

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

## **Unit 9: Optimization**

### **Lesson 2: Code Optimization Patterns**

*Developed by David A. Joiner*

*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>

Browse and search the full curriculum at <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>

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)

# Loop Optimization

# Principles of Loop Optimization

- Access memory in order when possible
  - Reading memory from cache is much faster than reading from RAM
  - Go through arrays in sequence rather than out of order or in large strides
  - Be aware of your rapidly changing index in 2D arrays (and keep your 2D arrays contiguous instead of using lists of lists).
- Minimize operations in loops
  - Look for loop invariant code
  - Look for opportunities to replace complex operations with simple ones
- Minimize overhead in loops
  - Move conditions outside of loops if possible
  - Pass arrays to functions instead of calling functions on elements of an array if possible
  - Replace simple functions with code. #define statements can keep your code clean when doing this.

# Array access examples

- `arraystride.c`: Order of loops over 2D array
  - This example allows you to loop through a 2D array changing elements, either in row-column order or in column-row order.
  - Knowing which is your rapidly changing variable, and looping over your rapidly changing variable, will allow for more efficient memory access.
- `unitstride.c`: Access array in order or in large steps
  - This example will allow you to access and set elements of an array either in steps of 1 (`a[0]`, `a[1]`, `a[2]`, etc.) or in steps of some stride length (`a[0]`, `a[10]`, `a[20]`,...).
  - Accessing memory out of order will require memory to have to be read into cache more often, and will slow down your code.

# Minimizing operations in loops

- `loopcondition.c`
  - This example will allow you to perform a loop operation with a different operation on the first and last items of the loop. The condition can either be inside of the loop or outside.
- `loopinvariantcode.c`
  - This example will have loop invariant code, either inside or outside of a loop.
  - Calculate your loop invariants outside of the loop, not in.
- `strengthred.c`
  - This example will compare the efficiency of `pow(x,2)` to `x*x`.
  - Special cases of complex functions that can be simplified should be.

# Minimizing overhead

- `inlining.c`
  - This example will compare the efficiency of replacing a small function with equivalent code.
  - While hardcoding repetitive calls can make for difficult to read code, and can violate software engineering principles, you can simplify this in C/C++ with the use of the `#define` statement, and in many cases the compiler can do it for you.
- `arrayfunc.c`
  - This example will compare passing an array to a simple function and looping within that function, compared to applying a simple function to each element of the loop.
  - Don't introduce unnecessary function overhead.