Linux for Cell Broadband Engine and PS3, Related Open Source Projects

Nov 2^{nd}, 2007

Hiroyuki Machida
What’s
Cell Broadband Engine
<Cell/B.E.>
* What’s Cell Broadband Engine
* Status of Linux Distro
* Cell/B.E. Performance
* Hello SPE
* Various OSS activities
Cell/B.E. - A Heart of PS3

* Heterogeneous Multi-core Processor
  - 1 PPE (Power Processor Element)
    * PPU + 512KB L2 Cache
    * PPU → PPC64 insn + VMX instructions, SMT/in-order
  - 8 SPE (Synergetic Processor Element)
    * Generic 4way SIMD Processor (SPU, incompat with PPC)
      + LS (Local Storage) + MFC (Mem. Flow Cntl)

* One: reserved for System Software
* Another: turned off for better yield rate
SPEs – Key of High Performance

* Design Strategies
  - “simpler structure and higher clock”
  - “more room for SPEs on silicon”

* PPE does NOT achieve same speed with same clock G5 (PPC970)
SPE Memory Architecture

* Like no other …

- Small (256KB) and High speed LS, instead of Cache
  * LS stands for Local Store
- Intelligent DMA (MFC, EA based, coherent check)
  * EA stands for Virtual Address Space

Able to control precise timing and amount of DMA
→ Peak Performance

Need to address what cache did
→ More efforts
DMA issued by SPE (MFC)

* MFC DMA address space to main memory is EA Space.
* Each LS can be mapped to EA space.
SPE Memory Architecture

* Like no other ...
- Small (256KB) and High speed LS, instead of Cache
  * LS stands for Local Store
- Intelligent DMA (MFC, EA based, Coherent Check)
  * EA stands for Virtual Address Space

Able to control precise timing and amount of DMA
→ Peak Performance

Need to address what cache did
→ More efforts
Status of Linux Distro for Cell/B.E. and PS3
Yellow Dog Linux

* Nov, 2006
  - YDL 5.0

* Jun, 2007
  - YDL 5.0.2
* April, 2007
  - Ubuntu 7.04

* Oct, 2007
  - Ubuntu 7.10
* May, 2007
- Fedora 7

* Nov, 2007
- Fedora 8 – Under Development
Oct, 2007
- Open Suse 10.3

Linux and Open Source Blog

October 6, 2007

OpenSUSE 10.3 On PS3

The spacy power team concentrated for openSUSE 10.3 on supporting the
Sony PlayStation 3, the major changes are:

- openSUSE 10.3 is fully
  installable with YAST on the
  Sony PlayStation 3.
- a hmv based bootloader
  (called peBStoD) is used for PS3.
- There is a development pattern for Cell development on PS3 to
easily install the needed packages.

More details on installing openSUSE 10.3 on PS3 can be found at

Besides the PS3, 10.3 also runs on the previously supported Apple
Power Mac, IBM POWER, and Pegasos PPC hardware for details see
http://en.opensuse.org/POWER.

2 Comments

1. wow, great article. Although i haven't seen someone did this
   before.

   wait, if it was in front of my PlayStation, then it means i want to
   play Final Fantasy or Tetris, not Linux anymore.

   btw, did the mouse and keyboard is a regular mouse and
   keyboard or especial for PS3 only?

   Comment by linux newbie — October 6, 2007 @ 2:19 pm

2. L-unknown wrote an interesting post today ohhie's a quick
   mesgIntroopenSUSE 10.3 is fully installable with YAST on the Sony
   PS3.

   Comment by linux newbie — October 6, 2007 @ 2:19 pm

3. welcome window users.

4. i am not windows.

4d. getting sure help

4e. sid 10 installation

4f. openoffice.org writer

4g. open source apps.

poll booth

Preferred distro poll has been ended, see new one.

Search

topics & categories

Applications/Software (446)

Brokers (122)
And More…

You can install your favorite Distro!
Cell/B.E. Performance

What can you do with SPEs
Examples - Finance & Recognition

Multi-period Stochastic Portfolio Optimizer

Performance of Important subroutine (Cholesky factorization)

<table>
<thead>
<tr>
<th>GFLOPS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell/B.E. 3.2GHz</td>
<td>175 (8SPE)</td>
</tr>
<tr>
<td>Core2Duo 2.6GHz</td>
<td>33 (2Core)</td>
</tr>
</tbody>
</table>

5 times faster!!

Real-Time Object Recognition with MPEG2 HD Stream

Object Recognition Speed (msec/frame)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell/B.E. 3.2GHz</td>
<td>27.1 (4SPE)</td>
</tr>
<tr>
<td>Core2Duo 3.0GHz</td>
<td>57.9 (2Core)</td>
</tr>
</tbody>
</table>

2 times faster!!
Multi-period portfolio management theory
- calculates the optimal portfolio in every future periods
- formulated as a large scale liner programming
Power of Cell Broadband Engine
Hiroyuki Machida / Sony Corp.

What is demonstrated

Real-Time Object Recognition with MPEG2 HD Stream

As an example of a High Performance Application enabled by the Cell Broadband Engine (Cell/B.E.), we demonstrate Real-Time Object Recognition with a MPEG2 HD stream, implemented using a version of OpenCV optimized for the Cell/B.E. For reference, we also show the same application running on a conventional PC equipped with the latest multi-core CPU. The PC cannot achieve such a real-time performance as the Cell/B.E..

<table>
<thead>
<tr>
<th>Hardware</th>
<th>mSec/frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell/B.E. 3.2GHz</td>
<td>27.1 (4SPE)</td>
</tr>
<tr>
<td>Core2Duo 3.0GHz</td>
<td>57.9 (2Core)</td>
</tr>
</tbody>
</table>

How it was improved

Object Recognition Speed

- Functions in OpenCV have been off-loaded to multi-core SIMD processors (SPE) inside Cell/B.E.

Hardware Information

PLAYSTATION®3

Patch or technical information availability

Cell/B.E. optimized OpenCV Project
http://cell.fixstars.com/opencv/index.php/OpenCV_on_the_Cell

Cell/B.E. optimized OpenCV Patches
https://sourceforge.net/projects/cvcell/

OpenCV Project
http://opencvlibrary.sourceforge.net/
Hello SPE

An Introduction to SPE Programming
**SPE Programming Environment**

* SPE management library - libspe2

* SPU toolchain - spu-gcc, ...
  - GCC, BINUTILS

* libc for SPE - newlib
  - SPE Optimized strings/mem functions, PPE offloading, ...

* SPE elf program launcher - elfspe

* Combined GDB – ppu-gdb
  - both PPU and SPU programs.

* PPU optimized toolchain (recommended)
  - ppu-gcc, ...
  - GCC, BINUTILS

---

Diagram of SPE runtime environment
Typical Cell/B.E. Program Execution Flow

* PPE Side
  - `spe_create_context()`
  - `spe_image_open()`
  - [1] `spe_program_load()`
  - [2] `spe_context_run()`

* SPE Side
  - [3] Data: Main Memory $\rightarrow$ LS
  - [5] Data: LS $\rightarrow$ Main Memory
  - [6] Signal to PPE program
Hello SPE

* elfspe allows small stand alone SPE program run directly

```c
#include <stdio.h>

int main(unsigned long long spe, unsigned long long argp, unsigned long long envp)
{
    printf("Hello SPE!\n");
    return 0;
}
```

% spu-gcc -Wall -Os -ffast-math -ftree-vectorize -ffunction-sections -fdata-sections -Wl,-gc-sections -o hello-spe.elf hello-spe.c

% ./hello-spe.elf
Hello SPE!

* For more details, please see “Cell Programming Primer” in PS3 Linux Distributor's Starter Kit
PS3 Linux Documentation

* Linux Kernel Overview
* How to Enable Your Distro
* Booting Linux and Installation
* Platform Specific Utilities
* Application Programming Environment
* Open Source Communities
* **Cell Programming Primer**

It’s a entry-level Cell/B.E. programming tutorial
Various OSS activities
Linux Distribution Starter’s Kit

* Latest Releases
  - V1.4.1 Aug 2007 Geoff’s Kernel.Org Git Tree Kernel
  - V1.5 Oct 2007 Performance Monitor Support

* Purpose
  - Providing technical information to create Linux distributions on PS3

* Contents
  - PS3 Linux Documentation
  - PS3 Linux kernel source
  - PS3 Platform utilities with source
  - PS3 framebuffer sample programs
  - PS3 Linux boot loader (kboot)

* CD-image

* Extracted (v1.5)
Contributions to The Latest Kernel

* Most PS3 support got mainlined in 2.6.23

* Become third contributed company in Japan
  - both in # of change lines and change sets

* Who wrote 2.6.23
  - [http://lwn.net/Articles/247582/](http://lwn.net/Articles/247582/)

* Who's writing Linux?
Summary of Community Activities

* OSS for CBE ML
  - Discussing Cell/B.E. open software, including PS3 Linux kernel, other Linux on Cell, libspe, and so on.
  - URL: https://ozlabs.org/mailman/listinfo/cbe-oss-dev

* Linux on PowerPC developers’ ML
  - URL: https://ozlabs.org/mailman/listinfo/linuxppc-dev

* GCC Web Site and ML
  - URL: http://gcc.gnu.org/

* Binutils Web Site and ML
  - URL: http://sourceware.org/binutils/

* GDB web Site and ML
  - URL: http://sourceware.org/gdb/

* Newlib Web Site and ML
  - The matter about newlib, which is used as C library for SPE, is discussed in Newlib ML.
  - URL: http://sourceware.org/newlib/

* kboot Web Site and ML
  - URL: http://kboot.sourceforge.net/

* Perfmon2
  - URL: http://perfmon2.sourceforge.net
Summary of Community Activities - 2

* Bullet Physics Library
  - SIMD and Vector math library also included in
  - http://sourceforge.net/projects/bullet/

* OpenCV for Cell
  - open source computer vision library

* Cell Broadband Engine Architecture forum @ IBM developersWorks

* Georgia Tech Cell BE Libraries
  - FFT, GZIP, MPEG2 and RC5
  - http://sourceforge.net/projects/cellbuzz
It’s Time to Try By Yourself !!

* Anyone can use favorite Linux Distro on PS3.

* Utility of SPE is key of high performance.

* Starting SPE programming is easy and must be fun.

* Various community activities have arisen.

Let’s Install Linux to your PS3 and get start SPE programming.
Appendix
Development Packages

* **IBM Cell BE SDK 3.0** - FC7 based packages

* Documents

* YDL 5.0.2 includes some of **IBM Cell BE SDK 2.0** packages

* Ubuntu 7.04 –Beta deb packages (**IBM Cell BE SDK 2.1** based)
  - deb http://people.ubuntu.com/~doko/ubuntu feisty-proposed/
  - deb-src http://people.ubuntu.com/~doko/ubuntu feisty-proposed/

* Ubuntu 7.10 will include some of **IBM Cell BE SDK 3.0** packages
Development Packages

* Mandatory
  - GCC for SPU
    * spu-gcc-4.1.1-107.ppc.rpm
    * spu-gcc-c++-4.1.1-107.ppc.rpm
  - BINUTILS for SPU
    * spu-binutils-2.17.50-8.33ppc.rpm
  - GDB for both PPU and SPU
    * ppu-gdb-6.6.50-28.ppc.rpm
  - newlib - libc for SPU
    * spu-newlib-1.15.0-82.ppc.rpm
  - libspe2 - SPE management library
    * libspe2-2.2.0-91.ppc.rpm / .ppc64.rpm
    * libspe2-devel-2.2.0-91.ppc.rpm / .ppc64.rpm
    * libspe2man-2.2.0-91.noarch.rpm
  - elfspe - SPE elf launcher
    * elfspe2-2.2.0-91.ppc.rpm
Development Packages

* Recommended
  
  - **PPU optimized toolchain**
    * **PPU BINUTILS**
      - ppu-binutils-2.17.50-32.ppc.rpm
    * **PPU GCC**
      - ppu-gcc-4.1.1-57.ppc.rpm
      - ppu-gcc-c++-4.1.1-47.ppc.rpm
      - ppu-gcc-fortran-4.1.1-57.ppc.rpm

  - **SIMD and Vector Math**
    * simd math 1.02 & vector math 1.01
    * As part of bullet physics lib
Cell/B.E. Programming Tips

* Consider to use ppu-gcc.
  - 20% faster code, according with some measurement.

* Be careful, default GCC ABI is up to configuration.
  - ppu-gcc 64bit (-m64) is default
  - gcc on Fedora 32bit (-m32) is default

* Recommended spu-gcc/spu-g++ options
  - -Os -ffast-math -ftree-vectorize
    -Wl,-gc-sections -ffunction-sections -fdata-sections
    -fno-rtti -fno-exceptions (g++)
  Use -O3 -funroll-all-loops, instead of -Os, for faster code

* Consider giving a hint to spu-gcc for branch prediction,
  - builtin_expect()
Summary of Community Activities

* **OSS for CBE ML**
  - Discussing Cell/B.E. open software, including PS3 Linux kernel, other Linux on Cell, libspe, and so on.
  - URL: [https://ozlabs.org/mailman/listinfo/cbe-oss-dev](https://ozlabs.org/mailman/listinfo/cbe-oss-dev)

* **Linux on PowerPC developers’ ML**
  - URL: [https://ozlabs.org/mailman/listinfo/linuxppc-dev](https://ozlabs.org/mailman/listinfo/linuxppc-dev)

* **GCC Web Site and ML**

* **Binutils Web Site and ML**
  - URL: [http://sourceware.org/binutils/](http://sourceware.org/binutils/)

* **GDB web Site and ML**
  - URL: [http://sourceware.org/gdb/](http://sourceware.org/gdb/)

* **Newlib Web Site and ML**
  - The matter about newlib, which is used as C library for SPE, is discussed in Newlib ML.
  - URL: [http://sourceware.org/newlib/](http://sourceware.org/newlib/)

* **kboot Web Site and ML**

* **Perfmon2**
  - URL: [http://perfmon2.sourceforge.net](http://perfmon2.sourceforge.net)
Summary of Community Activities - 2

* Bullet Physics Library
  - SIMD and Vector math library also included in
  - http://sourceforge.net/projects/bullet/

* OpenCV for Cell
  - open source computer vision library

* Cell Broadband Engine Architecture forum @ IBM developersWorks

* Georgia Tech Cell BE Libraries
  - FFT, GZIP, MPEG2 and RC5
  - http://sourceforge.net/projects/cellbuzz
Legal Statement

* My talk is based on public-available information and doesn't represent any of Sony Corp. and/or Sony Computer Entertainment Inc. positions and/or opinions.

* "Linux" is a registered trademark of Linus Torvalds.
* "PLAYSTATION" and "PS3" are registered trademarks and "Cell Broadband Engine" is a trademark of Sony Computer Entertainment Inc.
* "IBM" and "IBM (logo)" are trademarks or registered trademarks of International Business Machines Corporation.
* Other company, product, and service names/logs may be trademarks or service marks of others.