Case Study

Lecture 2

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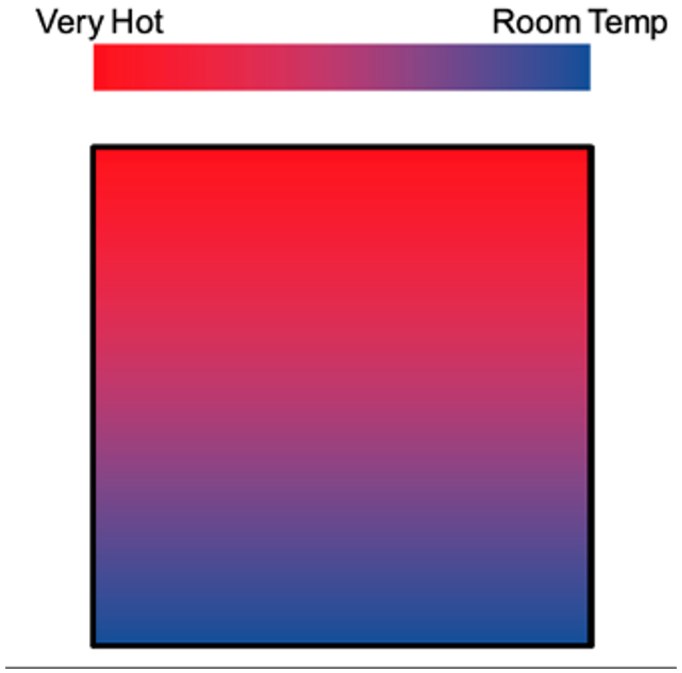
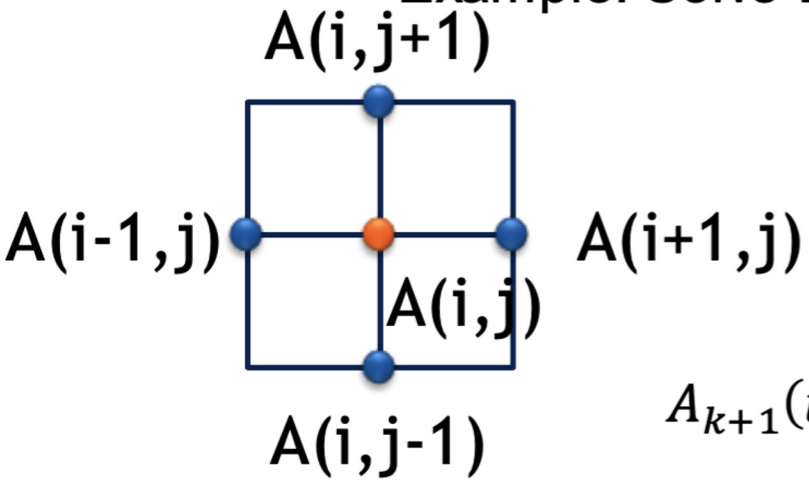
Laplace Heat Transfer

- A simple simulation of heat distributing across a metal plate
- Apply a consistent heat to the top of the plate
- Simulating the heat distribution across the plate



Laplace solver using Jacobi Iteration

- Iteratively converges to correct value (e.g. Temperature), by computing new values at each point from the average of neighboring points.
- Common, useful algorithm
- Example: Solve Laplace equation in 2D: $\nabla^2 f(x, y) = 0$



$$A_{k+1}(i,j) = \frac{A_k(i-1,j) + A_k(i+1,j) + A_k(i,j-1) + A_k(i,j+1)}{4}$$

```
while ( error > tol && iter < iter_max )
{
  error = 0.0;
```

Iterate until converged

Iterate across matrix elements

```
for( int j = 1; j < n-1; j++)
{
  for( int i = 1; i < m-1; i++ )
  {
    Anew[j][i] = 0.25 * ( A[j][i+1] + A[j][i-1] + A[j-1][i] + A[j+1][i]);
    error = fmax( error, fabs(Anew[j][i] - A[j][i]));
  }
}
```

Calculate new neighbors

Compute max error for convergence

```
for( int j = 1; j < n-1; j++)
{
  for( int i = 1; i < m-1; i++ )
  {
    A[j][i] = Anew[j][i];
  }
}
```

Swap input/output arrays

Profiling Sequential Code

LLVM

```
$ clang -Ofast -fopenmp -fno-inline -pg -o jacobi-serial
jacobi.c
Jacobi relaxation Calculation: 4096 x 4096 mesh
    0, 0.250000
  100, 0.002397
  200, 0.001204
  300, 0.000804
  400, 0.000603
  500, 0.000483
  600, 0.000403
  700, 0.000345
  800, 0.000302
  900, 0.000269
 total: 25.557923 s
```

NVC

```
$ nvc -O3  -o jacobi-serial jacobi.c
Jacobi relaxation Calculation: 4096 x 4096 mesh
    0, 0.250000
  100, 0.002397
  200, 0.001204
  300, 0.000804
  400, 0.000603
  500, 0.000483
  600, 0.000403
  700, 0.000345
  800, 0.000302
  900, 0.000269
 total: 23.364053 s
```

How are we going to parallelize Jacobi?

- OpenMP + Multicore – PDC's Dardel
  - Clang, AMD OpenMP
- OpenMP offloading to GPU – PDC's Dardel
  - Clang, AMD OpenMP
- OpenACC + Multicore – demo on LBNL's Perlmutter
  - NVIDIA HPC SDK
- OpenACC on GPU -- demo on LBNL's Perlmutter
  - NVIDIA HPC SDK