**Blue Waters Petascale Semester Curriculum v1.0**

**Unit 4: OpenMP**

**Lesson 5: Convolution in OpenMP (Heat Transfer example)**

**Sample Assessment**

*Developed by Maria Pantoja for the Shodor Education Foundation, Inc.*



*Except where otherwise noted, this work by The Shodor Education Foundation, Inc. is licensed under CC BY-NC 4.0. To view a copy of this license, visit*[*https://creativecommons.org/licenses/by-nc/4.0*](https://creativecommons.org/licenses/by-nc/4.0)

*Browse and search the full curriculum at*[*http://shodor.org/petascale/materials/semester-curriculum*](http://shodor.org/petascale/materials/semester-curriculum)

*We welcome your improvements! You can submit your proposed changes to this material and the rest of the curriculum in our GitHub repository at*[*https://github.com/shodor-education/petascale-semester-curriculum*](https://github.com/shodor-education/petascale-semester-curriculum)

*We want to hear from you! Please let us know your experiences using this material by sending email to* [*petascale@shodor.org*](mailto:petascale@shodor.org)

•**APPLY** basic OpenMP pragmas to accelerate a common scientific pattern

Sample Questions:

1. Rewrite provided code provided so instead of using only the neighbor to the North, South, East, and West uses also the neighbor

|  |  |  |
| --- | --- | --- |
| NW | North | NE |
| West | Center | East |
| SW | South | SE |

1. Ask students to change the Heat parameters like SPEED, Increase/decrease the number of iterations for the stencil, and make them explain the difference in results

•**USE** Profiler tools to evaluate bottlenecks in code

1. Use openMP timing functions to measure execution times of different loops and/or functions on the code. Example

**double start;**

**double end;**

**start = omp\_get\_wtime();**

... work to be timed ...

**end = omp\_get\_wtime();**

**printf(~Work took %f seconds\n~, end - start);**

•**IDENTIFY** which loops/task can be distributed with OpenMP pragmas(loop dependency)

1. Does the next loop contain a loop dependency?

for( i = 1; i<100; i++){

A(i) = B(i)+1

C(i) = A(i-1)\*2 <- yes here, to calculate this iteration we need the prev. one

}

1. Does the next loop contain a loop dependency?

for( i = 1; i<100; i++){

C(i) = A(i-1)\*2 <- yes here, to calculate this iteration we need the prev. one

}

1. Does the next loop contain a loop dependency?

for( i = 1; i<100; i++){

A(i) = B(i-1)\*2 <- no

}

•**COMPARE** sequential to distributed execution times

1. Ask students to change the number of OpenMP threads used and obtain runtimes of sequential code (also provided) vs. distributed code using those different process

Create a table and graphs to study execution

|  |  |
| --- | --- |
| Sequential | Execution time |
| OpenMP 1 Thread |  |
| OpenMP 2 Threads |  |
| …. |  |

Possible more Advanced Questions for Students:

* (code) The stencil code :
* Rewrite code for stencil so instead of hardcoding in the loop the neighbor cells, make the code more flexible and take this neighborhood and its coefficients as a filter passed in one input parameter
* (code) Change it to 3D stencil code
* If a stencil or convolutional filter is separable it can be applied first to rows and then two the columns. Which one may be faster for acceleration ?
* On the pragma omp for schedule(static,4) what does it mean? Useful in this example?
* Will a static, 8 work better?

Ask students to run code and modify:

* Enhance memory allocation using: mmap
* Change stencil to 9 points instead of just 4
* Explore Collapse() clause
* Explore the simd Aligned() clause