more powerful GPU, and key features like support for LPDDR5x memory, dual HDMI 2.1 outputs capable of dual 8K display, and an integrated PCIe 2.0 interface for faster storage and peripheral connectivity. This generational advancement will empower industrial and embedded applications with new levels of performance for high-resolution vision systems, complex AI inference, and advanced digital signage, solidifying the Compute Module's role as a premier system-on-module for professional developers.

The evolution from the Alpon X4 to the Alpon X5 AI represents a significant generational leap, moving from a capable perception-focused system to a powerful, integrated cognitive platform. While the Alpon X4 likely supported foundational computer vision models for tasks like object detection and basic recognition, the Alpon X5 is architected to orchestrate a complex, multi-model pipeline, seamlessly fusing real-time perceptual data from models like SCRFD and YOLO with the advanced reasoning and natural language capabilities of Large Language and Vision-Language Models (LLMs/VLMs). This transition, powered by enhanced hardware with superior processing cores and neural engine capabilities, transforms the system from a passive sensor into an intelligent analytic engine capable of real-time scene understanding, natural language interaction, and generating actionable, descriptive intelligence directly at the edge.

The ALPON X5 is a compact, industrial-grade single-board computer (SBC) designed specifically for demanding Edge AI and industrial IoT applications. It's not a consumer-grade device like a standard Raspberry Pi board but a robust system built around the powerful Raspberry Pi Compute Module 5 (CM5). Its primary purpose is to serve as the brain for complex tasks like machine vision, robotics, and automated systems, providing substantial processing power and a rich set of I/O interfaces in a rugged form factor.

Built around the formidable Raspberry Pi Compute Module 5 (CM5**)**, the ALPON X5 takes the familiar Raspberry Pi ecosystem and elevates it to an industrial level, supercharging it with a dedicated Neural Processing Unit (NPU) for efficient AI workloads. It represents a perfect synergy of high-performance general computing and specialized AI acceleration, packaged for real-world deployment[1].

2 Core Technology ALPON X5 " main components"

The ALPON X5 is architected as a high-performance Edge AI platform, integrating four core technological pillars that work in concert to deliver robust, efficient, and intelligent computing at the edge. The ALPON X5's capabilities stem from its intelligent design, which combines several key technologies:

2.1. High-Performance Compute Core: Raspberry Pi Compute Module 5 (CM5)

The CM5 Serves as the general-purpose processing brain.
Key Components:

- SoC: Broadcom BCM2712 with a CPU Quad-core Arm Cortex-A76 @ up to 2.4GHz. Provides the raw power for the operating system, data management, and complex application logic.
- RAM: LPDDR4X (4GB to 16GB). Ensures smooth handling of multiple processes and large datasets. Figure 1.1 is a photo of the module.

This foundation offers a modern, powerful, and software-compatible base from the renowned Raspberry Pi ecosystem [10].

Fig 1.1 Pi Compute Module 5

2.2. Dedicated AI Acceleration: Neural Processing Unit (NPU)

Fig 1.2 DEEPX DX-M1

DEEPX is a specialized co-processor for ultra-efficient AI inference.
Key Capability: Delivers several TOPS (Trillion Operations Per Second) of performance for running pre-trained neural network models (e.g., for object detection, classification, segmentation). AI Performance: 25 TOPS. Support S-O-T-A Algorithms: ResNet, MobileNet v1/v2/v3 SSD, EfficientNet, EfficientDet, YOLOv5, YOLOv7, YOLO8, DeepLabv3, PIDNet and the latest YOLO Models,VLM (CLIP etc.), the presentation of the module is in Figure 1.2

This is the "AI engine." It offloads intensive AI tasks from the CPU, enabling real-time, low-power AI inference that is orders of magnitude faster and more efficient than CPU-based processing. This is the definitive feature for Edge AI workloads [2].

2.3. Industrial-Grade I/O & Connectivity Fabric

Grade I/O provides robust and versatile interfacing for sensors, networks, and peripherals.
Key Components: Dual Gigabit Ethernet: For network redundancy, high-bandwidth camera streams, or network segmentation. PCIe Interface: Enables high-speed expansion with NVMe SSDs (for fast local storage) or other specialized cards.Wide-Voltage DC Input (12-24V): Allows direct integration into industrial, automotive, and outdoor power systems. And USB 3.0, GPIO, CSI/DSI: Maintains compatibility with a vast ecosystem of peripherals and HATs.

This pillar transforms the module from a compute board into a complete industrial system, capable of reliable operation in demanding environments.

2.4. Robust Thermal & Mechanical Design

The Mechanical Design ensures sustained performance and long-term reliability.
Key Features: Metal Enclosure: Often used for effective heat dissipation and physical protection. With Extended Operating Temperature Range engineered to perform reliably in non-climate-controlled settings (e.g., factory floors, outdoor enclosures) as shown in Figure 1.3.

This design guarantees that the high performance of the CPU and NPU can be maintained under continuous load, which is critical for 24/7 industrial applications.

Fig 1.3. Alpon X5 AI Metal enclosure

Table 1. ALPON X5 vs. Standard Raspberry Pi 5[3]

Feature	***ALPON X5 (with CM5)***	***Raspberry Pi 5***
Form Factor	Industrial carrier board + CM5	All-in-one consumer SBC
CPU	CM5's Quad-core Cortex-A76	Raspberry Pi 5's Quad-core Cortex-A76
AI Acceleration	**Yes, dedicated NPU (3-6 TOPS)**	No (relies on CPU/GPU, much slower)
I/O Robustness	Dual GbE, Wide-range DC input, PCIe	Single GbE, USB-C Power, No PCIe
Applications	**Industrial, Edge AI, Robotics**	Hobbyists, Education, Prototyping
Ruggedness	High (wide temp range, metal enclosure)	Standard

3. Synergistic Integration: The "Intelligent Edge" Result

The true power of the ALPON X5 lies not in these technologies in isolation, but in their integration of the components and design:

- The CM5 handles the complex operating system and application flow.
- The NPU dedicates itself to parallel AI computations upon request.
- The Industrial I/O seamlessly brings data in from high-speed sensors and cameras and connects to enterprise networks.
- The Robust Design ensures this all happens reliably, anywhere.

This synergy creates a unified platform that is greater than the sum of its parts, purpose-built for deploying sophisticated intelligence directly where data is generated—at the edge.

More over the following extension gives the Alpon X5 flexibility of communication, extension using PCI slot and accepting Pi Hats:

- Rugged I/O: Features like dual Gigabit Ethernet ports (for network redundancy or multiple camera streams), a wide-voltage 12-24V DC input, and robust connectivity make it suitable for harsh industrial environments.
- Expansion Capability: The inclusion of a PCIe slot is a game-changer, allowing for the addition of high-speed NVMe storage for data logging or specialized expansion cards.

- Compatibility: It retains the standard 40-pin GPIO header, ensuring access to the vast ecosystem of Raspberry Pi HATs and sensors.

4. Applications: Upgrading Industries with On-Device Intelligence

The ALPON X5 is built for scenarios where low latency, data privacy, and high reliability are paramount. Its applications span numerous industries:

4.1. Smart Manufacturing & Automated Optical Inspection (AOI)

AI-powered visual quality control on production lines. The ALPON X5, connected to high-resolution cameras, can inspect products in real-time for defects, measure dimensions, verify assembly, and sort items. Its NPU runs complex vision models instantly, rejecting faulty products without slowing down the line. i.e Pipe control and leak detection as shown in Fig 2 from [3] and [4].

Fig2. Oil Leak detection on Pipeline

4.2. Smart Retail & Security

Advanced video analytics for security and customer insight. In retail, it can analyze video feeds to count people, generate heatmaps of store traffic, and monitor shelf inventory. In security, it can detect intrusions, recognize license plates, or identify unusual behavior like loitering, all without sending sensitive video data to the cloud.

4.3. Intelligent Robotics & Autonomous Systems

Serving as the main computer for Autonomous Mobile Robots (AMRs) and robotic arms. The ALPON X5 processes data from cameras, LiDAR, and other sensors to enable real-time navigation, obstacle avoidance, and precise object manipulation. The NPU is crucial for tasks like "vision-based picking," where the robot must identify and locate specific items.

4.4. Agricultural Technology (AgriTech)

Precision agriculture and automated harvesting. Mounted on drones or farm machinery, the ALPON X5 can analyze crops to detect diseases, monitor health, and identify ripe produce for automated harvesting. This enables data-driven decisions to optimize yield and reduce waste.

4.5 Machine Vision & Automated Optical Inspection (AOI):

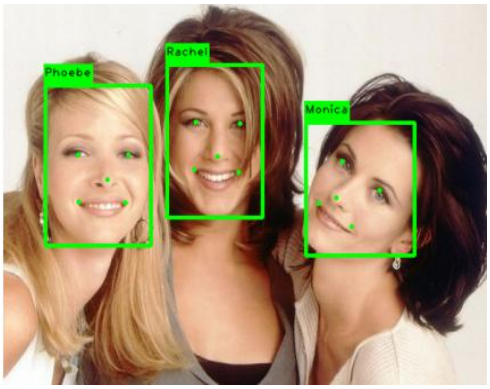
The product can be used in Identifying defects on a production line. In sorting objects based on visual characteristics. And reading barcodes and OCR.

4.6. Edge Computing & Networking

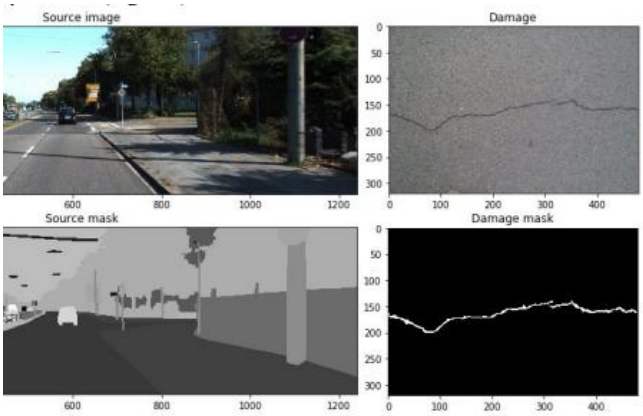
Acting as a powerful, customizable edge server or network appliance. With its dual Ethernet ports, PCIe slot (for adding a second network card), and powerful CPU, it can be deployed as a firewall, a VPN gateway, or a local server for processing IoT sensor data from a factory floor.

5. Tests

Some test were done using Alpon X5, and here is the results by photos in figure 3 a),b), c), d), e), f), and g)..



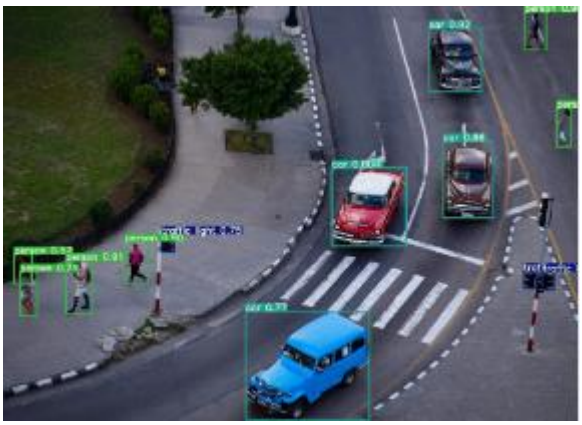
3.a SCRFD Face Detection [7]



3.b. Road Line damage detection using VGG16 and Mask[8]

3.c.YOLOPose Pose Detection Model from Kickstarter project [2]

3.d.YOLOv5 20 Channel Object Detection[2]



3.e.YOLO V7 Object Detection

3.f.YOLO V7 4 Channel Object Detect [2]

Fire is coming out of the car

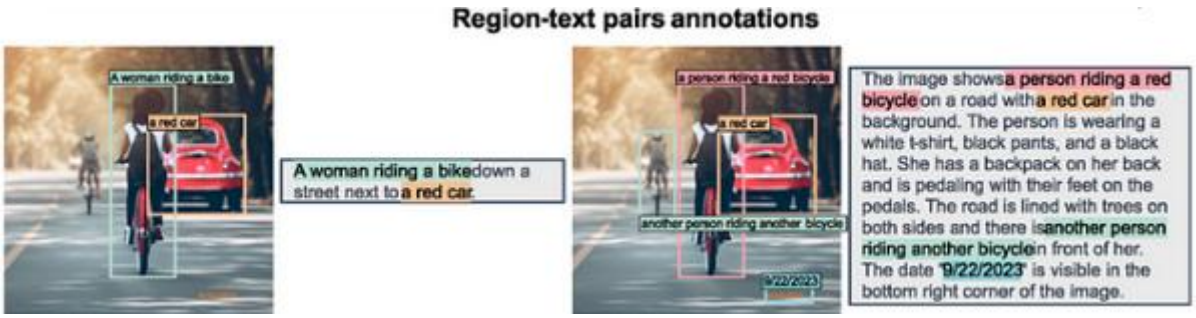


Fig 3.g.VLM (Video Language Model) [9]

6. Discusion

The "good results" are not from any single model, but from their orchestration.
Running multiple modern DNN models simultaneously is extremely demanding. The Alpon X5 provides the necessary CPU/GPU (likely NPU) power to do this without lag. If the Alpon X5 is an edge device, it allows for real-time processing without constant cloud dependency, ensuring low latency, data privacy, and reliability. Moreover, the platform is likely optimized to run these specific models efficiently, perhaps using TensorRT or similar SDKs to maximize throughput.

The discussion around the successful testing on the Alpon X5 highlights a pivotal trend in AI: the move from single-model solutions to integrated, multi-modal AI systems**.** By combining the low-level perceptual strengths of SCRFD, VGG16, and YOLO with the high-level cognitive reasoning of LLMs and VLMs, developers have created a system that doesn't just "see," but "understands and reports." The Alpon X5 serves as the critical enabling platform, providing the muscle to make this sophisticated AI brain work effectively in a practical, real-world setting. The "good results" are a testament to both the power of the individual models and, more importantly, the synergy achieved by their careful integration.

Conclusion

The ALPON X5 is more than just a computer; it is a complete Edge AI solution. By combining the robust, community-supported Raspberry Pi CM5 platform with the sheer power of a dedicated AI accelerator, it empowers engineers, developers, and businesses to deploy sophisticated intelligence directly into their products and processes. It stands as a testament to the future of computing—a future that is decentralized, intelligent, and happening right at the edge.

The ALPON X5 emerges as a transformative force in the industrial landscape, representing a significant leap from prototype to production-ready deployment. By synergizing the robust general-purpose computing of the Raspberry Pi CM5 with the specialized, high-efficiency processing of a dedicated Neural Processing Unit (NPU), it delivers the essential capability for real-time, on-device intelligence. This powerful combination directly addresses core industrial demands for enhanced productivity, quality, and autonomy. Its impact is vividly demonstrated across diverse applications, from revolutionizing quality control through automated optical inspection on production lines and empowering intelligent robotics for precise material handling, to enabling predictive maintenance and advanced security through intelligent video analytics. Ultimately, the ALPON X5 stands as a pivotal enabler of Industry 4.0, allowing businesses to embed sophisticated AI directly into their operations—ensuring lower latency, greater data privacy, and relentless reliability at the edge.

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