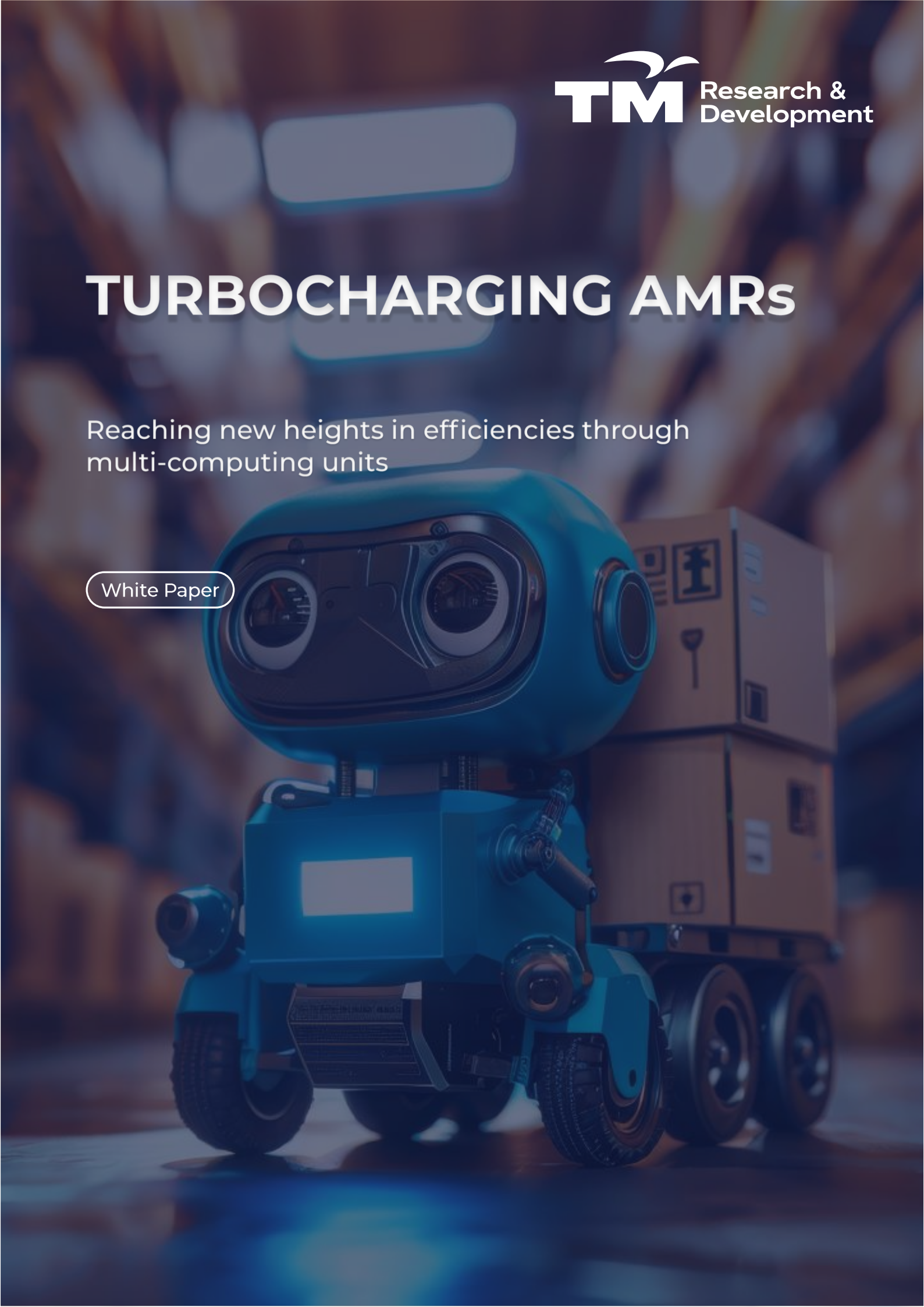
TM Research & Development

TURBOCHARGING AMRs

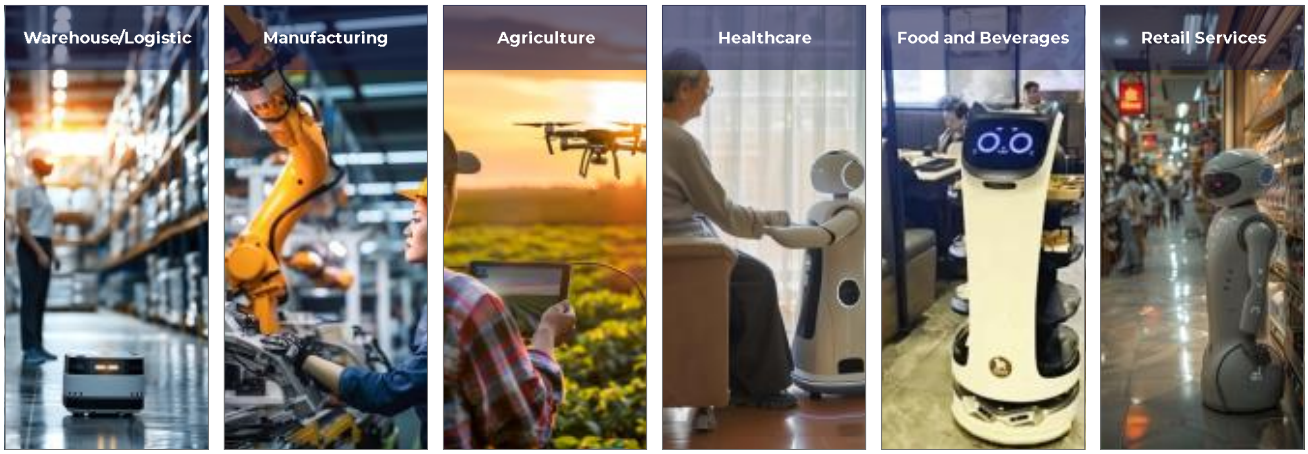
Reaching new heights in efficiencies through multi-computing units

White Paper

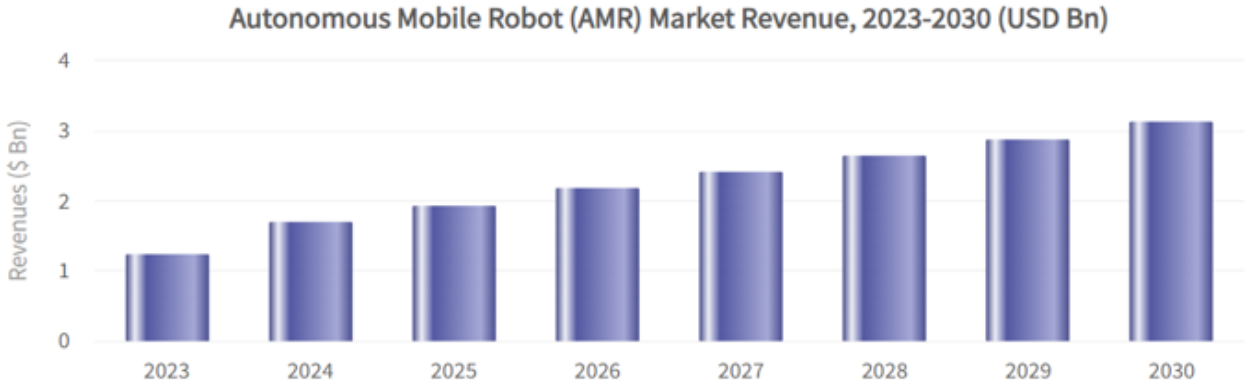


Executive Summary

The rapid advancement of robotics has brought significant changes across industries. At the forefront of this revolution are Autonomous Mobile Robots (AMRs), which are transforming operational landscapes with their independent task execution capabilities. AMRs are not just a technological innovation; they are a game changer in the fields ranging from logistics and manufacturing to healthcare and service industries.



The global AMR market, valued at USD 1.24 billion in 2023, is expected to reach USD 3.13 billion by 2030, reflecting a robust CAGR of 13.4%.* This growth underscores the increasing reliance on AMRs to drive efficiency and productivity.



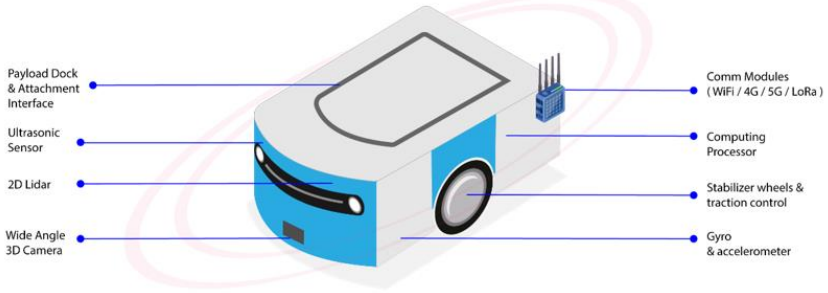
*Source: Next Move Strategy Consulting, 2024

While the vision of humanoid robots fully replacing human roles is still on the horizon, current AMR applications are already making significant strides. These robots work synergistically with humans to enhance various functional tasks, leading to greater efficiency and cost savings. One of the primary hurdles is overcoming processing bottlenecks that impedes decision-making speed and responsiveness.

This whitepaper delves into the intricacies of AMR technology, focusing on how multi-computing capabilities can significantly enhance performance, efficiency, and adaptability. By addressing the current processing bottlenecks, it aims to provide valuable insights and practical solutions for researchers, engineers, and industry experts dedicated to advancing AMR technologies.

The Eyes and Brains of an AMR

Autonomous Mobile Robots (AMRs) are self-navigating, intelligent robots capable of manoeuvring through challenging environments autonomously. They dynamically select paths, compensate for obstacles, and adjust their routes in real-time using a sophisticated blend of sensors, artificial intelligence (AI), and advanced algorithms.



Common Features of an AMR

Brain and Communication Hub

Computing Processor

This is the central system of the robot, processing all the sensory data, making decisions, and controlling its movements.

Comm Modules

These modules allow the robot to communicate with the outside world, sending and receiving data over WiFi, cellular networks (4G, 5G) or LoRa network.

Navigation Tool

2D LIDAR SCANNER

This laser-based sensor acts as the robot's "eyes," mapping its surroundings with 360-degree precision.

Wide-Angle 3D Camera

Offering depth perception beyond LiDAR, this camera provides rich visual information, allowing the AMR to recognize objects, people, and even subtle changes in the environment.

Sensing and Stability

Ultrasonic Sensors

These short-range detectors fill in the gaps where LiDAR and cameras might struggle, acting like proximity sensors for immediate obstacles or tight corners.

Gyro and Accelerometer

This dynamic duo provides crucial information about the robot's movement and orientation. The gyro tracks rotations, while the accelerometer gauges acceleration and tilt.

Mobility and Payload

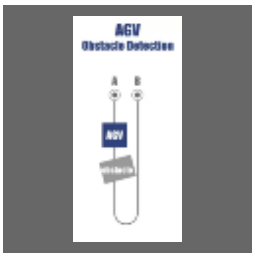
Stabilizer Wheels and Traction Control

These specialised wheels ensure smooth and stable movement even on uneven surfaces, while the traction control system optimises grip and prevents slippage.

Payload Dock / Interface Area

This is the robot's work zone, equipped with a standardised interface for attaching different payloads or tools.

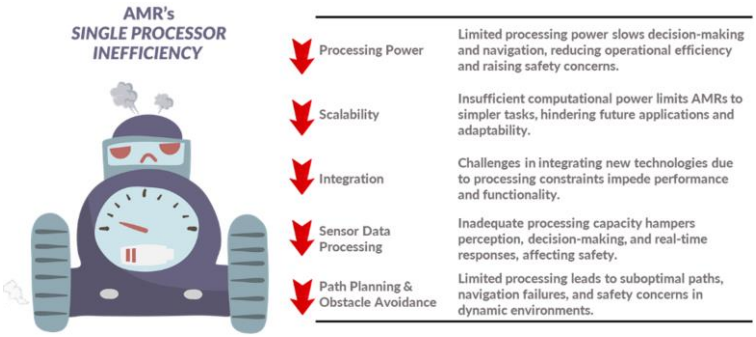
Unlike Automated Guided Vehicles (AGVs) that follow rigid, pre-programmed paths, AMRs are more like self-driving cars. Equipped with smart sensors and AI brains, AMRs navigate dynamically, adapting to their surroundings. This makes them incredibly flexible and adaptable, perfect for automating tasks in dynamic settings like warehouses, office buildings or factories.

Criteria	Autonomous Mobile Robots (AMRs)	Automated Guided Vehicles (AGVs)
	 	 
Navigation	Navigate autonomously using sensors, cameras, and AI to map their environment and plan routes in real-time. They can avoid obstacles and adapt to changes in their surroundings.	Follow predefined paths using physical guides like magnetic strips, wires, or optical markers. They cannot deviate from these paths and must stop if an obstacle is encountered.
Flexibility	Highly flexible and can be easily reprogrammed for different tasks or routes. Suitable for dynamic environments where changes are frequent.	Less flexible as they require physical changes to their guiding infrastructure for route modifications. Best suited for repetitive, high-volume tasks in stable environments.
Installation and Setup	Easier and quicker to deploy since they do not require extensive physical infrastructure.	Require significant setup time and cost due to the need for physical guides and markers.
Cost	Generally have a higher initial cost but can offer better long-term savings due to their flexibility and lower maintenance needs.	Lower initial cost but may incur higher long-term costs due to the need for infrastructure changes and maintenance.
Application	Ideal for environments that require adaptability and frequent changes, such as e-commerce warehouses.	Best for environments with consistent, repetitive tasks, such as manufacturing plants.

Overcoming Single Processor Bottlenecks

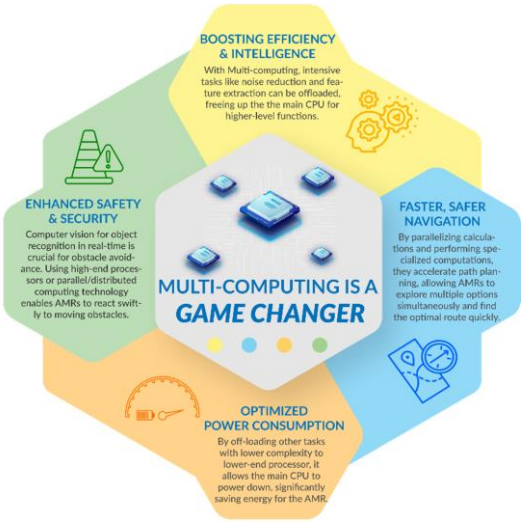
A typical AMR operates on a single processing unit managing all functionalities. However, this limitation hampers its true potential by restricting decision-making speed, dynamic navigation, and operational efficiency.

This bottleneck also restricts them to simpler tasks, impedes the adoption of new technologies, and affects sensor data processing, path planning, and obstacle avoidance, ultimately raising safety concerns to nearby patrons.



Multi-Computing To The Rescue (Solution)

Addressing the processing power bottleneck is crucial for unlocking the full potential of AMRs and ensuring their safe and efficient operation. Continued advancements in processor technology and the development of specialised AMR-specific chips are essential steps towards achieving this goal. Only then can AMRs truly transform industries and revolutionise the way we live and work.



Multi-computing Advantages over Single-computing for AMR applications

In a multi-computing approach, tasks are distributed across multiple processors based on their nature and priority. For instance, one processor might handle navigation and path planning, while another focuses on computer vision tasks, and a third manages communication and data logging. This distribution allows for parallel processing, significantly improving the AMR's overall performance and responsiveness.

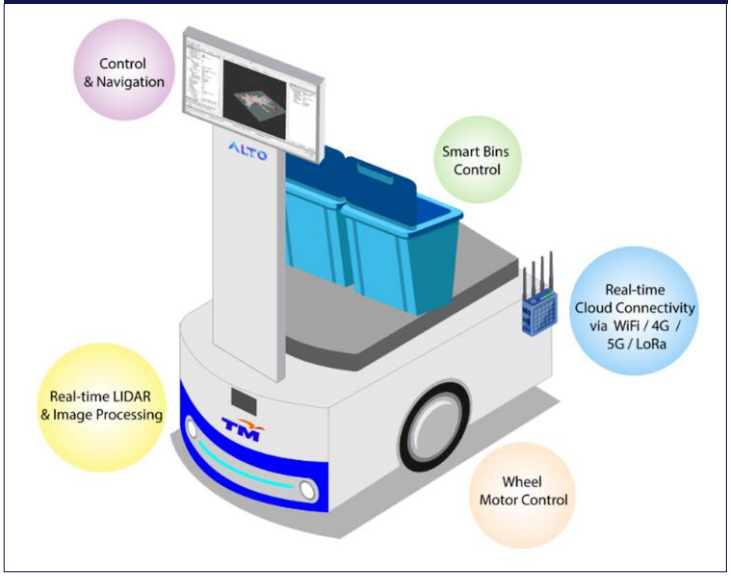
Our Work on Multi-Computing

At TM R&D, we have developed ALTO, a smart solution aimed at revolutionising indoor waste management in office buildings. ALTO, as an intelligent waste collection system, aims to address challenges in indoor waste management; namely inefficient waste collection, use of manual labour, and overall lack of data visibility related to office hygiene and waste disposal control.

ALTO - THE INDOOR SMART WASTE SOLUTION

At the heart of ALTO is an AMR with a customised smart bins payload and cloud connectivity that offers an automated solution for waste collection and disposal at any time, anywhere within indoor office buildings. ALTO consists of ROS-assigned functional modules based on ALTO operation.

ALTO'S FUNCTIONAL MODULES



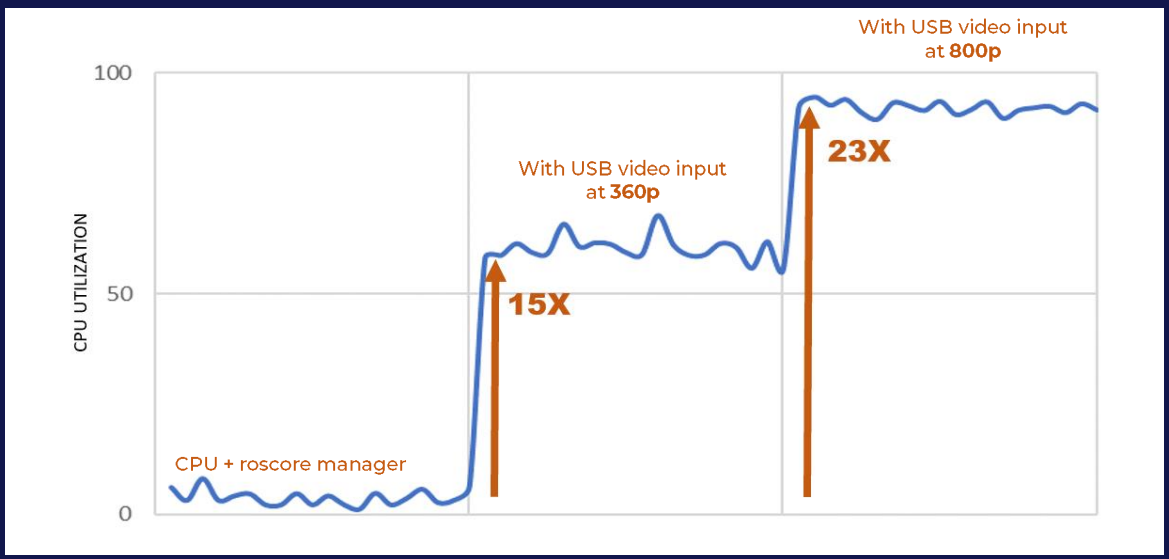
ALTO'S DASHBOARD

The major modules include control and navigation algorithms, real-time LIDAR and image processing, wheel motor control, smart bin control, and real-time cloud connectivity. For its base ALTO operation, all of these functional modules are dependent on only a single processor unit for all the processing requirements of the smart waste system.

MULTI-COMPUTING ADAPTATION

To further enhance ALTO's operational efficiency and performance, our recent efforts have focused on implementing a multi-computing approach. This is primarily done by distributed processing power assignments using multi-computing capability that optimizes functional modules for more efficient operation. By configuring load distribution via ROS, priority tasks assignment and power efficiency are achieved depending on the AMR's operational needs.

Previously, our testing of ALTO's computer vision module indicated critical CPU loading effects when using only a single processor. The development team performed computer vision module testing via optical image streams with real-time image processing and varying image resolutions. Using a single processor unit, minimal 4% CPU utilisation was recorded when running only on base CPU and roscore manager. This compares to an increased CPU utilisation of up to 15X when additional USB camera input and real-time image recognition (at 360p resolution) processes were run concurrently.



Increased CPU utilisation by 15X for 360p and 23X for 800p image processing, respectively, for ALTO computer vision module processes using a single processor.

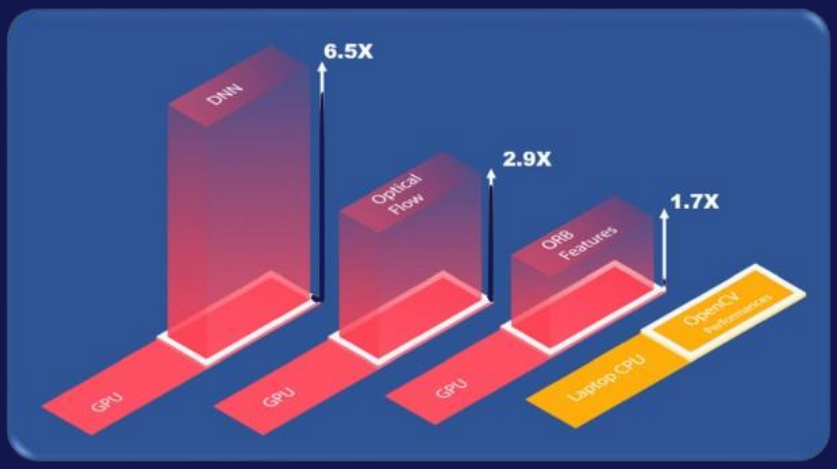
The CPU loading effect was further apparent at 800p resolution image processing, with up to 23X extra utilization load when compared to the baseline. To handle other AMR functional modules at the same time, the performance and efficiency of this single processor unit would definitely be compromised as the CPU would need to perform extra workloads, resulting in CPU throttling at the expense of the computer vision processing.

The increased CPU utilisation result indicates the strain and inefficiencies of a single processor for the whole AMR operation.

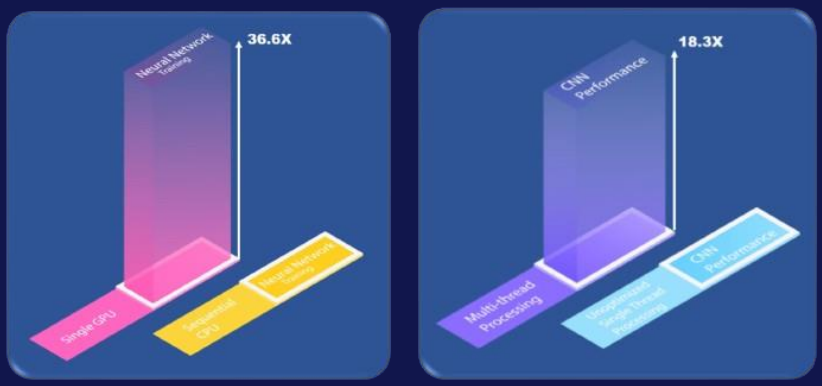
As an alternative, a parallel GPU-based multi-computing approach for robotic computer vision leads to better performance in complex environments and even more so if it involves deep learning applications.

Indeed, as referenced in multiple works, parallel or distributed processing methodologies are widely adopted to enhance performance and efficiency in computer vision processing and neural network computations.

For example, Cevera[1] reported how GPU processing, when compared to laptop CPU processing, improves image processing performance in ORB features processing (by 1.7X), optical flow processing (by 2.9X), and deep neural network processing (by 6.5X). In other reported works, training of the neural network using a single GPU is 36.6X more efficient than using sequential CPU training[2], while the inference speed of convolutional neural networks improved by 18.3X with enabled multi-thread processing compared with unoptimized single thread processing[3].



Overall improvements in image processing performance matrix with parallel GPU processing vs normal CPU [1].



Significant Neural Network processing improvements via single GPU processing [2] and multi-thread processing [3] when compared to sequential CPU or single thread processing, respectively.

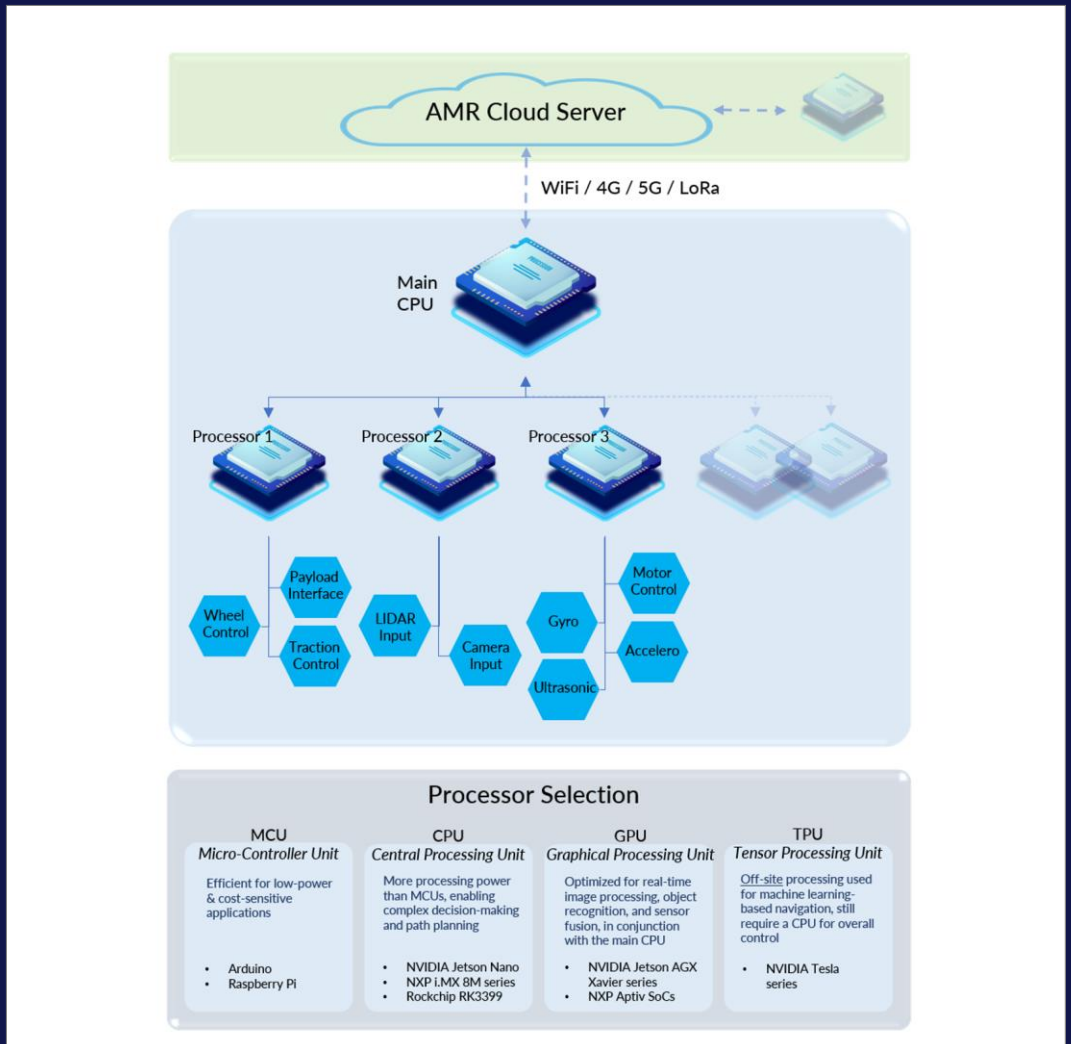
[1] Cervera, E., "GPU-Accelerated Vision for Robots with OpenCV and CUDA", IEEE Robotics & Automation Magazine, 2020
[2] Mochurad et al., "Parallel And Distributed Computing Technologies For Autonomous Vehicle Navigation", Radio Electronics, Computer Science, Control, 2023
[3] Zhou, X et al., "A pipelining strategy for accelerating convolution neural networks on ARM CPUs", Concurrency Computation Practice Experience, 2021

AMR PLATFORM FOR THE FUTURE

Here at TM R&D, the basis of our future AMR platform development will be centred on a multi-computing approach, with cloud connectivity and modularity support.

By offloading processing-heavy functional modules from the main CPU to other processors, the operational efficiency of AMRs can be achieved accordingly based on task priority, workflow optimisation, and design modularity needs. This ensures that for any future AMR use cases and customisations, the AMR functional modules and its overall operation will always be optimised for best performance and efficiency.

This approach also prepares AMRs for seamless integration with emerging technologies such as 5G and IoT. The increased processing power and distributed computing architecture allow for more complex data processing and real-time communication, enabling AMRs to become integral parts of smart, connected ecosystems.

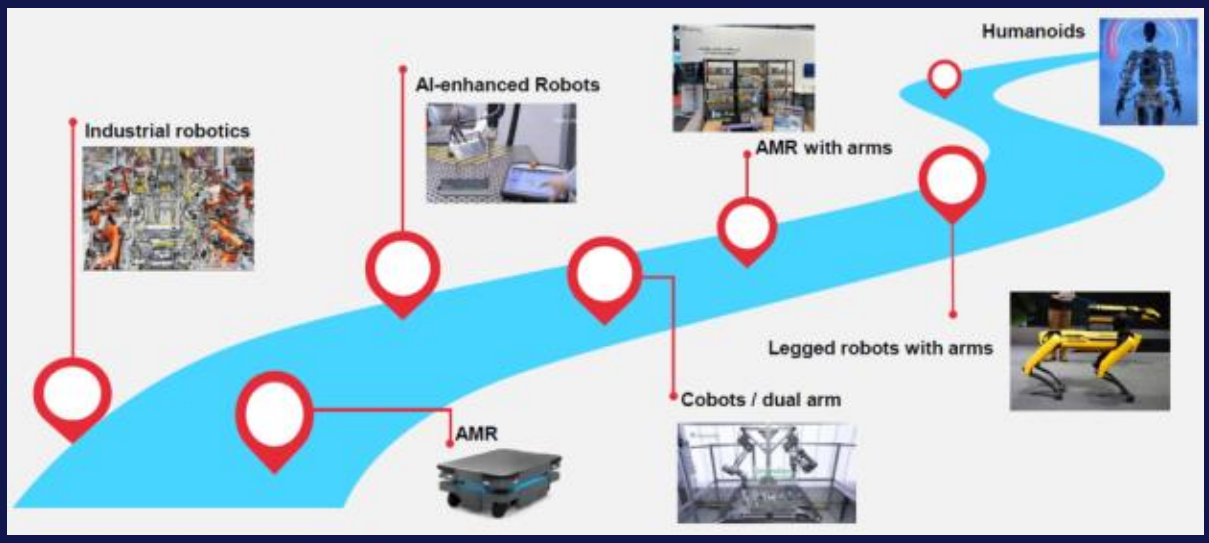


Multi-Computing Implementation in Modular AMR Platform Development

The Path Forward

As reported in the World Robotics Report 2023, humanoid robots are still in the early stage of development. In the meantime, software and use cases will be the driving force behind breakthrough applications for the masses.

Instead of replacing human workforces, the imminent advancements in AMRs and robotics will usher in an era of collaborative synergy, where humans and machines work together to achieve more than either could alone.



Source: World Robotics Report 2023

Looking ahead, we anticipate several key developments in AMR technology:

1. **Enhanced AI capabilities, allowing AMRs to make more complex decisions and adapt to unforeseen situations.**
2. **Improved human-robot collaboration through advanced sensing and communication technologies.**
3. **Integration of edge AI, enabling faster processing and reduced latency in AMR operations.**
4. **Exploration of quantum computing applications for solving complex optimisation problems in robotics.**

These advancements will not only improve AMR performance but also contribute to sustainability efforts. More efficient AMRs can help reduce energy consumption, optimise resource utilisation, and minimise waste in various industries.

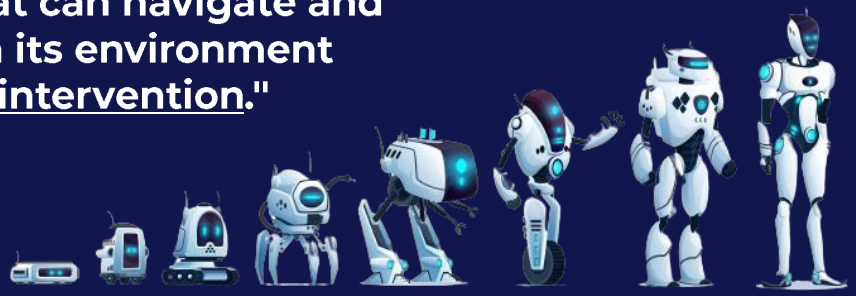
In this context, TM R&D, via its Centre of Excellence in Robotics and Sensing Technology, has already charted its far-reaching course in robotic innovations and is committed to developing market-ready and future-proof AMR solutions for the masses in areas such as waste management, security, warehouse logistics and healthcare.

One key innovation being pursued involves leveraging the power of multi-computing in elevating the modular AMR platform for increased efficiency, reliability, and future-proof scalability.

As we move forward, the potential economic impact of improved AMR efficiency through multi-computing is substantial. Industries can expect to see increased productivity, reduced operational costs, and new opportunities for innovation. However, challenges remain in implementing multi-computing in AMRs, including increased complexity and potential power consumption issues. Overcoming these challenges will be crucial in realizing the full potential of next-generation AMRs.

In conclusion, multi-computing stands as a key enabler in unlocking the true potential of AMRs. As we continue to push the boundaries of what's possible in robotics, the synergy between advanced hardware architectures and innovative software solutions will pave the way for AMRs that are not just more efficient, but also more adaptable, intelligent, and capable of transforming industries in ways we're only beginning to imagine.

"Autonomous Mobile Robot (AMRs) is type of robot that can navigate and perform tasks in its environment without human intervention."



"AI, robotics, and other forms of smart automation have the potential to bring great economic benefits, contributing up to $15 trillion to global GDP by 2030."

- PricewaterhouseCoopers (PwC)

Creator of Smarter Ecosystem for a better Malaysia

Established in 2000, TM R&D is the innovation arm for TM Group focusing on creating smarter ecosystems to make business and life easier for a better Malaysia. TM R&D's solutions are clustered around four (4) pillars namely Intelligent Platforms, Data Brokerage, Connectivity/Tools and IR4.0/Digital Solutions.

Growing from strength to strength since 2016, TM R&D has won multiple global awards and generated more than 2,800 Intellectual Property Rights (IPRs) and 1,400 digital assets to-date.

TM R&D's innovations are all developed in-house and cut across multiple verticals such as Utilities, Retail, Agriculture, Healthcare and Education with safety and productivity as the top priority.

As TM R&D continues to expand beyond connectivity and into smarter digital ecosystems, its role in TM has become more prominent and exciting.

We are looking for remarkable people to join us. People who are courageous enough to push boundaries, curious enough to experiment with new technologies, and who have the determination to drive new ideas forward. A new opportunity awaits you here in TM R&D.

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