`heat2d` Performance Report

20150607-141823

Abstract

This performance report is intended to support performance analysis and optimization activities. It includes details on program behavior, system configuration and capabilities, including support data from well-known performance analysis tools.

This report was generated using `hotspot` version `0.1`. Homepage `http://www.github.com/moreandres/hotspot`. Full execution log can be found at `~/.hotspot/heat2d/20150607-141823/hotspot.log`.

Contents

1 Program

This section provides details about the program being analyzed.

1. Program: `heat2d`.
   Program is the name of the program.
2. Timestamp: `20150607-141823`.
   Timestamp is a unique identifier used to store information on disk.
3. Parameters Range: `[32768, 33792, 34816, 35840, 36864, 37888, 38912, 39936, 40960, 41984, 43008, 44032, 45056, 46080, 47104, 48128, 49152, 50176, 51200, 52224, 53248, 54272, 55296, 56320, 57344, 58368, 59392, 60416, 61440, 62464, 63488, 64512]`.
   Parameters range is the problem size set used to scale the program.

2 System Capabilities

This section provides details about the system being used for the analysis.

2.1 System Configuration

This subsection provides details about the system configuration.

The hardware in the system is summarized using a hardware lister utility. It reports exact memory configuration, firmware version, mainboard configuration, CPU version and speed, cache configuration, bus speed and others.

The hardware configuration can be used to contrast the system capabilities to well-known benchmarks results on similar systems.

```
memory      7984MiB System memory
processor   Intel(R) Core(TM) i5-3320M CPU @ 2.60GHz
bridge      440FX - 82441FX PMC [Natoma]
bridge      82371SB PIIX3 ISA [Natoma/Triton II]
storage     82371AB/EB/MB PIIX4 IDE
network     82540EM Gigabit Ethernet Controller
bridge      82371AB/EB/MB PIIX4 ACPI
storage     82801HM/HEM (ICH8M/ICH8M-E) SATA Controller [AHCI mode]
```

The software in the system is summarized using the GNU/Linux platform string.

```
Linux-3.16.0-30-generic-x86_64-with-Ubuntu-14.04-trusty
```

The software toolchain is built upon the following components.

1. Host: `ubuntu`
2. Distribution: `Ubuntu, 14.04, trusty`.
   This codename provides LSB (Linux Standard Base) and distribution-specific information.
3. Compiler: `gcc (Ubuntu 4.8.2-19ubuntu1) 4.8.2`.
   Version number of the compiler program.
4. C Library: `GNU C Library (Ubuntu EGLIBC 2.19-0ubuntu6.6) stable release version 2.19`.
   Version number of the C library.

The software configuration can be used to contrast the system capabilities to well-known benchmark results on similar systems.

2.2 System Performance Baseline

This subsection provides details about the system capabilities.

A set of performance results is included as a reference to contrast systems and to verify hardware capabilities using well-known synthetic benchmarks.

The HPC Challenge benchmark [1] consists of different tests:

1. HPL: the Linpack TPP benchmark which measures the floating point rate of execution for solving a linear system of equations.
2. DGEMM: measures the floating point rate of execution of double precision real matrix-matrix multiplication.
3. PTRANS (parallel matrix transpose): exercises the communications where pairs of processors communicate with each other simultaneously.
4. RandomAccess: measures the rate of integer random updates of memory (GUPS).
5. STREAM: a simple synthetic benchmark program that measures sustainable memory bandwidth (in GB/s).
6. FFT: measures the floating point rate of execution of double precision complex one-dimensional Discrete Fourier Transform (DFT).

Table 1: Benchmarks

Benchmark	**Value**	**Unit**
hpl	0.00365811 TFlops	tflops
dgemm	1.72977 GFlops	mflops
ptrans	1.58619 GBs	MB/s
random	0.0544077 GUPs	MB/s
stream	7.00091 MBs	MB/s
fft	2.32577 GFlops	MB/s

Most programs will have a dominant compute kernel that can be approximated by the ones above, the results helps to understand the available capacity.

3 Workload

This section provides details about the workload behavior.

3.1 Workload Footprint

The workload footprint impacts on memory hierarchy usage.

```
heat2d: ELF 64-bit LSB  executable, x86-64, version 1 (SYSV), dynamically linked (uses shared libs), for GNU/Linux
```

Binaries should be stripped to better fit inside cache.

```
struct _IO_FILE {
int                         _flags;               /*     0     4 */

/* XXX 4 bytes hole, try to pack */

char *                      _IO_read_ptr;         /*     8     8 */
char *                      _IO_read_end;         /*    16     8 */
char *                      _IO_read_base;        /*    24     8 */
char *                      _IO_write_base;       /*    32     8 */
char *                      _IO_write_ptr;        /*    40     8 */
char *                      _IO_write_end;        /*    48     8 */
char *                      _IO_buf_base;         /*    56     8 */
/* --- cacheline 1 boundary (64 bytes) --- */
char *                      _IO_buf_end;          /*    64     8 */
```

```
char *                    _IO_save_base;        /*   72     8 */
char *                    _IO_backup_base;      /*   80     8 */
char *                    _IO_save_end;         /*   88     8 */
struct _IO_marker *       _markers;             /*   96     8 */
struct _IO_FILE *         _chain;               /*  104     8 */
int                       _fileno;              /*  112     4 */
int                       _flags2;              /*  116     4 */
__off_t                   _old_offset;          /*  120     8 */
/* --- cacheline 2 boundary (128 bytes) --- */
short unsigned int        _cur_column;          /*  128     2 */
signed char               _vtable_offset;       /*  130     1 */
char                      _shortbuf[1];         /*  131     1 */

/* XXX 4 bytes hole, try to pack */

_IO_lock_t *              _lock;                /*  136     8 */
__off64_t                 _offset;              /*  144     8 */
void *                    __pad1;               /*  152     8 */
void *                    __pad2;               /*  160     8 */
void *                    __pad3;               /*  168     8 */
void *                    __pad4;               /*  176     8 */
size_t                    __pad5;               /*  184     8 */
/* --- cacheline 3 boundary (192 bytes) --- */
int                       _mode;                /*  192     4 */
char                      _unused2[20];         /*  196    20 */

/* size: 216, cachelines: 4, members: 29 */
/* sum members: 208, holes: 2, sum holes: 8 */
/* last cacheline: 24 bytes */
};
struct _IO_marker {
struct _IO_marker *       _next;                /*    0     8 */
struct _IO_FILE *         _sbuf;                /*    8     8 */
int                       _pos;                 /*   16     4 */

/* size: 24, cachelines: 1, members: 3 */
/* padding: 4 */
/* last cacheline: 24 bytes */
};
```

The in-memory layout of data structures can be used to identify issues. Reorganizing data to remove alignment holes will improve CPU cache utilization.

More information `https://www.kernel.org/doc/ols/2007/ols2007v2-pages-35-44.pdf`

3.2 Workload Stability

This subsection provides details about workload stability.

1. Execution time:
   (a) problem size range: `32768 - 65536`
   (b) geomean: `23.32382` seconds
   (c) average: `23.32607` seconds
   (d) stddev: `0.32522`
   (e) min: `22.90810` seconds
   (f) max: `24.26887` seconds
   (g) repetitions: `32` times

The histogram plots the elapsed times and shows how they fit in a normal distribution sample.

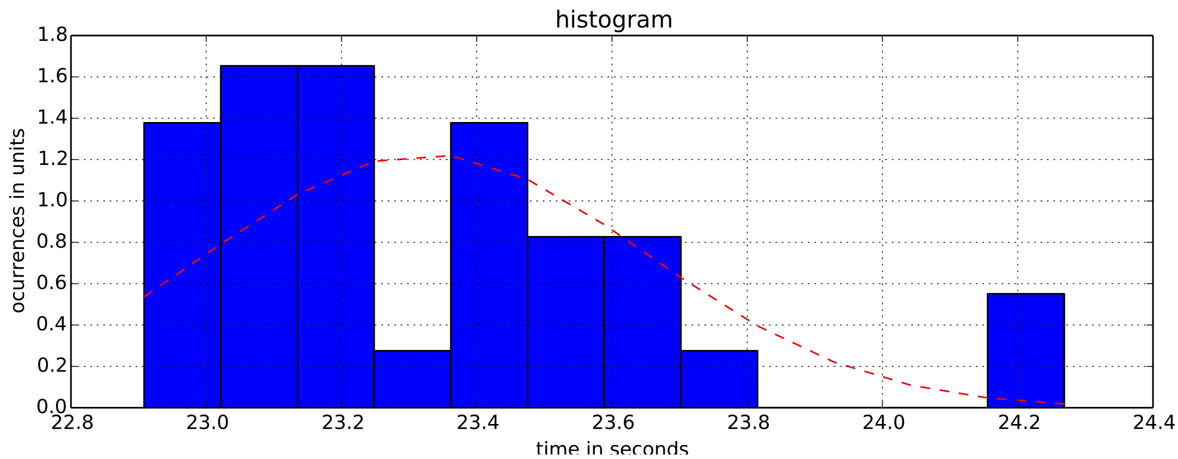

Figure 1: Results Distribution

The workload should run for at least one minute to fully utilize system resources. The execution time of the workload should be stable and the standard deviation less than 3 units.

3.3 Workload Optimization

This section shows how the program reacts to different optimization levels.

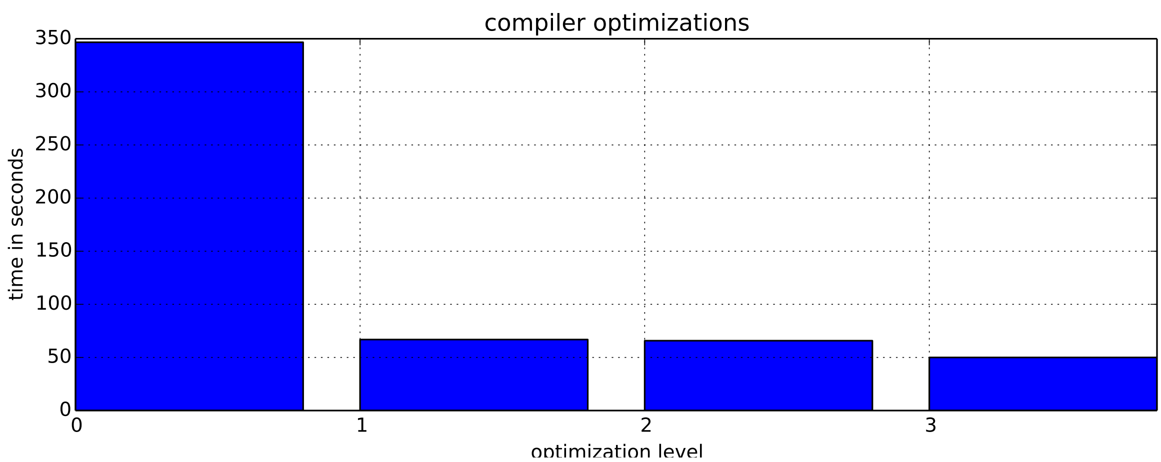

Figure 2: Optimization Levels

4 Scalability

This section provides details about the scaling behavior of the program.

4.1 Problem Size Scalability

A chart with the execution time when scaling the problem size.

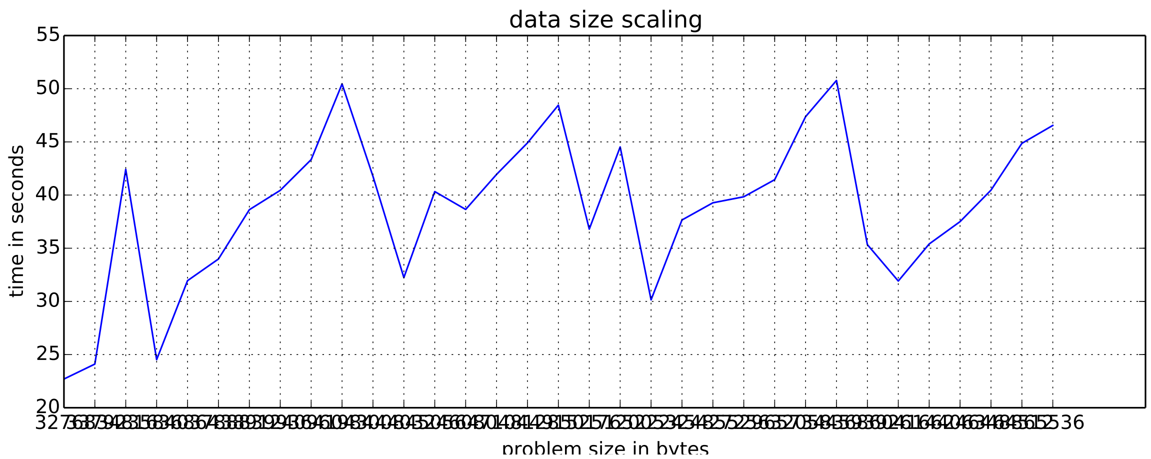

Figure 3: Problem size times

The chart will show how computing time increases when increasing problem size. There should be no valleys or bumps if processing properly balanced across computational units.

4.2 Computing Scalability

A chart with the execution time when scaling computation units.

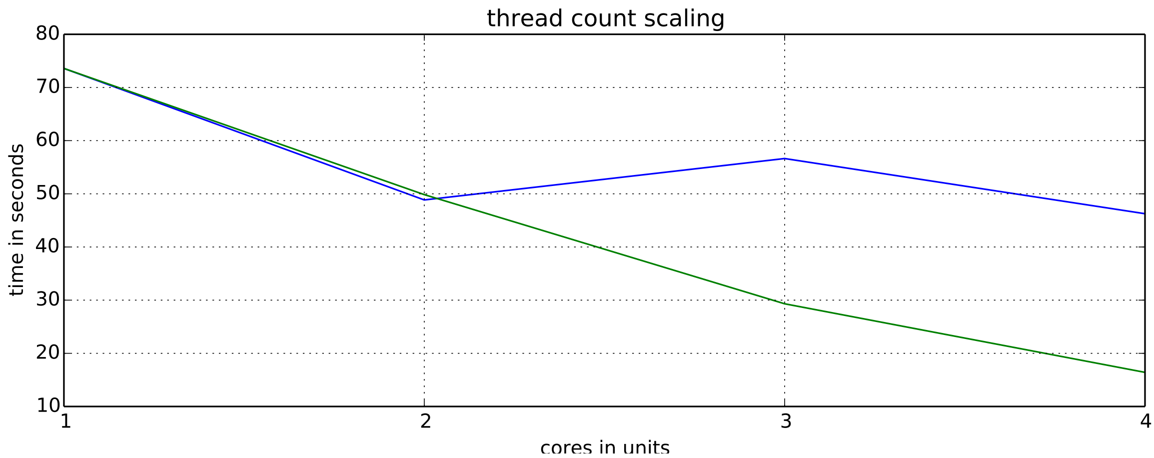

Figure 4: Thread count times

The chart will show how computing time decreases when increasing processing units. An ideal scaling line is provided for comparison.

The parallel and serial fractions of the program can be estimated using the information above.

1. Parallel Fraction: `0.67235`.
   Portion of the program doing parallel work.
2. Serial: `0.32765`.
   Portion of the program doing serial work.

Optimization limits can be estimated using scaling laws.

1. Amdalah Law for 1024 procs: `3.05200 times`.
   Optimizations are limited up to this point when scaling problem size. [2]
2. Gustafson Law for 1024 procs: `688.80974 times`.
   Optimizations are limited up to this point when not scaling problem size. [3]

5 Profile

This section provides details about the execution profile of the program and the system.

5.1 Program Profiling

This subsection provides details about the program execution profile.

5.1.1 Flat Profile

The flat profile shows how much time your program spent in each function, and how many times that function was called.

```
Flat profile:
Each sample counts as 0.01 seconds.
     cumulative   self              self     total
 time   seconds   seconds    calls  Ts/call  Ts/call  name
 29.65     41.38    41.38                             compute_one_iteration._omp_fn.1 (heat2d.c:78 @ 400d97)
 12.89     59.37    17.99                             compute_one_iteration._omp_fn.1 (heat2d.c:83 @ 400d93)
  9.89     73.18    13.81                             compute_one_iteration._omp_fn.1 (heat2d.c:82 @ 400d8f)
  9.66     86.67    13.49                             compute_one_iteration._omp_fn.1 (heat2d.c:83 @ 400d70)
  9.35     99.72    13.05                             compute_one_iteration._omp_fn.1 (heat2d.c:79 @ 400d50)
  6.74    109.13     9.41                             compute_one_iteration._omp_fn.1 (heat2d.c:81 @ 400d89)
  4.86    115.91     6.78                             compute_one_iteration._omp_fn.1 (heat2d.c:80 @ 400d69)
  4.40    122.06     6.15                             compute_one_iteration._omp_fn.1 (heat2d.c:80 @ 400d83)
  4.20    127.91     5.86                             compute_one_iteration._omp_fn.1 (heat2d.c:83 @ 400d63)
  3.65    133.01     5.09                             compute_one_iteration._omp_fn.1 (heat2d.c:75 @ 400bd0)
  2.08    135.91     2.90                             compute_one_iteration._omp_fn.1 (heat2d.c:79 @ 400d5c)
  2.08    138.81     2.90                             compute_one_iteration._omp_fn.1 (heat2d.c:83 @ 400d7b)
Call graph
granularity: each sample hit covers 2 byte(s) for 0.01 of 140.15 seconds
index  time     self  children    called     name
                                                 <spontaneous>
[19]      0.0     0.03    0.00                compute_one_iteration (heat2d.c:54 @ 400ee0) [19]
[23]      0.0     0.00    0.00   484290       frame_dummy [23]
```

The table shows where to focus optimization efforts to maximize impact.

5.2 System Profiling

This subsection provide details about the system execution profile.

5.2.1 System Resources Usage

The following charts shows the state of system resources during the execution of the program.

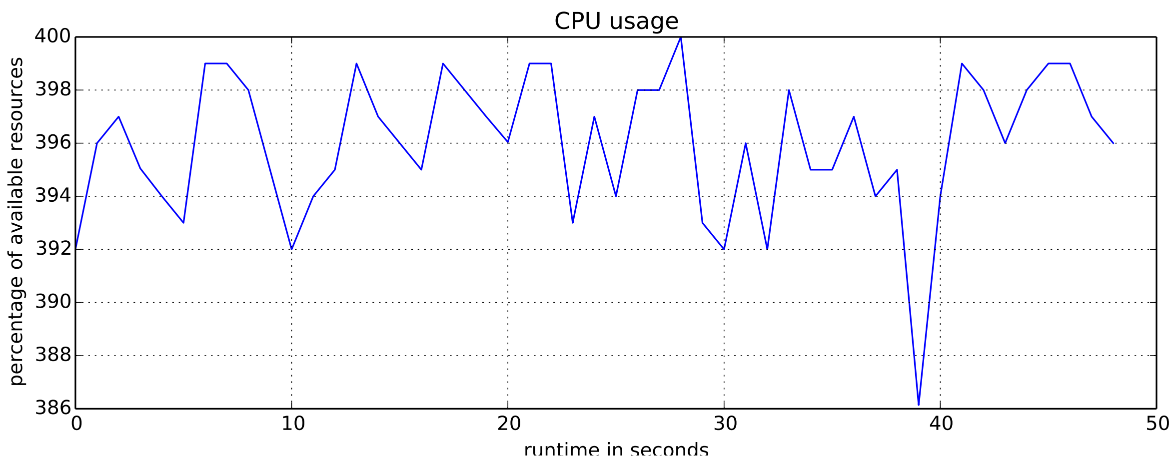

Figure 5: CPU Usage

Note that this chart is likely to show as upper limit a multiple of 100% in case a multicore system is being used.

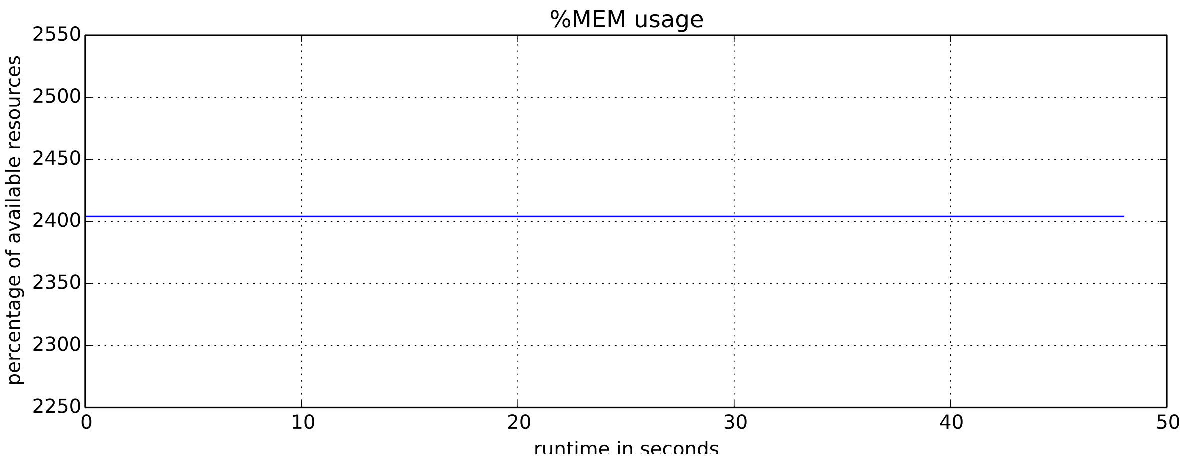

Figure 6: Memory Usage

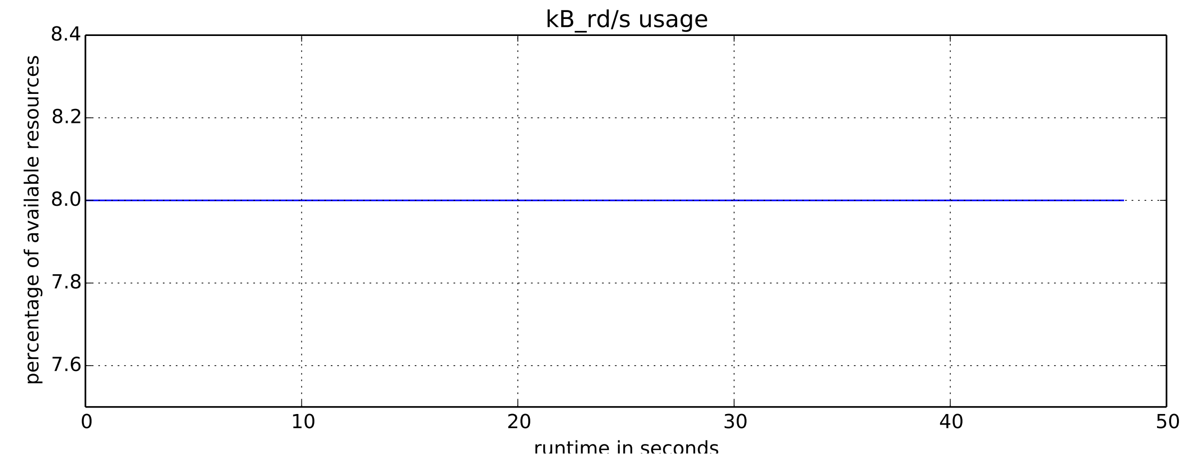

Figure 7: Reads from Disk

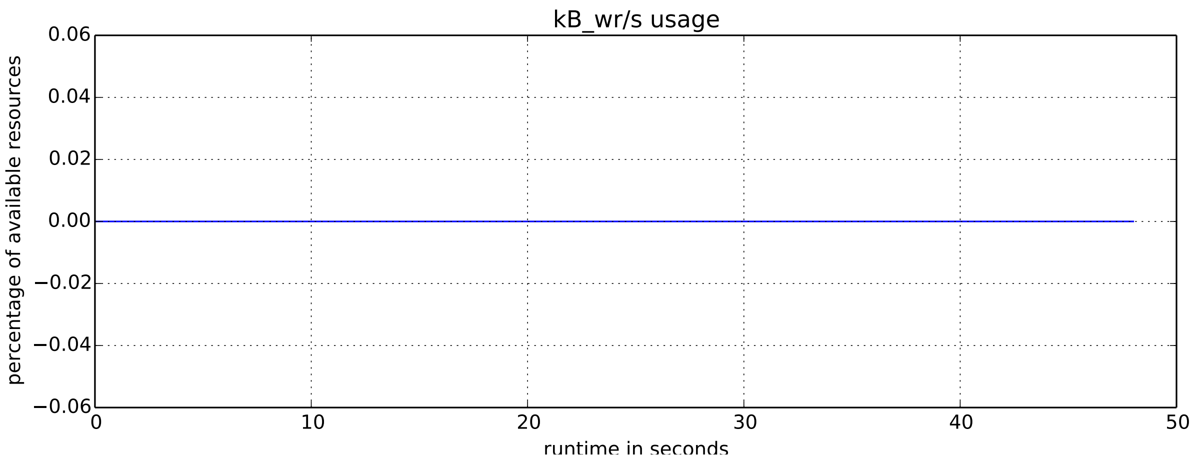

Figure 8: Writes to Disk

5.3 Hotspots

This subsection shows annotated code guiding the optimization efforts.

```
       :        solution[cur_gen][0][i] = solution[cur_gen][1][i];
       :        solution[cur_gen][CRESN - 1][i] = solution[cur_gen][CRESN - 2][i];
       :      }
       :    /* corners ? */
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
  3.52 :    400af3:       movsd  0x365a15(rip),xmm5        # 766510 <diff_constant>
  0.19 :    400b80:       lea    0x10(rcx),r11
```

```
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
       :         (solution[cur_gen][i + 1][j] +
       :          solution[cur_gen][i - 1][j] +
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
       :         (solution[cur_gen][i + 1][j] +
  0.23 :   400c13:       movhpd 0x8(r10,rax,1),xmm0
       :          solution[cur_gen][i - 1][j] +
       :          solution[cur_gen][i][j + 1] +
       :          solution[cur_gen][i][j - 1] -
       :          4.0 * solution[cur_gen][i][j]) * diff_constant;
  1.84 :   400c1a:       movsd  (rdx,rax,1),xmm1
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
       :         (solution[cur_gen][i + 1][j] +
       :          solution[cur_gen][i - 1][j] +
  8.31 :   400c1f:       movhpd 0x8(rax,rsi,1),xmm2
       :          solution[cur_gen][i][j + 1] +
       :          solution[cur_gen][i][j - 1] -
       :          4.0 * solution[cur_gen][i][j]) * diff_constant;
  1.51 :   400c25:       movhpd 0x8(rax,rdx,1),xmm1
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
       :         (solution[cur_gen][i + 1][j] +
  9.15 :   400c2b:       addpd  xmm2,xmm0
       :          solution[cur_gen][i - 1][j] +
       :          solution[cur_gen][i][j + 1] +
       :          solution[cur_gen][i][j - 1] -
       :          4.0 * solution[cur_gen][i][j]) * diff_constant;
  0.33 :   400c2f:       movapd xmm1,xmm2
  1.12 :   400c33:       mulpd  xmm3,xmm2
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
       :         (solution[cur_gen][i + 1][j] +
       :          solution[cur_gen][i - 1][j] +
  0.92 :   400c37:       addpd  (rdi,rax,1),xmm0
       :          solution[cur_gen][i][j + 1] +
  8.45 :   400c3c:       addpd  (r8,rax,1),xmm0
       :          solution[cur_gen][i][j - 1] -
  2.49 :   400c42:       subpd  xmm2,xmm0
       :          4.0 * solution[cur_gen][i][j]) * diff_constant;
  9.57 :   400c46:       mulpd  xmm4,xmm0
       :   /* corners ? */
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
       :   for (i = 1; i <= RESN; i++)
       :     for (j = 1; j <= RESN; j++)
       :       solution[next_gen][i][j] = solution[cur_gen][i][j] +
 12.58 :   400c4a:       addpd  xmm1,xmm0
 16.32 :   400c4e:       movlpd xmm0,(rcx,rax,1)
  8.25 :   400c59:       add    $0x10,rax
  1.10 :   400c5d:       cmp    $0x960,rax
  0.12 :   400c6c:       add    $0x970,r8
       :       solution[cur_gen][0][i] = solution[cur_gen][1][i];
       :       solution[cur_gen][CRESN - 1][i] = solution[cur_gen][CRESN - 2][i];
       :     }
       :   /* corners ? */
       : #pragma omp parallel for shared(solution,cur_gen,next_gen,diff_constant) private(i,j)
--
       :     {
       :       compute_one_iteration (sim_time);
```

```
        :   int temp;
        :   setup ();
        :   for (sim_time = 0; sim_time < final; sim_time += time_step)
   99.81 :   40079a:       movsd  0x365d5e(rip),xmm0        # 766500 <sim_time>
        :     {
        :       compute_one_iteration (sim_time);
        :       temp = cur_gen;
    0.19 :   4007a2:       mov    0x365d64(rip),eax        # 76650c <cur_gen>
        :   int temp;
        :   setup ();
        :   for (sim_time = 0; sim_time < final; sim_time += time_step)
        :     {
        :       compute_one_iteration (sim_time);
--
        :   int i, j;
        :   /* set boundary values */
        :   for (i = 0; i < CRESN; i++)
        :     {
        :       if (i < 256 || i > 768)
    5.64 :   400da0:       cmp    $0x200,eax
        :         solution[cur_gen][i][0] = solution[cur_gen][i][1];
        :       else
        :         solution[cur_gen][i][0] = MAX_HEAT;
    1.13 :   400dab:       movsd  0x135(rip),xmm1        # 400ee8 <_IO_stdin_used+0x18>
    0.28 :   400db3:       movsd  xmm1,(rdx)
    9.41 :   400db7:       add    $0x1,eax
    0.19 :   400dba:       add    $0x970,rdx
        : void compute_one_iteration()
        : {
        :   int i, j;
        :   /* set boundary values */
        :   for (i = 0; i < CRESN; i++)
    0.38 :   400dc1:       cmp    $0x2e,eax
        :       else
        :         solution[cur_gen][i][0] = MAX_HEAT;
        :     }
        :   for (i = 0; i < CRESN; i++)
        :     {
        :       solution[cur_gen][i][CRESN - 1] = solution[cur_gen][i][CRESN - 2];
    2.63 :   400dd0:       movsd  0x602a20(rbx,rax,1),xmm0
    4.23 :   400de2:       add    $0x970,rax
        :       if (i < 256 || i > 768)
        :         solution[cur_gen][i][0] = solution[cur_gen][i][1];
        :       else
        :         solution[cur_gen][i][0] = MAX_HEAT;
        :     }
        :   for (i = 0; i < CRESN; i++)
    1.79 :   400de8:       cmp    $0xb2220,rax
        :     {
        :       solution[cur_gen][i][CRESN - 1] = solution[cur_gen][i][CRESN - 2];
        :     }
        :   for (i = 0; i < CRESN; i++)
        :     {
--
        :   /* set boundary values */
        :   for (i = 0; i < CRESN; i++)
        :     {
        :       if (i < 256 || i > 768)
        :         solution[cur_gen][i][0] = solution[cur_gen][i][1];
    6.77 :   400e3b:       movsd  0x8(rdx),xmm0
   36.41 :   400e40:       movsd  xmm0,(rdx)
    2.92 :   400e44:       jmpq   400db7 <compute_one_iteration+0x37>
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
----------------------------------------------------------------------
        : Disassembly of section .text:
    0.27 :   147f70:       mov    rdi,rax
    0.55 :   147fb0:       movdqu (rsi),xmm0
    0.27 :   147fb4:       mov    rdi,rcx
    0.27 :   147fbf:       mov    rcx,r8
    0.27 :   147fcb:       mov    0x27625e(rip),rcx        # 3be230 <obstack_exit_failure+0x38>
```

```
   1.92 :   147fd2:       cmp    rcx,rdx
   0.27 :   148006:       add    rdx,rsi
   0.27 :   14807b:       movdqu xmm0,(r8)
   0.82 :   1480d7:       lea    -0x80(rdx),rdx
   0.55 :   1480e1:       movdqa (rsi),xmm4
   5.48 :   1480e9:       movaps 0x20(rsi),xmm2
   1.37 :   1480ed:       movaps 0x30(rsi),xmm3
   6.85 :   1480f1:       movdqa xmm4,(rdi)
   0.82 :   1480f5:       movaps xmm1,0x10(rdi)
   0.82 :   1480f9:       movaps xmm2,0x20(rdi)
   1.10 :   148101:       sub    $0x80,rdx
   0.55 :   148108:       movaps 0x40(rsi),xmm4
   0.82 :   14810c:       movaps 0x50(rsi),xmm5
   4.66 :   148110:       movaps 0x60(rsi),xmm6
   0.55 :   148114:       movaps 0x70(rsi),xmm7
   7.67 :   148118:       lea    0x80(rsi),rsi
   0.82 :   14811f:       movaps xmm4,0x40(rdi)
   0.27 :   148123:       movaps xmm5,0x50(rdi)
   0.82 :   148127:       movaps xmm6,0x60(rdi)
   1.10 :   14812b:       movaps xmm7,0x70(rdi)
   1.10 :   14812f:       lea    0x80(rdi),rdi
   0.27 :   148152:       movdqa xmm4,(rdi)
   3.29 :   148188:       lea    (r11,rdx,1),rdx
   0.27 :   148280:       sub    $0x10,rdx
   0.82 :   148284:       movdqa -0x10(rsi),xmm1
   0.82 :   148301:       movdqa -0x10(rsi),xmm0
   9.59 :   148306:       movaps -0x20(rsi),xmm1
   1.10 :   14830a:       movaps -0x30(rsi),xmm2
   8.77 :   14830e:       movaps -0x40(rsi),xmm3
   0.55 :   148312:       movdqa xmm0,-0x10(rdi)
   1.10 :   148317:       movaps xmm1,-0x20(rdi)
   0.55 :   14831b:       movaps xmm2,-0x30(rdi)
   2.19 :   14831f:       movaps xmm3,-0x40(rdi)
   0.27 :   148323:       sub    $0x80,rdx
   9.59 :   14832e:       movaps -0x60(rsi),xmm5
  11.23 :   148336:       movaps -0x80(rsi),xmm7
   1.10 :   14833a:       lea    -0x80(rsi),rsi
   1.92 :   14833e:       movaps xmm4,-0x50(rdi)
   1.10 :   148342:       movaps xmm5,-0x60(rdi)
   0.55 :   148346:       movaps xmm6,-0x70(rdi)
   0.82 :   14834a:       movaps xmm7,-0x80(rdi)
   1.10 :   14834e:       lea    -0x80(rdi),rdi
   0.27 :   148352:       jae    148301 <__nss_hosts_lookup+0x11081>
   0.27 :   148383:       sub    $0x40,rsi
   0.55 :   1483a0:       lea    (r11,rdx,1),rdx
   0.27 :   1499d0:       mov    -0x10(rsi),r11
------------------------------------------------------------------------
        : Disassembly of section .text:
  19.35 :   74d0:       mov    0x206af1(rip),rax        # 20dfc8 <omp_in_final_+0x203c18>
   4.30 :   74d7:       mov    fs:0x10(rax),rax
   2.15 :   74dc:       test   rax,rax
   2.15 :   74e1:       mov    (rax),eax
  72.04 :   74e3:       retq
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
--------------------------------------------------------------------
        : Disassembly of section .text:
   1.37 :   7fc82:       push   r14
   1.37 :   7fc89:       push   rbx
   1.37 :   7fc95:       mov    rsi,0x8(rsp)
   5.48 :   7fcbe:       cmp    0x340e7b(rip),rbp        # 3c0b40 <__malloc_initialize_hook+0x120>
   2.74 :   7fcc5:       ja     7fd39 <_IO_str_seekoff+0x2b99>
   5.48 :   7fd40:       ja     7fdbf <_IO_str_seekoff+0x2c1f>
   6.85 :   7fdbf:       mov    rbp,r9
   1.37 :   7fe08:       lea    0x58(rbx),r14
  15.07 :   7fe3f:       shr    $0xc,rax
   4.11 :   7fe43:       mov    rax,0x48(rsp)
   1.37 :   7fe5b:       add    $0x77,eax
   1.37 :   7fe6e:       add    $0x7c,eax
   1.37 :   7fe80:       sub    rax,0x10(rsp)
   2.74 :   7fe97:       mov    $0x2710,r15d
```

```
    1.37 :   7fe9d:       jmp    7fee6 <_IO_str_seekoff+0x2d46>
   16.44 :   7fee6:       mov    0x70(rbx),r12
    1.37 :   7feea:       cmp    r14,r12
    4.11 :   7fef3:       mov    0x8(r12),rsi
    1.37 :   7fefd:       cmp    $0x10,rsi
    1.37 :   80187:       cmp    $0x3ff,rbp
    2.74 :   801bf:       seta   cl
    1.37 :   8022c:       lea    0x20(rbp),rdx
    5.48 :   80234:       mov    rax,r12
    2.74 :   80314:       cmp    rax,rbx
    8.22 :   80365:       cmp    rax,rdx
    1.37 :   80858:       lea    0x33df01(rip),rax        # 3be760 <__malloc_hook+0x20>
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
-----------------------------------------------------------------------
         : Disassembly of section .text:
    1.96 :   7f058:       mov    0x10(rsp),esi
    1.96 :   7f07b:       je     7fb0c <_IO_str_seekoff+0x296c>
    1.96 :   7f081:       testb  $0x2,0x4(r12)
    3.92 :   7f0b8:       mov    0x341a72(rip),esi        # 3c0b30 <__malloc_initialize_hook+0x110>
    1.96 :   7f0be:       test   esi,esi
    1.96 :   7f0c6:       testb  $0x1,0x8(rbx)
    3.92 :   7f16a:       lea    0x58(r12),rdx
    7.84 :   7f180:       mov    rax,0x10(rbx)
    1.96 :   7f184:       mov    rdx,0x18(rbx)
    1.96 :   7f1a3:       mov    rbp,rax
    1.96 :   7f1aa:       mov    rax,0x8(rbx)
    1.96 :   7f1b2:       cmp    $0xffff,rbp
   21.57 :   7f3b8:       mov    $0x1,esi
    7.84 :   7f3bd:       mov    0x10(rsp),eax
    3.92 :   7f3c8:       je     7f3d8 <_IO_str_seekoff+0x2238>
    9.80 :   7f3d0:       jne    84bbb <malloc_info+0x2bb>
    5.88 :   7f4b6:       jne    84bd7 <malloc_info+0x2d7>
    3.92 :   7f4bc:       jmp    7f4c8 <_IO_str_seekoff+0x2328>
    1.96 :   7f54d:       add    r14,rbp
    3.92 :   7f588:       jb     7f490 <_IO_str_seekoff+0x22f0>
    1.96 :   7f595:       lea    0x33fa3c(rip),rdx        # 3befd8 <__malloc_hook+0x898>
    5.88 :   7faf0:       and    $0xfffffffffffffff8,rdx
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
-----------------------------------------------------------------------
         : Disassembly of section .text:
   12.00 :   82750:       push   rbp
   12.00 :   82760:       mov    (rax),rax
   16.00 :   82763:       test   rax,rax
    4.00 :   8276c:       mov    0x33b60d(rip),rax        # 3bdd80 <_IO_file_jumps+0x6e0>
   12.00 :   82777:       test   rbx,rbx
   16.00 :   82794:       jne    84dbb <malloc_info+0x4bb>
    4.00 :   827a8:       mov    rbx,rdi
    4.00 :   827b3:       mov    rax,rdx
    4.00 :   827bf:       je     827cc <__libc_malloc+0x7c>
   16.00 :   827c4:       jne    84dd6 <malloc_info+0x4d6>
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
-----------------------------------------------------------------------
         : Disassembly of section .text:
   31.58 :   82df0:       mov    0x33b0f1(rip),rax        # 3bdee8 <_IO_file_jumps+0x848>
   10.53 :   82df7:       mov    (rax),rax
   47.37 :   82dfa:       test   rax,rax
   10.53 :   82e10:       lea    -0x10(rdi),rsi
---------------------------------------------------------------------------
         : Disassembly of section .text:
   87.50 :   7490:       cmpq   $0xffffffffffffffff,0x206cf8(rip)        # 20e190 <omp_in_final_+0x203de0>
   12.50 :   7498:       jne    749f <GOMP_parallel_end+0xf>
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
-----------------------------------------------------------------------
         : Disassembly of section .text:
   28.57 :   85094:       callq  f1280 <__sbrk>
   28.57 :   850a3:       add    $0x8,rsp
   28.57 :   850aa:       retq
---------------------------------------------------------------------------
         : Disassembly of section .text:
   33.33 :   7460:       push   r12
```

```
   16.67 :   747e:       mov    rbp,rdi
   16.67 :   7488:       mov    rax,rcx
   33.33 :   748b:       jmpq   85f0 <omp_in_final+0x390>
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
------------------------------------------------------------------------
         : Disassembly of section .text:
 Percent | Source code & Disassembly of libc-2.19.so for cpu-clock
------------------------------------------------------------------------
--
 Percent | Source code & Disassembly of heat2d for cpu-clock
------------------------------------------------------------------
         : Disassembly of section .plt:
----------------------------------------------------------------------------
         : Disassembly of section .text:
   25.00 :   74f7:       mov    fs:0x28(rax),eax
   25.00 :   74fb:       retq
 Percent | Source code & Disassembly of heat2d for cpu-clock
------------------------------------------------------------------
         : Disassembly of section .plt:
 Percent | Source code & Disassembly of heat2d for cpu-clock
------------------------------------------------------------------
```

6 Low Level

This section provide details about low level details such as vectorization and performance counters.

6.1 Vectorization Report

This subsection provide details about vectorization status of the program loops.

```
Analyzing loop at heat2d.c:46
heat2d.c:46: note: not vectorized: loop contains function calls or data references that cannot be analyzed
heat2d.c:46: note: bad data references.
heat2d.c:43: note: vectorized 0 loops in function.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:46: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: versioning for alias required: can't determine dependence between solution[pretmp_108][pretmp_1
heat2d.c:75: note: versioning not yet supported for outer-loops.
heat2d.c:75: note: bad data dependence.
Analyzing loop at heat2d.c:77
heat2d.c:77: note: versioning for alias required: can't determine dependence between solution[pretmp_108][pretmp_1
heat2d.c:77: note: versioning for alias required: can't determine dependence between solution[pretmp_108][pretmp_1
heat2d.c:77: note: versioning for alias required: can't determine dependence between solution[pretmp_108][i_3][j_2
heat2d.c:77: note: versioning for alias required: can't determine dependence between solution[pretmp_108][i_3][_29
heat2d.c:77: note: versioning for alias required: can't determine dependence between solution[pretmp_108][i_3][j_3
heat2d.c:77: note: misalign = 8 bytes of ref solution[pretmp_108][pretmp_112][j_39]
heat2d.c:77: note: misalign = 8 bytes of ref solution[pretmp_108][pretmp_113][j_39]
heat2d.c:77: note: misalign = 0 bytes of ref solution[pretmp_108][i_3][j_26]
heat2d.c:77: note: misalign = 0 bytes of ref solution[pretmp_108][i_3][_29]
heat2d.c:77: note: misalign = 8 bytes of ref solution[pretmp_108][i_3][j_39]
heat2d.c:77: note: misalign = 8 bytes of ref solution[pretmp_106][i_3][j_39]
heat2d.c:77: note: num. args = 4 (not unary/binary/ternary op).
heat2d.c:77: note: not ssa-name.
heat2d.c:77: note: use not simple.
heat2d.c:77: note: num. args = 4 (not unary/binary/ternary op).
heat2d.c:77: note: not ssa-name.
heat2d.c:77: note: use not simple.
heat2d.c:77: note: num. args = 4 (not unary/binary/ternary op).
heat2d.c:77: note: not ssa-name.
heat2d.c:77: note: use not simple.
heat2d.c:77: note: num. args = 4 (not unary/binary/ternary op).
heat2d.c:77: note: not ssa-name.
heat2d.c:77: note: use not simple.
heat2d.c:77: note: num. args = 4 (not unary/binary/ternary op).
```

```
heat2d.c:77: note: not ssa-name.
heat2d.c:77: note: use not simple.
Vectorizing loop at heat2d.c:77
heat2d.c:75: note: vectorized 1 loops in function.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not consecutive access pretmp_106 = next_gen;
heat2d.c:75: note: not consecutive access pretmp_108 = cur_gen;
heat2d.c:75: note: not consecutive access pretmp_110 = diff_constant;
heat2d.c:75: note: Failed to SLP the basic block.
heat2d.c:75: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:79: note: can't determine dependence between solution[pretmp_108][pretmp_112][j_140] and solution[pretmp_
heat2d.c:79: note: can't determine dependence between solution[pretmp_108][pretmp_113][j_140] and solution[pretmp_
heat2d.c:79: note: can't determine dependence between solution[pretmp_108][i_3][j_146] and solution[pretmp_106][i_
heat2d.c:79: note: can't determine dependence between solution[pretmp_108][i_3][_149] and solution[pretmp_106][i_3
heat2d.c:79: note: can't determine dependence between solution[pretmp_108][i_3][j_140] and solution[pretmp_106][i_
heat2d.c:79: note: SLP: step doesn't divide the vector-size.
heat2d.c:79: note: Unknown alignment for access: solution
heat2d.c:79: note: SLP: step doesn't divide the vector-size.
heat2d.c:79: note: Unknown alignment for access: solution
heat2d.c:79: note: SLP: step doesn't divide the vector-size.
heat2d.c:79: note: Unknown alignment for access: solution
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heat2d.c:79: note: Unknown alignment for access: solution
heat2d.c:79: note: SLP: step doesn't divide the vector-size.
heat2d.c:79: note: Unknown alignment for access: solution
heat2d.c:79: note: SLP: step doesn't divide the vector-size.
heat2d.c:79: note: Unknown alignment for access: solution
heat2d.c:79: note: Failed to SLP the basic block.
heat2d.c:79: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:79: note: not vectorized: no vectype for stmt: vect_var_.72_169 = MEM[(double[2][302][302] *)vect_psoluti
 scalar_type: vector(2) double
heat2d.c:79: note: Failed to SLP the basic block.
heat2d.c:79: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:75: note: not vectorized: not enough data-refs in basic block.
heat2d.c:43: note: not vectorized: not enough data-refs in basic block.
Analyzing loop at heat2d.c:64
heat2d.c:64: note: misalign = 0 bytes of ref solution[pretmp_34][i_41][300]
heat2d.c:64: note: misalign = 8 bytes of ref solution[pretmp_34][i_41][301]
heat2d.c:64: note: not consecutive access _19 = solution[pretmp_34][i_41][300];
heat2d.c:64: note: not vectorized: complicated access pattern.
heat2d.c:64: note: bad data access.
Analyzing loop at heat2d.c:57
heat2d.c:57: note: not vectorized: control flow in loop.
heat2d.c:57: note: bad loop form.
heat2d.c:53: note: vectorized 0 loops in function.
heat2d.c:53: note: not consecutive access pretmp_34 = cur_gen;
heat2d.c:53: note: Failed to SLP the basic block.
heat2d.c:53: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:59: note: not vectorized: not enough data-refs in basic block.
heat2d.c:60: note: misalign = 8 bytes of ref solution[pretmp_34][i_40][1]
heat2d.c:60: note: misalign = 0 bytes of ref solution[pretmp_34][i_40][0]
heat2d.c:60: note: not consecutive access _12 = solution[pretmp_34][i_40][1];
heat2d.c:60: note: not consecutive access solution[pretmp_34][i_40][0] = _12;
heat2d.c:60: note: Failed to SLP the basic block.
heat2d.c:60: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:62: note: misalign = 0 bytes of ref solution[pretmp_34][i_40][0]
heat2d.c:62: note: not consecutive access solution[pretmp_34][i_40][0] = 2.0e+1;
heat2d.c:62: note: Failed to SLP the basic block.
heat2d.c:62: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:57: note: not vectorized: not enough data-refs in basic block.
heat2d.c:53: note: not vectorized: not enough data-refs in basic block.
```

```
heat2d.c:53: note: not vectorized: not enough data-refs in basic block.
heat2d.c:66: note: misalign = 0 bytes of ref solution[pretmp_34][i_41][300]
heat2d.c:66: note: misalign = 8 bytes of ref solution[pretmp_34][i_41][301]
heat2d.c:66: note: not consecutive access _19 = solution[pretmp_34][i_41][300];
heat2d.c:66: note: not consecutive access solution[pretmp_34][i_41][301] = _19;
heat2d.c:66: note: Failed to SLP the basic block.
heat2d.c:66: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:53: note: not vectorized: not enough data-refs in basic block.
heat2d.c:70: note: not vectorized: not enough data-refs in basic block.
Analyzing loop at heat2d.c:28
heat2d.c:28: note: not vectorized: number of iterations cannot be computed.
heat2d.c:28: note: bad loop form.
heat2d.c:18: note: vectorized 0 loops in function.
heat2d.c:20: note: misalign = 0 bytes of ref final
heat2d.c:20: note: not consecutive access final = 1.024e+3;
heat2d.c:20: note: Failed to SLP the basic block.
heat2d.c:20: note: not vectorized: failed to find SLP opportunities in basic block.
heat2d.c:22: note: not vectorized: not enough data-refs in basic block.
heat2d.c:26: note: not vectorized: not enough data-refs in basic block.
heat2d.c:36: note: not vectorized: not enough data-refs in basic block.
heat2d.c:18: note: not vectorized: not enough data-refs in basic block.
heat2d.c:30: note: not vectorized: not enough data-refs in basic block.
heat2d.c:18: note: not vectorized: not enough data-refs in basic block.
```

The details above shows the list of loops in the program and if they are being vectorized or not. These reports can pinpoint areas where the compiler cannot apply vectorization and related optimizations. It may be possible to modify your code or communicate additional information to the compiler to guide the vectorization and/or optimizations.

6.2 Counters Report

This subsection provides details about software and hardware counters.

```
 Performance counter stats for './heat2d' (3 runs):

     199110.369461      task-clock (msec)         #    3.944 CPUs utilized            ( +-  0.87 )
             3,562      context-switches          #    0.018 K/sec                    ( +- 11.48 )
                 8      cpu-migrations            #    0.000 K/sec                    ( +- 25.00 )
               427      page-faults               #    0.002 K/sec                    ( +-  0.08 )
   <not supported>      cycles
   <not supported>      stalled-cycles-frontend
   <not supported>      stalled-cycles-backend
   <not supported>      instructions
   <not supported>      branches
   <not supported>      branch-misses

      50.489125220 seconds time elapsed                                          ( +-  0.97 )
```

The details above shows counters that provide low-overhead access to detailed performance information using internal registers of the CPU.

References

[1] Piotr Luszczek and Jack J. Dongarra and David Koester and Rolf Rabenseifner and Bob Lucas and Jeremy Kepner and John Mccalpin and David Bailey and Daisuke Takahashi, *Introduction to the HPC Challenge Benchmark Suite*. Technical Report, 2005.

[2] Amdahl, Gene M., *Validity of the single processor approach to achieving large scale computing capabilities*. Communications of the ACM, Proceedings of the April 18-20, 1967, spring joint computer conference Pages 483-485, 1967.

[3] John L. Gustafson, *Reevaluating Amdahl's Law*. Communications of the ACM, Volume 31 Pages 532-533, 1988.

[4] OpenMP Architecture Review Board, *OpenMP Application Program Interface. http://www.openmp.org*, 3.0, May 2008.