High Performance Parallel Computing in the Motion Picture Industry

Technical Summary by
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Introduction

Computer graphics and animation is pushing the limits of technology. James Cameron's *Avatar* was rendered on some 4,000 computers hosting about 40,000 processors.[1] Render times ranged from 30 to 100 hours per frame.[2] For a 166 minute movie projected at the industry standard 24 frames per second, a conservative estimate puts the total time to render the film somewhere in the ballpark of 8 million compute-hours.

Yet the appetite and demand for increasingly sophisticated and visually stunning results only grows larger. Cameron speculates for *Avatar 2* the industry standard projection rate may increase to 48 or 60 frames per second.[3] This may double or nearly triple the time required to render a feature-length film. Meanwhile, media content produced for a "glasses-free 3D" viewing experience of new auto-stereoscopic displays requires each frame to be rendered from multiple camera angles. In order to achieve a high quality parallax, as many as eight or sixteen different camera angles may need to be rendered for each individual frame of animation,[4] increasing compute times by nearly another order of magnitude or more.

As computer generated motion picture production stands on this precipice, another industry has begun transition into a new era. This is the many-core revolution of the semiconductor industry. On the desktop, computers already have two, four or eight processing cores. In high-end servers, the number of processing cores may be greater than 64. Intel plans to unveil its new "Knights Corner" processor in 2013 which will boast more than 50 processing cores on a single chip,[5] thereby making the idea of hundreds of CPU processing cores in a single computer a soon-to-be reality.

Figure 1. James Cameron's *Avatar* was rendered on some 4,000 computers hosting about 40,000 processors. Render times ranged from 30 to 100 hours per frame.

For the computer graphics, animation and motion picture industries, this is a very exciting moment in history. It should serve as a foundation for practical motivations and inspirational dreams: to harness every drop of raw computing horsepower that these new hardware platforms have to offer is a paradigm shift that will open a new frontier of untold financial and artistic benefits.

The Problem of Scalability

There remains a significant obstacle to harnessing all the power of these new hardware platforms. It is the software.

Every software program has a parallel part and a sequential part. Using more processors will never make the sequential part of the program faster. In computer science, this is known as Amdahl's Law. The law states that the maximum speedup which may be obtained by adding more processors is determined by how parallel the software is. If the software is highly parallel, then greater speedups can be achieved by adding more processors. If the software is more sequential, then adding more processors only causes the parallel part to finish faster than the sequential part, leaving almost all processors waiting (i. e., idle) for the sequential part to finish. No further speedup can be achieved by adding more processors at this point, since it only results in more idle processors. Figure 2 illustrates this concept. For example, only a 10X improvement in speed can be achieved when the software is 90% parallel, even if an unlimited number of processors are available.

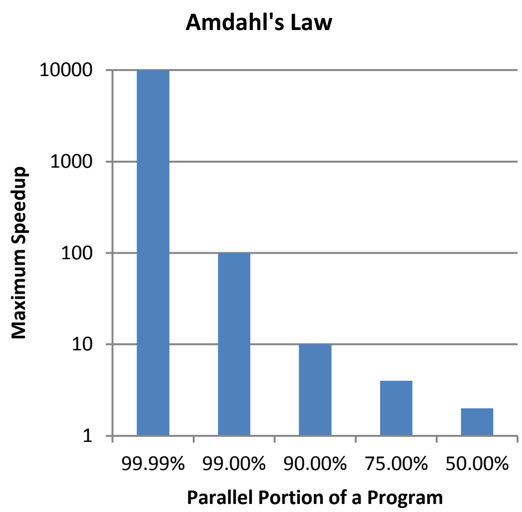


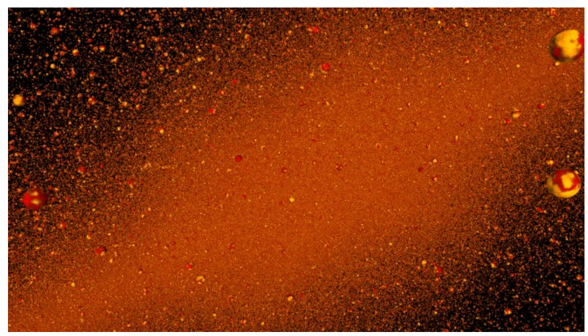
Figure 2. Amdahl's Law dictates the maximum speedup which may be obtained even if an unlimited number of processors are available. The maximum speedup is determined by the ratio of the parallel and sequential parts of a program.

Existing rendering software used in the motion picture industry is about 90% parallel.[6] This means that most users have not yet encountered the limiting factors of Amdahl's Law because most computers still have less than 10 processors. But in the next few years as the number of processors continues to grow, users are likely to become increasingly frustrated that they can't harness the full potential of the hardware they paid for! To do this would require a software solution that is at least 99% parallel or better.

The Solution

Sunfish has developed Meridian, a new rendering solution that reduces the sequential portion of the rendering process to a tiny fraction. Based on the mathematics of **modal interval arithmetic**, this patented rendering method abandons the older computer graphics image synthesis techniques of point sampling. The modal interval mathematical platform is naturally concurrent and runs in a small and constant memory footprint, allowing all of the raw power and full potential of many-core hardware to be utilized with almost nearly perfect efficiency.

Meridian is an analytical rendering engine that uses modal interval analysis to render nonlinear geometric functions directly into perfectly anti-aliased pixels. The result is unprecedented levels of high-quality image production, all in a naturally concurrent rendering platform that eliminates the RAM explosions and other sequential bottlenecks caused by traditional methods.



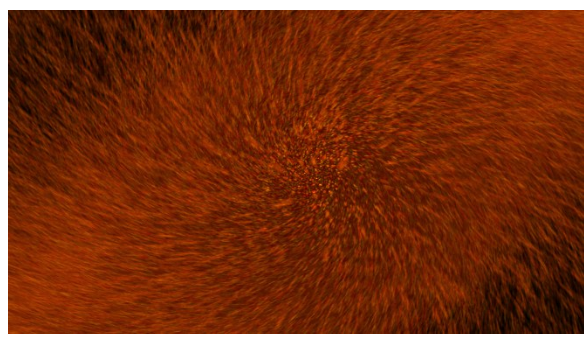


Figure 3. Above: 6 million particles, all rendered as spheres. Below: the same particles with camera motion blur

The Benchmark

To illustrate these facts, a rendering benchmark is performed on a production scene consisting of six million particles. Every single particle is rendered as a truly three-dimensional sphere (not as a point or two-dimensional disk, as is typical of existing or competing rendering software). Camera motion blur is enabled and consists of highly nonlinear, rapid movement with large amounts of rotation that would require a normal rendering application to use a large number of motion segments. An animation sequence of 24 high-definition frames (1920 by 1080 pixels) is rendered.

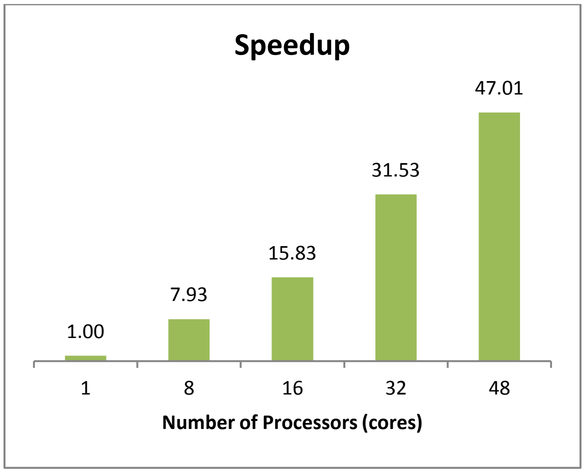


Figure 4. In a laboratory-tested benchmark consisting of 24 frames of animation, Meridian demonstrates nearly perfect 1:1 speedups over a single processor all the way to 48 processing cores.

The benchmark is performed on a Dell PowerEdge R815 server with four "Magny Cours" 1.9 GHz Opteron 6168 processors by AMD. Each AMD processor has 12 cores, so the computer has a total of 48 processing cores. The system has 32 GB RAM.

On a single processor, the benchmark takes a little more than 105 hours (about 4.38 days). As more processors are added, the speedup scales in an almost perfect 1:1 ratio. When the benchmark is run on 48 processors, the total elapsed time is about 2 hours and 14 minutes. This represents an almost perfect 48X speedup over the render time on a single processor. Figure 4 is a summary of the results.

Conclusion

In a laboratory-tested benchmark consisting of 24 frames of animation, Meridian demonstrates a nearly perfect 1:1 speedup over a single processor all the way to 48 processing cores. This level of efficiency is unprecedented in the modern motion picture industry and represents a breakthrough in high performance computing. Production studios willing to make the investment of upgrading their existing render farm to computers hosting a large number of cores (48 or more) can expect nearly linear speedups even on very large and complex production scenes for an almost immediate return on investment. The ability to harness all of the raw power of such tremendous computing resources represents a sea-change in the way visual effects can be produced. Results can be quantified and measured in different ways: shorter production times that give studios a capacity to produce more media content and generate more revenue, or improved visual quality in motion pictures due to higher frame rates and auto-stereoscopic viewing technologies.

[1] http://www.datacenterknowledge.com/archives/2009/12/22/the-data-crunching-powerhouse-behind-avatar/
[2] http://forwardthinking.pcmag.com/d/282570-james-cameron-tells-d8-how-he-made-avatar-in-3d
[3] http://www.switched.com/2011/04/02/james-cameron-to-achieve-reality-on-film-faster-frame-rates/
[4] http://en.wikipedia.org/wiki/Autostereoscopy
[5] http://en.wikipedia.org/wiki/Intel_MIC
[6] Apodaca, A. and Larry Gritz, "Advanced RenderMan: Creating CGI for Motion Pictures," Morgan Kaufmann, 1999, p. 146.