Status update of NVIDIA’s performance counters for Nouveau

Samuel Pitoiset

Nouveau & X.Org developer enthusiast

September 17th, 2015
Who am I?

Open source enthusiasm
- Nouveau & mesa contributor
  - performance counters (most of the time) & small GL bug fixes
- Google Summer of Code student in 2013 & 2014
- XDC talk last year in Bordeaux, France

Real life job
- Got my master degree last year
- HPC engineer at INRIA, Bordeaux
  - developing a source-to-source OpenMP compiler (Clang)
1 Introduction
   - What are performance counters?
   - NVIDIA’s perf counters
   - NVIDIA’s profiling tools

2 Case study

3 Reverse engineering

4 Nouveau & mesa

5 APIs & Tools

6 Conclusion
What are performance counters?

**Performance counters**
- are blocks in modern processors that monitor their activity
- count low-level hardware events such as cache hits/misses

**Why use them?**
- to analyze the bottlenecks of 3D and GPGPU applications
- to dynamically adjust the performance level of the GPU

**How to use them?**
- GUIs like NVIDIA Nsight and Linux Graphics Debugger
- APIs like NVIDIA CUPTI and PerfKit
- OpenGL extensions like GL_AMD_performance_monitor
NVIDIA’s performance counters

Two groups of counters exposed

- **compute counters** for GPGPU applications
  - ex: warps_launched, divergent_branch ...
- **graphics counters** for 3D applications
  - ex: shader_busy, texture_busy ...

Different types of counters

- **global** counters
  - collect activities regardless of the context
- **local** counters
  - collect activities per-context only
NVIDIA’s profiling tools

**Visual Profiler**
- cross-platform performance profiling tools for CUDA apps
- based on CUPTI API (expose compute-related counters)

**Nsight**
- Visual Studio plugin for profiling GL/D3D apps (Windows)
- based on PerfKit API (expose graphics-related counters)

**Linux Graphics Debugger**
- performance profiling tools for GL apps (SIGGRAPH’15)
- expose graphics-related counters on Linux (yeah!)
  - unfortunately, no API like PerfKit is provided
Summary

1 Introduction

2 Case study
   - Improve a GL app with NVIDIA’s tools
   - What about Nouveau?

3 Reverse engineering

4 Nouveau & mesa

5 APIs & Tools

6 Conclusion
How to improve performance of a GL app using perf counters?

Let’s try NVIDIA Linux Graphics Debugger!
Figure: A brain rendered in OpenGL with 165786 voxels
**Improve a GL app**

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<tr>
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The Perf counters include FPS, geom_busy, and shader_busy. The FPS value is 56, geom_busy is 1%, and shader_busy is 0.2%. The value for l2_read_sysmem_sections seems to be very high and is probably one of the bottlenecks.
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mmh...

l2_read_sysmem_sectors seems to **very high** and this is probably one of the bottlenecks!
Problem

- too many memory reads from the system memory
- due to the GPU fetching the vertices at every frame

\[1\] There are probably other bottlenecks but this is just a basic example
**Problem**
- too many memory reads from the system memory
- due to the GPU fetching the vertices at every frame

**Solution**
- use a vbo to store the vertices on the GPU

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- use a vbo to store the vertices on the GPU

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What about Nouveau?

No tools like Linux Graphics Debugger!

... but things are going to change!
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Perf counters project

- started since GSoC’13
- not a trivial project and a ton of work
  - reverse engineering (long and hard process)
  - kernel and userspace support (including APIs & tools)
What about Nouveau?

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- not a trivial project and a ton of work
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Goals & Benefits
- expose perf counters in a useful and decent manner
- help developers to find bottlenecks in their 3D applications.
Summary

1. Introduction

2. Case study

3. Reverse engineering
   - Compute-related counters
   - Graphics-related counters
   - Current status

4. Nouveau & mesa

5. APIs & Tools

6. Conclusion
Compute-related counters

Requirements

- CUDA and CUPTI API (CUDA Profiling Tools Interface)
- valgrind-mmt and demmt (envytools)
- cupti_trace from envytools repository
  - tool which helped me a lot in the REing process
Compute-related counters

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How does it work?

1. launch cupti_trace (ie. cupti_trace -a NVXX)
   - will automatically trace each hardware event exposed
2. grab a cup of coffee :) and wait few minutes
3. traces are now saved to your disk
4. analyze and document them
### Reverse engineering PerfKit on Windows

- really painful and very long process! :(
- no MMIO traces and no valgrind-mmt
- need to do it by hand (dump registers, etc)
  - very hard to find multiplexers
Graphics-related counters

Reverse engineering PerfKit on Windows
- really painful and very long process! :(  
- no MMIO traces and no valgrind-mmt  
- need to do it by hand (dump registers, etc)  
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Reverse engineering LGD on Linux
- this Linux Graphics Debugger saved my brain! :)  
- almost same process as compute-related counters;  
  - but not automatically because it’s a GUI.  
- really easy to find multiplexers this time.
Current status

- **DONE** means it’s fully reversed and documented
- **MOSTLY** means that some perf counters are reversed
- **WIP** means that I started the reverse engineering process
- **TODO** means that it’s on my (long) to do list

<table>
<thead>
<tr>
<th>Perf counters</th>
<th>Tesla</th>
<th>Fermi</th>
<th>Kepler</th>
<th>Maxwell</th>
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<tr>
<td>Graphics</td>
<td>MOSTLY(^1)</td>
<td>DONE</td>
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<td>TODO</td>
</tr>
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<td>Compute</td>
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\(^1\)Except per-context counters (requires PerfKit).
\(^2\)Need to RE new counting modes.
\(^3\)Only on GM107 and need to RE per-context counters logic.
Summary

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   - Kernel interface
   - Synchronization
5. APIs & Tools
6. Conclusion
Kernel interface

Why is a kernel interface needed?
- because **global counters** have to be programmed via MMIO
  - only root or the kernel can write to them

What the interface has to do?
- set up the configuration of counters
- poll counters
- expose counter’s data to the userspace (readout)
Synchronization

Synchronizing operations

- CPU: ioctlS
- GPU: software methods

Software method

- command added to the command stream of the GPU context
- upon reaching the command, the GPU is paused
- the CPU gets an IRQ and handles the command
**Perfmon work**

- expose low-level configuration of perf counters
  - include lot of signals/sources for Tesla, Fermi and Kepler
- allow to schedule/monitor perf counters from the userspace
  - based on nvif (ioctlS interface)
- no Perf support is planned for now!
NV50 driver

- patches series already submitted to mesa-dev (pending)
  - because this requires a libdrm release with nvif support
- will expose around 30 global perf counters
- will enable GL_AMD_performance_monitor

NVC0 driver

- patches still in my local tree but almost ready
- will expose around 80 global perf counters for Fermi/Kepler
Summary

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   - GL_AMD_performance_monitor
   - Nouveau PerfKit
   - Apitrace

6. Conclusion
GL_AMD_performance_monitor

**OpenGL extension**

- based on pipe_query interface
- drivers need to expose a group of GPU counters to enable it
GL_AMD_performance_monitor

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**Current status**
- released in mesa 10.6
- expose per-context counters on Fermi/Kepler
  - this requires compute support to launch kernels
- used by Apitrace for profiling frames (GSoC’15)
**GL_AMD_performance_monitor**

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**Cons**
- do not support round robin sampling and multi-pass events
- do not fit well with NVIDIA hardware (obviously)
Nouveau PerfKit

Linux version of NVIDIA PerfKit

- built on top of mesa (as a Gallium state tracker like VDPAU)
- needed to reverse engineer the API (return codes, etc)
  - around 100 unit/functional test have been written
- implemented libperfkit with both Windows and Linux support
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**Pros**
- allow support of round robin sampling and multi-pass events

**Current status**
- RFC submitted in June (around 1700 LOC, still in review)
- will expose more perf counters than gl_amd_perfmon
- no users for now but Apitrace could use PerfKit
Apitrace

GSoC’15 project
- add support for performance counters in the profiling view
- project by Alex Tru (mentored by Martin Peres)
GSoC’15 project

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DONE (but still not upstream)

- abstraction system for profiling in glretrace
  - support for GL_AMD_perfmon and Intel_perfquery
  - allow to query and to monitor metrics
Apitrace

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**DONE (but still not upstream)**
- abstraction system for profiling in glretrace
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**WIP**
- profiling view improvements for qapitrace
  - some minor parts are done but very basic visualization
Let’s go back to the case study but now with...

... Apitrace and Nouveau!
How to list available metrics?

- `glretrace -list-metrics <trace>`

**Backend GL_AMD_performance_monitor:**

**Group #0: Global performance counters.**
- Metric #0: `shader_busy` (type: CNT_TYPE_GENERIC, type: CNT_NUM_UINT64)
- Metric #1: `ia_requests` (type: CNT_TYPE_GENERIC, type: CNT_NUM_UINT64)
- Metric #2: `texture_busy` (type: CNT_TYPE_GENERIC, type: CNT_NUM_UINT64)

**Group #1: MP counters.**
- Metric #0: `active_cycles` (type: CNT_TYPE_GENERIC, type: CNT_NUM_UINT64)
- Metric #1: `active_warps` (type: CNT_TYPE_GENERIC, type: CNT_NUM_UINT64)

**Backend opengl:**

**Group #0: CPU.**
- Metric #0: `CPU Start` (type: CNT_TYPE_TIMESTAMP, type: CNT_NUM_INT64)
- Metric #1: `CPU Duration` (type: CNT_TYPE_DURATION, type: CNT_NUM_UINT64)
**Figure:** List of available metrics in Apitrace
Apitrace/Nouveau

How to profile a GL app?

```bash
$ glretrace -pframes="GL_AMD_perfmon: [0,65]" <trace>
```

```
# ia_requests
frame 285734
frame 285799
frame 285793
frame 285763
frame 285762
frame 285809
frame 285800
frame 285744
frame 285743
frame 285796
frame 285893
frame 285818
frame 285754
frame 285804
frame 285762
frame 285763
frame 285813
frame 285804
frame 285815
frame 285747
frame 285754
```

Rendered 20 frames in 0.3365 secs, average of 59.4344 fps
Figure: Very basic visualization with histograms in Apitrace
### Apitrace/Nouveau

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<td>17%</td>
</tr>
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<td>0.5%</td>
<td>1%</td>
</tr>
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<td>286000</td>
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<td>35</td>
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<tr>
<td>FPS</td>
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¹Without reclocking
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   - Current status
   - Future work
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Reverse engineering

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- perfmon work merged in Linux 4.3
- GL_AMD_performance_monitor merged in mesa 10.6
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Nouveau DRM & mesa
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Userspace tools
- GL_AMD_perfmon used by Apitrace!
- perf counters are going to be exposed in a useful manner. :)
Future work

**Short-term period**

- add more signals & sources for Fermi and Kepler
- rework the software methods interface
- release libdrm with nvif support (Ben Skeggs)
- complete the support of perf counters in mesa
  - this will expose GL_amd_perfmon on Tesla
  - this will expose lot of perf counters on Tesla, Fermi and Kepler
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Long-term period

- finish implementation of Nouveau PerfKit
  - and make something use it (Apitrace?)
- reverse engineer Maxwell performance counters
Thanks!

I would like to thank the X.Org board members for my travel sponsorship!

Feel free to ask questions...