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

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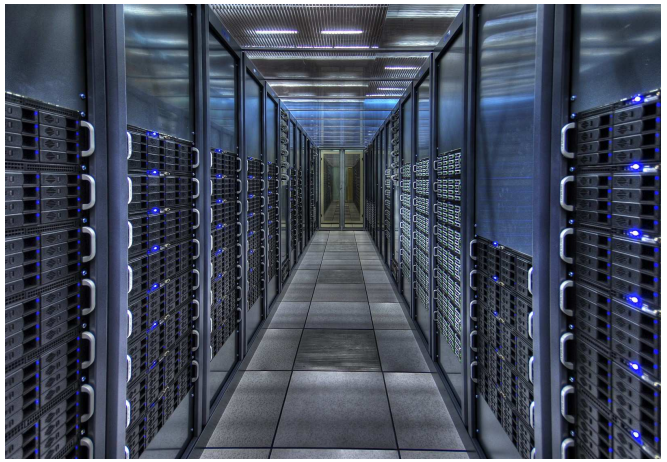
Introduction - 1

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.



Photograph: Roger Claus CERN, Date: 07 Aug 2010

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**.

Introduction - 2

- 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.

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, TCMallog usable by flag, IgProf usable by flag, ect.

- 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.

Systematic Profiling - 1

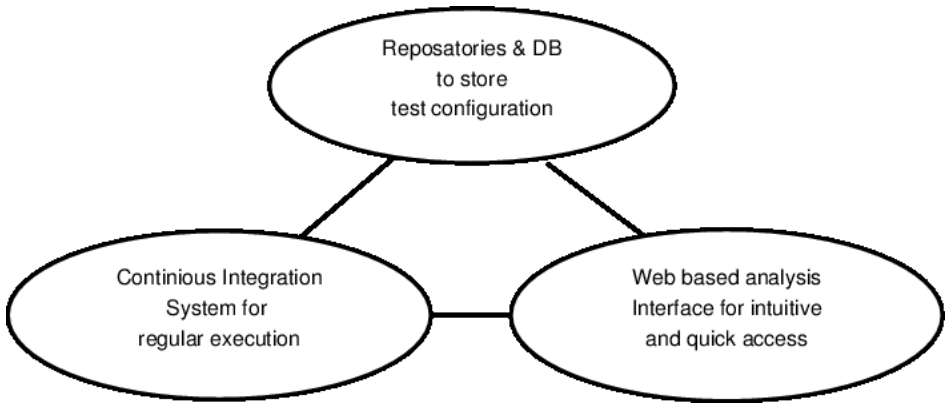
Problems

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

- Reduced use cases and limitations of tested code regions, makes them **incomparable**.
- Many are **unreproducible** 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.



Systematic Profiling - 2

Solution

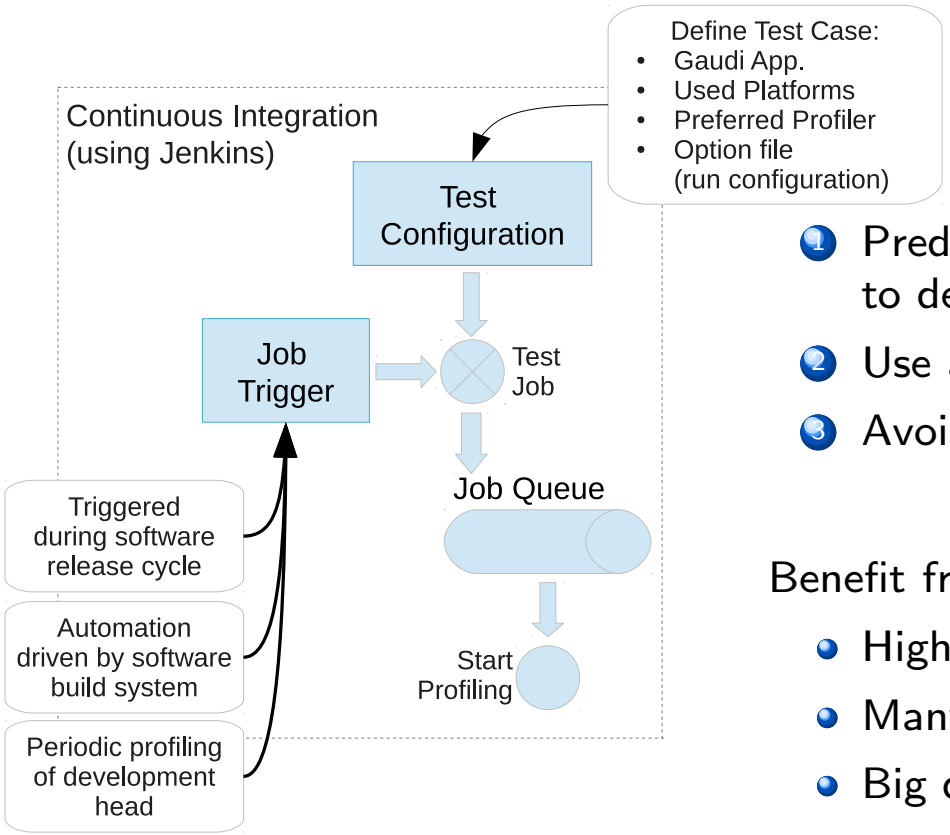
The **LHCb performance & regression (PR) Project**
A system to provide tools for test execution, collecting core information and support for analyzing profiles.

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.

Workflow of profiling - 1

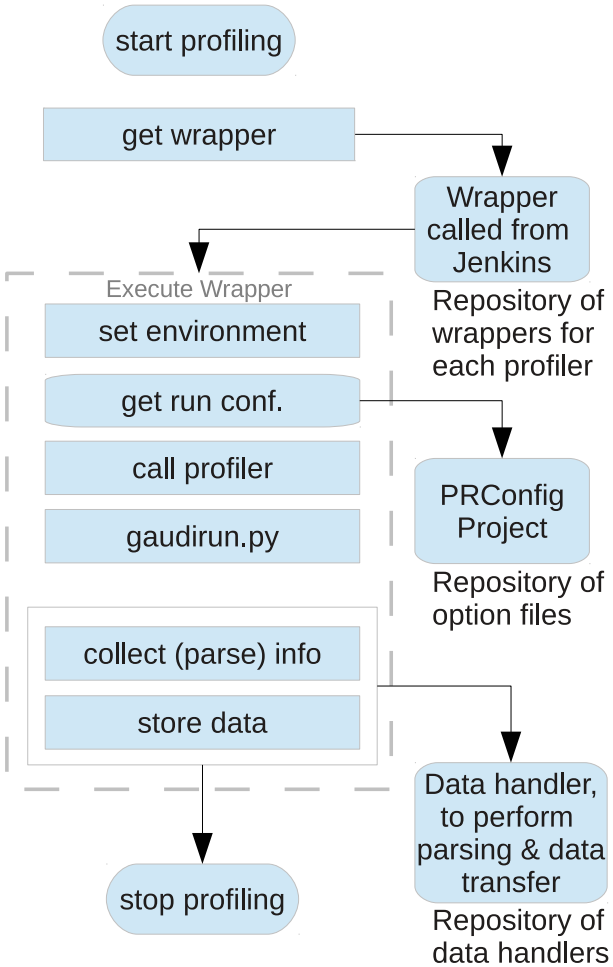


1. Predefine parametrized job configuration to define your test cases.
2. Use a job trigger for automated profile initiation.
3. Avoid overcommitting nodes (job queue).

Benefit from using Jenkins:

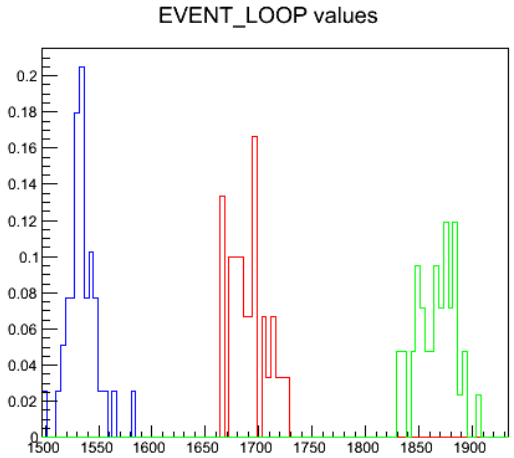
- Highly configurable.
- Many additions due to plug-in support.
- Big development and user community.

Workflow of profiling - 2

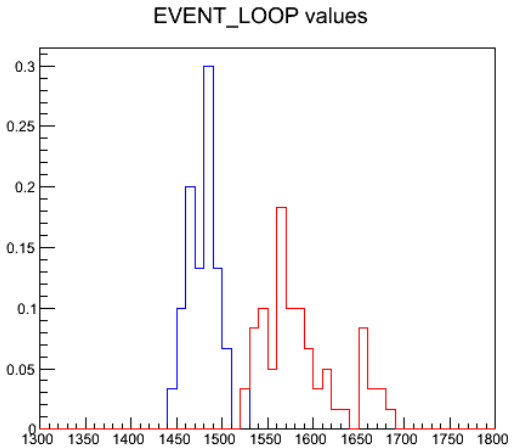


- Job configuration persists out of:
  - Parameter from test configuration.
    Environmental setup (like CMTCONFIG, MYSITEROOT, ext.) relies on test configuration.
  - Run configuration.
    Option files from PRConfig.
  - Profiler dependent setup.
    Choice of used profiler (wrapper) & handlers.
-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

Tracking General Performance - 1



(Blue) peak shows runtime per event in millisecond in Brunel v44r0 with intel's math library, (red) libm of glibc-2.5.65 and (green) libm glibc-2.5.107.



(Red) shows runtime of Brunel on SLC5 vs. (blue) SLC6.

Know your position

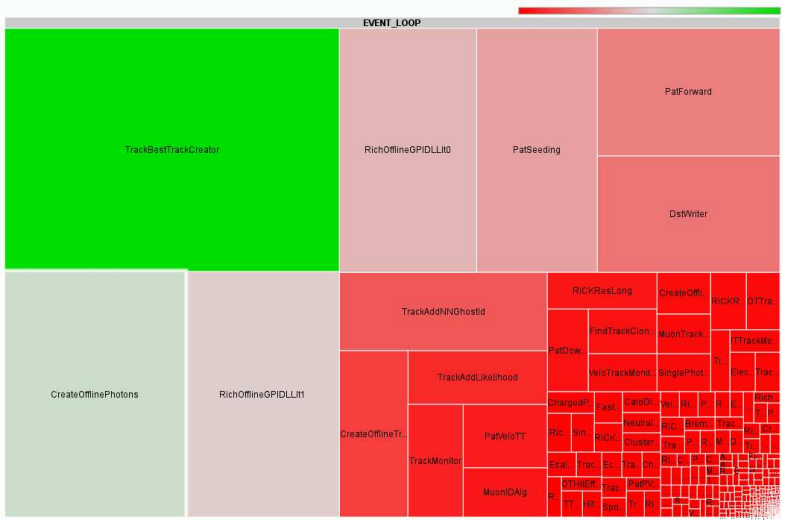
For tracking general performance it is important to know about the **overall performance of a specific test case** and to compare it cross single differing parameters like version or platform.

BASIC-Analysis: Shows attribute distribution

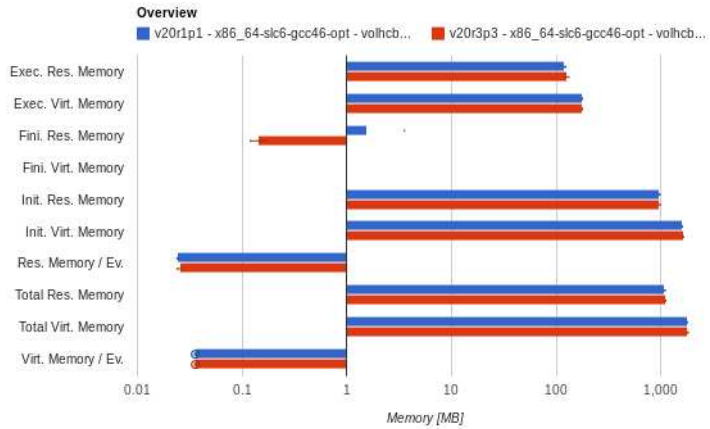
To visualize values of an attribute like event-loop (runtime per event) for multiple runs, the BASIC analysis shows the distribution. This can be compared with other run-configurations.

Visualization using ROOT diagrams.

Tracking General Performance - 2



Overview of runtime proportional to others.



Comparing memory for Moore between versions.

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.

1. TCK's (Trigger Configuration Keys) configure different set of algorithms, what makes the **definition of a default use case difficult**.
2. **Differences in same Algorithms** are expected. The first calling algorithm performs creation of certain objects. Algorithms do not have a fixed execution order.
3. **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.

References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Questions?