High performance embedded systems for medical imaging

Underlying Intel® technologies make it possible

High performance embedded systems for medical imaging

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This article shows how incorporating the latest embedded compute modules into medical imaging systems can provide users with higher quality images and help OEMs reduce design cycle times and lower costs.

■ High performance, embedded computers are having a huge impact in a number of industries. One of the most demanding applications is medical imaging. As health care providers are under pressure to more accurately diagnose more patients, this burden is passed along to OEMs developing next-generation medical imaging equipment such as MRI, CT, Digital x-ray and Ultrasound devices. Today, health care professionals are demanding lower cost systems that offer improved imaging capability. These systems incorporate 3-D and, in some cases, 4-D images that help users accurately diagnose and treat a variety of conditions.

Increased image processing complexity, the hallmark of this medical equipment, has an enormous impact on compute requirements. Here we will discuss how incorporating the latest embedded compute modules into imaging systems can provide users with higher quality images and help OEMs reduce design cycle times and lower development and production costs.

Competition is Fierce

Today a handful of OEMs supply the majority of medical imaging equipment and among these few companies competition is intense. Add to this atmosphere significant erosion in product pricing and you have a frenzied environment on your hands. To remain competitive, OEMS must continuously invest in new technologies that can improve performance and also lower costs. But it doesn't end after the sale. For these manufacturers, they need to offer long-life support once the system is in the field. These products are typically big ticket items and can cost well over one million Euros. As you can imagine, health care organizations expect long service life from these systems, and want the ability to upgrade as technology evolves.

"Using proven embedded systems in their designs can give OEMs an easy, cost effective method to reap the performance and cost benefits of the latest computing technologies," said Bob Ghaffari with Intel. "Embedded systems offer additional value over compute solutions intended for PC's or IT servers, in terms of product stability over many years, specialized package size, lower noise, and higher reliability."

Multiple Modalities, Oh My!

Health care professionals rely on computer-generated images to illustrate important information about a patient's health. High-quality images are crucial to accurately diagnose a patient or determine treatment. As an example, the data available in these images is invaluable in the early diagnosis and management of diseases including cancer and heart disorders. Some applications include real-time imaging used to provide feedback while performing procedures such as positioning a stent or other device inside someone's heart. In other cases, multiple modalities (CT, MRI, ultrasound, etc.) are used to provide optimal images. The reason being there is no single technique that is optimal for imaging all types of tissue. In these cases, compute systems are use to combine images from each modality into a composite image that provides more information than just looking at the images from different modalities separately.

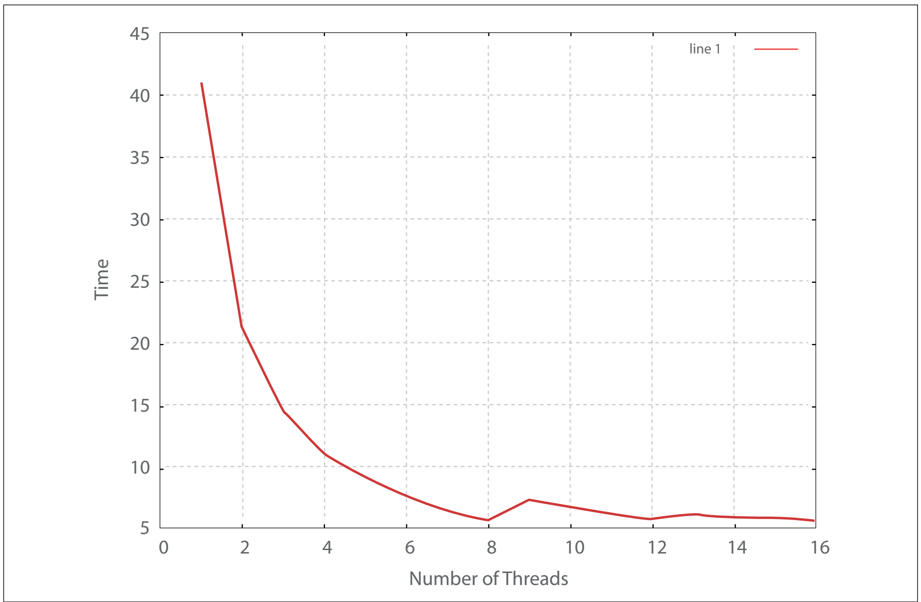
In addition to requiring the best images possible, safety is a crucial consideration. Many imaging systems use x-rays to provide a view of what is beneath a patient's skin. X-ray radiation levels must be kept at a minimum to protect both patients and staff. As a result, raw image data can be extremely noisy. In order to provide clear images, algorithms designed to reduce noise are used to process the raw data and extract the image data while eliminating the noise. In video imaging applications, data often has to be processed at rates of 30 images per second or more. Filtering noisy input data and delivering clear, high-resolution images at these rates requires tremendous compute power. The only way to get improved results is to increase the processing power of each machine.

Parallel Computing to the Rescue

Since a single general purpose processor is unable to provide the necessary processing power for high-speed image processing, there is a shift underway to move from serial to parallel processing. This divide and conquer method means multiple tasks can be performed in parallel. This approach has been well known in the area of "Super-Computing" for many years, but is relatively new to medical imaging systems.

Shifting the focus from increasing linear execution (clock) speed to increasing executions that can be performed in parallel, allows more data streams to be processed simultaneously. Multi-core processors can facilitate many data streams running in parallel. As an example, the chart below illustrate processing speed improving as the number of cores used increases. Here an imaging edge-detection algorithm that has been modified for parallel processing is running on a quad-core, dual-processor server. The eight cores available to the application deliver dramatically improved performance as the number of threads supported by the application approaches the number of cores.

As demonstrated in the data below, software must be multi-threaded to take full advantage of multi-core processors. Threading is a complex undertaking and requires the right tools to identify the sections of an application that are well-suited for parallel processing. However, the payoff is that the combination of multi-threaded software and multi-core servers means larger workloads can be handled with fewer machines. This leads to increased performance at a lower cost.



Processing speed is improving as the number of cores used increases.

RadiSys Procelerant RMS420 rack mount server

Co-Processors Equally Important

The latest CPUs offer up to four cores per chip. There is another class of chips that offer "scores of cores" per chip. Hardware co-processors such as Graphics Processing Units (GPUs) and Field-Programmable Gate Arrays (FPGAs), among others, are being used to take parallelization to the next level and deliver added performance in embedded systems. Attached to the motherboard, they offer supplemental, somewhat specialized processing functionality that helps offload some of the processing tasks that the processor would normally handle. While co-processors aren't new, advances in standard graphics hardware, in conjunction with new programming models and other tools have increased their popularity and they are becoming more widely used in embedded systems. Today they can play a key role in high-performance imaging systems.

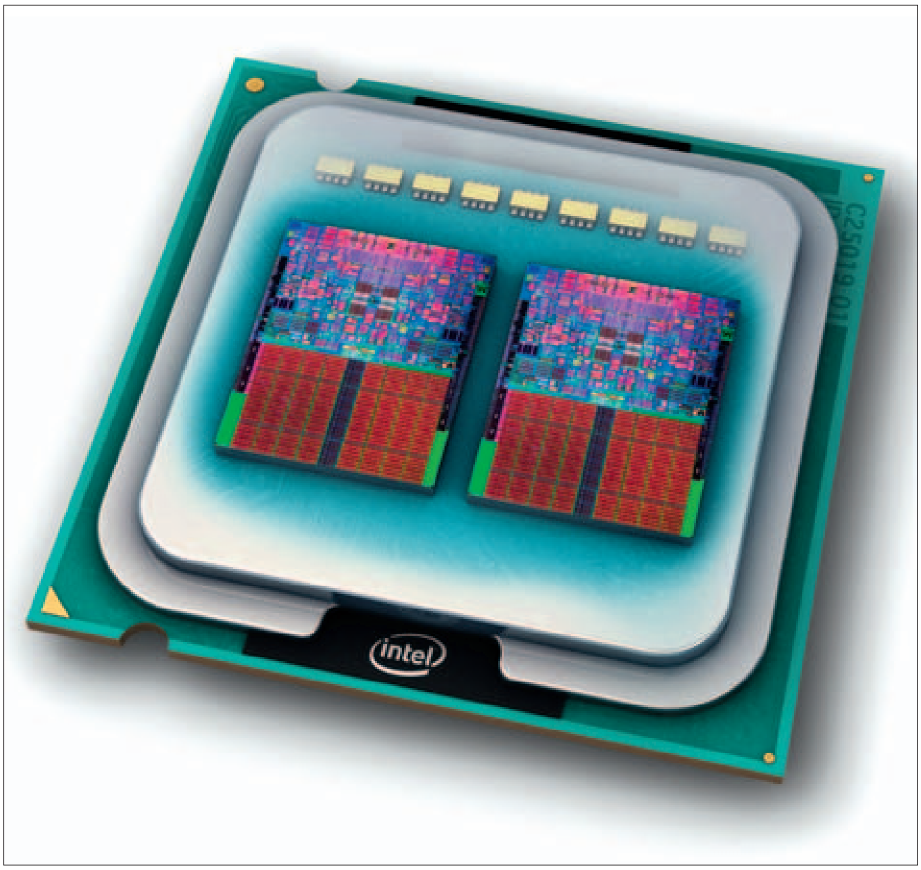
With availability of additional variables (multi-core processors, co-processors, etc.), OEMS have more options to optimize performance in the systems they design. However, more options leads to increased system complexity. In order to achieve optimal performance, developers need to understand not only the operation of the individual parts, but the ways in which they interact. New diagnostic tools are becoming available to analyze data flow and identify "bottlenecks" that may restrict system performance.

Several advancements, both hardware and software related, have lead to revolutionary changes in the world of high-performance computing. These improvements help deliver breakthrough performance, increased power efficiency and cost advantages that support larger workloads using fewer servers. These benefits are amplified when referring to high-end imaging applications.

System Constraints, Embedded Benefits

To this point, our discussion has focused on processing performance. However, the challenge for designers of medical imaging compute systems doesn't end when the processing performance requirements are satisfied.

There are additional constraints unique to medical imaging. These include package size, acoustic noise and long validation cycles. To put this in perspective, system designers are trying to package the compute performance of a



Intel® Core™2 Extreme quad-core processor

server farm in a form factor that would fit under the system operator's console. The most recent ultrasound systems are battery powered and resemble a laptop computer. Therefore, in addition to providing state-of-the art compute performance, embedded compute systems for medical imaging applications must also be engineered for low power, fit in a small footprint and emit very low levels of acoustic noise.

Medical systems typically have to be certified as safe and effective by regulatory agencies in the countries where they will be used. The validation process is often time-consuming and can be costly. Changes to the compute system can result in re-validation of the entire imaging system. Therefore, medical imaging system manufacturers often demand components and subsystems with production life-cycles on the order of five years. As anyone who has purchased a standard computer knows, this is not typical in the industry. Developers of embedded compute systems meet this requirement by carefully selecting components that are robust and whose suppliers will guarantee long-term availability.

Underlying Intel® Technologies Make it Possible

Intel® multi-core processors such as Intel® Core™ Duo and Intel® Dual-Core Xeon® processors have two or more execution cores within a single processor, providing breakthrough performance, increased productivity and enhanced digital output. Multi-core processors are used in embedded systems to help increase compute performance in certain applications, such as the medical equipment discussed here. Using multi-core processors, a single server can handle workloads that previously required multiple servers.

Additionally, multi-core processors offer energy-related benefits. They not only increase compute headroom relative to the energy they consume thereby reducing power costs, they also decrease the amount of wasted heat, which can also cut cooling costs.

"Our latest quad-core processor, known as Harpertown, offers the compute performance needed to support complex, high-end medical imaging applications," said Bob Ghaffari with Intel. "Harpertown is based on our 45 nanometer process technology and combines high performance with power efficiencies of low-power Intel® Core™ microarchitecture."

But its not processor technology alone that provides these advancements. In addition to its multi-core technology, Intel has developed supporting technologies that facilitate compute processing engines.

An example is Intel® Virtualization Technology (Intel® VT), which delivers improved computing benefits for both PCs and servers. Intel VT enables real-time performance maintenance while using virtualization to consolidate systems; system uptime can be increased by enabling software failover without redundant hardware; and software migration can be performed without compromising applications. Virtualization also allows legacy applications to co-exist with new applications by executing both software environments in parallel, and it provides the means for applications to take advantage of multi-core processors without re-architecting to accommodate multi-threaded execution.

RadiSys Delivers

RadiSys integrates the latest multi-core processors, including the new Intel® quad-core processor (codename Harpertown), and architecture features into embedded servers that deliver performance headroom to support larger workloads and new functionality. The company's long history of innovation and expertise ensures OEMs, and their customers, can take advantage of the latest technology today and in the future.

Recent advances in compute technology offer great performance improvements for medical imaging systems, but also add complexity to the system design. Integrating the latest embedded systems in designs of high-end medical imaging equipment can help OEMs maintain their position in that market segment. The combination of leading edge processing technology with expertise in long-life systems, high reliability and specialized packaging sets RadiSys apart. But the real benefit is that health care providers have the best equipment possible to diagnose and treat more patients, more effectively. ■