TPs MPI

Exercise 1: warm up

Run the **`test_graphic.py`** and **`test_mpi.py`** from the **Files for the Lab.zip** archive

- **`python3 test_graphic.py`**
- **`mpirun -n 2 python3 test_mpi.py`**

Run the codes in **Example of MPI code from the Lesson slides**

- Run and analyze at least **bcast.py**, **gather.py**, **scatter.py** and **reduce.py**
- Try **reduce.py** with 10 processes using the following command: **mpirun --oversubscribe -n 10 python3 reduce.py**

Exercise 2: passnumber

Consider that you have a number that is only available on the process with **`rank==0`**. You want to print it on the screen in all processes.
As an example, with 2 processes and the number **`42`** only available on the process with **`rank==0`**, the command **`mpirun -n 2 number.py`** could print:

```
At start in process of rank 0 the passnumber is 42
At start in process of rank 1 the passnumber is 0
After collective in process of rank 1 the passnumber is 42
After collective in process of rank 0 the passnumber is 42
```

Exercise 3: random generator

We will check if the random generator from numpy is reproducible. The goal is to generate arrays of random numbers on multiple processes, then to check if all the values are the same. We will use the command **`np.random.seed(0)`** that initializes the random generator with a particular starting point. The goal is the following:

- On each process, initialize the random generator
- On each process, generate 10 integers between 0 and 99 (see the **`rand.py`** file in the **Files for the Lab** folder for an example)
- Verify that the min and max of each of these 10 elements are the same on each array
- Print either **`true`** or **`false`** depending on the result
- Run it again without initializing the random generator (commenting the **`seed`** command)

Exercise 4: sum of N first integers

Compute in parallel the sum between 0 and an argument passed on the command line. We have a function **`cumul(a,b)`** that computes the sum of all values between a (included) and b (excluded). **`cumul(1,4)`** = 1+2+3 = 6. We assume the argument is a multiple of the number of processes. The goal of this exercise is to be able to compute the bounds (**`a`** and **`b`**) on each process independently

- Start with the sequential version and test it (`python3` **`cumul.py 100`** should give 4950)
- Compute the bounds **a** and **b** of **`cumul`** for each process without communication
- Finish the parallel version (using only one collective operation)

Exercise 5: teams of process

We want to make two teams of processes. The blue and the green ones. Only the process with **`rank==0`** has access to the file containing the information. As shown in the file **`teams.py`**, we will simulate this by generating random numbers in the node with **`rank==0`**. As an example, if the file contains **`[0, 1, 0, 1]`** and there are 4 processes, (with 0 for blue team and 1 for the green one), we could obtain:

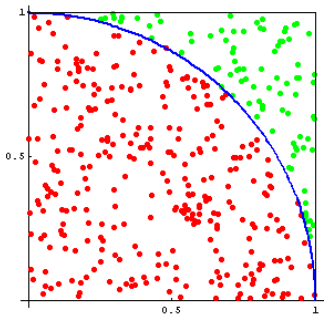
```
The file contains [0 1 0 1]
I am 0 and my team is blue
I am 2 and my team is blue
I am 3 and my team is green
I am 1 and my team is green
```

Exercise 6: position of the max

We want to know the position of the maximum in an array. The array is considered to be only in the process with **`rank==0`** but all processes know its length. A sequential example is in **`max_pos.py`**. To compute this position in parallel, we will

1. Distribute the array
2. Find the position and value of the local maximum
3. Send using a collective operation these two values to the node with **`rank==0`**
4. Compute using these values the position of the overall maximum

Exercise 7: Monte Carlo Simulation to compute π



Surface of circle is $\pi * r^2$ we will use this equation to compute π

1. Run the code in **`monte_carlo.py`**
2. Implement a parallel version of the same algorithm where
    a. All the processes know the total number **`nb`** of random draws to do
    b. There is no communication at the beginning
    c. There is only one communication at the end (no **`send`**/**`receive`**, only collectives)
    d. Only process of rank 0 prints the result
3. Print the value of **`inside`** for each process. Do not forget to initialize the random generator differently for each process.
4. Compare the time for 1, 2 and 4 processes with a constant total number of random draw
5. Same with higher value of **`nb`** taking at least 2 seconds for 1 process

Exercise 8: Contrast stretching

The goal is to stretch the contrast of images converted to grayscale.

1. Run the code in **`stretching-base.py`**
   In this code, two different methods are used to stretch the contrast (**`f_one`** and **`f_two`**): Test both. You have to close the color picture to go to the next step. You have to close the gray picture to finish the execution.
2. Parallelize the code
    - Only process with **`rank==0`** loads and saves the image
    - Compute *max* and *min* in parallel
    - Use the *stretch functions* (**`f_one`** and **`f_two`**) in parallel
    - Make it so that processes with an even rank use **`f_one`**, while processes with an odd rank use **`f_two`**
    - Compare the time for 1, 2 and 4 processes

The result for the input image on the right (in color) should be like the one in grayscale for 4 processes.

Exercise 9: Power of a matrix

We want to obtain the nth power of a square matrix. We assume that **`n`** and the matrix size **`N`** are known constants. The file **`mult.py`** contains an example of a sequential method. For information, you can manipulate numpy matrices in the same way as arrays. To create a matrix of size NxN containing only zeros, you can write **`mat=np.zeros((N, N))`**. The signature should be equal for your code and for the sequential code.

Exercise 10: Maximum number of divisors

The number of divisors of a number `nb` is the number of positive integers `i` such as

```
nb % i == 0
```

The goal of this exercise is to compute the maximum number of divisors for all numbers below `N`, i.e. for all `nb` from `1` to `N`.
For each version of the code (question 1., 2. and 3. below), print also the time needed to do the computation (both total time, and time to run the loop without the collective operation).

1. Run the sequential program **`primes.py`**
2. Implement the parallel version with blocks of work (only using collective operations)

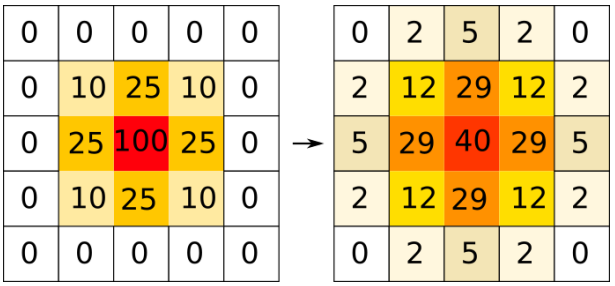
3. Implement the parallel version by distributing the work one by one (only using collective operations)

4. Compare the time of each version and explain

Exercise 11: Heat propagation

To compute heat propagation in a matrix representing an object, we have to apply the following formula for all points:

$V_{k+1}(i,j) = (V_k(i-1, j) + V_k(i, j-1) + V_k(i, j) + V_k(i+1, j) + V_k(i, j+1)) / 5$



The code in **`heat.py`** generates such a matrix and makes it evolve over several iterations (representing time).

Modify the code to make it run in parallel. Check the signature and plot time in function of the number of processes. You can use `Send`, `Isend`, `Recv` and `Irecv` functions for this sole exercise.