Case Study

Intel® Core™ Processors
Intel® Distribution of OpenVINO™ Toolkit
Intel® AI Box

Intel and DFI Launch Automatic Number Plate Recognition (ANPR) System to Develop Flexible AI-Empowered Traffic Management

"Modern industrial computers need to run more and more AI loads to fulfill a large variety of customer needs. This means that in addition to ensuring stable operation in extreme temperature, high vibration, and other harsh environments, the customization of industrial computers for different scenarios and further innovations in AI computing power optimization and power consumption reduction will serve as a key development path in the future."

- Jarry Chang
Senior Director, DFI Management Center

Overview

The rapid and accurate identification and investigation of vehicles with fake number plates, vehicles without number plates, overloaded vehicles, and vehicles in violation of traffic laws to ensure safe and orderly traffic is a key concern for traffic management agencies across the world. As such, more and more agencies have begun to deploy Automatic Number Plate Recognition (ANPR) systems based on deep learning algorithms in monitored road sections. The system improves number plate recognition algorithms, rationally configures network parameters, optimizes the weights of each layer, and carries out repeated training and testing based on a large amount of data. As the system is able to achieve number plate recognition at an accuracy close to or even better than that of the human eye, it has become a powerful assistant for traffic management.

Mobile number plate recognition systems have seen wider application in monitored road sections without any fixed surveillance cameras deployed owing to its advantages in flexibility, agility, and cost of deployment. These systems face huge challenges as they must be able to provide strong computing power capable of supporting AI loads under the premise of miniaturization and low power consumption.

DFI and Intel have partnered to launch an Automatic Number Plate Recognition (ANPR) system that supports mobile deployment. Equipped with DFI industrial computers powered by Intel® Core™ processors and optimized for AI inference through Intel® Distribution of OpenVINO™ Toolkit, the system is capable of quickly identifying and comparing vehicle number plate information to provide data support for traffic management. More importantly, the system achieves ultra miniaturization and ultra-low power consumption, and can be easily powered by a mobile power supply to satisfy the needs of mobile number plate recognition. At present, Chunghwa Telecom, Taiwan's largest fixed-line telecommunications, data communications, and mobile communications company, has successfully deployed the system to provide efficient solutions for mobile traffic management in Taiwan.

Automatic Number Plate Recognition Systems Serve as a Key Foundation for Smart Transportation

ANPR refers to the use of technologies such as computer vision, machine learning, road-side units (RSUs), on-board units (OBUs), and short-range communications to realize automatic number plate recognition in a manner that does not rely on human operation. ANPR systems can digitize number plate data to mark key vehicle information with digital labels, thereby providing a simple and efficient means for the smart positioning and tracking of vehicles and the realization of real-time monitoring and event processing.

At present, ANPR systems have seen wide application across a variety of scenarios, including electronic toll collection (ETC), parking management, and traffic violation monitoring, and have

become a key foundation of smart transportation systems. Using parking management scenarios as an example, ANPR systems can identify and calculate the time each vehicle stays in the parking lot, realize automatic fee collection, and provide parking guidance in accordance with the parking space situation to save on manpower and improve parking efficiency.

Driven by strong user demand, the global ANPR market has grown rapidly. According to a report by MarketsandMarkets, the ANPR market is expected to grow from USD 2.3 billion in 2020 to USD 3.8 billion in 2025, representing a compound annual growth rate (CAGR) of 10.0% during the forecast period[1]. The primary factors driving the growth of the ANPR market include security, surveillance, and traffic management applications; the growth of infrastructure in emerging economies; increased government funding for intelligent transportation systems (ITS); and increased use of video analysis technology to intelligently monitor vehicles.

From a technical perspective, ANPR systems can be divided by those based on short-range RSU-OBU communication and those based on computer vision. ANPR systems based on computer vision work by analyzing the video/image captured by surveillance cameras, locating the key image frame, segmenting and identifying the number plate position, then obtaining the number plate data. As ANPR systems based on computer vision do not require customization and are capable of meeting the needs of a greater amount of number plate recognition scenarios, they are generally considered to have wider development potential.

Early ANPR systems primarily relied on optical character recognition (OCR) technology based on conventional machine learning. The downside of this method is that it must be modeled for specific application scenarios. Once the scenario changes, the mode will either fail or its accuracy will drop sharply, meaning that it cannot meet wider ANPR application requirements.

To resolve these issues, an ANPR system based on deep learning was introduced. The solution is capable of using artificial neural networks (ANNs) for feature extraction and classification. The solution supports deployment across many different application scenarios without the need for modification, thereby significantly accelerating the time-to-market of ANPR systems and improving their accuracy. ANPR systems based on deep learning are made up of four key components, namely image preprocessing, number plate positioning, number plate segmentation, and character recognition. They support the extraction of local image features for recognition through convolutional neural networks (CNNs).

The primary goal of image preprocessing is to feed the key frames of the vehicle video through a global binarization or other algorithm to facilitate subsequent processing. For number plate positioning, the geometric and texture features of the number plate are often used with algorithms that integrate edge detection and projection to reduce interference and improve accuracy. Number plate segmentation requires the use of thresholding methods to perform character segmentation, after which CNN recognition is performed on the segmented character image to realize the highest accuracy. Methods such as feature matching can be used during this process to check characters that are prone to errors to further improve recognition accuracy.

By improving number plate recognition algorithms and carrying out repeated training and testing based on a large amount of data, real-time number plate recognition at an accuracy close to or even better than that of the human eye can be achieved to improve the overall feasibility of number plate recognition systems.

In terms of deployment methods, ANPR systems can be divided into fixed, mobile, and portable. While fixed ANPR systems are the most widely used, mobile ANPR systems are indispensable for scenarios such as mobile traffic management. This white paper outlines case studies of the partnership between Chunghwa Telecom, DFI, and Intel to plug holes in traffic management through mobile ANPR systems.

Mobile ANPR System

Traffic management agencies must deal with the large amount of traffic violations that occur every day. As an example, commercial vehicles may use methods such as overloading or travelling through restricting areas (or approved areas during restricted periods) for financial gain. In addition to noise pollution, air pollution, and other problems, these violations may pose serious traffics safety hazards. To avoid punishment, vehicle owners may use fake number plates or other methods to engage in repeated traffic violations.

With the continuous growth of traffic flow and increasing public demand for traffic order and efficiency, traffic management agencies must also continuously strengthen their ability to crack down on traffic violations. Focusing on intersection monitoring system + AI vision recognition applications, vision solution providers have developed mature and effective smart transportation monitoring systems that realize the smart recognition of traffic violations. This solution is however not realistic for road sections that do not have (or lack the conditions to have) an intersection monitoring system deployed.

[1] https://www.marketsandmarkets.com/Market-Reports/anpr-system-market-140920103.html

An ANPR system that supports mobile deployment can help solve this problem. Such a system can remove scenario limitations, support deployment anytime and anywhere through mobile power and wireless networks, and provide traffic management agencies with a variety of advantages.

Greater Flexibility and Rapid Deployment

Rapid deployment of ANPR systems can be realized through light vehicles such as motorcycles to identify and provide alerts for violations such as vehicles with fake number plates and vehicles with no number plates to flexibly meet the requirements of smart traffic management in different scenarios.

Lower Total Cost of Ownership (TCO)

Mobile ANPR systems do not require specialized deployment, will not affect the existing traffic structure, and can even reduce the impact caused by construction and road closures. With low power consumption and relatively low infrastructure requirements, mobile ANPR systems help save on both deployment and procurement costs.

Rapid Response to Sudden or Temporary Traffic management Requirements

Mobile ANPR systems help traffic management agencies make flexible decisions based on their local conditions. For example, the systems can be temporarily deployed to a road section in which traffic violations have suddenly increased. Mobile ANPR systems can also be organically integrated with other traffic management systems to realize 3D traffic management functionality.

Despite their advantages, the implementation of mobile ANPR systems faces many challenges in terms of computing power, price performance, durability, and power consumption.

Computing Power

As ANPR systems rely on inference from the deep learning model to realize the segmentation, positioning, and recognition of license plate images, they have high demands for computing power.

Power Consumption

To realize mobile deployment, the AI computing devices on the ANPR system must be smaller in size and boast lower power consumption to support rapid assembly and long battery life.

Price Performance

Most ANPR systems rely on GPUs for inference, leading to higher hardware procurement costs along with additional costs in terms of power consumption, space, and development. The large-scale deployment of ANPR systems in traffic scenarios will amplify costs and force traffic management agencies to seek more economical solutions.

Durability

When deployed in road tests, mobile ANPR systems were found to face challenges such as fluctuations in temperature and humidity, sun and rain, and impact from foreign objects on a regular basis. The equipment must possess excellent durability and environmental adaptability to maintain stable and consistent performance through changes to environmental factors such as temperature, humidity, and vibration. The need for a fanless design also leads to greater challenges to heat dissipation and durability.

The challenges outlined show that independent GPU solution are not feasible as despite their powerful parallel floating-point calculation capabilities, discrete graphics cards equipped with GPUs tend to be larger and consume more energy, making it difficult to carry out long-term mobile deployment. High-density floating-point operations are bound to place a large amount of pressure on the energy efficiency, concurrency, and data storage/migration of systems, making it difficult to meet the flexibility requirements of different application scenarios during inference calculations. Furthermore, ARM solutions are not able to realize cross-platform, cross-OS, and cross-CPU operations required by applications.

Modern CPUs have been optimized for conventional AI algorithms, boast significantly enhanced AI inference performance, have excellent advantages in terms of energy consumption and compatibility, and are projected to serve as the ideal infrastructure platform or mobile ANPR systems. CPUs offer more powerful data processing functionality and can effectively handle a variety of loads. On this basis, Intel has conducted in-depth explorations on the end-to-end technical advantages of CPU-based ANPR systems with partners such as DFI.

Intel Core Processors and Intel Distribution of OpenVINO Toolkit Brings Mobile Number Plate Recognition to Life

For application scenarios such as traffic violation monitoring, Intel provides the Intel® AI Box, which fully integrates leading Intel hardware, software, and AI algorithms to help both partners and end customers at all levels accelerate the development and design of edge AI applications through mature platform-level functionality.

DFI has designed an industrial computer based on Intel AI Box. Equipped with Intel Core processors and excellent thermal dissipation, the industrial computer provides a rich variety of customizable power control functions through BIOS and supports the operation of number plate recognition applications within the power consumption range of 10-30W. Owing to DFI's wealth of experience in the R&D of durable industry-grade computers, the industrial computer is dustproof, vibration/shock-resistant, resistant to electromagnetic interference, capable of operating in extreme temperatures, and capable of continued operation in outdoor environments.

The Intel Core processors equipped to the DFI industrial computer offer outstanding performance in terms of AI inference, power consumption, and size. With support for different operating system platforms, capacity to meet a wide range of load requirements, and a wealth of product performance options, Intel Core processors serve as an ideal platform for edge AI inference applications. 11th Gen Intel Core processors come integrated with Intel deep learning acceleration technologies along with Intel Advanced Vector Extensions 512 (AVX-512) and Vector Neural Network Instructions (VNNI) for significantly improved AI performance.

During the Chunghwa Telecom application case study, Chunghwa Telecom also used the OpenVINO toolkit for inference acceleration.

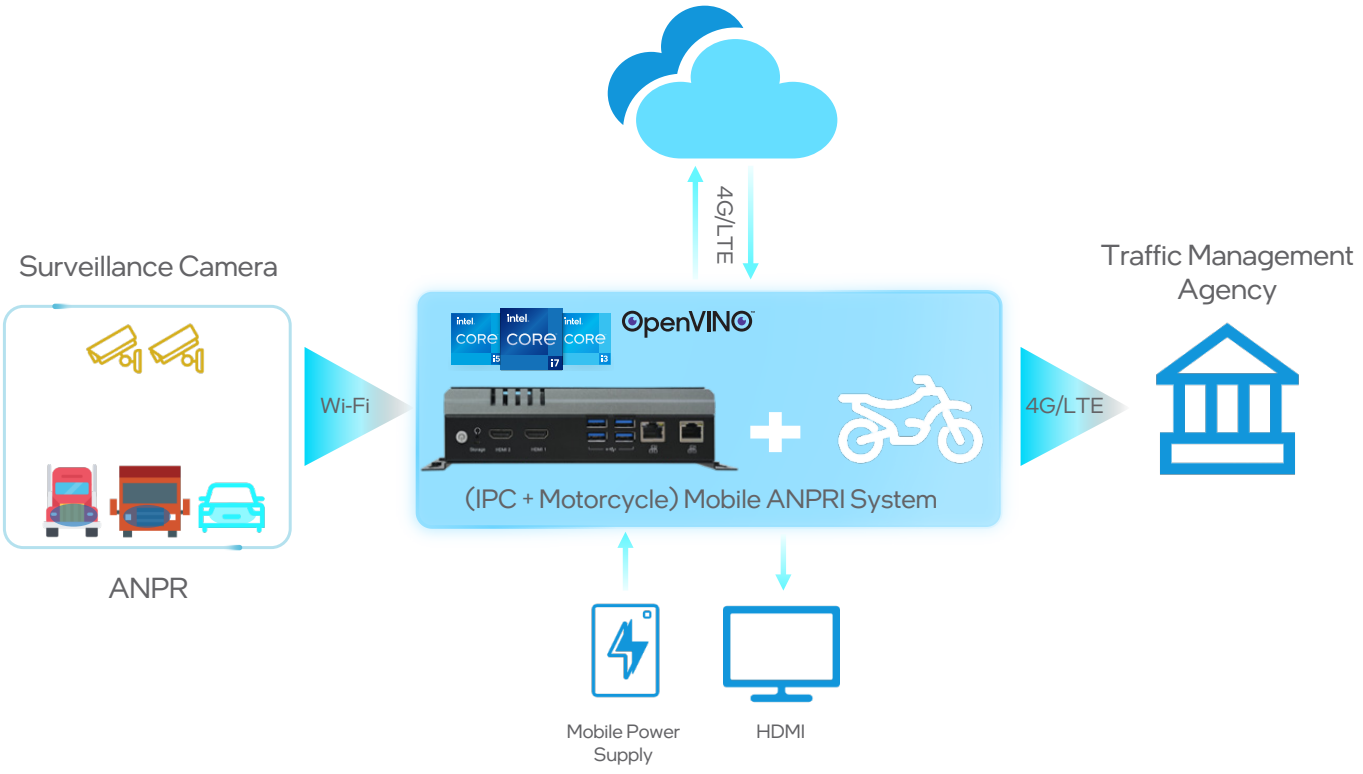

Figure 1: Application Framework of Mobile ANPR Systems

With support for the acceleration of deployment across a wide range of deep learning inference applications and solutions, the OpenVINO toolkit provides developers with industry-standard AI frameworks along with standard or custom layers to seamlessly integrate deep learning inference with applications, and scale/optimize workloads through Intel hardware (including accelerators). Through the built-in Model Optimizer (MO) for pre-inference models and the Inference Engine (IE) for dedicated hardware acceleration, the OpenVINO toolkit support neural network acceleration and deployment across a variety of Intel platforms, significantly increasing the speed of image inference without sacrifice accuracy.

Model Optimizer is a cross-platform command line tool that facilitates the conversion between training and deployment environments, static model analysis, and adjustment of deep learning models to realize high performance on terminal devices. Model Optimizer also supports offline model conversion from mainstream frameworks (including TensorFlow/ ONNX models) to an intermediate representation (IR), while Inference Engine provides a unified cross-platform C, C++, and Python API for inference acceleration and optimization.

The OpenVINO toolkit helped Chunghwa Telecom's ANPR system efficiently and accurately recognize number plates in monitored road sections. The solution has greatly reduced the deployment costs of Chunghwa Telecom's ANPR system while maintaining acceptable performance indicators and effectively improving flexibility. Intel Core processors also incorporate Intel® HD Graphics, which allows developers to transfer their visual loads to iGPU for execution for powerful performance and agile scalability.

Compared with previous generation processors, 11th Gen Intel Core/ Celeron processors offer greater advantages in terms of performance.

Test data (Fig. 2) shows that compared with the i7-8700T, the i7-1185G7 offers around 100% increased performance, while the Celeron 6305E offers around 30% increased performance. As 11th Gen Intel Celeron processors are more economical while also meeting performance indicators, they are the more cost-effective choice[2].

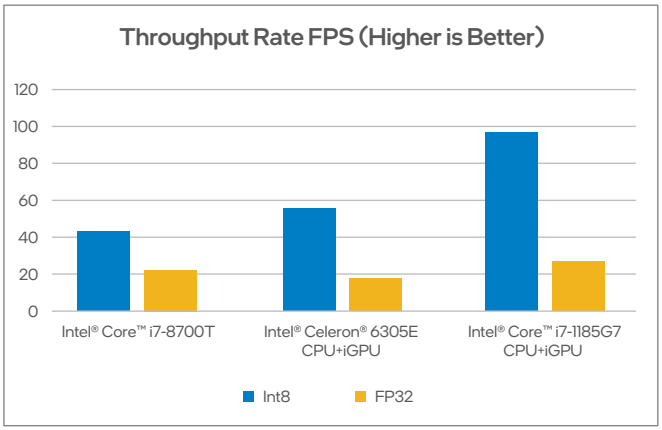

Figure 2: Performance Comparison of ANPR Systems on Different Platforms

The OpenVINO toolkit also integrates GStreamer video streaming tools (VAAPI, labav, etc.), Inference Engine (IE), OpenCV, and other function libraries to create the DL Streamer GStreamer Video Analytics Pulgin (GVA), which helps developers create applications that can take advantage of hardware-accelerated computing components in a convenient manner.

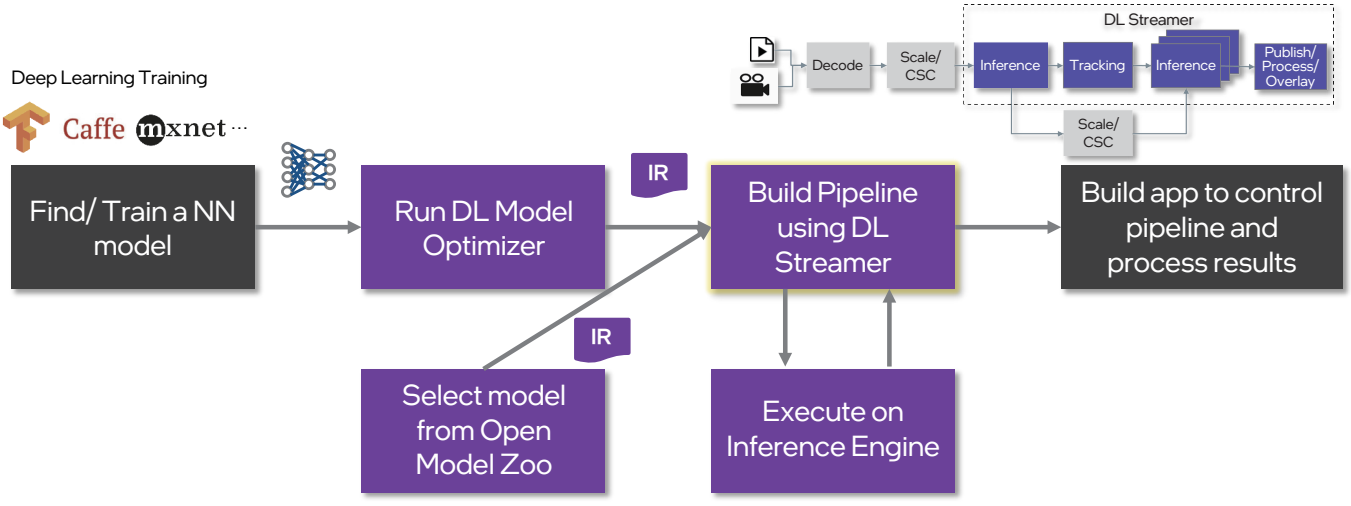

Figure 3: DL Streamer Development Process

[2] https://docs.openvino.ai/latest/openvino_docs_performance_benchmarks_openvino.html
For workloads and configurations visit www.Intel.com/PerformanceIndex. Results may vary.

Deployed at the edge in a mobile manner, DFI industrial computers will push the number plate recognition result to the cloud, after which the result is compared with the massive cloud number plate database to locate and push violations such as false number plates to traffic management agencies, thereby constructing a cloud-edge-end integrated smart number plate recognition system.

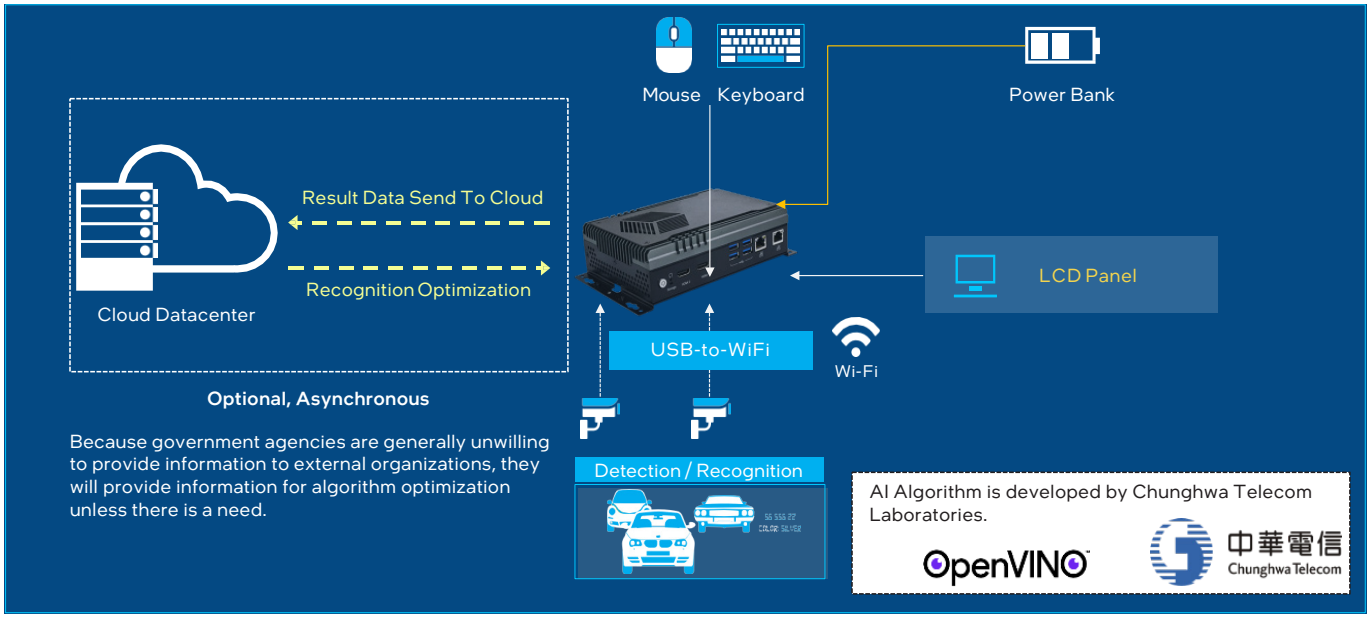

Figure 4: Number Plate Recognition Process

Perfect Capture of Traffic Violations

The Chunghwa Telecom ANPR system provides Taiwanese traffic management agencies with mobile, flexible, and cost-effective smart traffic management functionality. When integrated with the Chunghwa Telecom intersection monitoring system, the ANPR system supports the monitoring and management of traffic scenarios in a more comprehensive and three-dimensional manner. Equipped with Intel Core processors and the OpenVINO toolkit, the system offers a variety of advantages.

- **High Computing Power Supports Automatic Number Plate Recognition:** Data shows that high-performance Intel CPUs provide the Chunghwa Telecom ANPR system with the ability to realize real-time number plate recognition across multiple video streams at an FPS of over 60[3] and results quickly pushed after comparison. The system is capable of meeting the demands of image analysis under different scales of traffic and realizing flexible deployment.
- **Ultra-Low Power Consumption and Support for Flexible Mobile Deployment:** The Chunghwa Telecom ANPR system operates at an ultra-low power consumption of 15-20W, enabling powering through a mobile power supply and ensuring a full-system battery life exceeding 2 hours[4].

Figure 5: The ANPR System in Operation

- **Rapid Handling of Traffic Violations:** Supported by the strong computing power and flexible deployment of the system, traffic warden can rapidly detect violations such as the access of prohibited road sections or fake number plates in a manner that does not require the deployment of additional personnel. The system also helps significantly increases the deterrence of traffic violations.

[3] Test results provided by Chunghwa Telecom and DFI.

[4] Tested with a mobile power capacity of 16000mW. Test results provided by Chunghwa Telecom and DFI.

In December 2020, Taiwanese traffic management agency deployed the Chunghwa Telecom ANPR system in certain road sections and set up notice boards in front of the equipment to deter the illegal access of sand and gravel vehicles. In less than a month, the system handled 26 incidents of illegal gravel vehicle access, playing a key role in maintaining good traffic order and improving the commuter experience[5].

Intel® oneAPI allows users to quickly migrate algorithms to other Intel platforms to meet performance, power consumption, and other requirements at a conversion rate of up to 89%[6]. An open, standards-based, and cross-architecture programming model, Intel openAPI aims to simplify the development process across multiple architectures by providing developers with a programming model applicable to all architectures, eliminating barriers between code, and removing the need to rewrite software for different hardware platforms, all without compromising on performance. Intel openAPI accelerates the development process by providing familiar languages and standard cross-architecture libraries and tools, greatly reducing the complexity of using different code libraries, programming languages, programming tools, and workflows.

DFI and Intel Partner to Create Smarter Transportation Systems

Smart transportation is a key way method to realize enhanced economic and social efficiency, along with the construction of smart cities. With cloud-to-end solutions for different application scenarios such as smart transportation management, smart cockpits, and self-driving, Intel is working with partners to integrate leading technologies and innovation capabilities to accelerate the global innovation process in the field of smart transportation.

Building on existing achievements, DFI and Intel will work closely explore the applications of a newer generation of low-power Intel Core processors in the system to further reduce power consumption while improving performance to achieve higher durability and provide an AI assistant for traffic management.

The companies plan to further expand the results of their partnership to the wider world. Through the integration of smart image recognition algorithms and high-performance AI computing power, they seek to meet the needs of a larger range of regions in terms of number plate and model recognition, help improve the smart perception and rapid disposal capabilities of the transportation sector, and work together to realize more efficient and compliant traffic.

In addition to continuously improving performance, usability, and energy consumption on the basis of realized platforms, DFI and Intel are also committed to gradually extending AI-related applications to GPUs based on the new Intel® Xᵉ architecture to achieve the agile scaling of AI loads across different hardware to meet the needs of a wider range of AI applications. Their efforts include:

- The development of hardware equipment (such as industrial computers) based on the Intel platform that are equipped with next-gen Intel Core processors with higher performance, durability, energy conservation, and energy efficiency; along with the utilization of software tools such as the OpenVINO toolkit to continuously optimize software and AI algorithms to achieve the integrated delivery of software and hardware.
- The development of an application system built around the Intel AI application framework for AI and other innovative technologies to provide customers with more flexible solutions.

> "By utilizing Intel processors and the OpenVINO toolkit, we have solved a key problem faced by mobile ANPR systems. By providing sufficient AI inference performance under the premise of low power consumption, we can ensure that the solution ultimately meets the demands of traffic management. This case study successfully confirms that CPU-based terminals can serve as an efficient platform for AI inference while realizing greater advantages in terms of cost, size, and efficiency. "
>
> **- Wei-Yuan Cheng**
> Researcher, Business Solutions Laboratory,
> Telecommunication Laboratories, Chunghwa Telecom

[5] https://news.ltn.com.tw/news/society/breakingnews/3395246

[6] Test results provided by Chunghwa Telecom and DFI.

- The realization of cross-architecture software migration, operation, and optimization through new chip solutions such as the Intel X® GPU and Intel oneAPI toolkit to achieve high scalability in more scenarios.

Looking ahead, the companies will work together to construct a smart ecosystem for more industry scenarios, facilitate the integration and innovation of products and solutions, and strengthen the communication and cooperation between upstream and downstream industries such as original equipment manufacturers (OEMs), independent software vendors (ISVs), and system integrators (SIs) to help resolve issues faced by customers and further digital transformation.

About DFI

A key member of the Qisda Corporation, DFI is a company with four decades of experience, the world's leading supplier of high-performance computing technology across multiple industries, and the third-largest manufacturer of industrial computers in Taiwan. With its innovative designs and advanced quality management system, DFI's industry-grade solutions help customers optimize their equipment and operations in scenarios such as industrial automation, medical care, gaming, transportation, energy, mission-critical operations, and smart retail.

About Chunghwa Telecom

Chunghwa Telecom is the largest telecommunication service provider in Taiwan. Its primary operations cover fixed-line communications, mobile communications, and broadband; the provision of ICT services such as big data, information security, and cloud and Internet data centers to enterprise customers; and the development of emergent technology services such as IoT and AI to create high-quality communication environments and a more convenient digital experience. The company is also actively developing partnerships with global telecommunications companies to promote internationalization. In recent years, Chunghwa Telecom has actively invested in various corporate social responsibility efforts that have received widespread recognition from professional organization on a global scale. Through the formulation of corporate social responsibility codes of practice and the legalized development of its governance structure, Chunghwa Telecom has demonstrated its ambition and willingness to fulfill its corporate social responsibility.

About Intel

Intel (Nasdaq: INTC) is an industry leader, creating world-changing technology that enables global progress and enriches lives. Inspired by Moore's Law, we continuously work to advance the design and manufacturing of semiconductors to help address our customers' greatest challenges. By embedding intelligence in the cloud, network, edge and every kind of computing device, we unleash the potential of data to transform business and society for the better. To learn more about Intel's innovations, go to newsroom.intel.cn and intel.cn.