Memory allocation profiling in real-world applications

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› 18/08/2016

CERNopenlab

Challenge

CERN operates a network of six accelerators and a decelerator. Each machine in the chain increases the energy of particle beams before delivering them to experiments or to the next more powerful accelerator. Two linear accelerators generate low energy particles. Linac2 accelerates protons to 50 MeV for injection into the Proton Synchrotron Booster (PSB), and Linac3 provides heavy ions at 4.2 MeV/u for injection into the Low Energy Ion Ring (LEIR). The Proton Synchrotron Booster increases the energy of particles generated by the proton linear accelerator before they are transferred to the other accelerators. Free pancakes at R2. The Low Energy Ion Ring (LEIR) accelerates the ions from the ion linear accelerator, before transferring them to the Proton Synchrotron (PS). This accelerator was commissioned in 2005, after having been reconfigured from the previous Low Energy Antiproton Ring (LEAR). The 28 GeV Proton Synchrotron (PS), built during 1954—1959 and still operating as a feeder to the more powerful SPS. The Super Proton Synchrotron (SPS), a circular accelerator with a diameter of 2 kilometres built in a tunnel, which started operation in 1976. It was designed to deliver an energy of 300 GeV and was gradually upgraded to 450 GeV. As well as having its own beamlines for fixed-target experiments (currently COMPASS and NA62), it has been operated as a proton–antiproton collider (the SppS collider), and for accelerating high energy electrons and positrons which were injected into the Large Electron–Positron Collider (LEP). Since 2008, it has been used to inject protons and heavy ions into the Large Hadron Collider (LHC). The On-Line Isotope Mass Separator (ISOLDE), which is used to study unstable nuclei. The radioactive ions are produced by the impact of protons at an energy of 1.0–1.4 GeV from the Proton Synchrotron Booster. It was first commissioned in 1967 and was rebuilt with major upgrades in 1974 and 1992. The Antiproton Decelerator (AD), which reduces the velocity of antiprotons to about 10% of the speed of light for research of antimatter. The LHC represents a large-scale, worldwide scientific cooperation project. The LHC tunnel is located 100 metres underground, in the region between the Geneva International Airport and the nearby Jura mountains. It uses the 27 km circumference circular tunnel previously occupied by the Large Electron-Positron Collider (LEP) which was shut down in November 2000.

Source: Wikipedia: CERN

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  - Data throughput increasing
  - Hardware architecture changing

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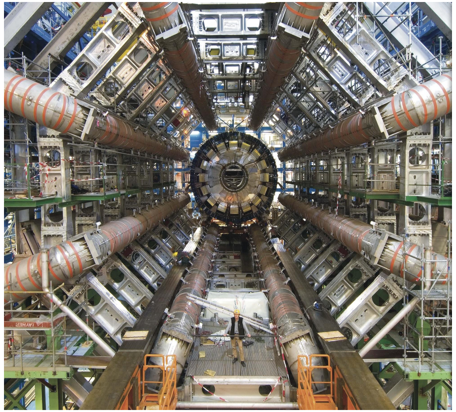
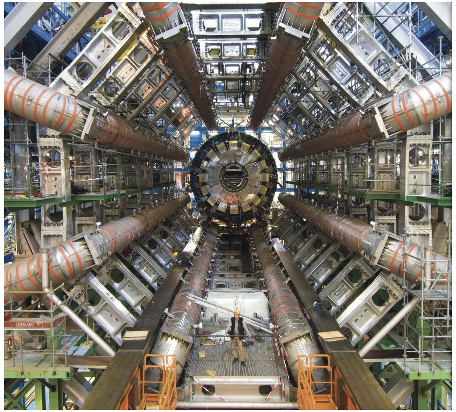
  - online and offline computing in CERN experiments



ATLAS - cern60.web.cern.ch

Motivation

- **Memory bottleneck**
  - Data throughput increasing
  - Hardware architecture changing
- **Create statistics to detect memory waste**
- **Target application**
  - online and offline computing in CERN experiments
  - any real-world data-intensive application



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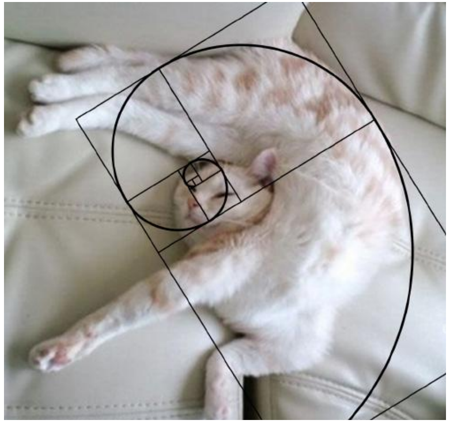
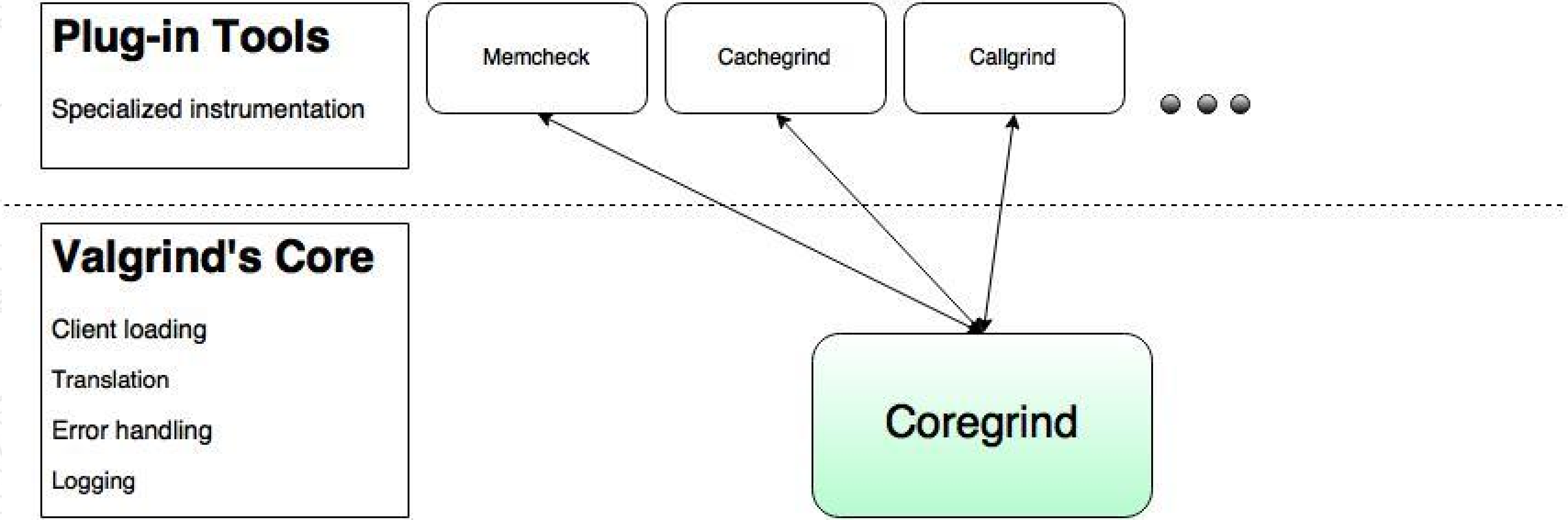


Fibonacci cat - pinterest.com

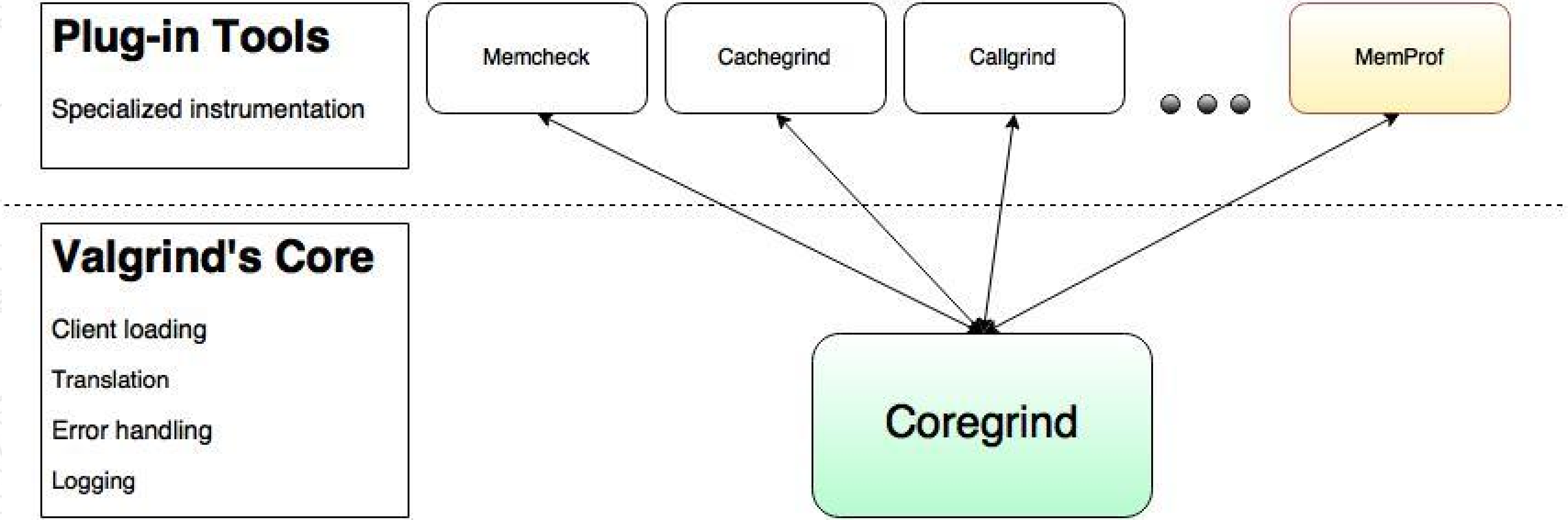
Valgrind

- popular open source project
- analysis at runtime
- 100% coverage
- multithread support
- modular architecture

Valgrind Architecture



MemProf


Plug-in Tools
Specialized instrumentation
Memcheck
Cachegrind
Callgrind
MemProf
Valgrind's Core
Client loading
Translation
Error handling
Logging
Coregrind

MemProf

- **unused memory != memory leak**

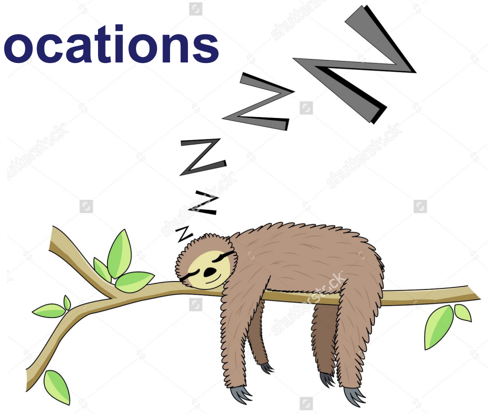
MemProf

- unused memory != memory leak

Source: Shutterstock

MemProf

- unused memory != memory leak
- Tracks memory allocations and deallocations
- Collects relevant info
- Multithreading support
- Memory access patterns



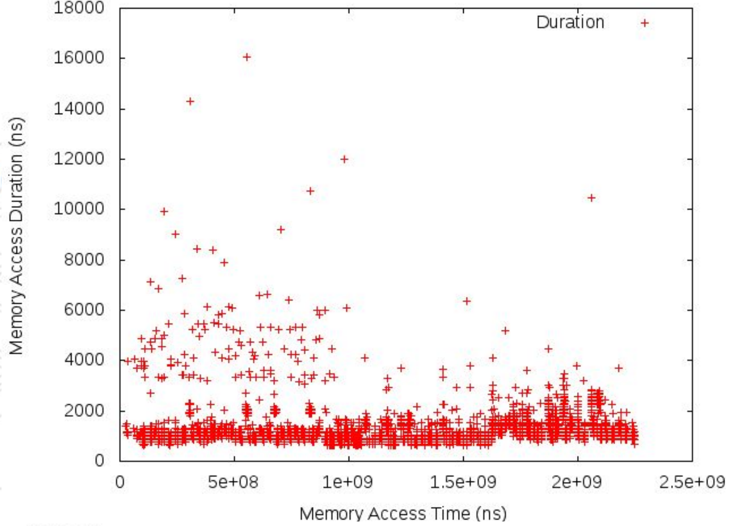
Source: Shutterstock

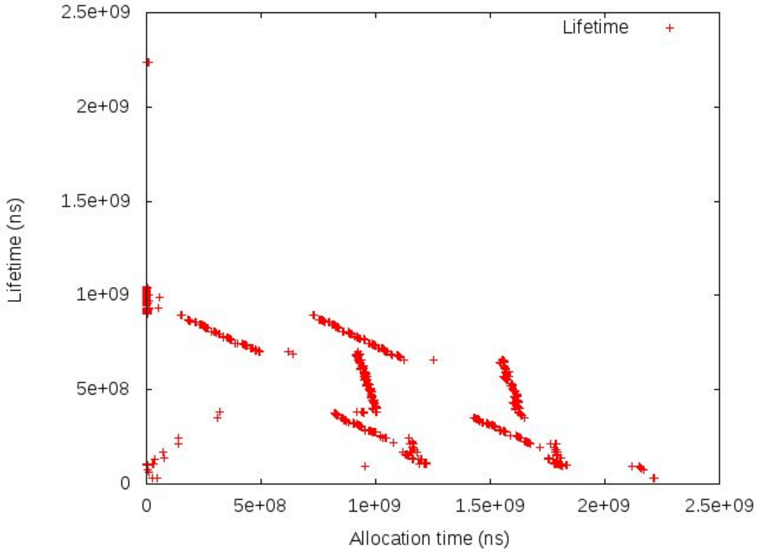
MemProf

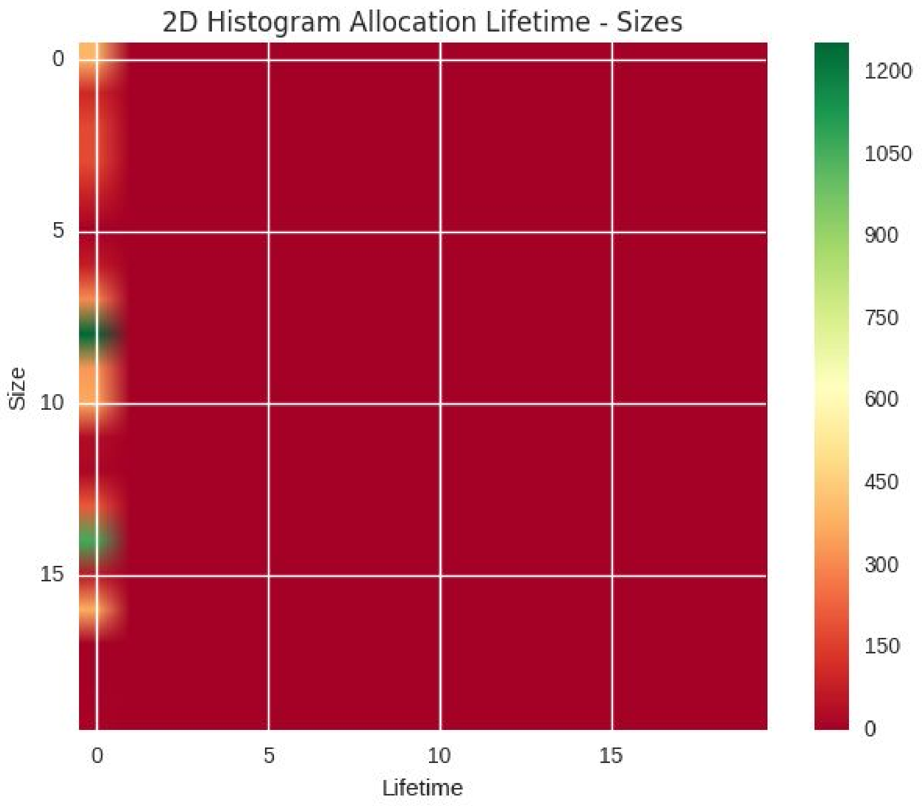
- unused memory != memory leak
- Tracks memory allocations and deallocations
- Collects relevant info
- Multithreading support
- Memory access patterns
- Further work:
  - Compression
  - Track read / write operations

Source: Shutterstock

Results







Background image: Shutterstock

Thank you !

- Thanks to my supervisors:
  - Omar Awile
  - Nathalie Rauschmayr
  - Sami Kama
- Thanks to Openlab Team