Measurement: Overview
Performance Evaluation of Computer Systems

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Events and States

Events
Typically, performance metrics talk about events. For example:
- Operation (or method or function or transaction) start (finish).
- Network packet transmission (reception).
- Memory reference.
- Disk access.
- ...

States
Alternatively, performance metrics may relate to system state. Events mark system state changes.
**Metrics**

Metrics are related to events and states in several typical ways:

- **Event-Count or Event-Time Metrics**
  A metric counts or times event occurrences
  (dynamic instruction count, I/O throughput, time tick ...).

- **Secondary Event Metrics**
  A metric tracks state attributes on event occurrences
  (packet sizes, exception locations, calling contexts ...).

- **Event Profiles**
  A metric creates overall system profile
  (execution time distribution, utilization ...).
Measurement Approaches

- **Event Driven Measurement**
  Getting control to collect metric information on every event (for example mechanism to increment (hardware) counter on cache miss).

- **Trace Collection**
  Recording a trace of events together with useful parts of system state (for example collecting stack dump for method invocation trace).

- **Sampling**
  Recording system state at certain intervals to estimate the metric of interest (for example collecting execution profile).

- **Indirect**
  Deriving the value of a metric that is difficult (or impossible) to measure from other metric(s) (for example collecting object lifetimes).
Two Big Problems with Measurement

**Overhead**

Measurement can incur (possibly very big) overhead:

- time executing measurement code
- consumed storage space or network bandwidth
- consumed program memory or system resources
- ...

**Perturbation**

Measurement can change observed system behavior:

- including measurement overhead in measurements
- changing behavior during execution
  - synchronization artefacts
  - changes in optimization
  - ...
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Example: Event-Driven Interval Measurement

We often ask what happened during an operation:

- How long did it take?
- How many cache misses happened while the operation executed?
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- How many cache misses happened while the operation executed?

In general, simple code does the job:

```plaintext
before = read_value ();
// run the operation of interest
after = read_value ();
results.append (after - before);
```
Example: Event-Driven Interval Measurement

We often ask what happened during an operation:

- How long did it take?
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```c
before = read_value ();
// run the operation of interest
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results.append (after - before);
```

Let us look at potential for overhead and perturbation.
Interval Measurement Memory Overhead

The results storage consumes memory which means:

- Application has less available memory.
  Could cause swapping or behavior change (less memory for buffers ...)
- Application has less cache available to it.
  Changes amount of (capacity) cache misses.
- Application has different memory layout.
  Changes amount of (conflict) cache misses.
- Higher (or different) load for memory allocator or garbage collector.

In some cases reducing memory overhead by these methods can help:

- Compress data.
  Even simple methods such as using fewer bits.
- Process data immediately.
  Online computation of metrics such as average possible.
- Use cache-friendly patterns to store the data.
Interval Measurement Time Overhead

```cpp
before = read_value ();
// run the operation of interest
after = read_value ();
results.append (after - before);
```

If measured value is time, part of code above is included in result:

- Reading and recording the `before` value.
- Call and return to (from) the operation.
- Reading the `after` value.

Of course, other metrics (like cache misses) may have similar overhead. This overhead might be measured and compensated, but it is very difficult.
Interval Measurement Perturbations

More complex perturbation effects possible:

- Time to store results may affect scheduling and alter minute timing of later measurements.
- With measurement included, optimizations might be reduced (register allocation, pipelining, branch prediction ...).
- More function calls also affect execution (safe points, stack ...).
Interval Measurement Perturbations

Important questions:
- Can this be avoided?
- How much does this matter?

Initial measurement guidelines:
- Keep measurement code as simple as possible. Especially avoid conditional branching. Same path for warmup and measurement.
- Measure only operations taking long time (large counter values).
- The measured operation should take at least 100-1000 times longer than the measurement overhead.