Automotive Image Recognition Processor "IMAPCAR"

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Abstract

The IMAPCAR is a moving image recognition processor equipped with the functions, performance, quality and reliability required for automotive image recognition.

IMAPCAR is marketed as an automotive device of NEC Electronics Corporation based on the "IMAP architecture featuring parallel operations of multiple processors." This solution is the result of studies achieved by NEC Media and Information Research Laboratories. The device is expected to function as an eye for vehicles designed to meet the recent rise in the awareness of car safety issues.

Keywords

moving image recognition, parallel processor, SIMD, VLIW, extended C language, GUI debugger, automotive quality, high reliability, Synchronous SRAM

1. Introduction

Social awareness of car safety has been increasing recently, and the automotive safety devices that can recognize outside images and function as the "eyes of the vehicle" are attracting special attention. Since image recognition in automobile applications needs to be in real time, the devices used in image recognition are required to feature a high processing performance. At the same time, the low power consumption required for embedded usage and the quality and reliability expected of automotive components are also essential features of such devices.

The IMAPCAR (**Photo**) is a processor that can meet the requirements for automotive image recognition applications by achieving both high processing performance and low power consumption based on the parallel operation of 128 processor elements (PEs).

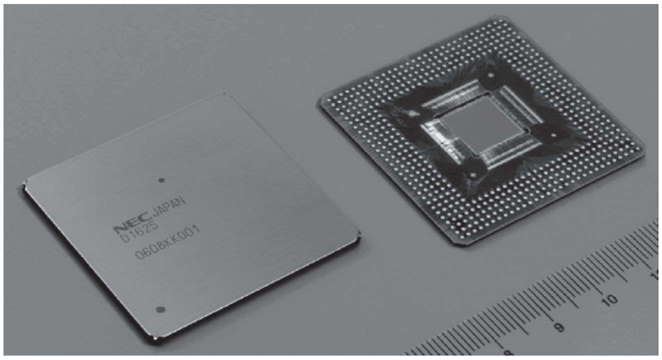

Photo IMAPCAR.

2. Development Status

The development of the IMAPCAR has its origin in the research into the parallel image processor at NEC Media and Information Research Laboratories (hereinafter referred to as "the Lab").

The Lab proposed a parallel architecture using memory-integrated processor arrays in 1990, established the basic architecture as the "IMAP-1" and demonstrated its effectiveness in the following year. The IMAP-1 incorporated 8 PEs per 1 chip. The IMAP-1 system was composed of 64 chips and the peak performance of the system was 12.8 GOPS (Giga Operations Per Second). Then, it evolved into the IMAP-Vision with 32 PEs and to the IMAP-CE with 128 PEs and 50GOPS peak per-

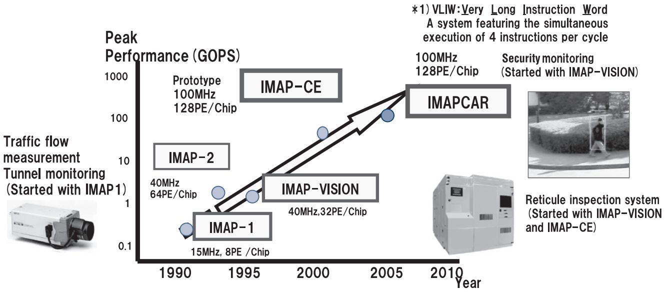

Fig. 1 Evolution of IMAP.

formance, which became the basis of the IMAPCAR (**Fig. 1**).

At the Automotive Systems Division, NEC Electronics Corporation, we took over the technology of IMAP-CE from the Lab, commercialized the 128 PEs, 100GOPS IMAPCAR by adding peripherals and improving the automotive quality and reliability, and started its mass production in 2006. It was in September 2006 that an actual vehicle mounting the IMAPCAR was eventually released to the market.

3. IMAP Architecture

The IMAP architecture achieves a high processing performance by processing a large amount of data simultaneously thanks to its high parallel processing capability. As the performance can be improved by parallel processing, the operating frequency is reduced to the relatively low value of 100MHz, which has contributed significantly to the reduction of the power consumption of the device.

The features of the IMAP architecture can be summarized as follows:

① SIMD (Single Instruction Multiple Data) computation using 128 PEs;

② 4-way VLIW (Very Long Instruction Word) with simultaneous execution of 4 instructions per cycle provided for each PE;

③ Independent RAM provided for each PE.

The SIMD computation using 128 PEs is very effective for high-speed image processing and provides the key to the high performance of the IMAP architecture.

With the traditional image processing method using high-performance processors, the pixel data is read sequentially from the memory (raster scanning) and computation is applied on a per-pixel basis (**Fig. 2**).

On the other hand, with the SIMD computation of the IMAP, 128 PEs processes the pixels of each line in simultaneous par-

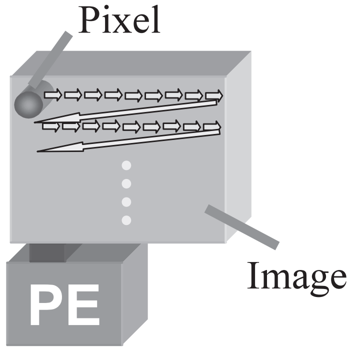

Fig. 2 Image of traditional processing.

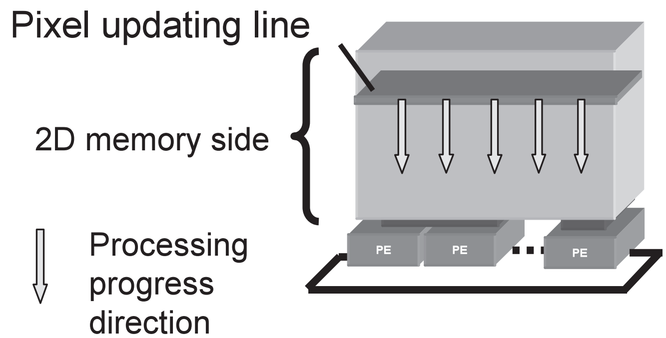

Fig. 3 Image of processing with SIMD of IMAP.

allel operations (**Fig. 3**). The simultaneous processing of the data on the line indicated by the "pixel updating line" in Fig. 3 can reduce the processing loops dramatically and enables high-speed processing compared to the traditional processing on a per-pixel basis.

In general, image processing often consists of applying the same computation to every pixel in the image. The SIMD computation of the IMAP architecture makes use of this characteristic of image processing in order to achieve a high processing speed.

4. Features of IMAPCAR Products

4.1 Device Features

The IMAPCAR is a product that is based on the high processing performance of the IMAP architecture and features the addition of the functions, quality and reliability required for use as an automotive processor.

Fig. 4 shows the system block diagram and **Table** shows the

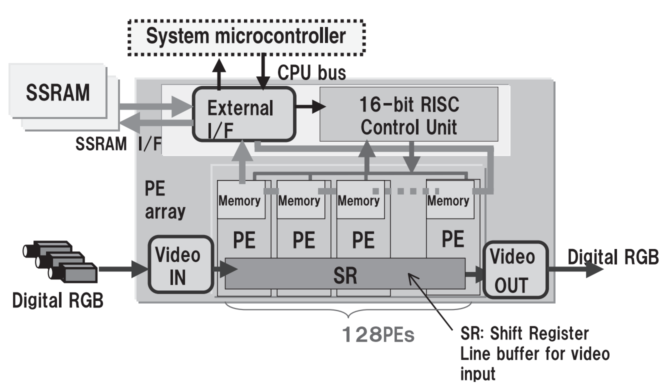

Fig. 4 IMAP system block diagram.

general specifications.

The features of the IMAPCAR products include the following:

① 100GOPS processing performance (@ 100MHz operation);
② Low power consumption below 2W;
③ Automotive capability (temperature, quality and reliability);
④ High flexibility and extendibility due to comprehensive software-based processing.

The IMAPCAR has improved the high performance it inherited from the IMAP-CE (from 50GOPS to 100GOPS) by changing some of the operators in the PEs from 8-bit to 16-bit models.

Commercialization as an automotive device necessitates expansion of the operating temperatures to cover –40 to +85°C as well as a thorough overhaul of quality improvements. We have provided the IMAPCAR product with optimum quality for automotive use for example by; ① setting a 100% verification rate (coverage) aiming at eliminating all penetration of design bugs; ② achieving a 100% failure detection rate and aiming at eliminating output of defective products by thorough shipment inspections; ③ managing the production process by the combined efforts of the production plant and quality control department.

In order to improve the reliability as a system, we have also developed a dedicated memory (SSRAM) for automotive use. This device is equipped with an error correction/detection (ECC and Parity) function to achieve the high reliability required for automobile use.

In addition to high performance, high quality and high reliability, the IMAPCAR also features excellent flexibility and extendibility thanks to the use of software in all of its processing operations (without using image processing dedicated circuitry). As the recognition target and the environment surrounding the target of image recognition varies widely, tuning to obtain the required recognition accuracy is often required up to the last minute before the final commercialization. The inbuilt ease of modification or correction of software processing of the product is thus suitable for such an application. In addition, the software processing can easily deal with additional features or the improvement of accuracy that may be required in the future without the need to change the hardware; it will thus contribute greatly to the time-to-market requirements of the user.

Table General specifications.

	IMAPCAR	IMAP/SSRAM
Package	500-pin ABGA	100-pin QFP
Operating frequency	100MHz	100MHz
Processors	1 (CP) + 128 (PEs)	–
Universal registers	16-bit × 26 × 1CP 8-bit × 28 × 128PEs	–
Instruction execution cycle	1 cycle	–
Memory	Program cache 32KB Data cache 2KB Stack memory 4KB Image RAM 256KB	1MB With ECC 256KB, With Parity 768KB
Supply voltage	1.2V ±0.15V (Internal) 3.3V ±0.3V (External)	1.2V ±0.15V (Internal) 3.3V ±0.3V (External)
Main functions	• Image data I/O (8-bit × 2ch/8-bit × 3ch) • Host I/F (20MHz) • Memory I/F (100MHz/64MB) • Interrupt (Image 6ch, universal 3ch, host 1ch)	• Error detection ECC function (256KB, 1-bit correction, 2-bit detection) Parity function (768KB, 1-bit detection)
Operating temperatures	-40～+85℃	-40～+85℃

4.2 Application Development Solutions

At NEC Electronics we know that our basic mission is to market the IMAPCAR device. However, since this device is involved in a specialized field of image processing, recognition and parallel processing, we are also able to offer some solutions that are of relevance to general applications developments.

As a part of this activity, we are presently creating a library of software components regarding image processing and parallel processing that can facilitate development of image processing applications. This library is expected to back up the applications development of users because it allows them to build the desired image processing recognition applications by simply selecting and combining the required processing components from the library.

We also support users in developing the applications they need by offering an estimation of the processing performance when a user algorithm developed on a PC is executed on the IMAPCAR, assisting porting of applications from the PC to the IMAPCAR and providing algorithms based on long years of image processing and recognition studies at the Lab.

We are providing not only IMAPCAR device but also solutions including the image processing and recognition software that match user needs.

5. Development Environment

Every image processing operation of the IMAPCAR is executed with the software. The applications are programmed using the 1DC (One-Dimensional C), which is the C language extended for programming the parallel processing of IMAPCAR, and the execution files are generated using a special compiler.

For the development environment, we provide the SDBIMAP, which is a dedicated debugger equipped with GUI (**Fig. 5**) to support the development of image recognition and processing applications.

The development environment and tools have been evaluated fully in consideration of their usage in the development of automotive devices aimed at the release of products with an especially high quality.

6. Applications of IMAPCAR

The IMAPCAR can be used as the recognition engine of automotive image recognition application systems that are being put to practical use one after another.

Specifically, it may be suitable for the following applications:

- Road line recognition: Lane keeping system, navigation accuracy interpolation, etc.
- Forward and backward vehicle recognition: Auto cruising system, etc.
- Pedestrian recognition: Pre-crash safety system, etc.
- Traffic signal/sign recognition: Driving support system, etc.

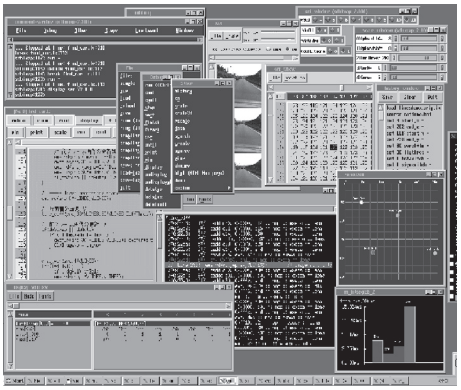

Fig. 5 SDBIMAP screen.

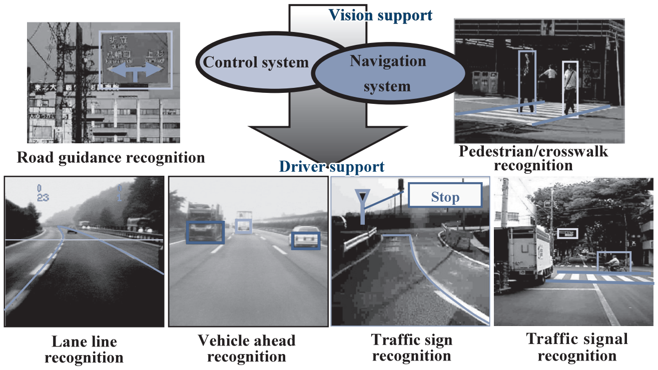

Fig. 6 Examples of image recognition.

Since the processing operations of IMAPCAR are executed at the software level, it can also be used in various systems for recognizing various other objects by simply modifying the software (**Fig. 6**).

IMAPCAR is for the present defined as an automotive device because the requirements in this field are the most advanced. However the performance may be demonstrated for any system that requires recognitions of moving images.

7. Future Development

Requirements for image recognition functions by the automobile industry are at a very high level, and this level is expected to rise further as the recognition target and the environment surrounding the target become more complicated in the future.

To deal with this trend, we are planning to improve the performance and function of the IMAP core based on the IMAPCAR and advance it to the next-generation processor “IMAPCAR2.” The IMAPCAR2 will be equipped with the performance and memory capacity that can meet the requirements for 2010 and beyond and will also enable a size reduction of the equipment.

In order to promote incorporation of IMAPCAR for a large variety of applications and in all kinds of vehicles from low-end to high-end models, we will expand the IMAPCAR as a product series that can offer optimum solutions.

8. Conclusion

Since the Japanese Government declared that Japan intends to halve traffic accident deaths by 2015 (to 5,000 persons), Japanese automobile and parts manufacturers have been coordinating their efforts for improving the safety of automobiles. The IMAPCAR contributes to these efforts by functioning as the eyes of a vehicle that is designed to detect dangers and recognize situations. It aims at the day when traffic accidents are completely eliminated thanks to the IMAPCAR device being mounted in all automobiles. Our intention is to continue developments in this field of more improved products and solutions in the future.

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