Profiling

- profiling = quantitative debugging
  - measure performance, resource usage
    - CPU time
    - memory consumption
    - latency, througput
  - here focus on CPU time (on Linux x86)
    - first thing to try if your program is *slow*
  - search for *performance bugs*
- previously: qualitative debugging
  - search for *failures*, resp. *incorrect behaviour*

Profiling through Logging

- similar to *printf* style debugging
  - add *logging code* with time stamps
  - logging code removable at compile time
  - logging code enabled / disabled at run time
- Debug performance through logging:
  - wrap logging code around *phases*
  - run test cases with logging enabled
  - analyze time spent in phases
  - reiterate and refine phases as necessary

C code for Logging

```
#ifdef INCLUDE_LOGGING_CODE

static void timestamp (void) {
      getrusage (RUSAGE_SELF, &u);
      seconds = u.ru_utime.tv_sec + 1e-6 * u.ru_utime.tv_usec;
      seconds += u.ru_stime.tv_sec + 1e-6 * u.ru_stime.tv_usec;
      fprintf (log_file, "%.2f", seconds);
}

#define LOG(code) do { \
  if (!logging_enabled) break; \
  timestamp (); \
  fprintf (log_file , ":%s:%d: ", __FILE__, __LINE__); \
  code; \
  fputc (' ', log_file); fflush (log_file); \
} while (0)

#else

#define LOG(code) do { } while (0)

#endif
```

Statistics

- Add code to count important events
  - find event types on which you think the performance depends linearly:
    - number of requests, decisions, updates, etc.
  - avoid Heisenberg effect
    - counting should be cheap
    - if statistics are cheap keep them in release code
  - optionally include / disable statistics at compile / run time
- similar to *printf* style debugging!

Where is the Hot-Spot?

- Logging / Statistics are not sufficient
  - inaccurate, manual instrumentation / analysis
- Apply *Low Hanging Fruit* Principle
  - profile, and **only** optimize hot spot
  - do not forget:
    - 90% time spent in one part of the program, then improving this part (the hot spot) could speed up your program 10x
    - if it is only 50% then only at most 2x
    - if it is only 20% then only at most 1.25x

Gprof

- compiler (gcc) instruments program
  - counts number of executions of each function
  - counts number of times an edge is traversed in the callgraph of a program
  - samples time spent in each function
- running the program dumps this information to *gmon.out*
- *gprof a.out* reads program and dump
  - produces *flat* and *call graph* profile

Sampling CPU Time

- need support by OS / processor
  - OS generates interrupt every 1/100 seconds
  - signal handler looks up frame pointer
  - return address in frame gives code offset
  - from code offset we get function *f*
  - increase execution count of *f*
- problem: timing not accurate
  - run test case multiple times
- Heisenberg issues ...

Performance Counters

- high resolution counters
  - more accurate time stamps
    - wall clock time stamps
    - system wide
  - also allow sampling / counting other events
    - data cache hits / misses
    - almost no overhead
    - system wide
- root access needed!

Oprofile

- system wide profiler for Linux
  - needs special kernel module
  - root access
  - only works on some platforms
  - comes for instance with 'ubuntu'
- comparison to gprof
  - more accurate, less overhead
  - no recompilation nor relinking

Google Perftools

- sampling based user space tool
  - no recompilation
  - relinking can be avoided with *LD_PRELOAD*
  - nice analysis tools, e.g. graphical
- compared to Oprofile
  - easier to use
  - clearly shows hotspots
  - less platforms

Using Coverage Tools

- originally for counting number of lines / branches executed
- main purpose is to detect untested code
- can be used to generate *program slice* for one test case
- very accurate, but also very slow > 10x
- example: *gcov + gcc*
- number of times a line is executed does not need to be linearly related to time spent in this function