TRACK II

ADVANCED DISTRIBUTED-MEMORY PROGRAMMING

HANDS ON EXERCISES

2024 IHPCSS

BRIDGES2 SETUP

Connecting

```
ssh <username>@bridges2.psc.edu
```

Exercises

```
cp -r /jet/home/akirby/IHPCSS2024-mpi/exercises ~/.
```

Modules

1) allocations/1.0
2) psc.allocations.user/1.0
3) intel-mpi/2021.10.0

➢ `module load intel-mpi`

Interactive Reservations

➢ `./interactive8-day1.sh`

➢ `./interactive8-day2.sh`

Slides(pptx): https://github.com/ackirby88/IHPCSS2024-mpi

LECTURE SLIDES

Slides (pptx)/Code on Github

```
git clone https://github.com/ackirby88/IHPCSS2024-mpi
```

EXERCISE.1

DERIVED DATA TYPES

Four Programs

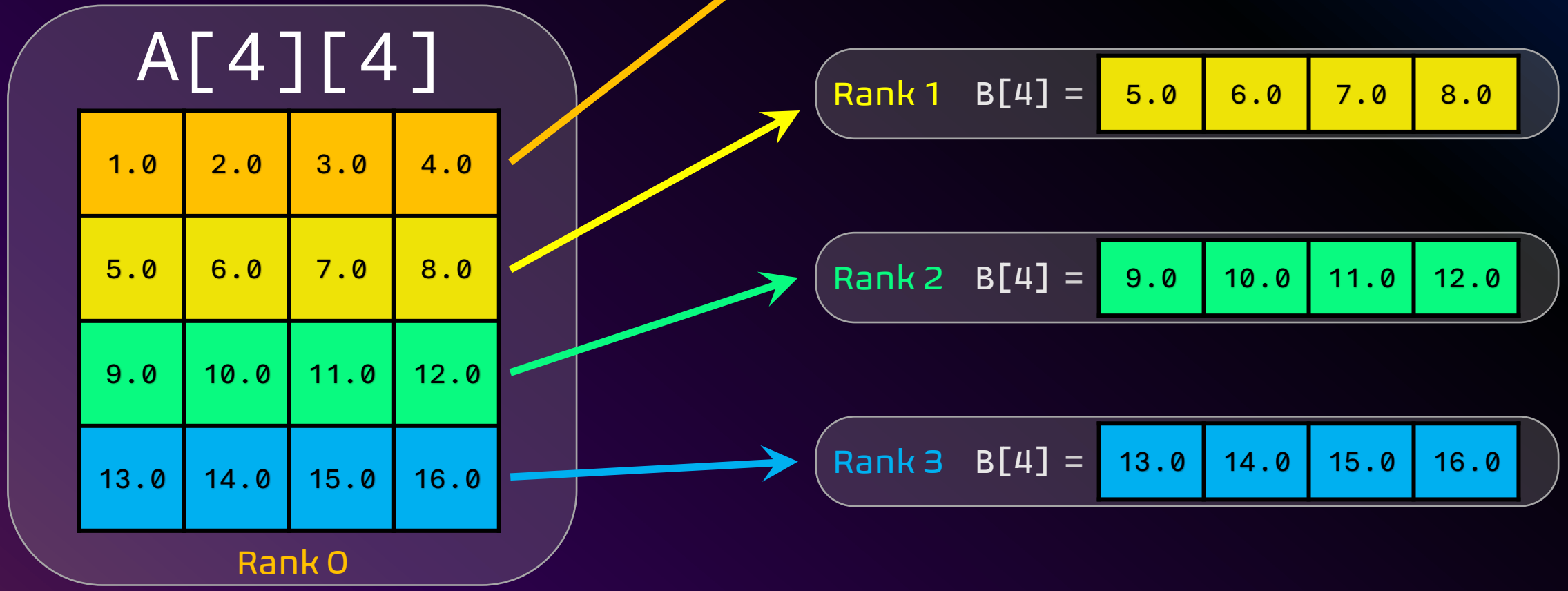
- ✓ ddt.1.contiguous
- ✓ ddt.2.vector
- ✓ ddt.3.indexed
- ✓ ddt.4.struct

A[4][4]

1.0	2.0	3.0	4.0
5.0	6.0	7.0	8.0
9.0	10.0	11.0	12.0
13.0	14.0	15.0	16.0

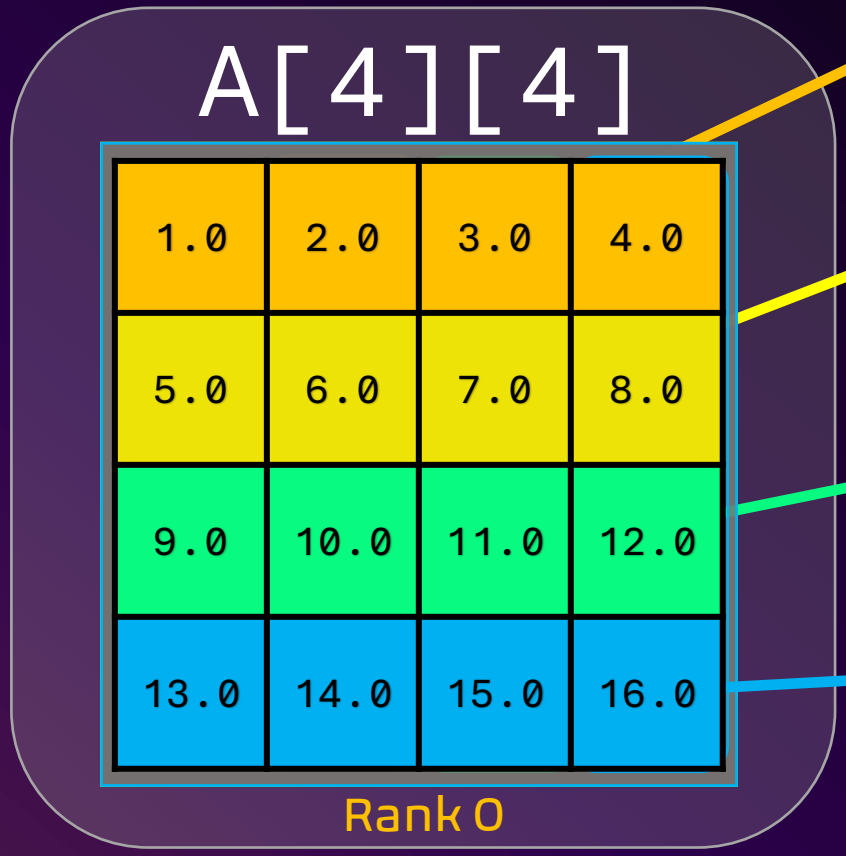
EXERCISE.1 ddt.1.contiguous DERIVED DATA TYPES

```
int MPI_Type_contiguous(
    int count,
    MPI_Datatype oldtype,
    MPI_Datatype *newtype);
```



EXERCISE.1 ddt.2.vector DERIVED DATA TYPES

```
int MPI_Type_vector(
    int count,
    int blocklen,
    int stride,
    MPI_Datatype oldtype,
    MPI_Datatype *newtype);
```



Rank 0 B[4] = 1.0 5.0 9.0 13.0

Rank 1 B[4] = 2.0 6.0 10.0 14.0

Rank 2 B[4] = 3.0 7.0 11.0 15.0

Rank 3 B[4] = 4.0 8.0 12.0 16.0

EXERCISE.1 ddt.3.indexed DERIVED DATA TYPES

```
int MPI_Type_indexed(
 int count,
 int *array_of_blocklens,
 int *array_of_displacements,
 MPI_Datatype oldtype,
 MPI_Datatype *newtype);
```

Rank 0

A[16]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

- Block Count
- Block Lengths
- Displacements

Rank 0 B[6] = | 6 | 7 | 8 | 9 | 13 | 14 |

Rank 2 B[6] = | 6 | 7 | 8 | 9 | 13 | 14 |

Rank 1 B[6] = | 6 | 7 | 8 | 9 | 13 | 14 |

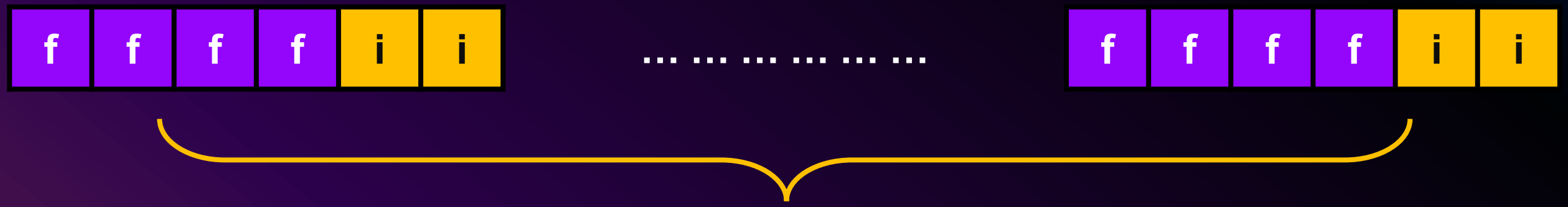
Rank 3 B[6] = | 6 | 7 | 8 | 9 | 13 | 14 |

EXERCISE.1 ddt.4.struct DERIVED DATA TYPES

```
int MPI_Type_create_struct(
      int count,
      int *array_of_blocklens,
MPI_Aint *array_of_displacements,
MPI_Datatype *array_of_types,
MPI_Datatype *newtype);
```

```
typedef struct {
    float x, y, z, velocity;
    int n, type;
} Particle;

Particle particles[NELEM];
```



EXERCISE.1 DERIVED DATA TYPES

Four Programs

- ✓ ddt.1.contiguous
- ✓ ddt.2.vector
- ✓ ddt.3.indexed
- ✓ ddt.4.struct

Step 1: `cp -r /jet/home/akirby/IHPCSS2024-mpi/exercises ~/.`

Step 2: `cd exercises/Exercise.1-DerivedDataTypes/{c or f90}`

Step 3: Complete the "TODO" tasks in each of the programs.

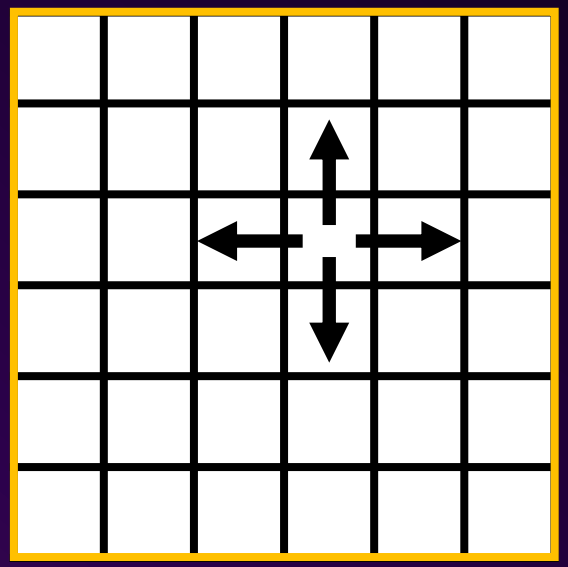
SOLUTIONS: `cd exercises/Exercise.1-DerivedDataTypes/.soln`

EXERCISE.2 CARTESIAN VIRTUAL TOPOLOGIES

Step 1: cd `exercises/Exercise.2-CartesianTopology/{c or f90}`

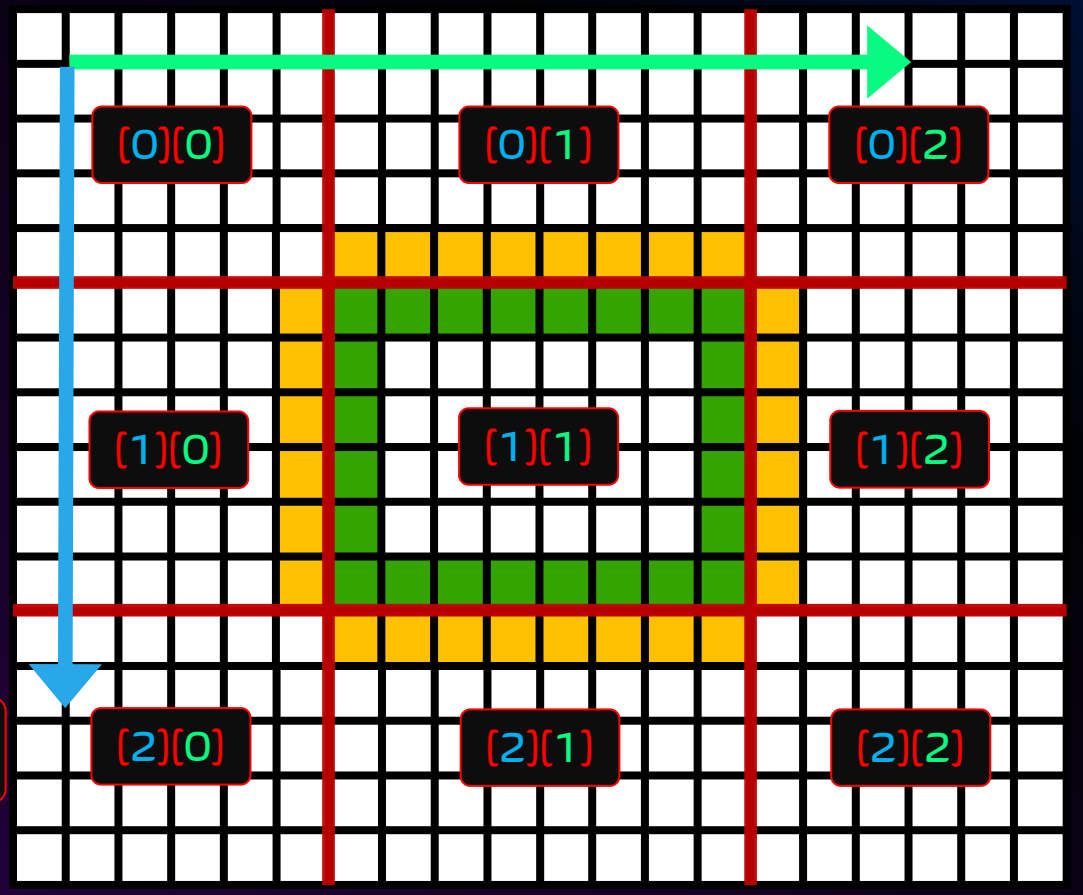
Step 2: Complete the "TODO" tasks in stencil_cart_shift.{c or f90}

$$-\Delta u(x,y) = f$$



4 Neighbors

Typical Communication Pattern

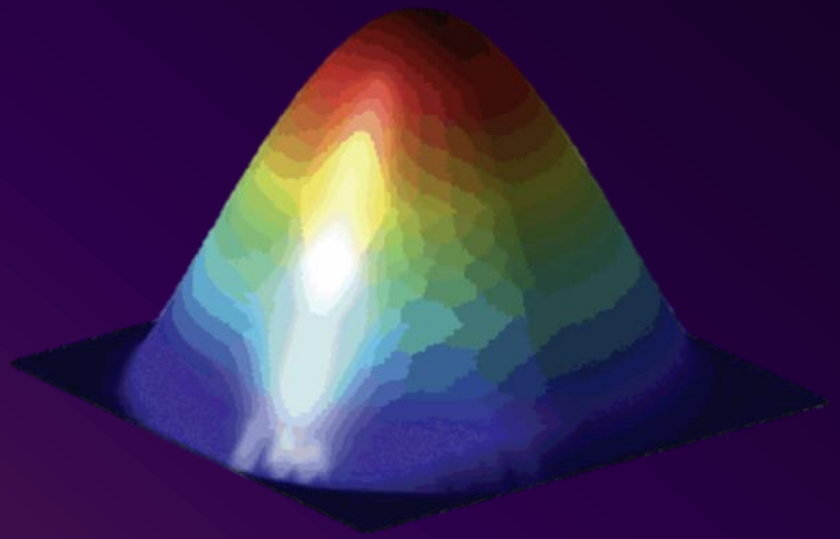


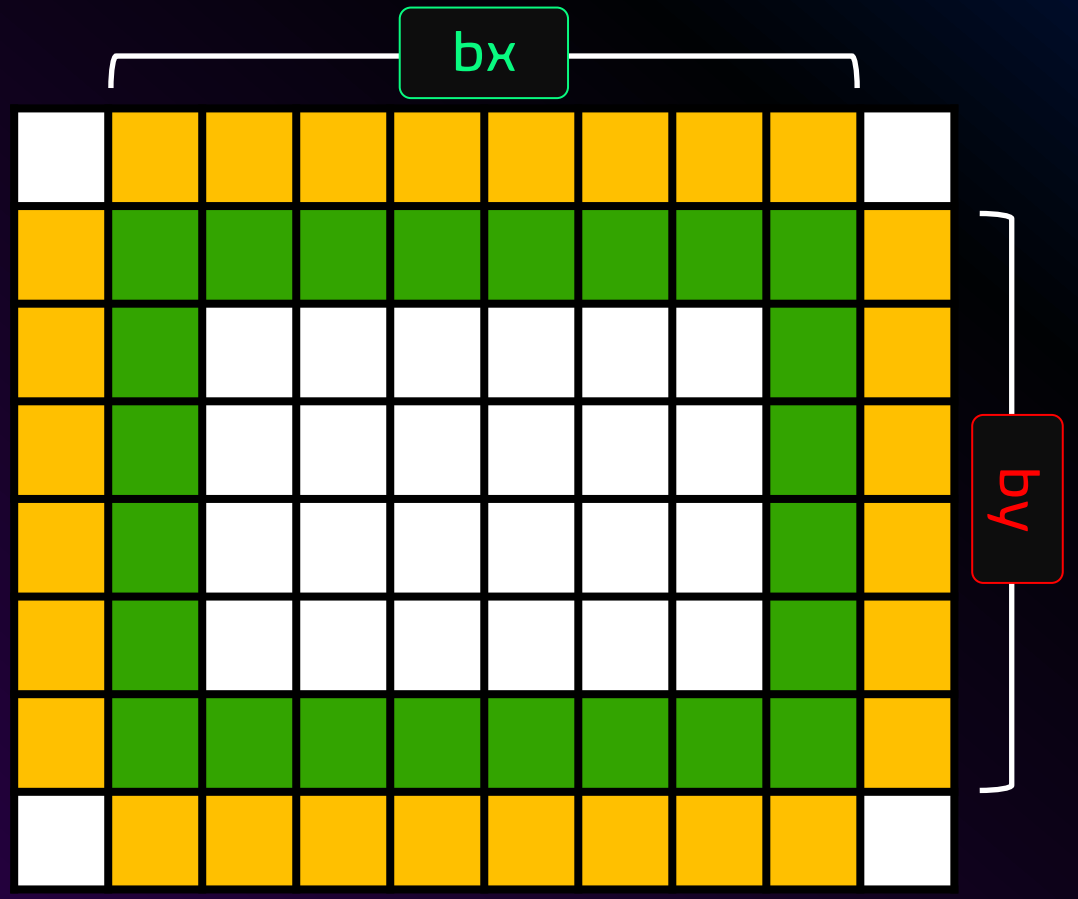
EXERCISE.2 CARTESIAN VIRTUAL TOPOLOGIES

Step 1: cd `exercises/Exercise.2-CartesianTopology/{c or f90}`

Step 2: Complete the "TODO" tasks in stencil_cart_shift.`{c or f90}`

$$-\Delta u(x,y) = f$$

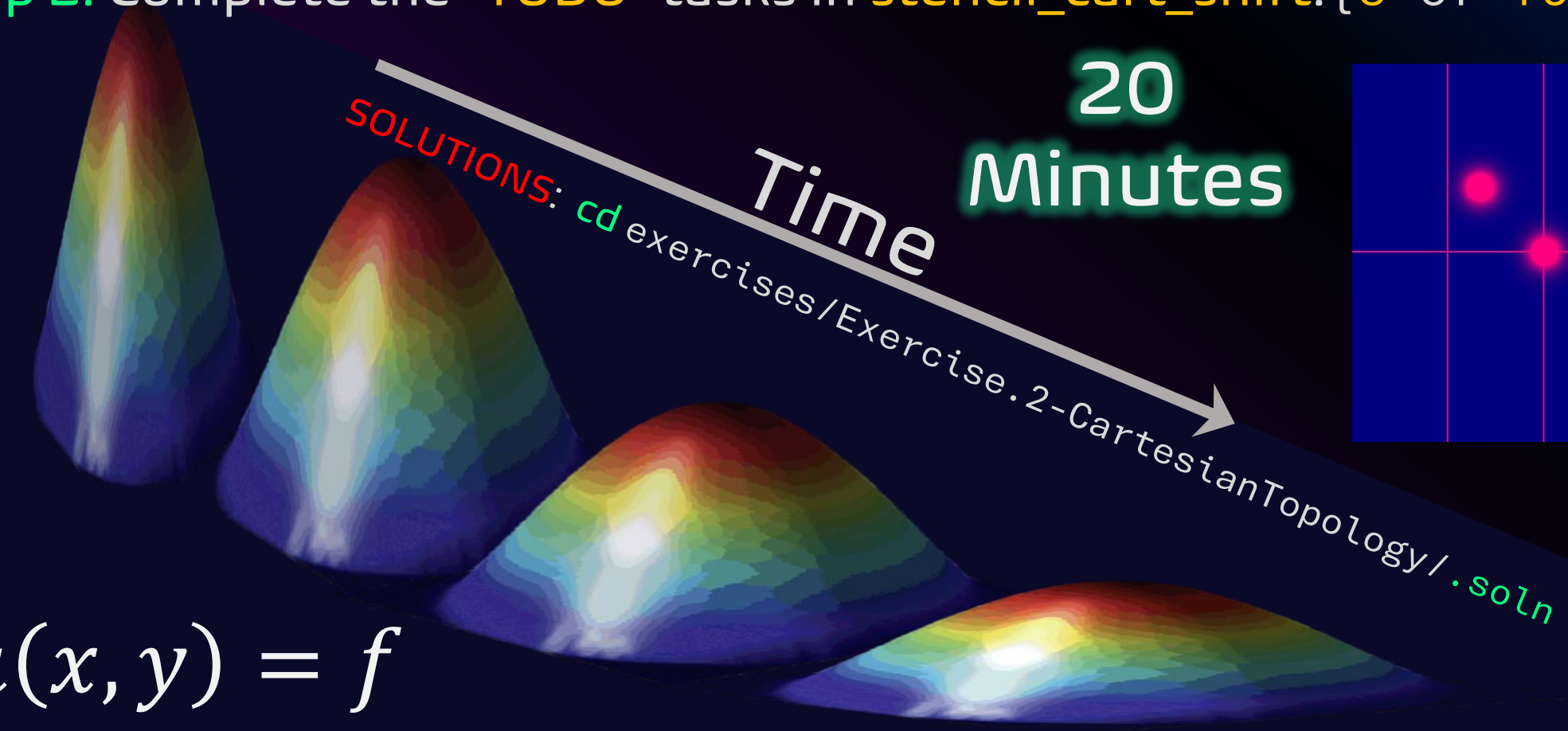




EXERCISE.2 CARTESIAN VIRTUAL TOPOLOGIES

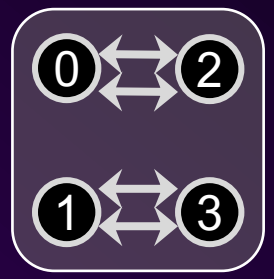
Step 1: `cd exercises/Exercise.2-CartesianTopology/{c or f90}`

Step 2: Complete the "TODO" tasks in stencil_cart_shift.`{c or f90}`

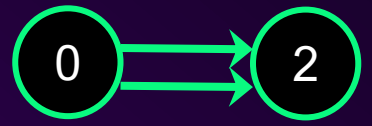


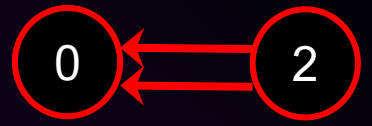
$$-\Delta u(x,y) = f$$

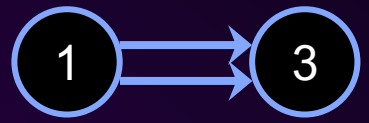
EXERCISE.3 DISTRIBUTED GRAPH TOPOLOGIES



Makes a new communicator to which topology information has been attached.







MPI Process 0

MPI Process 1

MPI Process 2

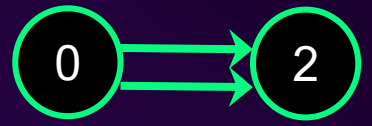
MPI Process 3

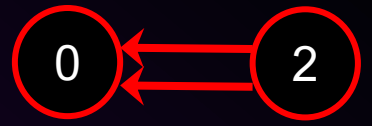
Every MPI process may specify 0, 1 or more edges.
The edges specified do not have to contain the MPI process that passes them.

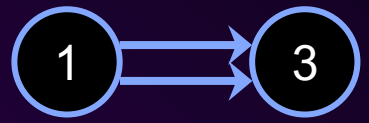
EXERCISE.3 DISTRIBUTED GRAPH TOPOLOGIES

Step 1: cd exercises/Exercise.3-GraphTopology/{c or f90}

Step 2: Complete the "TODO" tasks in mpi_dist_graph_create.{c or f90}





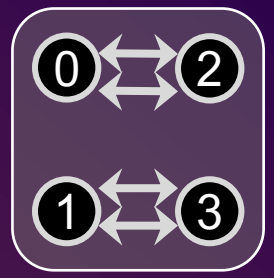


MPI Process 0

MPI Process 1

MPI Process 2

MPI Process 3



Look at the new rank reordering.
Does it make sense? Why?*

20 Minutes

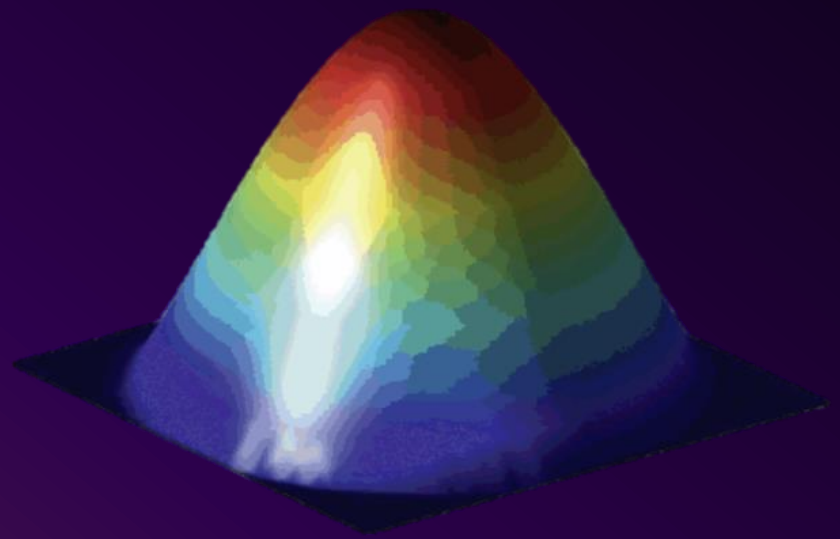
* May not reorder due to MPI Vendor implementation.

EXERCISE.4 NEIGHBORHOOD COLLECTIVES

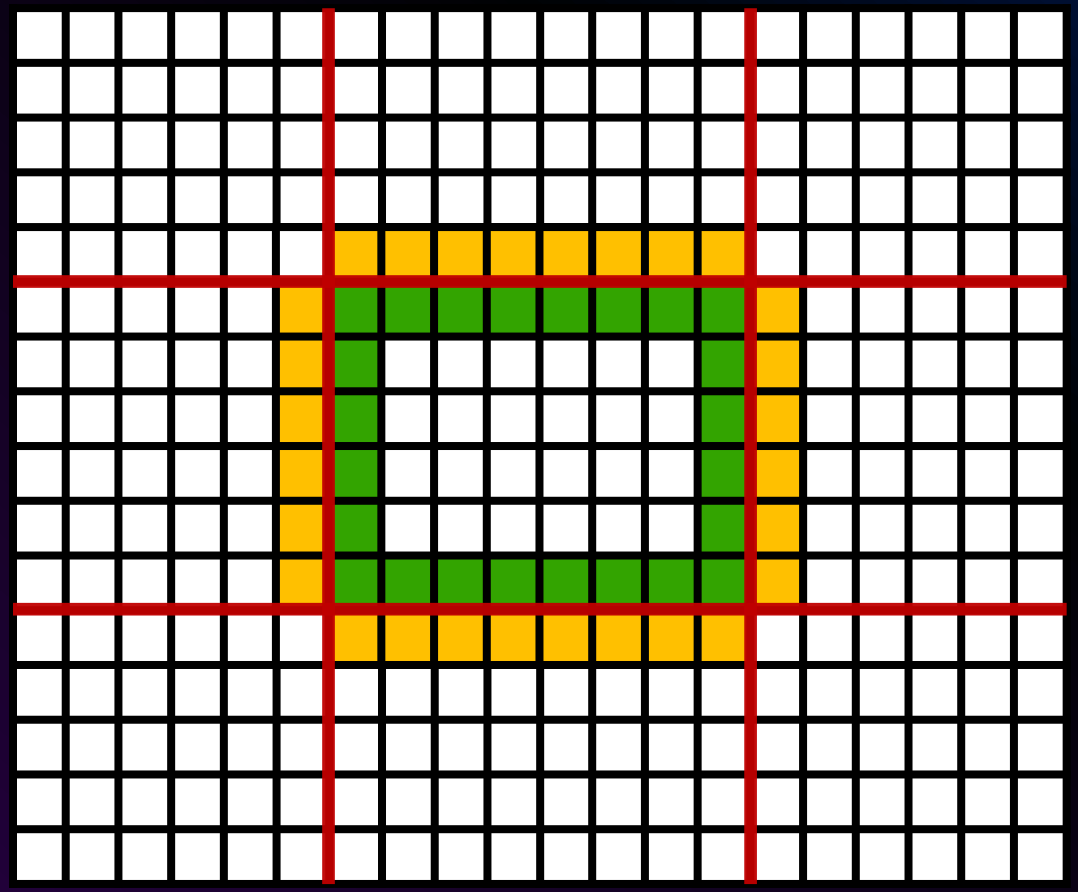
Step 1: cd `exercises/Exercise.4-NeighborhoodCollectives/{c or f90}`

Step 2: Complete the "TODO" tasks in `stencil_mpi_carttopo_neighcolls.{c or f90}`

$$-\Delta u(x,y) = f$$



4 Neighbors
Typical Communication Pattern



EXERCISE.4 NEIGHBORHOOD COLLECTIVES

Step 1: cd `exercises/Exercise.4-NeighborhoodCollectives/{c or f90}`

Step 2: Complete the "TODO" tasks in `stencil_mpi_carttopo_neighcolls.{c or f90}`

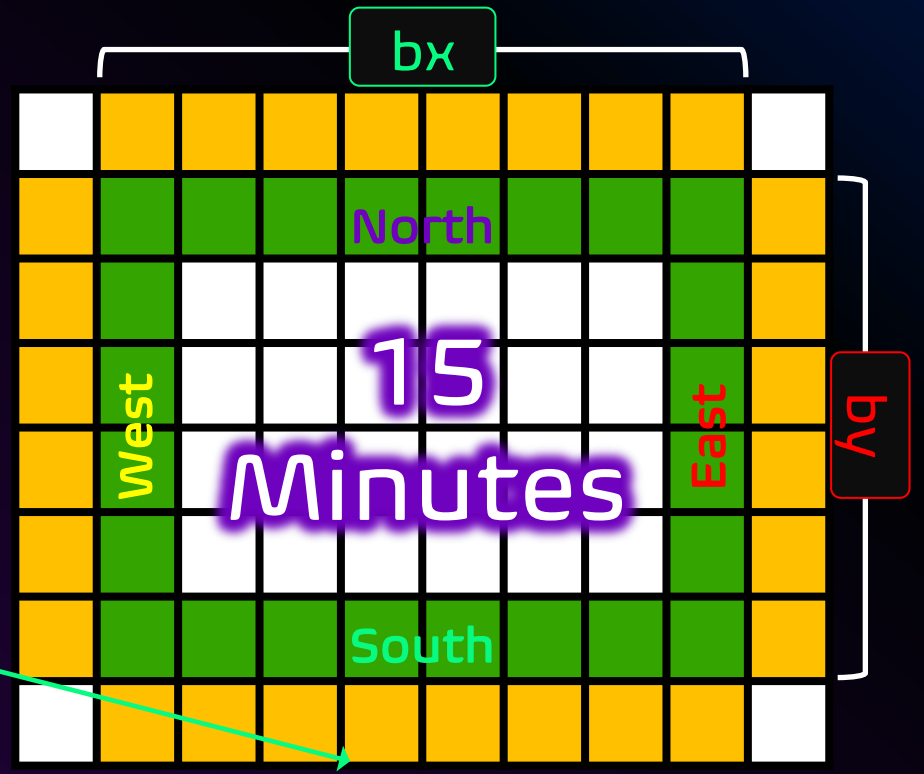
Pack Send Buffer (green cells)

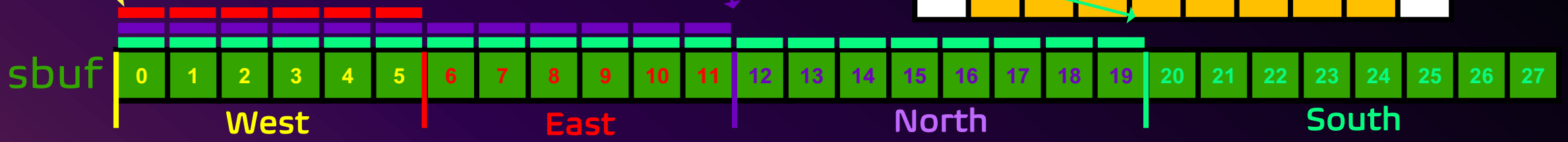
- West, East, North, South

Recall Neighbor Ordering (X-, X+, Y-, Y+)

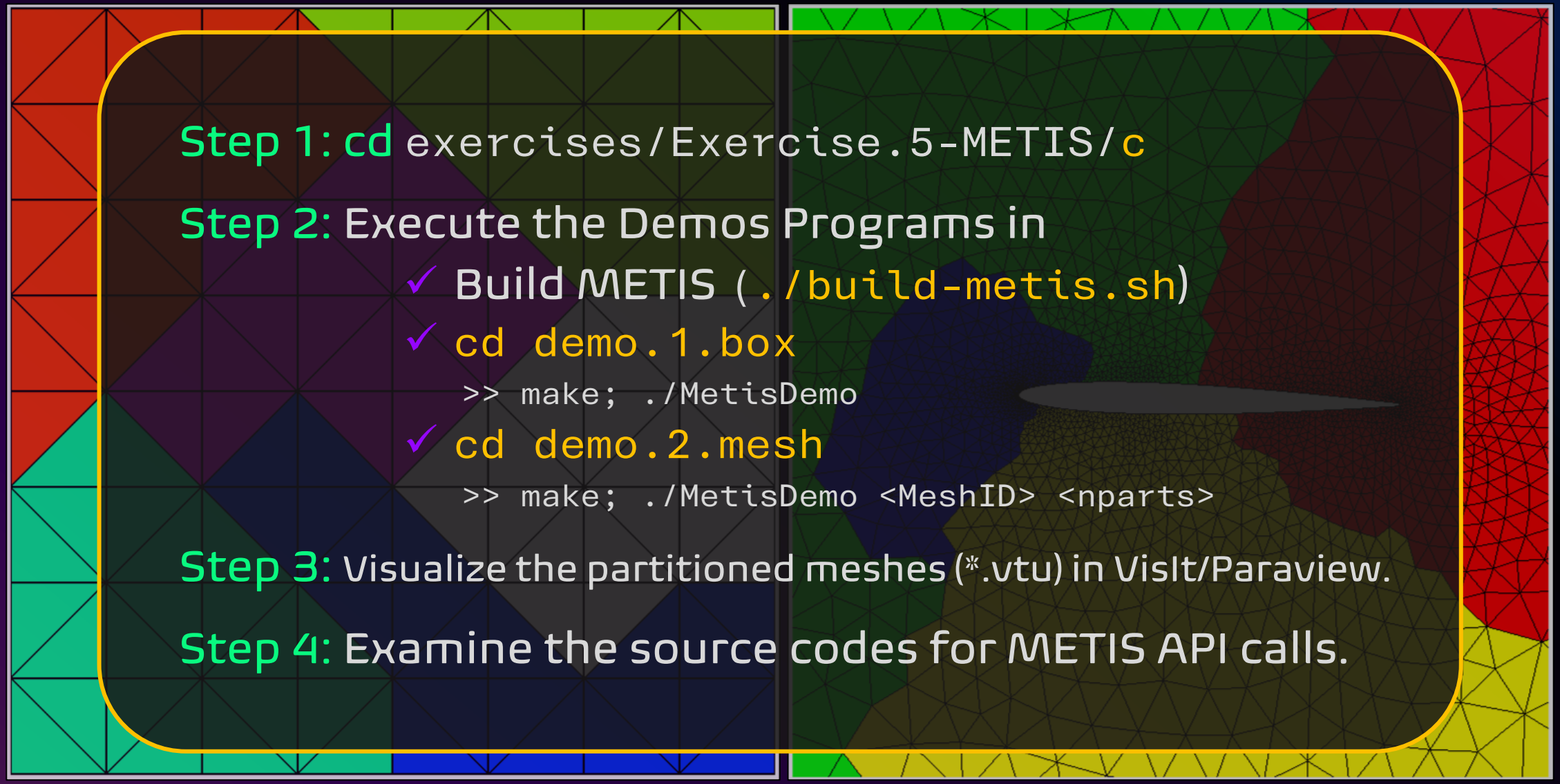
Counts(4) = {?, ?, ?, ?}

Displacements(4) = {?, ?, ?, ?}





EXERCISE.5 GRAPH PARTITIONING WITH METIS



Step 1: cd exercises/Exercise.5-METIS/c

Step 2: Execute the Demos Programs in

- ✓ Build METIS (./build-metis.sh)
- ✓ cd demo.1.box

  >> make; ./MetisDemo
- ✓ cd demo.2.mesh

  >> make; ./MetisDemo <MeshID> <nparts>

Step 3: Visualize the partitioned meshes (*.vtu) in VisIt/Paraview.

Step 4: Examine the source codes for METIS API calls.