APPS ON SPEED

IMPROVING THE PERFORMANCE OF C++ APPLICATIONS

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OUTLINE

- Motivation
- Preparation
- Tooling
- Qt Tips & Tricks

MOTIVATION

RUN EVERYWHERE

Shiny Qt apps on low-end embedded hardware?

Sure!

FASTER IS (PERCEIVED) BETTER

Increase your users productivity.

DO MORE

... in less time.

ENERGY EFFICIENCY

Save costs, trees and battery time!

PREPARATIONS

LET OTHERS WORK FOR YOU

Enable optimizations ***and*** debug symbols for both applications and libraries!

```
g++ -O2 -g ...
```

```
cmake -DCMAKE_BUILD_TYPE=RelWithDebInfo
```

```
qmake CONFIG+=release QMAKE_CXXFLAGS+=-g
```

TESTING TESTING TESTING

Cover the code to be optimized by unit tests.

- Prevent regressions.
- Keep functionality - don't overoptimize.
- Don't be afraid of (extensive?) refactoring.

BENCHMARKING

Write a benchmark for every function you optimize.

- Always do a before/after comparison.
- Minimize code coverage per benchmark.
- Choose an adequate problem size.
- QTestLib has `QBENCHMARK`.

THE ROOT OF ALL EVIL

Don't microoptimize, know the 90%/10% rule.

- Beware of premature optimizations!
- Yet keep premature pessimizations in mind.

KNOWLEDGE IS KING

The more you know, the better you can optimize.

- Use existing solutions, don't reinvent the wheel.
- Know your `<algorithm>`'s.
- Beware: *"Faster"* code might be slower for less data.

TOOLING

LINUX PERF

Performance analysis tools for Linux

- Fast, sampling based wall time profiling.
- Versatile: hardware & software counters, tracepoints
- Cross platform: works wherever Linux runs

LINUX PERF: TOP

Find system-wide hotspots.

Profile across process boundaries.

```
$ sudo perf top

Samples: 10K of event 'cycles', Event count (approx.): 2036162123
2.93%  quickopenbench             QBasicAtomicInt::deref()
2.38%  benchhashes                BenchHashes::typeRepo()
2.34%  libc-2.18.so               _int_malloc
2.17%  libc-2.18.so               _int_free
2.12%  benchhashes                QHash<KDevelop::IndexedString, DataT>::findNode(
1.96%  libc-2.18.so               malloc
1.87%  libkdevplatformtests.so    QBasicAtomicInt::ref()
1.59%  libQtCore.so.4.8.5         0x00000000001b0d37
1.53%  benchhashes                BenchHashes::remove()
1.48%  quickopenbench             QBasicAtomicInt::ref()
1.33%  benchhashes                QHash<KDevelop::IndexedString, DataT>::isEmpty()
1.31%  libkdevplatformproject.so  QVector<QString>::at(int) const
1.27%  benchhashes                std::__detail::_Mod_range_hashing::operator()(un
1.03%  benchhashes                std::_Hashtable<KDevelop::IndexedString...
...
```

LINUX PERF: RECORD/REPORT

Profile individual processes, see callgraphs.

```
$ perf record -g dwarf <yourapp>
# or attach to a running app:
# perf record -g dwarf -p $(pidof <yourapp>)
$ perf report
```

```
-  14.57%  quickopenbench  libkdevplatformproject.so  [.] QVector<QString>::at(int
- QVector<QString>::at(int) const
  - 98.94% KDevelop::Path::operator<(KDevelop::Path const&) const
    - bool qMapLessThanKey<KDevelop::Path>(KDevelop::Path const&, KDevelop::Path c
      + 65.32% QMap<KDevelop::Path, ProjectFile>::mutableFindNode(QMapData::Node**
      + 34.68% QMap<KDevelop::Path, ProjectFile>::remove(KDevelop::Path const&)
    + 0.99% generatePathOrUrl(bool, bool, QVector<QString> const&)
-   6.82%  quickopenbench  libkdevplatformproject.so  [.] KDevelop::Path::operator
  - KDevelop::Path::operator<(KDevelop::Path const&) const
    + 99.93% bool qMapLessThanKey<KDevelop::Path>(KDevelop::Path const&, KDevelop:
+   4.60%  quickopenbench  libQtCore.so.4.8.5         [.] 0x00000000000b25e8
+   3.29%  quickopenbench  libkdevplatformtests.so    [.] QBasicAtomicInt::ref()
+   3.15%  quickopenbench  quickopenbench             [.] QBasicAtomicInt::deref()
+   3.14%  quickopenbench  libQtCore.so.4.8.5         [.] QString::compare(QString
+   2.85%  quickopenbench  libkdevplatformproject.so  [.] QVector<QString>::size()
+   2.52%  quickopenbench  libkdevplatformtests.so    [.] qt_noop()
...
```

LINUX PERF: STAT

Gather performance counter statistics.

```
$ perf stat <yourapp>
Performance counter stats for '<yourapp>':

  5606.202068 task-clock                #    0.473 CPUs utilized
      604,632 context-switches          #    0.108 M/sec
          146 cpu-migrations            #    0.026 K/sec
        1,740 page-faults               #    0.310 K/sec
5,983,888,876 cycles                    #    1.067 GHz                     82.94%
3,373,405,595 stalled-cycles-frontend   #   56.37% frontend cycles idle    82.82%
2,305,588,563 stalled-cycles-backend    #   38.53% backend  cycles idle    67.53%
5,558,174,058 instructions              #    0.93  insns per cycle
                                        #    0.61  stalled cycles per insn  83.62%
1,224,492,195 branches                  #  218.417 M/sec                   82.90%
  22,178,629 branch-misses              #    1.81% of all branches         83.81%

11.845618581 seconds time elapsed
```

LINUX PERF: QTESTLIB IN QT5

Fast, reliable benchmark counting CPU cycles.

```
$ yourQTestLibBench -perf

...
RESULT : tst_QVector::calibration():
     6,121,714 CPU cycles per iteration (total: 6,121,714, iterations: 1)
...
```

LINUX PERF

Already good, but so much potential for more!

- Custom trace points enable custom tools to be build.
- **Proper UI *desperately* needed!**

INTEL® VTUNE™

"Commercial perf with a good UI."

- Fast, sampling based wall time profiling.
- Excellent visualizations, good workflow.
- Proprietary
- Free license for non-commercial Linux work.
- **Most features require Intel CPUs!**

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Profile Overview

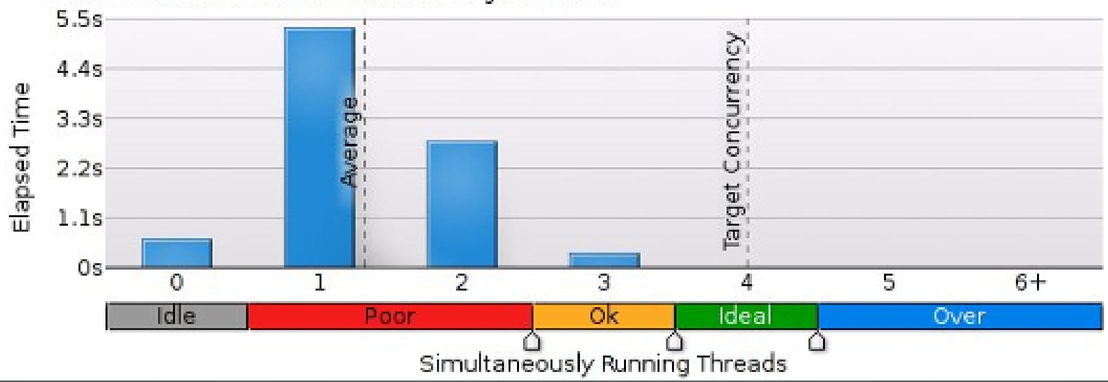
Top Waiting Objects

This section lists the objects that spent the most time waiting in your application. Objects can wa
synchronizations. A significant amount of Wait time associated with a synchronization object refl
parallelism.

Sync Object	Wait Time	Wait Count
Sleep	13.190s	15,072
Futex 0xe9ec8d73	0.009s	2,426
poll	0.091s	260
Futex 0x6e1f8871	0.002s	257
Mutex 0xbf7f3edc	1.267s	175
[Others]	9.761s	729

Thread Concurrency Histogram

This histogram represents a breakdown of the Elapsed Time. It visualizes the percentage of the
simultaneously. Threads are considered running if they are either actually running on a CPU or a
Thread Concurrency is a measurement of the number of threads that were not waiting. Thread C
in the runnable state and not consuming CPU time.



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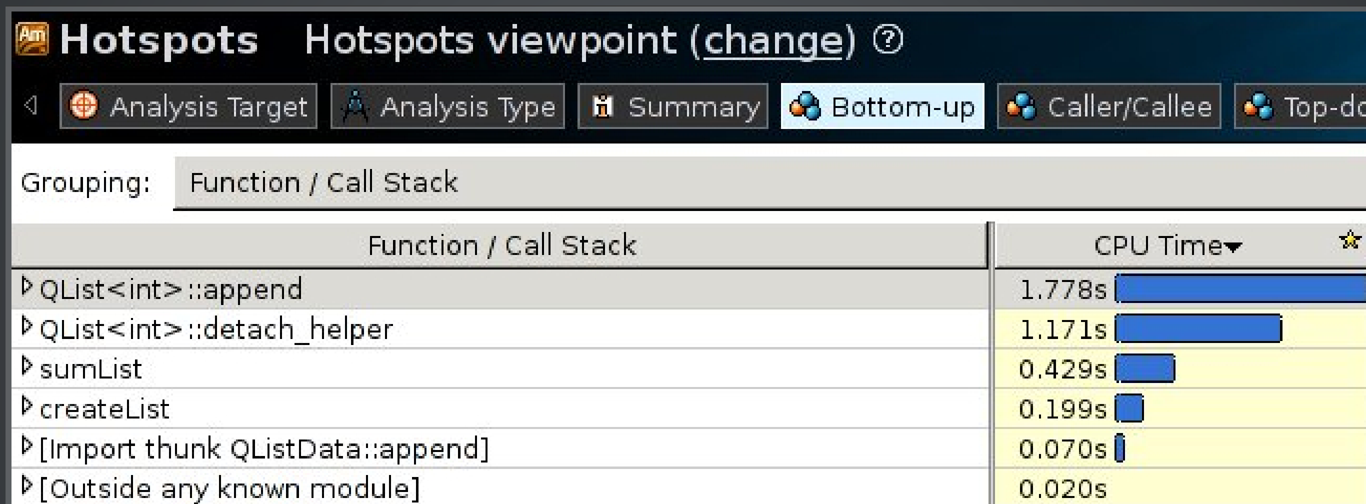
Detecting CPU hotspots



Hint: **Don't use `QList`** by default.
Prefer `QVector` with `Q_DECLARE_TYPEINFO(Type, Q_MOVABLE_TYPE)`.

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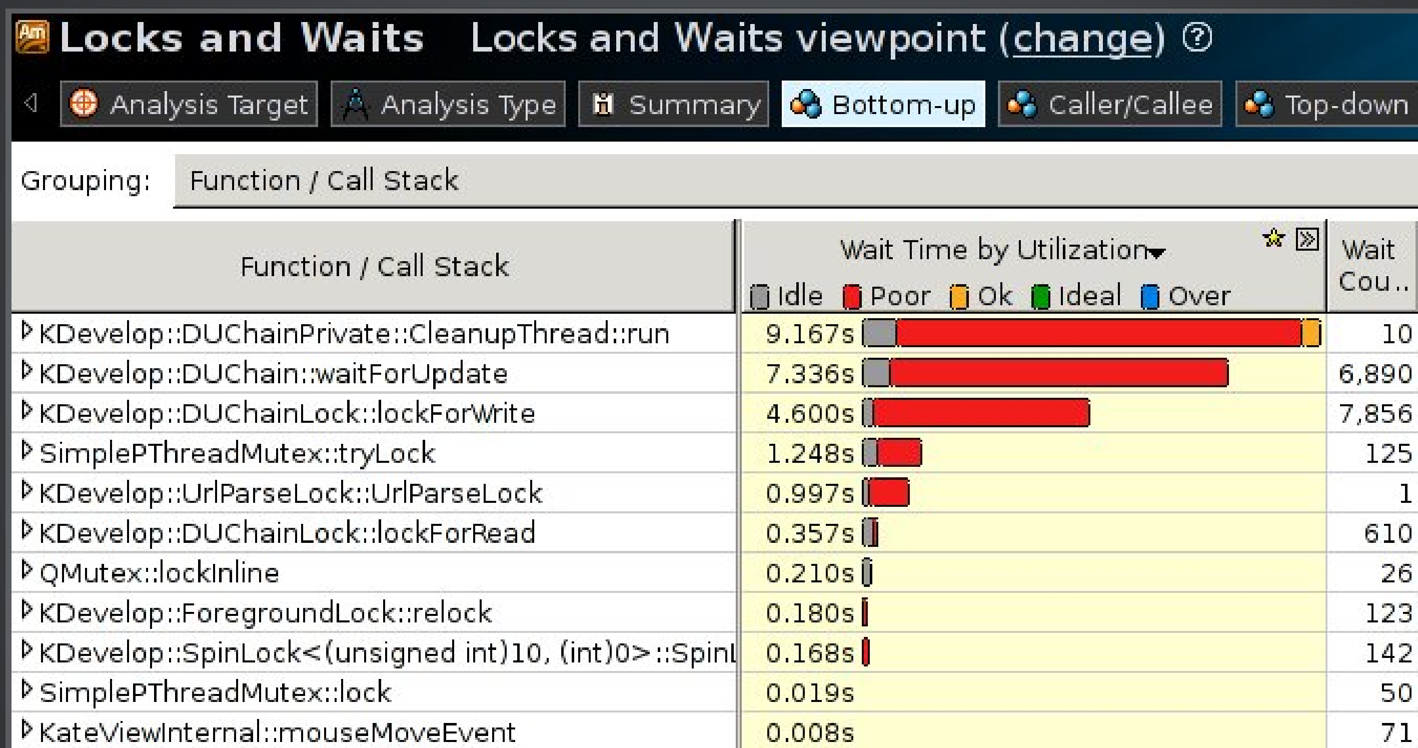
Finding Locks and Waits



Note: Not all waits are bad - an idle `QThread` will wait in the eventloop e.g.

Hint: Prefer asynchronous, task-based code over locking.

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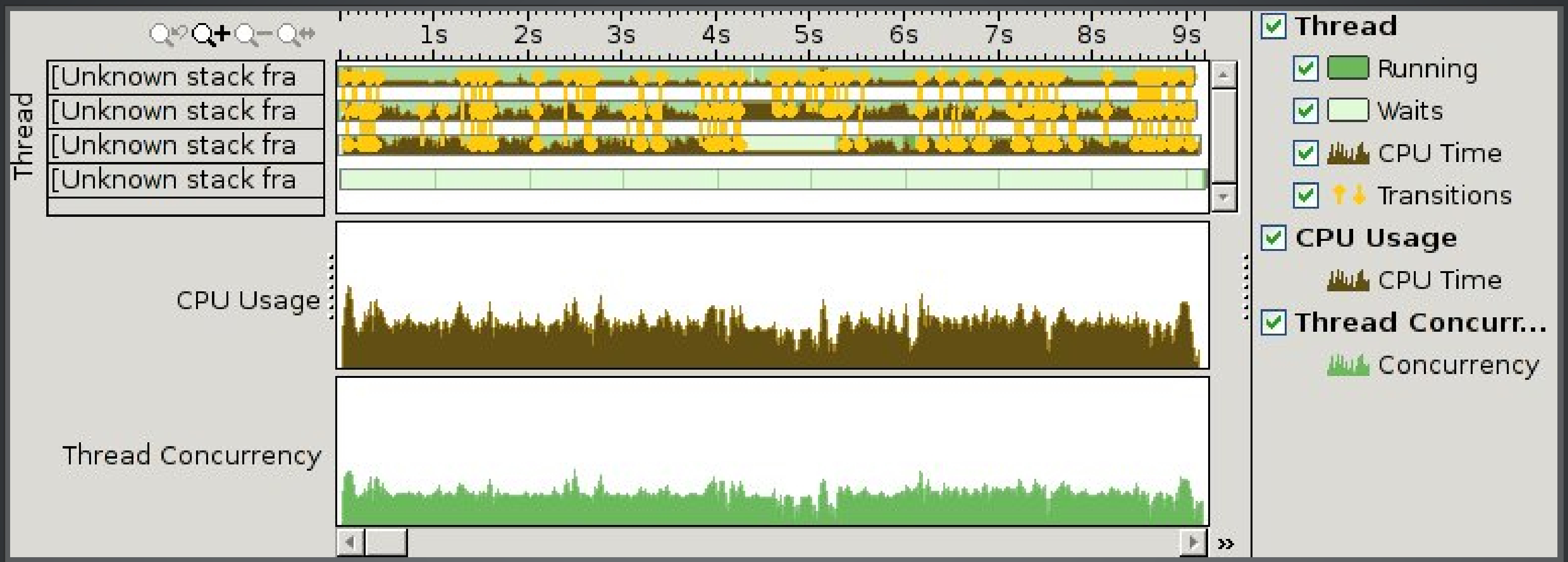
Per-Thread CPU Usage, Context Switches, Waits



Hint: Prefer asynchronous, task-based code over locking.

Hint: Use value semantics, don't share data between multiple threads.

VALGRIND

The developer's swiss army knife.

Available on Linux, Mac; x86 and ARM supported.

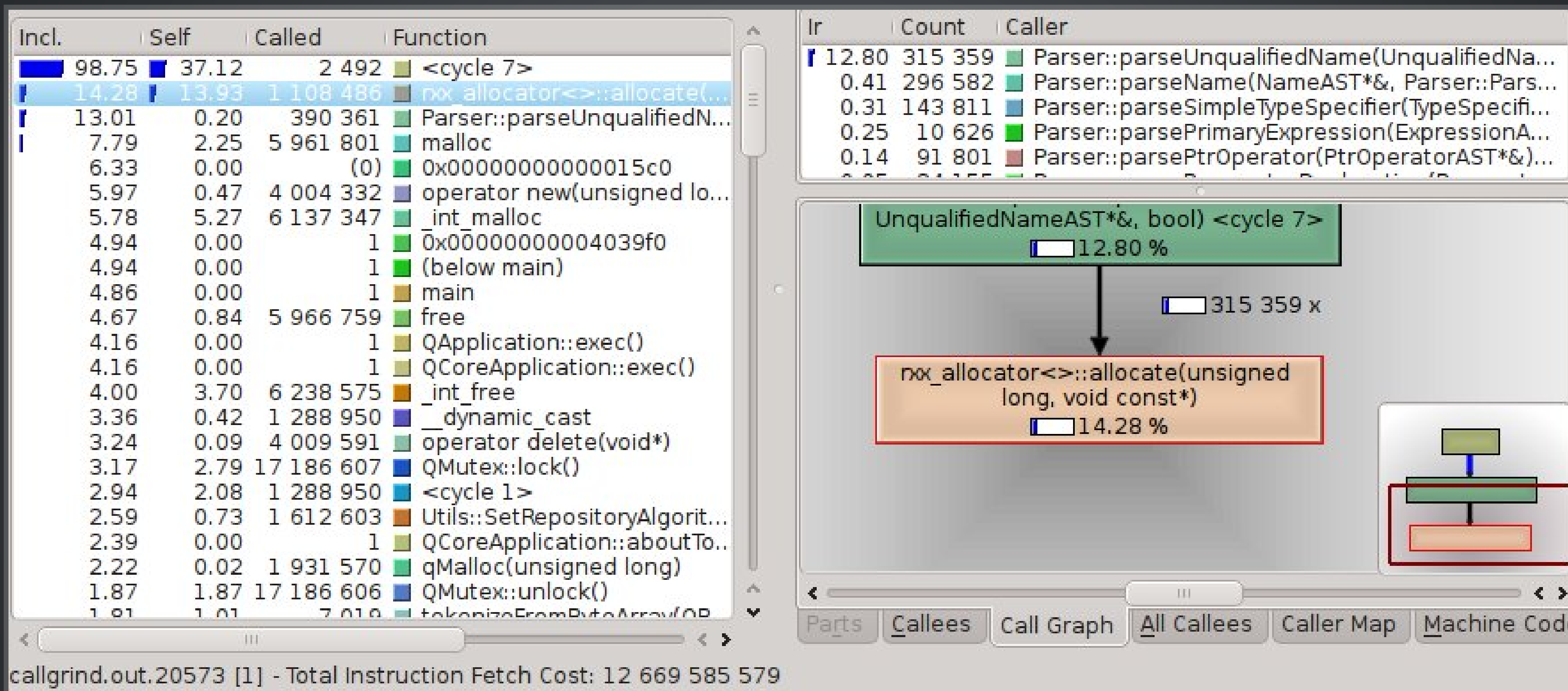
- **Callgrind:** deterministic instruction profiler
- **Massif:** heap profiler

```
$ valgrind --tool={massif,callgrind} <yourapp>
```

Sadly large overhead, very slow

Hint: For apps using a JIT compiler (i.e. via `QtScript`, `QtWebKit`, `QML`, `QRegularExpression`), add the following argument to valgrind: `--smc-check=all-non-file`.

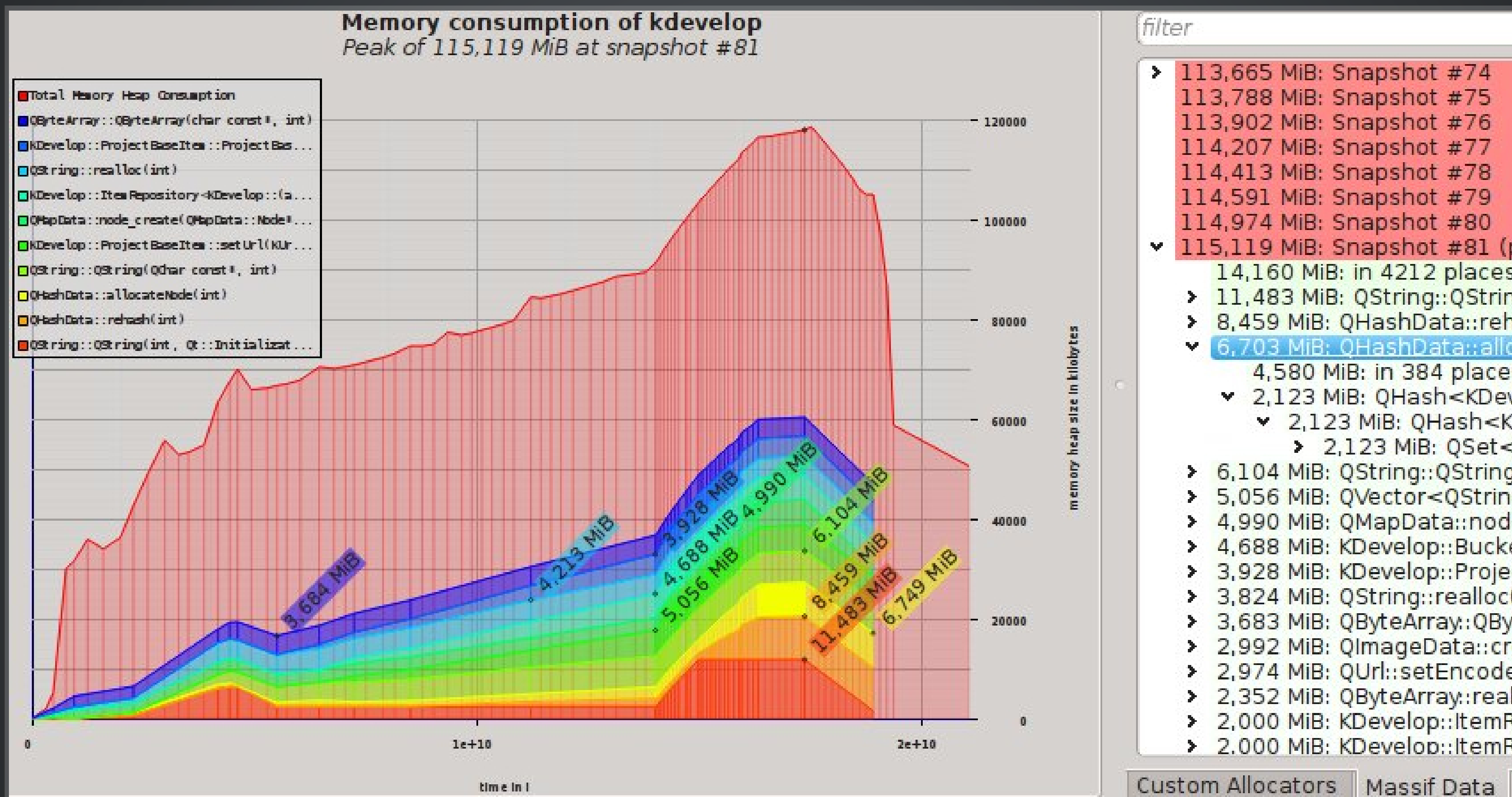
KCACHEGRIND



Todo: Wouldn't it be nice to view `perf.data` files like this?

Hint: Cleanup Qt results: `--fn-skip="QMetaObject::activate*" --fn-skip="QMetaObject::metacall*" --fn-skip="*::qt_metacall*" --fn-skip="*::qt_static_metacall*"`

MASSIF VISUALIZER



Note: Every allocation you save improves runtime performance!

PMAP

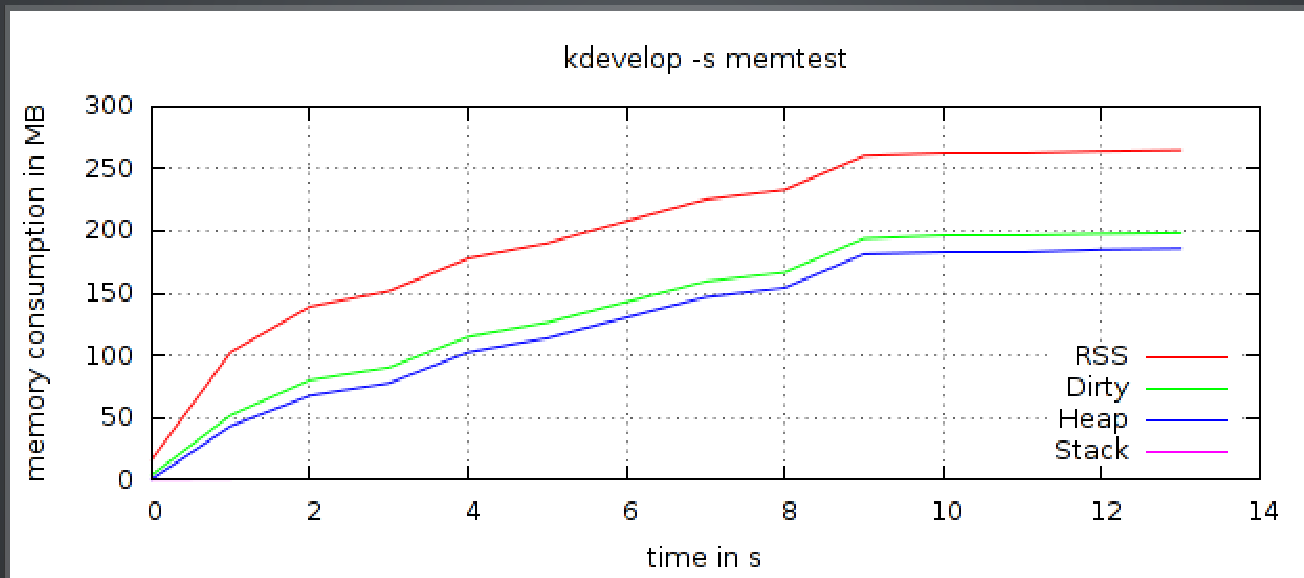
Track per-process memory consumption over time.

- Works nicely on embedded linux systems.
- Could be ported to OS X, Windows
- Download: **github.com/milianw/shell-helpers**

PMAP: SINGLE PROCESS

Record and show RSS, Heap and Stack over time.

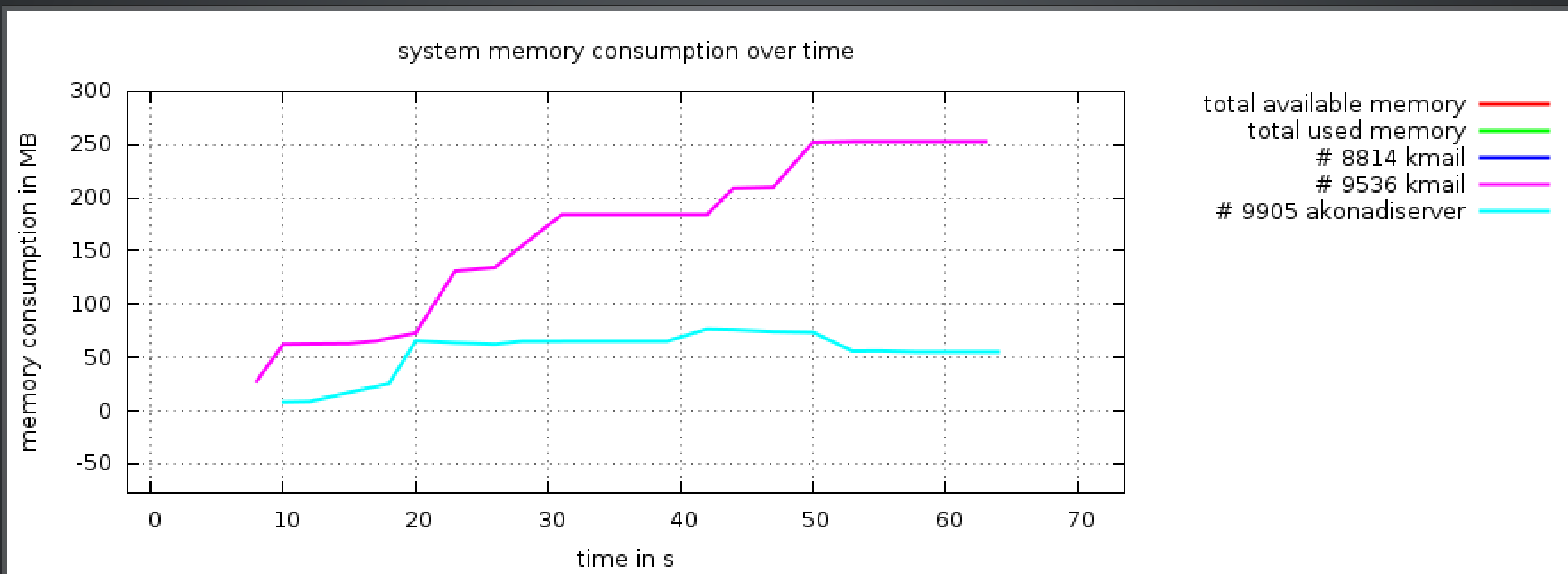
```
$ track_memory.sh <yourapp>
# wait until finished, then
$ show_memory.sh mem.log.PID
```



PMAP: SYSTEM WIDE

Record and show RSS and total memory over time.

```
$ system_track_memory.sh [filter apps]
$ system_show_memory.sh mem.log.system.PID
```



QT TIPS & TRICKS

QSTRING ALLOCATIONS

```
bool containsAt(const QString& source, const QString& needle, int pos)
{
  return needle == source.mid(pos, needle.size());
}

// common usage example:
containsAt(longString, "myNeedle", 42);
```

Two QString allocations per call!

`source.mid(pos, needle.size())`

`QString("myNeedle")`

QSTRING ALLOCATIONS: IMPROVED

```
bool containsAt(const QString& source, const QString& needle, int pos)
{
  return needle == source.midRef(pos, needle.size());
}
// common usage example:
containsAt(longString, QStringLiteral("myNeedle"), 42);
```

No runtime allocations!

```
Slow variant: 54.7 msecs / 153000985.4 CPU cycles
Optimized:     6.7 msecs /  19049591.6 CPU cycles
Improvement:  ~87%
```

QSTRING PARSING

Tokenize strings containing repeated keywords.

```
// common input: foo bar foo bar foo bar ...
QVector<QString> tokenize(const QString& input)
{
  QVector<QString> ret;
  Tokenizer tokenizer;
  Token token;
  while(tokenizer.nextToken(&token)) {
    ret.append(input.mid(token.start, token.end));
  }
}
```

100% memory overhead.

QSTRING PARSING

Interning: Leverage implicit sharing.

```
QString tokenText(const QStringRef& token)
{
  static const QVector<QString> keywords = {
      QStringLiteral("foo"),
      QStringLiteral("bar"),
      ...
  };
  auto it = std::find(keywords.begin(), keywords.end(), token);
  if (it != keywords.end()) {
    // hot path: no string allocation, and we share memory
    return *it;
  } else {
    // slow path
    return token.toString();
  }
}
```

```
Slow variant: 198.3 msecs
Optimized:    153.9 msecs
Improvement:  ~22%, no memory overhead (keywords are shared)
```

THREAD-SAFE MESSAGE PASSING

Use Qt's Signal/Slots for efficient message passing.

```
class Worker : public QObject {
  Q_OBJECT
public:
  Worker(QThread *thread) {
    moveToThread(thread);
    connect(thread, &QThread::finished, this, &QObject::deleteLater);
  }
  void work(const QString& input) { // thread safe dispatching
    QMetaObject::invokeMethod(this, "workInternal", Q_ARG(QString, input));
  }
private slots:
  // only called from background thread
  void workInternal(const QString& input) {
    const QString result = doExpensiveStuff(input);
    emit finished(result); // will be queued and sent to listeners
  }
signals:
  void finished(const QString& result);
};
```

THE END

QUESTIONS? FEEDBACK?

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