Image Processing

A case study for a domain decomposed MPI code

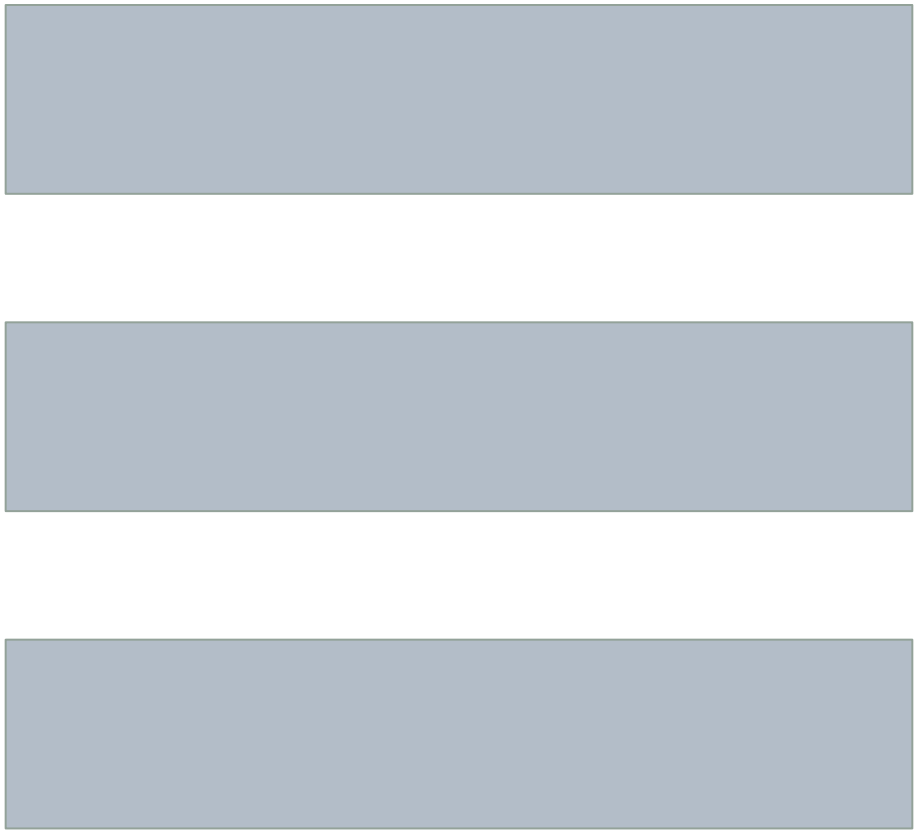
Reusing this material

Domain Decomposition 1

- Starting with a big array:

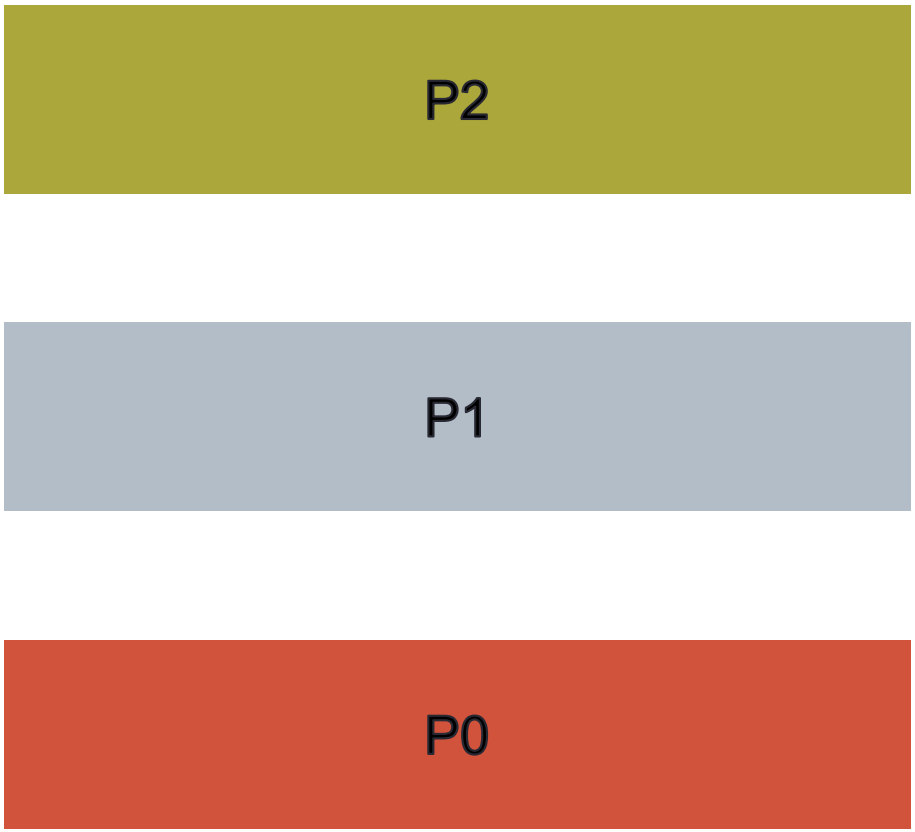
Domain Decomposition 2

- Split it into pieces:



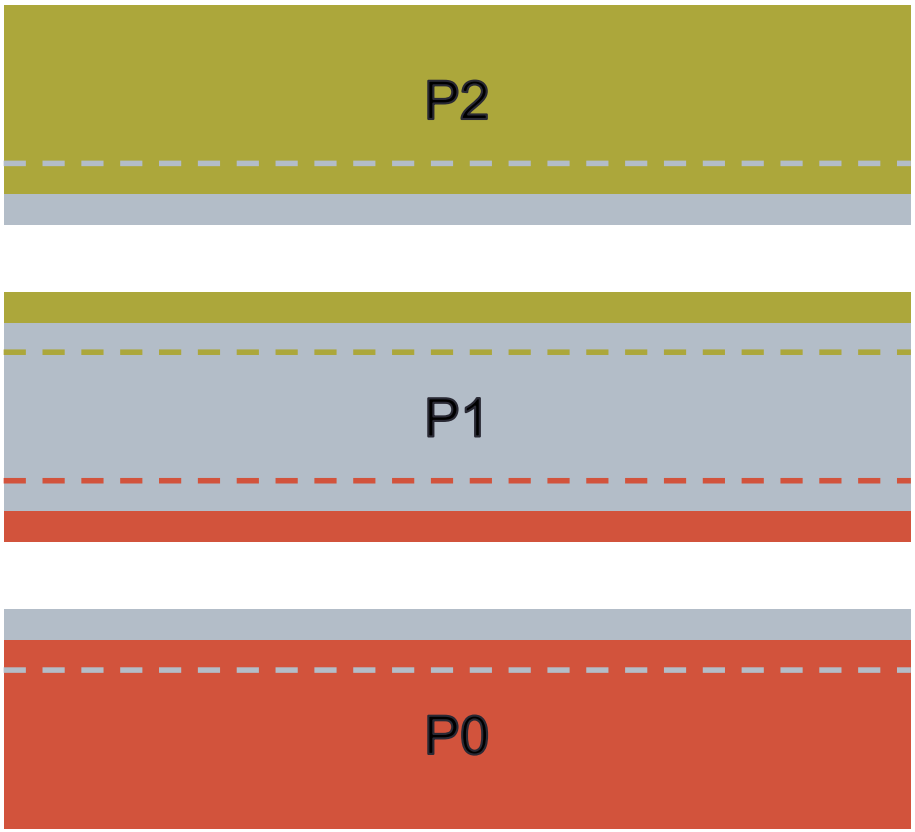
Domain Decomposition 3

- Assign pieces to processes:



Domain Decomposition 4

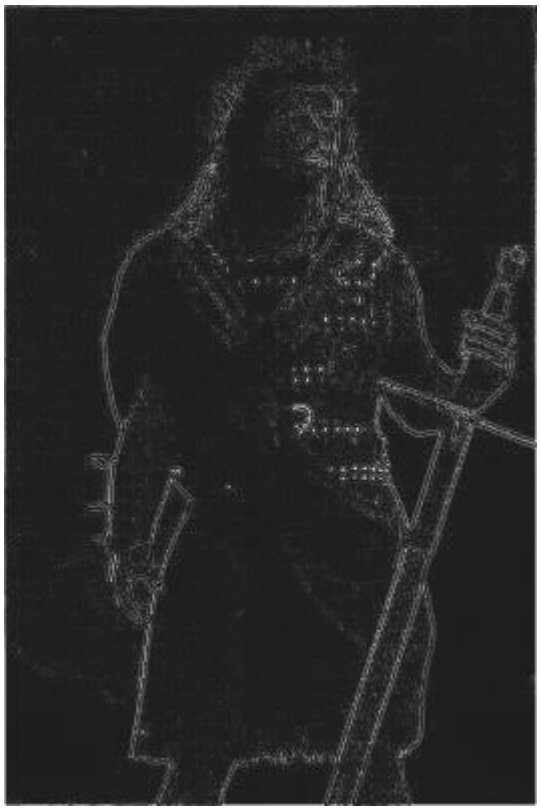
- Use halos to deal with nearest-neighbour interactions



Edge detection / image reconstruction

single pass

hundreds of iterations



Edge detection

- Compare pixel to its four nearest neighbours
  - pixel values are from 0 (black) to 255 (white)

$$edge_{i,j} = image_{i+1,j} + image_{1,j+1} + image_{i-1,j} + image_{i,j-1} - 4\,image_{i,j}$$

- What about the boundary conditions?
  - use non-periodic boundaries
  - pixels off the edge of the image (e.g. $image_{M+1,j}$) are set to white

- Pad 2D arrays with halos
  - in serial code, all halo values set to 255 (i.e. white)

Image reconstruction

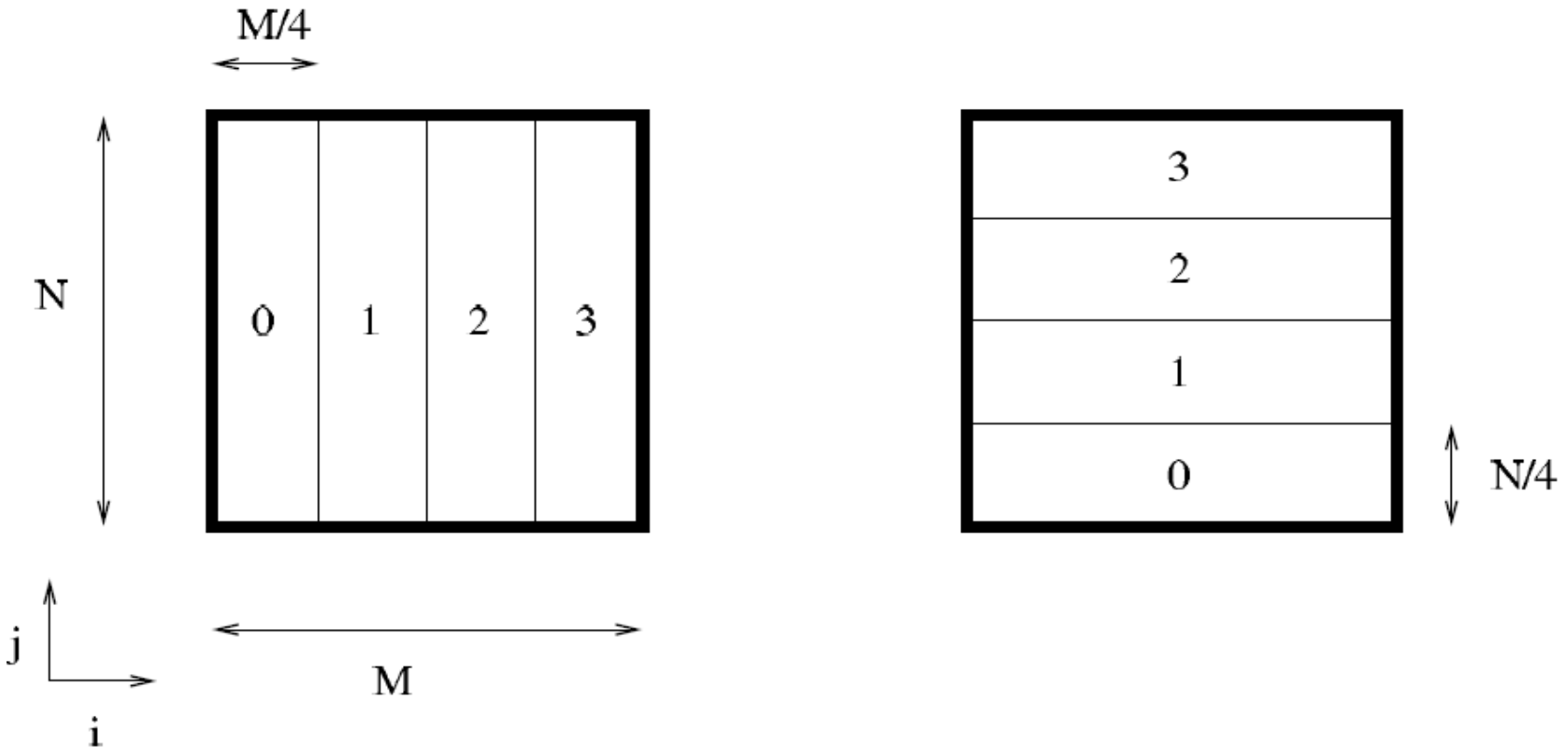
- Jacobi Solver to undo the simple edge detection algorithm (a five-point stencil)
  - simple example of discretised partial differential equation with nearest-neighbour interactions
  - actually solving $\nabla^2 image = edge$

$$new_{i,j} = \frac{1}{4}\left(old_{i+1,j} + old_{1,j+1} + old_{i-1,j} + old_{i,j-1} - edge_{i,j}\right)$$

- Repeat many times
  - in parallel, must update halo values from neighbours every iteration

Domain Decomposition

- Different choices in C and Fortran



The case study

- I provide you with:
  - More detailed printed instruction
  - Tar-ball (Choice of C or Fortran)
    - Input routine
    - Output routine
    - Couple of input files
- Tasks
  - Write a serial code (with halos for fixed boundary conditions)
    - ***check that the serial code works!!***
  - Distribute the work onto the processors; separate reconstructions
  - Get the halos exchanged; single reconstruction, identical to serial
  - Further suggestions on the instruction sheet

Viewing the Images

- Images are in a very old-fashioned text-based format
  - Portable Grey Map (PGM)
  - easy to read and write

- You may not be able to view PGM files on your laptop
  - could install *ImageMagick* suite (which contains *display*)
    - `user@laptop:~> display image.pgm`
  - may have problems with the input edge files (contain negative values!)
    - `user@laptop:~> sed 's/\-//g' edge.pgm | display -`

- Viewing program on ARCHER2 (wrapper round display)
  - fixes the potential issue with negative values
    - `user@archer2:~> module load imagemagick`
    - `user@archer2:~> pgmdisplay image.pgm`