CS601: Software Development for Scientific Computing

Autumn 2024

Week7: Tools for profiling, debugging, and more..

Valgrind

- Suite of tools for debugging and profiling
  - `memcheck` and `cachegrind` are popular ones
    - `cachegrind` is cache and branch-prediction profiler.
    - `memcheck` is a memory error detector.

- Demo of cachegrind tool with matmul
  - https://valgrind.org/docs/manual/cg-manual.html

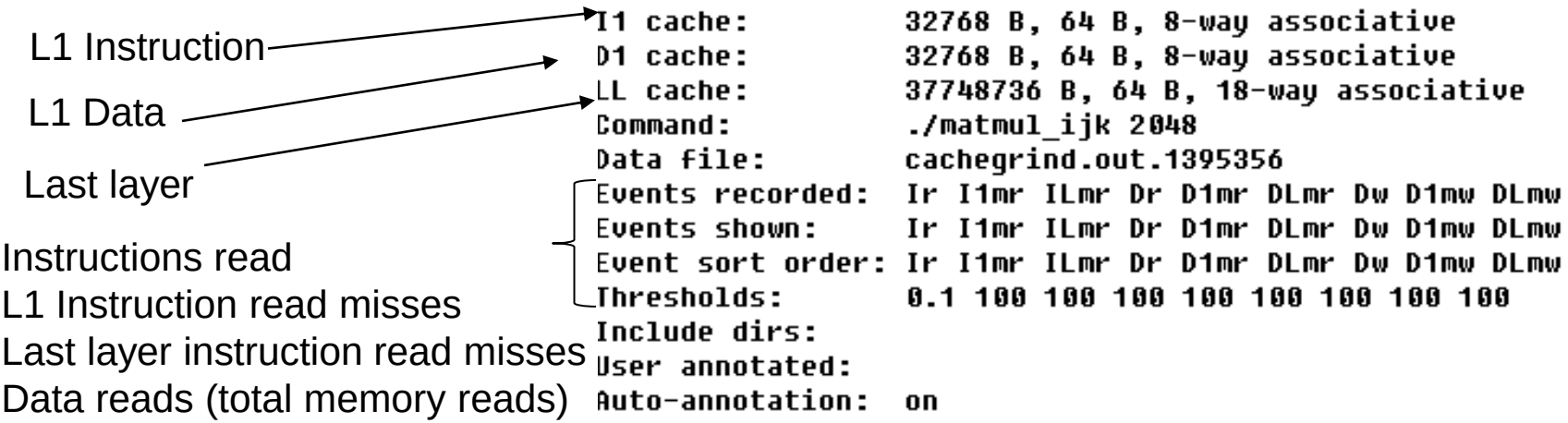
- Demo of memcheck with matmul

Steps to use `cachegrind`

- Example: `matmul.cpp`
  1. Compile with `-g` and create a target.
  2. Run as: `valgrind --tool=cachegrind ./matmul 2048`
  3. Output of `cachegrind` is dumped in a file that has the format `cachegrind.out.xxxxxx` where xxxxx is the process ID
  4. Use `cg_annotate` to get annotated output
     1. E.g. `cg_annotate cachegrind.out.12345`

cachegrind

- Visualizing cache transactions



- Instructions read
- L1 Instruction read misses
- Last layer instruction read misses
- Data reads (total memory reads)
- L1 data read misses
- Last layer data read misses
- Data writes (total memory writes)
- L1 data write misses
- Last layer data write misses

Total last layer misses = `ILmr + DLmr + DLmw`

cachegrind

- Visualizing cache transactions (**ijk** loop ordering of matmul)

```
--------------------------------------------------------------------------------
Ir                    I1mr (L1 read miss)          ILmr (LL instruction read miss)          Dr (Data read == number of memory reads)
--------------------------------------------------------------------------------
438,803,764,234 (100.0%) 2,267 (100.0%) 2,157 (100.0%) 189,231,226,540 (100.0%)

D1mr (L1 Data read miss)                 DLmr (LL data read misses)
10,740,872,902 (100.0%) 7,827,585,951 (100.0%)

Dw (Data write = number of memory writes)                 D1mw (L1 data cache write miss)                 DLmw (LL data write miss)
8,674,338,548 (100.0%) 1,586,278 (100.0%) 1,582,786 (100.0%)
```

cachegrind

- Visualizing cache transactions (**ikj** loop ordering of matmul)

```
--------------------------------------------------------------------------------
Ir                   I1mr (L1 read miss)         ILmr (LL instruction read miss)         Dr (Data read == number of memory reads)
--------------------------------------------------------------------------------
438,803,764,251 (100.0%) 2,267 (100.0%) 2,157 (100.0%) 189,231,226,544 (100.0%)

D1mr (L1 Data read miss)                DLmr (LL data read misses)
1,223,946,667 (100.0%) 1,004,088,043 (100.0%)

Dw (Data write = number of memory writes)          D1mw (L1 data cache write miss)          DLmw (LL data write miss)
8,674,338,550 (100.0%) 1,586,278 (100.0%) 1,582,786 (100.0%)
```

Total last layer misses are much lesser than that in ijk loop!

GNU gprof

- Usage:
  - Compile your program with `-pg` flag
  - Execute your program as normal
    - A file `gmon.out` is generated
  - `gprof <yourexecutable>`