Systematic profiling to monitor and specify the software refactoring process of the LHCb experiment

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October 14th, 2013
Computing environment

- **Distributed computing**: Worldwide LHC Computing Grid, Cloud technology, HLT computing farm.
- **Parallel processing**: Multi-Threading, Multi-Processing and GPU processing is advancing.
- **Virtualization**: Used in Grid and Cloud.
- Recently **volunteer computing** using BOINC.

LHCb software frameworks and applications

- **Gaudi**, the *general data processing framework* of LHCb, is a *template C++ framework* to provide basic services and tools. Gaudi *applications are using Gaudi to implement algorithms* (software modules) to perform the event processing.

Applications which are using Gaudi are:
- Moore, High-Level-Trigger (HLT) framework.
- Brunel, offline-reconstruction.
- Gauss, monte-carlo simulation framework.
- and others.

Gaudi is **used by LHCb, ATLAS and other non-LHC experiments**.
Software is **continuously evolving**

- Continuous source-code development.
  
  *New or improved algorithms, services or tools.*

- Integration of external software.
  
  *E.g. transition from Root 5 to Root 6 will integrate Cling.*

**Software refactoring** during Long Shutdown (LS1) and beyond:

- HLT splitting in HLT1 and HLT2.
  
  *More filtering by increasing quality and precision.*

- Introducing GaudiMP for moldable job submission in the Grid. [1]
  
  *Reduce memory consumption by exploiting parallelism.*

- Redesigning Gaudi for Gaudi-Hive. [2]
  
  *Introducing multi-threading to increase CPU exploitation.*

**Advancing technology**

- Performance impact of new Platforms.
  
  *Changing OSes, New hardware architectures.*

- New compiler optimizations.
  
  *Auto-vectorization, auto-parallelization, profile guided optimization.*

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**Always the same questions**

- **Is it worth it?** *How is the expected and final performance impact?*
Integrated Profiling

Profiling Information

- Integrate profilers into your environment
  e.g. Valgrind accessible from AFS, TCMalloc usable by flag, IgProf usable by flag, etc.

- Insert routines for instrumentation
  GaudiAuditor can be used to insert routines within event-loop.

- Profile your development progress
  Everyone is required to profile his work.

Many implementations have been conducted successful:

- Timing- and MemoryAuditor (using process info.)
- Precise timing per function, algorithm, library and more using IntelAuditor [4].
- HW-Event based profiling (cache-misses, branch-prediction, ...)
- Sophisticated memory analysis (shadow memory, heap analysis)
- Creation of call-graphs

Important

Integration of profiling tools to be accessible throughout nodes and instrumentation is an important step for high-performance software, and already performed for the Gaudi-Framework.
Problems

Usage of profiling must go above the temporal use! But:

- Reduced use cases and limitations of tested code regions, makes them incomparable.
- Many are un reproducible due to unknown test configuration.
- Apply only for uncommon or unrepresentative use cases.
- Are labor intensive if done regularly and precise.

Idea

- **General use cases** give approximated profiles to become comparable.
- Processing on a limited set of representative reference data.
- Test configuration must be stored to become reproducible.
- **Regular execution** in a serious of same test runs to increase precision and keep track on changes.
- **Facilitate analysis** by unifying profile results into a single web application.
Solution

The **LHCb performance & regression (PR) Project**

* A system to provide tools for test execution, collecting core information and support for analyzing profiles.

**Major goal:** Observe general performance to estimate resource consumption and to find anomalies in these. Hence we perform a kind of top-down analysis.

Technical requirements

- Flexible and extensible integration into the LHCb PR project of any profiling tool.
  
  *Create and parse reports to store profiling results using data handlers.*

- Quick access to general and detailed performance information of executed profiles.
  
  *Customized visualization to browse results intuitive and comprehensive using a web interface.*

- Reduce work by investigating generic ways of navigation and visualization.
  
  *Use a productive web application framework, reuse visualization tools.*

- Automation in case of regular profiling and warning generation.
Predefine parametrized job configuration to define your test cases.

Use a job trigger for automated profile initiation.

Avoid overcommitting nodes (job queue).

Benefit from using Jenkins:

- Highly configurable.
- Many additions due to plug-in support.
- Big development and user community.
Workflow of profiling - 2

- **Job configuration persists out of:**
  - Parameter from test configuration.
    - Environmental setup (like CMTCONFIG, MYSITEROOT, ext.) relies on test configuration.
  - Run configuration.
    - Option files from PRConfig.
  - Profiler dependent setup.
    - Choice of used profiler (wrapper) & handlers.

- **Wrapper perform:**
  - Setup of environment
  - Call of profiler and execution of test job.
  - Choice of data handlers for collecting core information.

- **Handler perform:**
  - Parsing information from profiles.
  - Hook data to storage element for later import to DB.
For tracking general performance it is important to know about the overall performance of a specific test case and to compare it across single differing parameters like version or platform.

To visualize values of an attribute like event-loop (runtime per event) for multiple runs, the BASIC analysis shows the distribution. This can be compared with other run-configurations.

Visualization using ROOT diagrams.
Keep an eye on Modules

Plenty of modules (algorithms/libraries) are profiled. **Single changes can affect all Modules** in runtime. Profile *regular also with minor software changes* to find the origin.

OVERVIEW-Analysis: Overview about attributes

Attributes can be specific modules or categories of performance, like resident memory. Plenty of attributes are available. The **overview analysis gives a quick impression** and makes comparisons between few versions and platforms possible.

Visualization using Google Charts.
Use case High-Level-Trigger

**Structural Problem**
Some further structural problems have been found by profiling Moore.

- **TCK’s (Trigger Configuration Keys) configure different set of algorithms**, what makes the **definition of a default use case difficult**.
- **Differences in same Algorithms** are expected. The first calling algorithm performs creation of certain objects. Algorithms do not have a fixed execution order.
- **Runtime environment** in HLT computer farm **differs** from execution with test jobs on a local machine. Indeterminism in complex environments makes profiles varying and be less expressive for source-code performance.

1) & 3) increases the **differences between test-cases and production**. Differences rely partially on **indeterministic influences** which make performance comparison less accurate.

2) can be addressed by segregating **call-stacks for each algorithm**, but uses a lot of space. E.g. VTune is not delivering such information in great details by command-line.
Conclusions & Perspective

Conclusions:

- LHCb PR has shown to be **easily usable** to point out **core issues** of performance.
- Benefit from **automated profiling** for a series of regular profiles allowing statistical analysis.
- **Flexible extensible framework** to integrate further tools for profiling.
- Using **clear visualization** with support to propagate results **assures improvements** in performance.

**Don’t reinvent the wheel:**

- Jenkins has shown to be highly valuable.
- Django is speeding up adaption in the web-based analysis interface.
- Use available profilers, that has demonstrate their usability.

Future perspective:

- **Function-call stack as complementary** information should be accessed and integrated into the web interface.
- **EBS** is currently not integrated but **has shown more and more to be effective** to find software performance issues.
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Questions?