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Information Technology Services

Parallel Programming Workshop

Brought to you by

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Registration

- Please make sure you're signed in.
- Won't need a computer this morning
  - unless you need a calculator to add integers

Plan Of Action

- Monday Morning
  - Parallel Concepts
- Monday Afternoon
  - Define an example problem
  - Work with serial code
  - Develop psuedo programming / parallel description
- Tuesday
  - Intro To MPI
  - Map psuedo program to MPI calls
  - Template parallel example
- Wednesday
  - Performance analysis

Concepts

- Throw out some terminology
- Manual exercises to identify concepts
- Capture concepts on the board
- Relate them to program analysis when appropriate.

Parallel Programming Models

Based on the problem type, there may be one method of parallel programming preferred over another:

- Distributed Memory
- Shared Memory
- Hybrid

Often dictated by the architecture of a specific machine, but any method possible on any machine.

Exercise 1

- The data set: 5 numbers on a card.
- Desired analysis: summation
- Any volunteer?
- Anyone want to play time keeper?

Conceptually, what process was followed?

Ex 1 Outcomes

- A task – some unit of work, here summing 1 card.
  - If the work is being done on a computer it could be handled in:
    - program / process
    - thread
- Communication in the form of input and output. May be:
  - Implicit, as in a serial program.
  - Explicit, as we'll see eventually in parallel programs.
- Just basic stuff – work to be done and data to be worked on.

Exercise 2

- Make life a little harder: 4 cards, 5 numbers each.
- Someone want to play time keeper?

Ex. 2 Outcomes

- Break down the activity involved.
- Anything different?
- How many tasks?
- How do the input and output compare with Ex 1?

Alternate Approach 1

- Again, 4 cards to sum.
- Tell me when you are done with a card, and I'll give you the next card.
- Time keeper alert.

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Alternate Outcomes

- Example of “master / slave” task distribution.
- Overhead – extra work required to handle the coordination.
    - More communication for coordination.
    - More data movement – same amount of data, but note additional activity to handle 1 card at a time – communication latency.

Exercise 3

- Try it again, only with two volunteer adders.

1st Alternate Approach

- Hand out 1 card at a time

2nd Alternate Approach

- “Broadcast” 4 cards to each adder.
- Adder 1 does first two cards.
- Adder 2 does last two cards.

Exercise 3 Outcomes

- Introduce new terminology:
  - Number of adders – the ***size*** of the adder pool.
  - The ID of an adder – the ***rank*** of an adder.
- Adders must be able to identify tasks.
  - How to determine even/odd (card set on each card).
  - How to stop looking for tasks when all are consumed.

Concept Summary

- What programming models?
- Types of parallelism?
- Planning requirements?

Exercise 4

Example of *sharing memory* simply because you **all** can see **all** the data.

	A	B	C	D	E
1	6	3	13	78	35
2	49	60	138	34	79
3	59	108	139	188	110
4	137	50	4	167	189
5	83	136	215	26	140
6	0	187	77	216	51

Sums

Total

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Ex 4 Outcomes

- Benefits?
- Difficulties?

Concept Summary

- Shared memory lets all processors see all data.
- Shared Memory Model is growing in popularity as more cores per node become available, and new devices such as GPUs become common place.
- Hybrid or Heterogeneous models are becoming important as the needed to combine Shared and Distributed models increase.

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Parallel Thinking

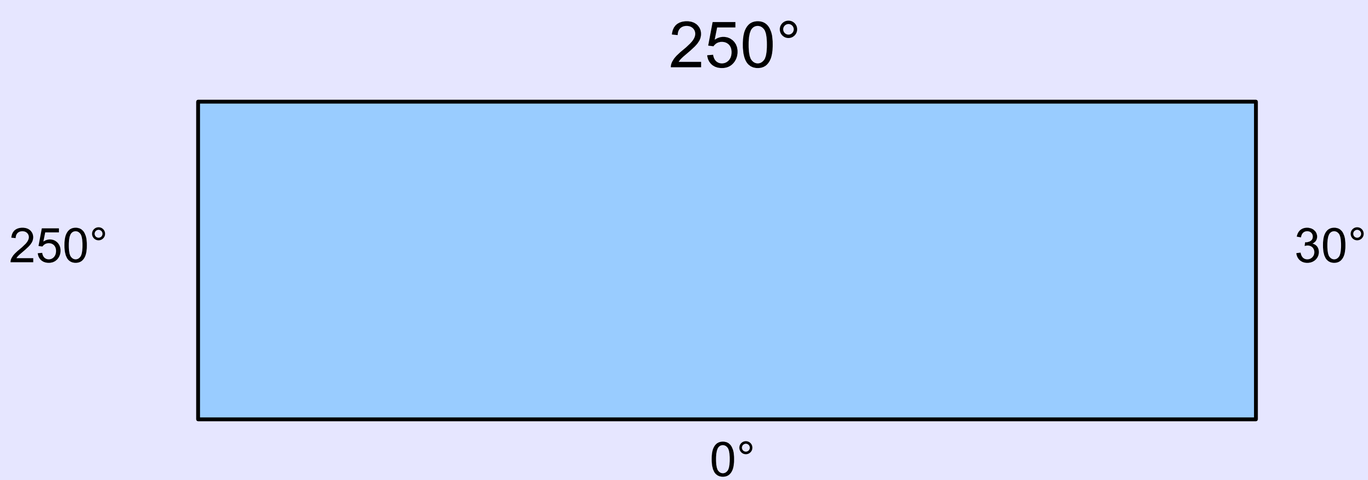
- What kind of questions do you need to consider when approaching a new problems?

Task	**Overhead**	**Distribution**	**Load Balance**
Size (Workers)	**Rank (Position)**	**Scalability**	**Synchronize**
Correctness	**Overlap**		

Break

The Laplace Heat Equation

- For a real problem, consider how to go about solving the Laplace Heat Equation in 2-D. Idea is to determine the temperature at any point on a surface, given the temperature at the boundaries:



Formal Solution

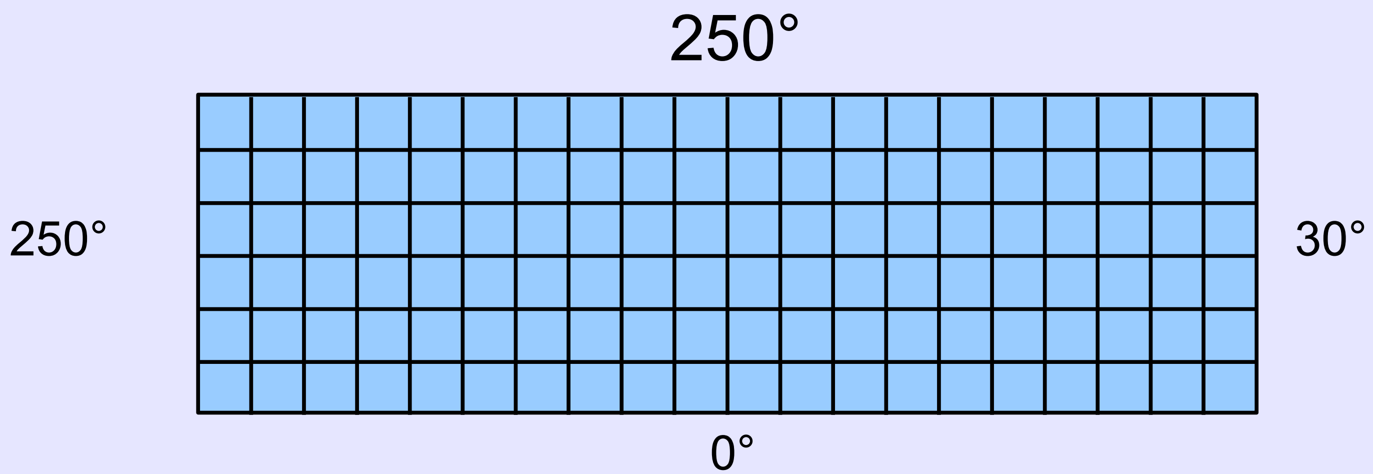
The solution must satisfy:

$$\nabla^2 \phi = 0$$

with the application of Dirichlet boundary conditions (constant values around edge of region.

The Serial Solution

Subdivide the surface into a mesh of points.



Apply the following *5-point stencil* iteratively until the temperature stops changing (new temp approximates old temp):

$$T_{i,j}^{n+1} = 0.25 * \left(T_{i-1,j}^{n} + T_{i+1,j}^{n} + T_{i,j-1}^{n} + T_{i,j+1}^{n} \right)$$

Serial Program

- Grab a copy of the program named:

  `/work/jalupo/laplace_solver_serial.f90`
- Open with “less” or “vi” so you can follow along.
- Anyone have trouble reading Fortran?
- Anyone not know how to compile and run a Fortran program?

Main Components

- **`program laplace_main`** – program main line.
- **`subroutine laplace`** – the actual solver. It also allocates memory to hold the 2-D mesh based on the requested rows and columns.
- **`subroutine initialize`** – sets the internal temperatures to 0.
- **`subroutine set_bcs`** – sets up the boundary conditions.

Compiling Fortran

- Here is a quick summary of how to compile and run this particular program (assumes default environment):

```
$ ifort -o laplace laplace_solver_serial.f90
$ ./laplace
```

- You should see the following line of text on your screen:

```
Usage: laplace nrows ncols niter iprint relerr
```

Now try executing the program with some real numbers:

```
$ ./laplace 100 200 3000 300 0.001
```

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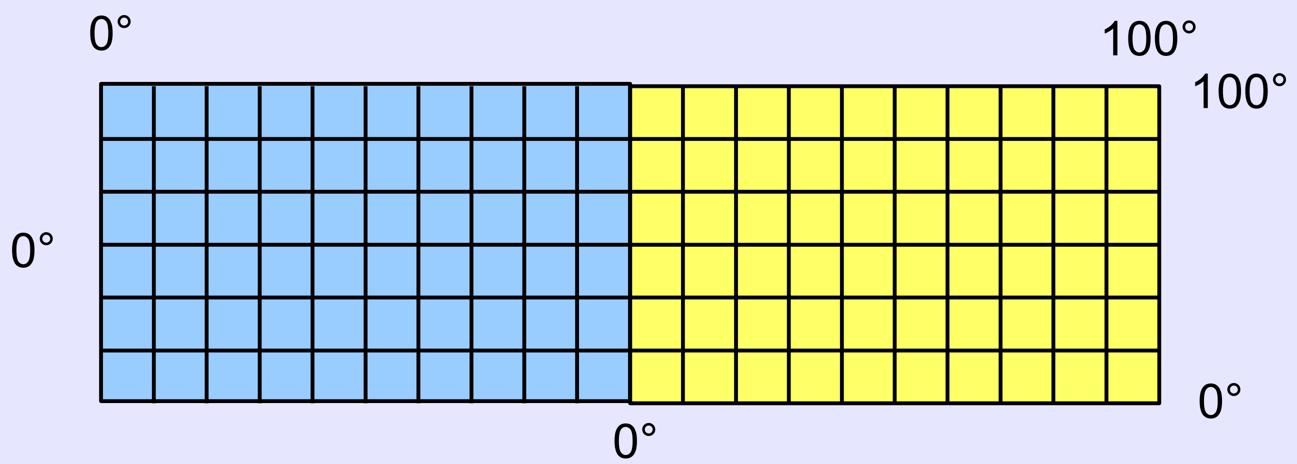
Decomposition

- Assuming 2 processors, let's divide the surface in half.



What overhead do we have to consider adding to make this give the same answer?

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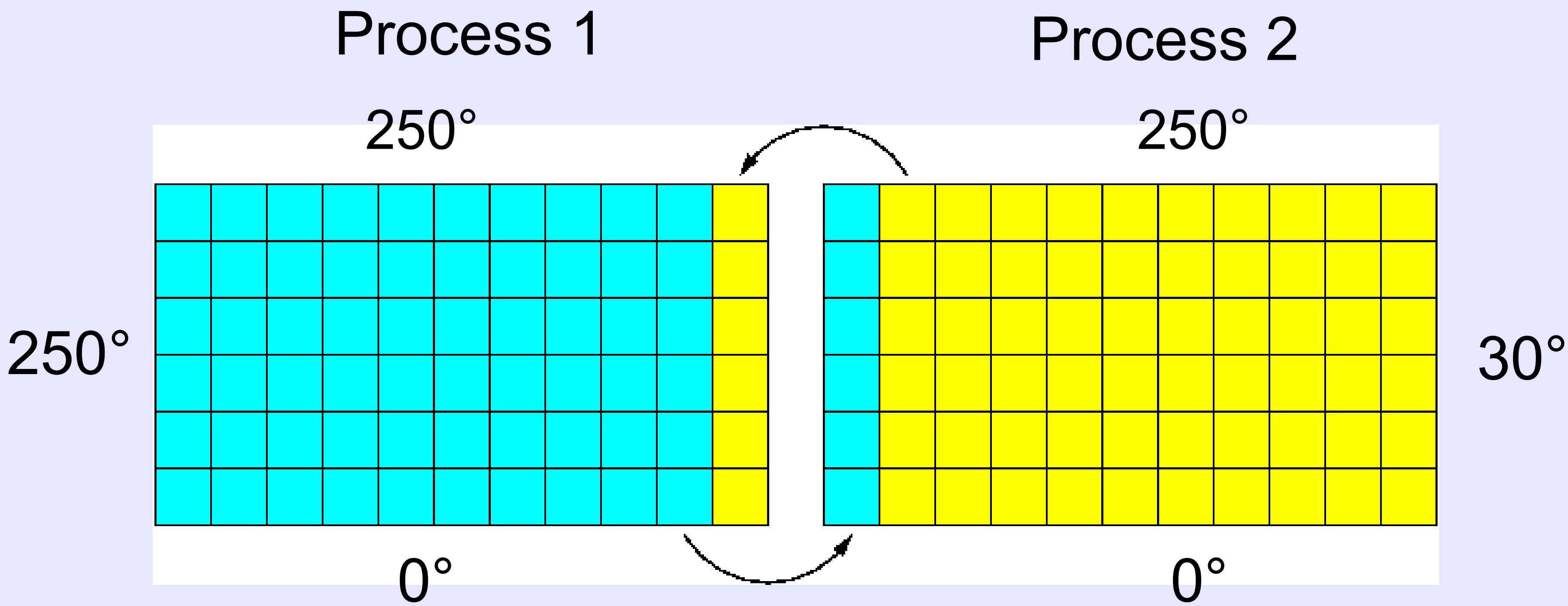
Ghost Cells



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Overhead

- Breaking up the problem so multiple processes can work on it introduces *overhead*:
  - Logic must be added so each process knows which part of the mesh it is expected to work on. This directly impacts how the code will start up.
  - Communication must be added so data from adjoining regions can be properly updated.
  - Code must be added so the final results can be communicated. This directly impacts how the code will report results and terminate.
- A serial program is not the same as a parallel program running on 1 processor!

Domination

- Clearly, if you increase the number of processes working on this problem, the amount of communication required increases.
- With a few processes, this problem exhibits the property of being *compute dominated*.
- When the number of processes approach the number of mesh points, it becomes *communication dominated*.
- All parallel programs exhibit one form or the other depending on the problem specifics.

LUNCH

Parallel Thinking

- What kind of questions do you need to consider when approaching a new problems?

Task	**Overhead**	**Distribution**	**Load Balance**
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Correctness	**Overlap**		