**Homework 3**

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**Problem 1. Programming Models**

**Problem 3. Code Profiling & Performance Counters**

1. Performance profiling

|  |  |  |  |
| --- | --- | --- | --- |
| Function index | Function name | The number of calls | percentage of execution time |
| 1 | miniFE::matvec\_std<miniFE::CSRMatrix<double, int, int>, miniFE::Vector<double, int, int> >::operator()(miniFE::CSRMatrix<double, int, int>&, miniFE::Vector<double, int, int>&, miniFE::Vector<double, int, int>&) | 201 | 30.09% |
| 2 | frame\_dummy | 1597918831 | 11.08% |
| 3 | std::\_Rb\_tree<int, int, std::\_Identity<int>, std::less<int>, std::allocator<int> >::\_S\_key(std::\_Rb\_tree\_node<int> const\*) | 57598102 | 6.52% |
| 4 | std::\_Rb\_tree<int, int, std::\_Identity<int>, std::less<int>, std::allocator<int> >::\_S\_value(std::\_Rb\_tree\_node<int> const\*) | 435792686 | 4.48% |
| 5 | int\* std::lower\_bound<int\*, unsigned long>(int\*, int\*, unsigned long const&) | 32768000 | 3.69% |
| 6 | \_\_gnu\_cxx::\_\_aligned\_membuf<int>::\_M\_ptr() | 435883250 | 3.22% |
| 7 | std::\_Rb\_tree\_node<int>::\_M\_valptr() | 435883250 | 2.99% |
| 8 | miniFE::decide\_how\_to\_shrink(Box const&, Box const&) | 719 | 2.99% |

1. Amdahl’s Law

Speedup = 1/(1 - 0.3009 + 0.3009 / 5) = 1.32

1. Performance Counters
2. When running *perf stat ./miniFE.x -nx 40 -ny 80 -nz 160* by default:

Text

Description automatically generated

1. Measure Instructions; CPU cycles (and also show IPC, instructions per cycle); Branch instructions; Branches misses (mispredictions)

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1. Measure Cache references; L1 data cache load misses; L1 instruction cache load misses; LLC (last level cache) loads; LLC (last level cache) load misses; Data TLB load misses

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**Problem 4. Performance Counters**

1. Re-run my program across different loop nest orderings on the machine where I am using ‘perf’

|  |  |
| --- | --- |
| Loop nest orderings | Time |
| I-J-K | 14.641327 s |
| I-K-J | 0.716340 s |
| J-K-I | 27.432645 s |

1. Use ‘perf’ to see performance counters
2. I-J-K

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1. I-K-J

Graphical user interface, text

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1. J-K-I

Graphical user interface, text

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From the three screenshots above, the first column of performance counter stats represents the raw counter numbers. We are easy to tell from those numbers that I-K-J has the least number of all kinds of cache misses, while J-K-I has the most and I-J-K stays in between. In summary, performance counter results explain why these three patterns have different performance.