Cell Broadband Engine™: and Cell/B.E. based blade technology

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Cell/B.E. Chief Scientist

IBM Systems and Technology Group

Cell Broadband Engine is a trademark of Sony Computer Entertainment Inc.
Cell BE background
CMOS Device Scaling Effects and Technology Improvements: Technology Limits Frequency
Microprocessor Trends

- Single Thread performance power limited
- Multi-core throughput performance extended
- Hybrid extends performance and efficiency
Memory Managing Processor vs. Traditional General Purpose Processor

Cell
BE

AMD

IBM

Intel
Cell BE applications
Cell BE Processor Isn't Just for Games.

Innovative Chip is best high-performance embedded processor of 2005

We chose the Cell BE as the best high-performance embedded processor of 2005 because of its innovative design and future potential. Even if the Cell BE accumulates no more design wins, the PlayStation 3 could drive sales to nearly 100 million units over the likely five-year lifespan of the console. That would make the Cell BE one of the most successful microprocessors in history.

“...Cell BE could power hundreds of new apps, create a new video-processing industry and fuel a multibillion-dollar build out of tech hardware over ten years.”

-- Forbes

“It was originally conceived as the microprocessor to power Sony's [PS3], but it is expected to find a home in lots of other broadband-connected consumer items and in servers too.”

-- IEEE Spectrum
Industry workloads well-suited to Cell/B.E. technology

Focused Common Workload Characteristics/Requirements

Real-time Analytics
- Processing of Data
- Information Synthesis
- Analysis

Visualization
- Presentation of Data
- Modeling, Simulation,
  Image processing, Rendering

- EDA
- Financial markets
- Seismic
- A&D
- Medical Imaging
- Digital Video Surveillance
- Media & Entertainment

- Financial markets
- Media & Entertainment
Many Applications for Cell/B.E. Beyond Gaming

I.B.M. to Build Supercomputer Powered by Video Game Chips
By JOHN MARKOFF
(NY Times): September 7, 2006

Mercury/Mentor Graphics
45nm OPC tool

Fraunhofer
PV4D Medical Imaging

Boston Univ.
Bioinformatics: FBDD

SCEI / Pande (Stanford)
folding@home PS3 client

Rapidmind(TM) / RTT

Structural Analysis
digitalmedics.de

IBM iRT raytracer prototype
### Client statistics by OS

<table>
<thead>
<tr>
<th>OS Type</th>
<th>Current TFLOPS*</th>
<th>Active CPUs</th>
<th>Total CPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>164</td>
<td>172703</td>
<td>1798091</td>
</tr>
<tr>
<td>Mac OS X/PowerPC</td>
<td>8</td>
<td>9391</td>
<td>105647</td>
</tr>
<tr>
<td>Mac OS X/Intel</td>
<td>13</td>
<td>4188</td>
<td>23712</td>
</tr>
<tr>
<td>Linux</td>
<td>36</td>
<td>21449</td>
<td>245348</td>
</tr>
<tr>
<td>GPU</td>
<td>43</td>
<td>732</td>
<td>4246</td>
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<tr>
<td>PLAYSTATION®3</td>
<td>1000</td>
<td>40305</td>
<td>255338</td>
</tr>
<tr>
<td>Total</td>
<td>1264</td>
<td>248768</td>
<td>2432382</td>
</tr>
</tbody>
</table>

Total number of non-Anonymous donators = 808390

Last updated at Sun, 23 Sep 2007 09:49:22

DB date 2007-09-23 09:51:47
Neocortex Bottom-UP Engine
( Brain-Inspired Computing )
Jayram Moorkanikaran, Andrew Felch, Jeff Furlong, Ashok Chandrashekar, Matthew Johnson, Nikil Dutt, Richard Granger, Alex Nicolau, Alex Veidenbaum

<table>
<thead>
<tr>
<th>Classical Neural Network</th>
<th>Brain Inspired Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on simple model of neurons</td>
<td>Based on detailed model of brain</td>
</tr>
<tr>
<td>Abstract network</td>
<td>Hierarchical networks</td>
</tr>
<tr>
<td>Not scalable</td>
<td>Scalable</td>
</tr>
<tr>
<td>Mostly supervised training</td>
<td>Supervised and non-supervised training</td>
</tr>
</tbody>
</table>

Sample recognition of stool using WORD
Quarto Lugar no Concurso da IBM – Projeto FaceDetect
- O projeto desenvolveu um software que reimplementa o algoritmo de Viola Jones, de forma otimizada para o Cell, usando a biblioteca do OpenCV.
- Desenvolvemos métodos eficientes para processar o algoritmo nos processadores sinergísticos do Cell/BE.
- Na implementação, foi utilizada abordagem específica para o classificadores.
- Restrição de imagem de 24 x 24 pixels
- Algoritmo baseado em stump para reduzir a estrutura de dados para os classificadores.
Cell BE technology and systems roadmaps
Cell BE enables scalable, shared architecture with full consumer to professional potential
Cell Broadband Engine Architecture™ (CBEA) Technology Competitive Roadmap

Performance Enhancements/Scaling

Cost Reduction

Cell/B.E. (1+8)
90nm SOI

Cell/B.E. (1+8)
65nm SOI

Cell/B.E. (1+8)
45nm SOI

Advanced Cell/B.E.
(1+8eDP SPE)
65nm SOI

Next Gen
(2PPE’+32SPE’)
45nm SOI
~1 TFlop (est.)

All future dates and specifications are estimations only; Subject to change without notice. Dashed outlines indicate concept designs.

Cell BE Roadmap Version 5.1 7-Aug-2006
Cell Broadband Engine Architecture Blades
IBM BladeCenter QS20 and beyond

BladeCenter QS20
- 2 Cell/B.E. processors
- 1PPE + 8SPE
- SP: 460 GFLOPS per Cell blade
- DP: 42 GFLOPS per Cell blade
- 1 GB memory

BladeCenter QS21
- 2 Cell/B.E. processors
- 1PPE + 8SPE
- SP: 460 GFLOPS per Cell blade
- DP: 42 GFLOPS per Cell blade
- Next Generation I/O chip
- 2 GB memory

BladeCenter QS2Y
- 2 CBEA-compliant processors
- 1PPE + 8eDP SPE
- SP: 460 GFLOPS per blade
- eDP: 217 GFLOPS per blade
- Up to 32 GB memory
- PCI Express™ x16 slots

BladeCenter QS2Z
- First CBEA teraflop processor
- 2PPE+32 eSPE
- Power Architecture compliant
- ~2 TFLOPS SP per blade
- ~1 TFLOPS DP per blade
- Next generation memory technology

SDK 1.1
SDK 2.1
SDK 3.0
SDK 4.0
SDK 5.0

2006
2007
2008
2009-2010

All future dates and specifications are estimations only; Subject to change without notice.

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Cell BE software based on an open approach
Cell/B.E. Software Fundamentals

- Published architecture
- Open source based collaboration
- Low barrier to entry (PlayStation®3)
- Everyone can contribute
- Enterprise & industrial solutions
  - E.g. RHEL
  - Services offerings
- Robust acceleration framework
  - DaCS / ALF
IBM SDK for Multicore Acceleration and related tools

The IBM SDK is a complete tools package that simplifies programming on IBM BladeCenter QS 21

- **IBM XL C/C++ compiler***
  Optimized compiler for use in creating Cell/B.E. optimized applications. Offers:
  * improved performance
  * automatic overlay support
  * SPE code generation

- **Accelerated Library Framework (ALF)**
- **Data Communication and Synchronization (DaCS)**
- **Basic Linear Algebra Subroutines (BLAS)**
- **Standardized SIMD math libraries**

- **Eclipse™-based IDE**

- **GNU tool chain**

- **Simulator**

- **Performance Tools**

*XL C/C++ compiler single source is available in beta, dual source is planned to GA on 10/19/07 with an announce on 10/16/07
ALF Architecture

Input Data
Cell is not alone: Industry direction towards C/GPU
AMD Fusion is the codename for a future next-generation microprocessor design and the product of the merger between AMD and ATI, combining general processor execution as well as 3D geometry processing and other functions of today's GPUs into a single package. This technology is expected to debut in the timeframe of late 2008 or early 2009; as a successor of the latest microarchitecture, referred as "K8L". Four platforms focus on the four different aspects of usage:

- General Purpose
- Data Centric
- Graphics Centric
- Media Centric

Speed increase
There is to be an expected speed increase with the Fusion. Because the GPU and CPU will be on the same die, information transfer between the CPU and GPU/GPU memory will significantly increase since there will be no need for the information to travel on a bus as there is with current motherboards.

In an interview with Exec VP of AMD, Mario Rivas, CRN.com claims that: “With its Fusion program, AMD hopes to deliver multicore products using different kinds of processing blocks. A GPU, for example, will excel in multiple parallel computational tasks, while the CPU will take on heavy number-crunching duties. The Fusion-based processors, with the CPU and GPU integrated in a single architecture, should make the life of software programmers and application developers much easier, Rivas added.”  This could signal that the design of Fusion has been going on for sometime.
Project Larrabee — Intel has begun planning products based on a highly parallel, IA-based programmable architecture codenamed "Larrabee." It will be easily programmable using many existing software tools, and designed to scale to trillions of floating point operations per second (Teraflops) of performance. The Larrabee architecture will include enhancements to accelerate applications such as scientific computing, recognition, mining, synthesis, visualization, financial analytics and health applications.

- Senior VP Pat Gelsinger - IDF Spring 07
Evolution of nVidia GPUs toward Generalized Purpose

The current trend that GPU makers are building to have customers use the GPU as a generalized data-parallel coprocessor.

- "Unified Shaders"
  - GPUs legacy hardware was strongly tailored to the Graphics task with 3 major components, these have now been unified
  - nVidia introduced CUDA (Compute Unified Device Architecture) Programming model with the G80

Evolution in Compute Power for nVidia GPUs

- The current version G80 is quoted at 520 SP GFLOPS

- Customers are looking at this trend and demonstrating interest in using GPUs for general compute processing

Current GPU Design Points are still several steps short of the Cell BE Design Point

- SPE have:
  - Significantly more memory
  - Much better Inter-process communication between cores
  - Full software Control of the local store and memory Hierarchy
  - Double Precision
  - Hardware based Security
  - Advanced Scatter Gather functionality
  - Go a step beyond pure streaming models
- Cell Includes a General Purpose Processor

Chips Compared by type and transistor count

<table>
<thead>
<tr>
<th>Chip Type</th>
<th>CPU</th>
<th>Transistors</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD Athlon 64 X2</td>
<td>CPU</td>
<td>154 m</td>
</tr>
<tr>
<td>Cell</td>
<td>CPU</td>
<td>241 m</td>
</tr>
<tr>
<td>Intel Core 2 Duo</td>
<td>CPU</td>
<td>291 m</td>
</tr>
<tr>
<td>Intel Pentium D 900</td>
<td>CPU</td>
<td>376 m</td>
</tr>
<tr>
<td>ATI X1950 XTX</td>
<td>GPU</td>
<td>384 m</td>
</tr>
<tr>
<td>Intel Core 2 Quad (QX6700)</td>
<td>CPU</td>
<td>582 m</td>
</tr>
<tr>
<td>nVidia G8800 GTX (G80)</td>
<td>GPU</td>
<td>681 m</td>
</tr>
</tbody>
</table>
Conclusions
Conclusions

- Cell Broadband Engine technology is a fundamental advance in processor design
- IBM leverages Cell BE in blade servers, we are now on our second generation with more to come
- IBM has identified seven application areas for the QS21 that especially benefit from the technology
- Software support is maturing and we have great momentum with the academic community due to our open software strategy
- Cell is but the first heterogeneous multi-core ...
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