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Assignment: 2
Course: CPSC 424/524

Modules:

```
[ff242@omega2 ~]$ module list

Currently Loaded Modules:
  1) StdEnv (S)    2) Langs/Intel/15.0.2

  Where:
   S:  Module is Sticky, requires --force to unload or purge
```

Environment:

```
[ff242@omega2 ~]$ which icc
/home/apps/fas/Langs/Intel/2015_update2/composer_xe_2015.2.164/bin/intel64/icc
[ff242@omega2 ~]$ icc --version
icc (ICC) 15.0.2 20150121
Copyright (C) 1985-2015 Intel Corporation.  All rights reserved.
```

Commands:

Task 1:

```
srun --pty --x11 -p cpsc424 -c 1 -t 1:00:00 --mem-per-cpu=4gb --
ntasks=1 --nodes=1 bash
./run_seq.sh
```

Task 2 & 3

```
srun --pty --x11 -p cpsc424 -c 8 -t 1:00:00 --mem-per-cpu=4gb --
ntasks=1 --nodes=1 bash
./run_omp.sh
./run_omp_tasks.sh
```

Output:

See appendix at the end of this report.

Task 1 (Serial Program):

	Elapsed Time	Area
#1	69.406440	1.506678
#2	69.382245	1.506678
#3	69.370539	1.506678
#4	69.624382	1.506678
#5	69.385037	1.506678
Average	69.361441	1.506678

Task 2 (OpenMP Program (Loop Directives)):

1. Without schedule or collapse:

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.30	59.24	31.63	19.42
Elapsed Time (#2)	69.29	59.23	31.63	19.41
Elapsed Time (#3)	69.29	59.19	31.65	19.40
Elapsed Time (#4)	69.30	59.26	31.65	19.41
Elapsed Time (#5)	69.29	59.18	31.65	19.40
Average Elapsed Time	69.29	59.22	31.64	19.41
Area (#1)	1.5066	1.5067	1.5066	1.5067
Area (#2)	1.5066	1.5067	1.5066	1.5069
Area (#3)	1.5066	1.5068	1.5067	1.5065
Area (#4)	1.5066	1.5066	1.5068	1.5067
Area (#5)	1.5066	1.5067	1.5066	1.5067
Average Area	1.5066	1.5067	1.5067	1.5067

2. With schedule:

schedule(static,1)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.28	34.79	17.42	8.76

Elapsed Time (#2)	69.30	34.78	17.42	8.77
Elapsed Time (#3)	69.28	34.79	17.40	8.76
Elapsed Time (#4)	69.29	34.74	17.41	8.80
Elapsed Time (#5)	69.29	34.77	17.42	8.76
Average Elapsed Time	69.29	34.77	17.41	8.77
Area (#1)	1.5066	1.5067	1.5069	1.5068
Area (#2)	1.5066	1.5067	1.5070	1.5068
Area (#3)	1.5066	1.5068	1.5066	1.5066
Area (#4)	1.5066	1.5067	1.5068	1.5068
Area (#5)	1.5066	1.5068	1.5068	1.5065
Average Area	1.5066	1.5067	1.5068	1.5067

schedule(static,10)

Number of Threads	**1**	**2**	**4**	**8**
Elapsed Time (#1)	69.30	34.77	17.42	8.77
Elapsed Time (#2)	69.29	34.73	17.43	8.76
Elapsed Time (#3)	69.30	34.78	17.42	8.77
Elapsed Time (#4)	69.30	34.73	17.42	8.76
Elapsed Time (#5)	69.29	34.73	17.41	8.76
Average Elapsed Time	69.30	34.75	17.42	8.76
Area (#1)	1.5066	1.5067	1.5068	1.5068
Area (#2)	1.5066	1.5067	1.5066	1.5067
Area (#3)	1.5066	1.5066	1.5067	1.5068
Area (#4)	1.5066	1.5066	1.5066	1.5067
Area (#5)	1.5066	1.5067	1.5068	1.5065
Average Area	1.5066	1.5067	1.5067	1.5067

schedule(dynamic)

Number of Threads	**1**	**2**	**4**	**8**
Elapsed Time (#1)	69.29	34.78	17.41	8.76
Elapsed Time (#2)	69.30	34.73	17.40	8.77
Elapsed Time (#3)	69.29	34.77	17.40	8.76

Elapsed Time (#4)	69.29	34.73	17.41	8.77
Elapsed Time (#5)	69.30	34.79	17.42	8.76
Average Elapsed Time	69.29	34.76	17.41	8.76
Area (#1)	1.5066	1.5069	1.5068	1.5067
Area (#2)	1.5066	1.5067	1.5067	1.5068
Area (#3)	1.5066	1.5068	1.5066	1.5067
Area (#4)	1.5066	1.5066	1.5066	1.5067
Area (#5)	1.5066	1.5068	1.5067	1.5067
Average Area	1.5066	1.5068	1.5067	1.5067

schedule(dynamic,10)

Number of Threads	**1**	**2**	**4**	**8**
Elapsed Time (#1)	69.30	34.74	17.42	8.76
Elapsed Time (#2)	69.29	34.78	17.42	8.75
Elapsed Time (#3)	69.30	34.78	17.42	8.76
Elapsed Time (#4)	69.29	34.78	17.42	8.76
Elapsed Time (#5)	69.29	34.78	17.42	8.77
Average Elapsed Time	69.29	34.77	17.42	8.76
Area (#1)	1.5066	1.5067	1.5067	1.5067
Area (#2)	1.5066	1.5066	1.5065	1.5067
Area (#3)	1.5066	1.5067	1.5067	1.5066
Area (#4)	1.5066	1.5066	1.5068	1.5068
Area (#5)	1.5066	1.5067	1.5067	1.5068
Average Area	1.5066	1.5067	1.5067	1.5067

schedule(guided)

Number of Threads	**1**	**2**	**4**	**8**
Elapsed Time (#1)	69.29	34.73	17.41	8.76
Elapsed Time (#2)	69.29	34.76	17.43	8.76
Elapsed Time (#3)	69.29	34.74	17.42	8.77
Elapsed Time (#4)	69.29	34.80	17.39	8.82
Elapsed Time (#5)	69.30	34.73	17.41	8.76

Average Elapsed Time	69.29	34.73	17.41	8.77
Area (#1)	1.5066	1.5068	1.5066	1.5068
Area (#2)	1.5066	1.5067	1.5068	1.5067
Area (#3)	1.5066	1.5067	1.5067	1.5067
Area (#4)	1.5066	1.5067	1.5067	1.5067
Area (#5)	1.5066	1.5068	1.5067	1.5068
Average Area	1.5066	1.5067	1.5067	1.5067

3. With collapse (running 3 instead of 5 tasks to save time):

schedule(static,1) collapse(2)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.31	34.83	17.46	8.79
Elapsed Time (#2)	69.30	34.83	17.55	8.78
Elapsed Time (#3)	69.30	34.80	17.44	8.78
Average Elapsed Time	69.30	34.82	17.48	8.78
Area (#1)	1.5066	1.5067	1.5069	1.5067
Area (#2)	1.5066	1.5068	1.5067	1.5065
Area (#3)	1.5066	1.5066	1.5066	1.5066
Average Area	1.5066	1.5067	1.5067	1.5066

schedule(static,10) collapse(2)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.29	34.83	17.44	8.77
Elapsed Time (#2)	69.30	34.81	17.45	8.78
Elapsed Time (#3)	69.29	34.80	17.52	8.86
Average Elapsed Time	69.29	34.81	17.47	8.80
Area (#1)	1.5066	1.5065	1.5067	1.5068
Area (#2)	1.5066	1.5069	1.5068	1.5067
Area (#3)	1.5066	1.5068	1.5067	1.5066
Average Area	1.5066	1.5067	1.5067	1.5067

schedule(dynamic) collapse(2)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.29	34.84	17.46	8.78
Elapsed Time (#2)	69.30	34.83	17.45	8.79
Elapsed Time (#3)	69.30	34.84	17.47	8.78
Average Elapsed Time	69.30	34.84	17.46	8.78
Area (#1)	1.5066	1.5066	1.5066	1.5068
Area (#2)	1.5066	1.5067	1.5066	1.5067
Area (#3)	1.5066	1.5069	1.5066	1.5066
Average Area	1.5066	1.5067	1.5066	1.5067

schedule(dynamic,10) collapse(2)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.29	34.80	17.45	8.79
Elapsed Time (#2)	69.29	34.81	17.46	8.78
Elapsed Time (#3)	69.29	34.80	17.47	8.78
Average Elapsed Time	69.29	34.80	17.46	8.78
Area (#1)	1.5066	1.5066	1.5067	1.5068
Area (#2)	1.5066	1.5066	1.5067	1.5067
Area (#3)	1.5066	1.5066	1.5067	1.5067
Average Area	1.5066	1.5066	1.5067	1.5067

schedule(guided) collapse(2)

Number of Threads	1	2	4	8
Elapsed Time (#1)	69.29	34.80	17.47	8.78
Elapsed Time (#2)	69.30	34.80	17.46	8.78
Elapsed Time (#3)	69.30	34.83	17.46	8.79
Average Elapsed Time	69.30	34.81	17.46	8.78
Area (#1)	1.5066	1.5068	1.5066	1.5067
Area (#2)	1.5066	1.5068	1.5069	1.5066
Area (#3)	1.5066	1.5068	1.5067	1.5067
Average Area	1.5066	1.5068	1.5067	1.5067

The schedule clause improves performance, although different schedules have no significant difference on performance.

Additionally, the collapse clause doesn't make much of a performance difference, other than the ones resulted from the schedule clause.

Task 3 (OpenMP Program (Tasks)):

1. **Each cell is a task:**

Number of Threads	1	2	4	8
Elapsed Time (#1)	74.52	38.24	19.59	10.79
Elapsed Time (#2)	74.52	38.30	19.56	10.72
Elapsed Time (#3)	74.53	38.26	19.60	10.77
Average Elapsed Time	74.52	38.27	19.58	10.76
Area (#1)	1.5066	1.5067	1.5067	1.5067
Area (#2)	1.5066	1.5068	1.5068	1.5067
Area (#3)	1.5066	1.5066	1.5068	1.5067
Average Area	1.5066	1.5067	1.5068	1.5067

2. **Each row is a task:**

Number of Threads	1	2	4	8
Elapsed Time (#1)	74.33	37.32	18.82	9.55
Elapsed Time (#2)	74.33	37.33	18.85	9.55
Elapsed Time (#3)	74.34	37.30	18.83	9.56
Average Elapsed Time	74.33	37.32	18.83	9.55
Area (#1)	1.5066	1.5067	1.5067	1.5068
Area (#2)	1.5066	1.5067	1.5067	1.5066
Area (#3)	1.5066	1.5066	1.5067	1.5068
Average Area	1.5066	1.5067	1.5067	1.5067

3. **Threads create task:**

Number of Threads	1	2	4	8
Elapsed Time (#1)	74.52	37.87	18.95	9.54
Elapsed Time (#2)	74.53	37.83	18.98	9.52
Elapsed Time (#3)	74.53	37.86	18.98	9.54
Average Elapsed Time	74.53	37.85	18.97	9.53
Area (#1)	1.5066	1.5065	1.5067	1.5066
Area (#2)	1.5066	1.5067	1.5068	1.5068
Area (#3)	1.5066	1.5067	1.5069	1.5068
Average Area	1.5066	1.5066	1.5068	1.5067

4. Having each cell correspond to a task has the worst performance, because of the significant overhead of creating and destroying tasks.

   Having each row correspond to a task has slightly better performance, because the overhead is reduced with fewer number of tasks. However, there are still way too many rows.

   Having task creation shared by all threads performs similarly to having each row corresponds to a task.

   Comparing all with part 2, program that use tasks performs better than one that doesn't use scheduler, but performs worse than one that uses scheduler.

   When only one thread exists, program that uses tasks performs even worse than one that doesn't use scheduler. Again, this is due to the significant overhead of creating and destroying tasks.

Appendix:

```
[ff242@omega2 ff242_ps2_cpsc424]$ srun --pty --x11 -p cpsc424 -c 1 -t 1:00:00 --mem-per-cpu=4gb --ntasks=1 --nodes=1 bash
srun: error: x11: no local DISPLAY defined, skipping
[ff242@c30n02 ff242_ps2_cpsc424]$ ./run_seq.sh

==================== make ==============================
icc -g -O3 -xHost -fno-alias -std=c99 -c mandseq.c
icc -g -O3 -xHost -fno-alias -std=c99 -c drand.c
icc -g -O3 -xHost -fno-alias -std=c99 -o mandseq mandseq.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp mandomp.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-schedule.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-schedule mandomp-schedule.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-collapse.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-collapse mandomp-collapse.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks mandomp-tasks.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-row.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-row mandomp-tasks-row.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-allthreads.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-allthreads mandomp-tasks-allthreads.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm

============ Task 1: Serial Program ====================
Time spent = 69.341559. Area = 1.506678.

================== clean up ============================
rm -f mandseq mandomp mandomp-schedule mandomp-collapse mandomp-tasks mandomp-tasks-row mandomp-tasks-allthreads *.o
```

```
[ff242@c30n01 ff242_ps2_cpsc424]$ ./run_omp.sh
```

```
======================== make ==============================
icc -g -O3 -xHost -fno-alias -std=c99 -c mandseq.c
icc -g -O3 -xHost -fno-alias -std=c99 -c drand.c
icc -g -O3 -xHost -fno-alias -std=c99 -o mandseq mandseq.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp mandomp.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-schedule.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-schedule mandomp-schedule.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-collapse.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-collapse mandomp-collapse.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks mandomp-tasks.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-row.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-row mandomp-tasks-row.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-allthreads.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-allthreads mandomp-tasks-
allthreads.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm

========== Task 2: OpenMP Program (Loop Directives) ===========

========== 1. Without schedule or collapse ===================
Number of threads = 1
Time spent = 68.395302. Area = 1.506678.
Number of threads = 2
Time spent = 59.203987. Area = 1.506836.
Number of threads = 4
Time spent = 31.656015. Area = 1.506894.
Number of threads = 8
Time spent = 19.435805. Area = 1.506714.

========== 2. schedule(static,1) ==============================
Number of threads = 1
Time spent = 69.325517. Area = 1.506678.
Number of threads = 2
Time spent = 34.746911. Area = 1.506660.
Number of threads = 4
Time spent = 17.435820. Area = 1.506812.
```

Number of threads = 8
Time spent = 8.762601. Area = 1.506698.

========== 2. schedule(static,10) ==========
Number of threads = 1
Time spent = 69.302315. Area = 1.506678.
Number of threads = 2
Time spent = 34.746787. Area = 1.506840.
Number of threads = 4
Time spent = 17.443520. Area = 1.506724.
Number of threads = 8
Time spent = 8.762902. Area = 1.506700.

========== 2. schedule(dynamic) ==========
Number of threads = 1
Time spent = 69.303113. Area = 1.506678.
Number of threads = 2
Time spent = 34.776455. Area = 1.506680.
Number of threads = 4
Time spent = 17.436992. Area = 1.506760.
Number of threads = 8
Time spent = 8.775986. Area = 1.507006.

========== 2. schedule(dynamic,10) ==========
Number of threads = 1
Time spent = 69.306246. Area = 1.506678.
Number of threads = 2
Time spent = 34.816975. Area = 1.506842.
Number of threads = 4
Time spent = 17.416151. Area = 1.506784.
Number of threads = 8
Time spent = 8.776349. Area = 1.506818.

========== 2. schedule(guided) ==========
Number of threads = 1
Time spent = 69.298829. Area = 1.506678.
Number of threads = 2
Time spent = 34.766539. Area = 1.506716.
Number of threads = 4
Time spent = 17.407272. Area = 1.506786.
Number of threads = 8
Time spent = 8.769465. Area = 1.506798.

========== 3. schedule(static,1) collapse(2) ==========

Number of threads = 1
Time spent = 69.298830. Area = 1.506678.
Number of threads = 2
Time spent = 34.869743. Area = 1.506792.
Number of threads = 4
Time spent = 17.472634. Area = 1.506684.
Number of threads = 8
Time spent = 8.780624. Area = 1.506618.

========== 3. schedule(static,10) collapse(2) ==========
Number of threads = 1
Time spent = 69.305643. Area = 1.506678.
Number of threads = 2
Time spent = 34.867803. Area = 1.506616.
Number of threads = 4
Time spent = 17.523204. Area = 1.506638.
Number of threads = 8
Time spent = 8.861267. Area = 1.506812.

========== 3. schedule(dynamic) collapse(2) ==========
Number of threads = 1
Time spent = 69.300942. Area = 1.506678.
Number of threads = 2
Time spent = 34.825259. Area = 1.506686.
Number of threads = 4
Time spent = 17.475274. Area = 1.506816.
Number of threads = 8
Time spent = 8.800324. Area = 1.506738.

========== 3. schedule(dynamic,10) collapse(2) ==========
Number of threads = 1
Time spent = 69.309390. Area = 1.506678.
Number of threads = 2
Time spent = 34.811011. Area = 1.506750.
Number of threads = 4
Time spent = 17.468126. Area = 1.506728.
Number of threads = 8
Time spent = 8.787248. Area = 1.506714.

========== 3. schedule(guided) collapse(2) ==========
Number of threads = 1
Time spent = 69.300451. Area = 1.506678.
Number of threads = 2
Time spent = 34.850653. Area = 1.506910.

```
Number of threads = 4
Time spent = 17.469861. Area = 1.506656.
Number of threads = 8
Time spent = 8.782062. Area = 1.506830.

====================== clean up ==============================
rm -f mandseq mandomp mandomp-schedule mandomp-collapse mandomp-tasks mandomp-
tasks-row mandomp-tasks-allthreads *.o




[ff242@c30n01 ff242_ps2_cpsc424]$ ./run_omp_tasks.sh

======================== make ==============================
icc -g -O3 -xHost -fno-alias -std=c99 -c mandseq.c
icc -g -O3 -xHost -fno-alias -std=c99 -c drand.c
icc -g -O3 -xHost -fno-alias -std=c99 -o mandseq mandseq.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp mandomp.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-schedule.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-schedule mandomp-schedule.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-collapse.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-collapse mandomp-collapse.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks mandomp-tasks.o drand.o
/home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-row.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-row mandomp-tasks-row.o
drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -c mandomp-tasks-allthreads.c
icc -g -O3 -xHost -fno-alias -std=c99 -openmp -o mandomp-tasks-allthreads mandomp-tasks-
allthreads.o drand.o /home/fas/cpsc424/ahs3/utils/timing/timing.o -lm

=============== Task 3: OpenMP Program (Tasks) ================

============== 1. tasks by cell ==============================
Number of threads = 1
Time spent = 74.523564. Area = 1.506678.
```

Number of threads = 2
Time spent = 38.271254. Area = 1.506812.
Number of threads = 4
Time spent = 19.636760. Area = 1.506672.
Number of threads = 8
Time spent = 10.785935. Area = 1.506942.

========== 2. tasks by row ==========
Number of threads = 1
Time spent = 74.339207. Area = 1.506678.
Number of threads = 2
Time spent = 37.407147. Area = 1.506666.
Number of threads = 4
Time spent = 18.823447. Area = 1.506772.
Number of threads = 8
Time spent = 9.555730. Area = 1.506790.

========== 3. tasks by all threads ==========
Number of threads = 1
Time spent = 74.527203. Area = 1.506678.
Number of threads = 2
Time spent = 37.858074. Area = 1.506788.
Number of threads = 4
Time spent = 18.975060. Area = 1.506684.
Number of threads = 8
Time spent = 9.546428. Area = 1.506694.

========== clean up ==========
rm -f mandseq mandomp mandomp-schedule mandomp-collapse mandomp-tasks mandomp-tasks-row mandomp-tasks-allthreads *.o