Session 5
Profiling

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Large code bases

Performance counters

Unsuitable: too much code to annotate.
Which section(s) of the code takes most of the time?

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Profiling to keep focus

1. Find hotspots (where most time is spent)
2. Measure performance of hotspots
3. Optimise hotspots

Profiling: types

Sampling

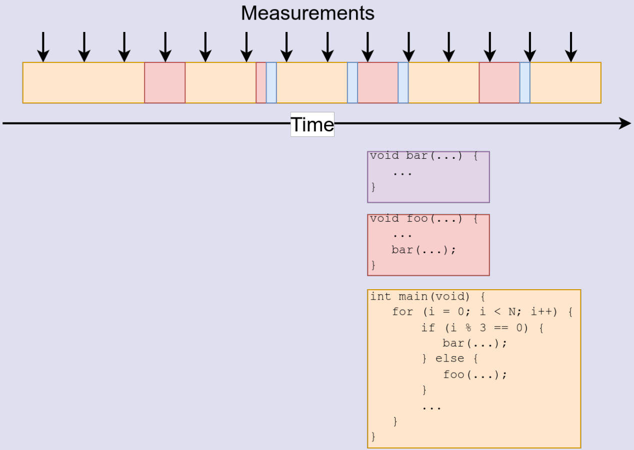
- ✓ Works with unmodified executables
- ✗ Only a statistical model of code execution
- ✗ Not very detailed for volatile metrics
- ✗ Needs long-running application

Instrumentation

- ✓ Maximally detailed and focused
- ✗ Requires annotations in source code
- ✗ Preprocessing of source required
- ✗ Can have large *overheads* for small functions.

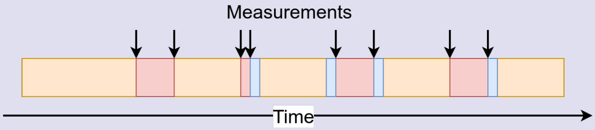
Sampling

- Program interrupts
- Periodic measurements
- Snapshot of the stack
- Potentially inaccurate



Tracing

- Explicit measurement
- Extremely accurate
- Less information
- More work




```
void bar(...) {
   ...
}
```

```
void foo(...) {
   Enter("foo")
   ...
   bar(...);
   Exit("foo");
}
```

```
int main(void) {
   for (i = 0; i < N; i++) {
       if (i % 3 == 0) {
          bar(...);
       } else {
          foo(...);
       }
       ...
   }
}
```

Sampling profiles with `gprof`

Workflow

1. Compile with profiling information and debugging symbols

```
gcc -pg -g <source_file> -o <executable_name>
```

2. Run code to produce file `gmon.out`

3. Generate output with

```
gprof <executable_name> gmon.out    # flat profile and
                                    # call graph

gprof -A <executable_name> gmon.out # annotated source
```

Instrumentation & sampling

- Code is instrumented by GCC
- Automatic tracing of all calls
- Triggering of measurement is sampling based (not every call)
- Trade-off approach

Output

- *flat profile:* time in function, number of function calls
- *call graph:* which function call which
- *annotated source:* number of time each line is executed

Output: the *flat profile*

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls   s/call   s/call  name
 99.82      5.70     5.70        2     2.85     2.85  basic_gemm
  0.18      5.71     0.01        1     0.01     0.01  zero_matrix
  0.00      5.71     0.00        3     0.00     0.00  alloc_matrix
  0.00      5.71     0.00        3     0.00     0.00  free_matrix
  0.00      5.71     0.00        2     0.00     0.00  random_matrix
  0.00      5.71     0.00        1     0.00     5.71  bench
  0.00      5.71     0.00        1     0.00     0.00  diff_time
```

“Total” and “self” time

```
int main(void) {
    for (i = 0; i < N; i++) {
        if (i % 3 == 0) {
            bar(...);
        } else {
            foo(...);
        }
        ...
    }
}
```

Output: the *call graph*

```
                    Call graph (explanation follows)


granularity: each sample hit covers 4 byte(s) for 0.18% of 5.71 seconds

index % time    self  children    called     name
                0.00    5.71       1/1           main [2]
[1]    100.0    0.00    5.71       1         bench [1]
                5.70    0.00       2/2           basic_gemm [3]
                0.01    0.00       1/1           zero_matrix [4]
                0.00    0.00       3/3           alloc_matrix [5]
                0.00    0.00       3/3           free_matrix [6]
                0.00    0.00       2/2           random_matrix [7]
                0.00    0.00       1/1           diff_time [8]
-----------------------------------------------
                                                 <spontaneous>
[2]    100.0    0.00    5.71                 main [2]
                0.00    5.71       1/1           bench [1]
```

Annotated source

```
       static void tiled_packed_gemm(int m, int n, int k,
                                     const double * restrict a, int lda,
                                     const double * restrict b, int ldb,
                                     double * restrict c, int ldc)
  2 -> {
         const int ilim = (m / TILESIZE) * TILESIZE;
         const int jlim = (n / TILESIZE) * TILESIZE;
         const int plim = (k / TILESIZE) * TILESIZE;
         ...
       }

       static void alloc_matrix(int m, int n, double **a)
  3 -> {
         ...
       }
```

Optimisation workflow

1. Identify hotspot functions
2. Find relevant bit of code
3. Determine algorithm
4. Add instrumentation markers (see exercise)
5. Profile with more detail/use performance models.

Exercise 6: Finding the hotspot

1. Split into small groups
2. Download the `miniMD` application
3. Profile with `gprof`
4. Annotate hotspot with `likwid` Marker API
5. Measure operational intensity
6. Ask questions!