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
- changing behavior during execution
- ▶ synchronization artefacts
- ▶ changes in optimization
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- 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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In general, simple code does the job:

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

```c
before = read_value ();
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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.