Neusoft Computed Tomography on Intel® Xeon® Processor E5-2600 v3

Background

Neusoft Medical Systems Co., Ltd. is a leading manufacturer of medical equipment including Computed Tomography (CT), Magnetic Resonance Imaging (MRI), X-ray, Ultrasound, Positron Emission Tomography (PET), Linear Accelerator, and In Vitro Diagnostic (IVD). For more information about the company, see [1].

Neusoft CT is its key digital health solution focusing on medical image processing, i.e., computing the axial images of the target using specific sophisticated algorithms.

CT scanning is used to create detailed 2D or 3D images of areas inside the body, such as the brain, lungs, abdomen, and bones. Doctors use CT scans to help diagnose medical conditions. For example, doing a head scan can help detect internal bleeding or swelling of the arteries. Scanning skeletal structures of a patient after an accident can reveal more information about the injuries.

Figure 1 shows a typical CT scanning system that can scan the full human body.

Figure 1. Neusoft NeuViz* 64 In/En 64-Slice CT Scanner System
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Subsequent sections will talk more about CT and how Intel® Xeon® processor E5-2600 v3 helps improve CT scanning performance.

What is CT?
CT is a process that uses special equipment to create a series of X-ray images taken from many different angles to produce cross-sectional images of specific areas of a scanned object. At first the X-ray equipment collects data by emitting X-ray through the scanned object with the X-ray detector positioned on the opposite side of the X-ray source. Depending on the scanned parts (soft tissues, bones, blood) the amount of X-ray received at the X-ray detector will vary. After finishing collecting data, images are reconstructed using a process called backprojection.

The Backprojection algorithm is based on a mathematical model that involves the Fourier Slice Theorem (FST) which employs matrix manipulations and is used to reconstruct the images from the X-ray data. Details on how backprojection is mathematically implemented are given in references [9] [10].

Below are some example CT images.

Figure 2. Coronary Artery Stents

Figure 3. Pulmonary Arteries

Figure 4. CTA Runoffs

Figure 5. Fat Analysis
New Intel® Instruction and Neusoft CT Performance

As stated in the previous section, FST is used in backprojection to reconstruct the image. FST involves matrix manipulations, including matrix multiplication.

One of the new features of the Intel® Xeon® processor E5-2600 v3 product family is the support of a new instruction called three-operand fused multiply-add (FMA3). Replacing add and multiply operations with single multiply-add operations helps improve performance speeds of backprojection calculations. In addition, since FMA3 is implemented in the hardware, the speed of this operation is considerably improved.

The following compilers support FMA3:
Microsoft Visual C++® 2012 and later
Gcc 4.7.0 and later
Intel® C++ compiler 14.0 and later

Performance test procedure

To prove that the new Intel instruction, FMA3, improves the performance of Neusoft CT, we performed tests on two platforms. One system was equipped with Intel Xeon processor E5-2697 v3 and the other with Intel® Xeon® processor E5-2697 v2.

Test configurations

System equipped with Intel Xeon processor E5-2697 v3
- **System:** Pre-production
- **Processors:** Intel Xeon processor E5-2697 v3 @2.6GHz
- **Memory:** 32GB DDR4-2133MHz
System equipped with Intel Xeon processor E5-2697 v2

- **System**: Pre-production
- **Processors**: Intel Xeon processor E5-2697 v2 @2.7GHz
- **Memory**: 32GB DDR3-1600MHz

**Operating System**: Microsoft Windows Server® 2012 R2

**Application**: Neusoft CT CPU Reconstruction Module

**Test results**

Figure 7 shows the results on a system equipped with the Intel Xeon processor E5-2697 v3 and on a system equipped with the Intel Xeon processor E5-2697 v2 with no FMA3 implemented. The performance improvement of 1.3X is due to the faster DDR4 memory and more cores on Intel Xeon processor E5-2697 v3.

![Comparison between Intel® Xeon® processor E5-2697 v3 and Intel® Xeon® processor E5-2697 v2](image)

**Figure 7**: Comparison between Intel® Xeon® processor E5-2697 v3 and Intel® Xeon® processor E5-2697 v2 with no FMA3
Figure 8 shows the results of executing Neusoft’s application on a system equipped with Intel Xeon processor E5-2697 v3 with and without FMA3. Implementing FMA3 helps improve the performance by 1.17X.

![Figure 8](image.png)

Figure 8. Comparison between versions of Neusoft’s application with FMA3 and without FMA3

Figure 9 shows the results on a system equipped with Intel Xeon processor E5-2697 v3 with FMA3 implemented and on a system equipped with Intel Xeon processor E5-2697 v2 without FMA3 implemented. The performance improvement of 1.52X is due to better hardware (faster DDR4 memory and more cores on Intel Xeon processor E5-2697 v3) and implementing the FMA3 instruction.
Figure 9. Comparison between versions of Neusoft’s application with FMA3 and without FMA3

Note: Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark* and MobileMark*, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Conclusion

Obtaining CT scan images quickly helps speedup the diagnosis process thus increasing the chance of saving lives. Neusoft CT makes use of FMA instructions in its image reconstruction module to improve the throughput. By replacing the add and multiply operations with the FMA3 instruction, which was introduced in the Intel Xeon processor E5-2600 v3 product family, the performance of the image reconstruction module was significantly improved.
References

[9] https://books.google.com/books?id=2hdRiYZp3YcC&pg=PA11&lpg=PA11&dq=back+projection+and+matrix+multiplication&source=bl&ots=DnBRl0iT7&sig=krkW1IRILLvTgiDQziJAUk8pbFs&hl=en&sa=X&ei=R0tNVeKsJNfs0ASOo4GQBw&ved=0CCgQ6AEwAQ#v=onepage&q=back%20projection%20and%20matrix%20multiplication&f=false

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