Case Study

2nd Generation Intel® Core™ Processor Family

Digital Signal Processing

Radar Image Processing Gets a Speed Boost from Intel® Advanced Vector Extensions

NASoftware Ltd. achieves significant performance gains by optimizing VSIPL functions for Intel® AVX

NASoftware is releasing a set of VSIPL functions optimized for Intel® AVX, a key new innovation in the 2nd generation Intel® Core™ processor-based microarchitecture.

Overview

The trend toward floating-point-intensive computation is on the rise across industry segments, fueling demand for increased computing performance. This trend is evident in general-purpose applications such as image, video and audio processing, as well as in complex engineering applications, including 3-D modeling and analysis, scientific simulation, financial analytics and high-performance computing (HPC).

Intel® Advanced Vector EXtensions (Intel® AVX) provides an infrastructure and building blocks for meeting these escalating performance requirements. Intel AVX is a new 256-bit set of instructions developed by Intel to benefit floating-point-intensive applications. An extension to Intel® SSE (Intel® Streaming SIMD Extensions), Intel AVX was introduced as part of the new 2nd generation Intel® Core™ processor family for embedded platforms. Intel AVX improves software performance through wider vectors, a new extensible syntax and rich functionality.

NASoftware Ltd., a UK-based software company specializing in optimized digital signal processing (DSP) libraries, algorithms and services, is taking advantage of Intel AVX to enable improved performance for radar image processing applications. The company's latest software tool is one of the first Vector Signal Image Processing Libraries (VSIPL) optimized for Intel AVX, giving embedded board manufacturers and end users access to a level of performance they can't get elsewhere today.

NASoftware's new AVX-enabled library – a highly optimized and fully multithreaded implementation of the VSIPL industry standard – is yielding impressive results on the latest Intel® multicore platforms. Benchmark tests show that Intel AVX can accelerate the performance of some common radar image processing functions nearly two-fold when compared to SSE. According to NASoftware, providing more speed at less power makes a huge difference to radar applications that need to process vast amounts of complex data in real time. The company also recognizes that moving quickly to bring customers an AVX-optimized VSIPL implementation helps give it a competitive edge in a demanding marketplace.

The Challenge: Real-Time Processing of Complex Algorithms

By its nature, radar image processing is highly computationally intensive. An analog (radio frequency) signal pulse is sent, then the reflected signal is captured and converted to a digital signal for ease of analysis. The digital signal typically consists of complex numbers in fixed-point format, but essentially every radar algorithm immediately converts that input data into floating-point format before processing it. This is done to maintain precision – a must for radar applications.

The big challenge is making high-accuracy, computationally intensive algorithms run in real time to keep up with the speed of the radar. Because the radar constantly spews out huge volumes of complex data, and because all of that data requires large amounts of processing, fast computation is critical. Thus, the faster your hardware can run, the more algorithms you can implement and compute in real time.

NASoftware (NAS) understands this challenge and develops specialized tools to address it. Founded in 1978 as a spin-off from the University of Liverpool, NAS initially provided consulting services to the UK Ministry of Defence, primarily in the area of Synthetic Aperture Radar (SAR). More recently, NAS has broadened into developing optimized libraries and other software tools for the HPC and DSP markets, including VSIPL and other vector libraries for advanced processors.

VSIPL, an open industry standard commonly used in U.S. and European military DSP applications, is designed to be processor-neutral but allows for extensive processor-specific optimizations. The NAS VSIPL library, for example, is designed to take full advantage of a target processor's SIMD (single instruction, multiple data) features, such as Intel SSE.[1] Typically, it provides acceleration at a factor of six to eight compared to non-SIMD implementations. On multicore and shared memory systems, the NAS library is multithreaded, automatically providing scalable performance for larger problems.

Mike Delves, chairman of NASoftware, says Intel® processors are a good choice for VSIPL optimization because they provide high performance at low power. Those are key requirements for the end users of NAS libraries, who are primarily contractors developing radar and sonar image processing applications for defense.

VSIPL: An Open Industry Standard for Signal Processing

The Vector Signal Image Processing Library (VSIPL) is a standardized set of functions and an open application programming interface (API) that offers developers a highly efficient and portable set of algorithms for signal and image processing applications.

Mandated by many U.S. Department of Defense (DoD) contracts, VSIPL provides the computational middleware for a wide range of vector, signal processing and image processing functions while abstracting the hardware implementation details. Using a library that conforms to VSIPL makes software portable across processor architectures and new generations of hardware platforms, thus helping to extend and future-proof a developer's application codes.

The scope of the VSIPL API includes support functions, scalar functions, element functions, signal processing functions and linear algebra functions.

VSIPL was defined by a team of embedded signal and image processing hardware and software vendors, academics, application developers and U.S. government research labs. Initial development of the VSIPL specification was sponsored by DARPA (Defense Advanced Research Projects Agency), the research and development arm of the DoD, and released in 2000. The current version of the standard, VSIPL 1.3, was released in early 2008.

Commercial implementations of VSIPL are currently available from a number of hardware and software vendors, including NASoftware.

For more information about VSIPL, visit www.vsipl.org.

"Intel low-voltage processors currently have the highest performance per watt on many types of signal processing functions," Delves says. "Our customers know this and they're moving to Intel processors, so they want us to support Intel architecture."

Intel® AVX: Key Features and Benefits

The new Intel® Advanced Vector Extensions (Intel® AVX) can dramatically increase signal processing performance when compared to previous processor generations.

Feature	Benefits
Wider Vectors ▪ Increased from 128-bit to 256-bit ▪ Two 128-bit load ports	Higher peak FLOPS with good power efficiency
Enhanced data rearrangement ▪ Use new 256-bit primitives to broadcast single or multiple data elements into 256-bit destination registers, efficiently manipulate floating-point data, or conditionally mask loads and stores.	Organize, access and pull only necessary data more quickly and efficiently
Three and four operands ▪ Non-destructive source for both AVX 128 and AVX 256	Fewer register copies, better register use for vector and scalar code
Flexible unaligned memory access support	More opportunities to fuse load and compute operations
Extensible new opcode (VEX)	Code size reduction

Solution: Intel® AVX-optimized VSIPL

To address marketplace demands, NAS jump-started an Intel® AVX development program by working with early samples of silicon for the 2nd generation Intel Core processor-based microarchitecture. The goal was to provide board manufacturers with Intel AVX-optimized VSIPL signal processing library functions coinciding with the initial release of the next-generation Intel processors in early 2011.

"All our customers are extremely interested in Intel AVX and want AVX-optimized VSIPL," Delves says. "It gives them a competitive edge in a market which is going to be taking up Intel AVX as fast as it can because it's a dramatic improvement over SSE."

Intel AVX accelerates floating-point compute performance by doubling the size of the floating-point (vector) SIMD registers from 128 to 256 bits. This enhanced performance can significantly accelerate demanding signal and image processing applications such as commercial air transportation radars, ruggedized navigation systems and remote medical image processing. When the Intel AVX instruction set is used in conjunction with other microarchitecture enhancements in the 2nd generation Intel Core processor family, it can provide as much as a two-fold performance improvement in FLOPS (floating-point operations per second) output.

Results: Significantly Improved Performance

Benchmark tests[2] bear this out. Using a beta version of its Intel AVX-optimized VSIPL, NAS compared the SSE performance of some typical VSIPL operations to the equivalent performance on an Intel AVX-enabled platform (with the SSE and AVX code running on the same hardware). The study was conducted using DSP algorithms developed by NAS and the Intel® Integrated Performance Primitives (IPP) library under a series of VSIPL wrappers. Table 1 shows the maximum performance gains achieved in the study relative to the theoretical 2X speedup from the wider vector registers. (Note that the optimal percentages shown in this table generally reflect short vector lengths. As the length of the vector increases the percentage of cache misses increases, requiring more accesses to slower system memory.)

To see all the results of NASoftware's study of VSIPL performance on Intel AVX-enabled platforms, download the full report titled "AVX Optimizations: VSIPL Benchmarks" at www.nasoftware.co.uk/home/attachments/avx_report3.pdf.

As part of another study, NAS examined the vector processing performance of an AVX-optimized radar processing algorithm called SAR/MTI (Synthetic Aperture Radar/Moving Target Indicator). SAR/MTI is a highly advanced and computationally intensive algorithm used in sophisticated radar image processing applications.

Consider the scenario of a Category 5 hurricane bearing down on a city in the darkness of night. Driving rain and 60mph winds have grounded police helicopters, but unmanned reconnaissance aircraft flying above the storm are beaming real-time radar images to an emergency response center, providing critical information as roads out of

About 2nd generation Intel® Core™ Processors

Released in early 2011, the 2nd generation Intel® Core™ processor family is based on the next-generation Intel® microarchitecture (formerly code-named "Sandy Bridge"). The new microarchitecture is delivered on Intel's cutting-edge 32nm process technology with second-generation high-k metal gate transistors. These innovations in manufacturing and transistor design enable Intel to deliver the next generation of Intel® Core™ i7, Core i5 and Core i3 processors with higher levels of computing performance and better energy efficiency.

When paired with compatible Intel® chipsets, these processors offer developers an advanced platform that meets the requirements of a broad range of embedded, compute-intensive applications, including retail and transaction solutions, digital signage, digital security surveillance, radar detection, ruggedized navigation systems, gaming platforms, communications, medical equipment and industrial automation. With support for both quad-core and dual-core configurations, 2nd generation Intel Core processors improve the performance and efficiency of multithreaded applications, with the option for hardware support of vital security and management functions.

Besides Intel® AVX, enhancements include next-generation Intel® Turbo Boost Technology[3] and a new "ring" architecture that allows the processor's built-in graphics engine to share resources such as cache with the processor's core to increase a device's computing and graphics performance while maintaining energy efficiency.

Table 1. Maximum performance gains using Intel® AVX over SSE

Operation	Maximum Speed Increase
1D in-place complex-to-complex FFT	87%
2D in-place complex-to-complex FFT	67% (Other data sizes achieved 79%)
Multiple in-place complex FFTs	96%
Complex Matrix Transpose	27% (Other data sizes achieved 53%)
Complex Vector Multiply	93%
Vector Sine	75%
Vector Cosine	61%
Vector Square Root	86%
Vector Scatter	92%
Vector Gather	93%

Table 2. Performance differential on actual advanced radar application

Algorithm	Tested Platform	2 Threads (dual-core) Seconds[a]	4 Threads (quad-core) Seconds[a]
SAR	2nd generation Intel® Core™ processor with Intel® AVX	0.067	0.043
	2010 Intel® Core™ i5 processor with Intel® SSE 4.2	0.135	0.121[a]
	Speed increase	2.0X	2.8X[a]
SAR/MTI	2nd generation Intel® Core™ processor with Intel® AVX	8.959	5.598
	2010 Intel® Core™ i5 processor with Intel® SSE 4.2	15.197	13.667[a]
	Speed increase	1.7X	2.4X[a]

[a]Timing reflects graphics rendering turned off; relative speed-up with graphics on is equivalent.

the city become blocked. As reports filter in about evacuation routes, emergency response teams need to know if cars are still getting through at a certain intersection. In such a scenario, the SAR/MTI algorithm can be used to extract high-resolution data on ground features and combine it with the positions of slow-moving and fast-moving vehicles in a specific area of the disaster zone, providing a detailed, real-time map of a potentially blocked road.

As Table 2 shows, the NAS study found that the version of the SAR/MTI radar processor optimized for Intel AVX runs almost twice as fast as the non-optimized version on a dual-core Intel platform, and almost two and a half times as fast on a quad-core Intel platform. In the table, NAS is comparing the Intel AVX-enabled platform to an Intel SSE-enabled platform at the same operating frequency. It should be noted that the Intel AVX-enabled platform has two or four physical cores. The Intel SSE-enabled machine has two physical cores and four cores with hyper-threading.

Business Benefits of Intel AVX

Delves says that by taking advantage of Intel AVX and other micro-architecture enhancements in 2nd generation Intel Core processors, NAS can assure much better performance for radar image processing functions to customers who license its library. To developers of radar applications, roughly doubling performance means roughly half as many boards are needed in an aircraft, which translates to less cost. It also translates to smaller, cooler and lighter systems that use less power.

"For radar and the like, we're looking at the high end of digital signal processing," Delves says. "The case for using Intel processors in these kinds of applications is strengthened massively by Intel AVX. You get more performance at low power than with competing DSPs."

He adds that Intel processors also provide the advantage of a broad set of mature development tools for the end users of NAS libraries. Those development tools also come into play at NAS, where programmers make use of the Intel® ICC Compiler and the Intel® VTune™ Performance Analyzer.

Besides giving radar application developers a speed boost, Delves says, NAS is seen as being a leader in bringing AVX-optimized VSIPL to the DSP marketplace. That competitive differentiator also extends to the embedded board manufacturers who package NAS' AVX-optimized VSIPL with their hardware. According to NAS, customers developing boards suited to radar image processing applications are taking quick and early advantage of having access to a VSIPL optimized for Intel AVX.

For More Information

For more information on Intel® Advanced Vector EXtensions, visit www.intel.com/software/avx.

To learn more about NASoftware, visit www.nasoftware.co.uk/home/index.php/products.

Solution provided by:

[1] SSE is Intel's term for the SIMD instruction set architecture implemented in previous generations of processors. Intel has enhanced Intel SSE with AVX 1.0.

[2] All benchmark test data in this case study provided by NASoftware Ltd.

[3] Requires a system with Intel® Turbo Boost Technology capability. Consult your PC manufacturer. Performance varies depending on hardware, software and system configuration. For more information, visit http://www.intel.com/technology/turboboost.

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