Explanation

Notice

First, since we could assume that `sendtype` and `recvtype` will only be `MPI_INT`, then the original function

```
My_Allgather(
    const void* sendbuf, int sendcount, MPI_Datatype sendtype,
    void* recvbuf, int recvcount, MPI_Datatype recvtype,
    MPI_Comm comm
)
```

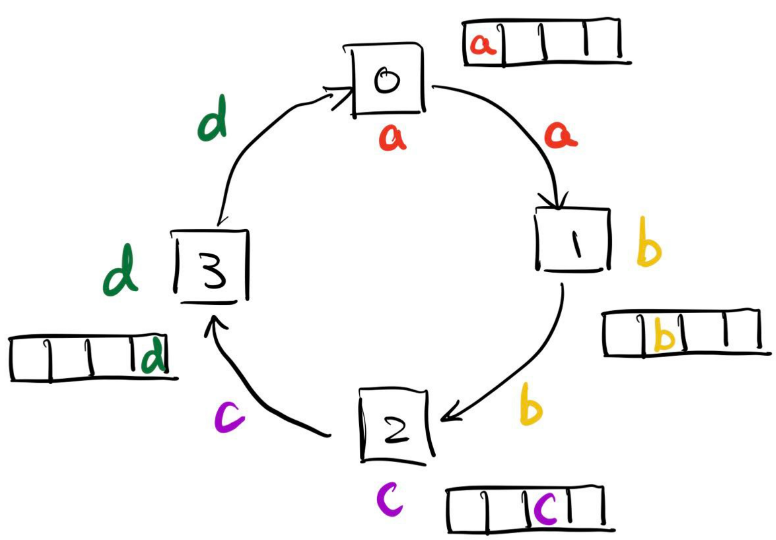
could actually just be reduced to

```
My_Allgather_Int(
    const void* sendbuf, int sendcount,
    void* recvbuf, int recvcount,
    MPI_Comm comm
)
```

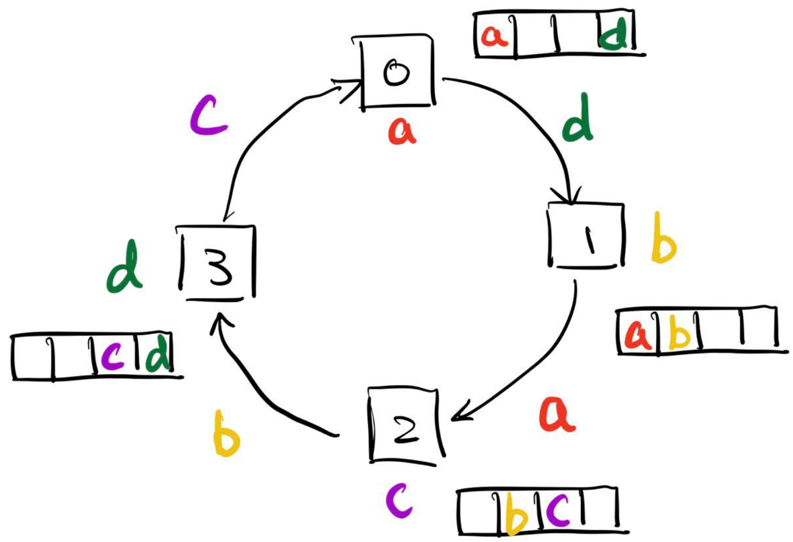
and they have no difference (the latter will be used through the homework).

Small Example

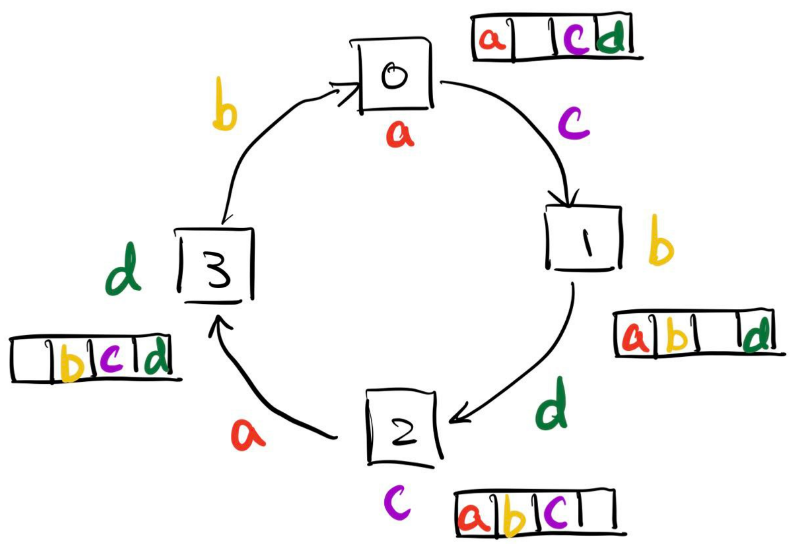
Suppose we have 4 processes, they store `a`, `b`, `c` and `d`, respectively. They first need to put their own data `sendbuf` into their own `recvbuf`. Then, they do following operation (the arrow indicates the data being sent):



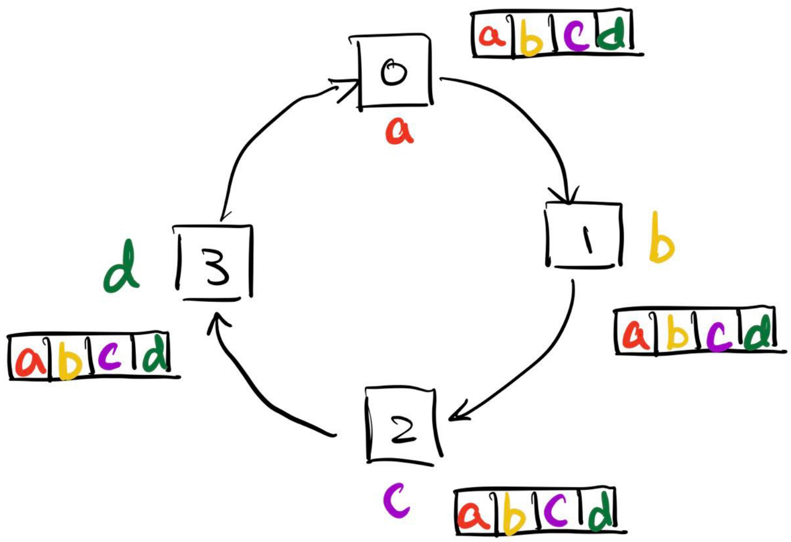
and then:



and then:



and in the end:



We could see that for `Process 0`, it does the following:

- Iteration `0`: receive `d` from `Process 3`, and send `a` to `Process 1`
- Iteration `1`: receive `c` from `Process 3`, and send `d` to `Process 1`
- Iteration `2`: receive `b` from `Process 3`, and send `c` to `Process 1`

From this small example, we see that each process only communicates two neighbors. Given the current process `rank` and total number of processes `count`, it communicates to its `forward_neighbor` which has rank `(rank + 1) % size`, and `backward_neighbor` which has rank `(rank - 1 + size) % size`. We see that for this particular example, the for loop execute for `size - 2` iterations, and that in each iteration `i`, it sends `(rank - i + size) % size` element, and receives the `(rank - i - 1 + size) % size`. Note that after each iteration, we must use `MPI_Barrier` to synchronize all processes, this ensures that the data that is going to send in next iteration is available.

Caveats

The core logic is explained above. However, notice that for the operation explained above, we couldn't just use `recvbuf` passed as parameter to store the data we receive from other processes, what if, say in the example above, all the processes has `sendcount = 4`, the `Process 1` only have `recvcount = 2` but `Process 2` have `recvcount = 3`. Then, the data that go to `Process 2` via the transfer in `Process 1` will be limited to only have size `2` data, which is less than the size `3` data required by `Process 2`. In other words, we lost some data if we just use `recvbuf`.

Therefore, notice few implication in the function itself:

- For all processes, `max(recvcount) ≤ min(sendcount)`, you cannot call the function with `sendcount` less than `recvcount`. What does that mean if you want to more than you could possibly get ? (This will result in `undefined` behavior).
- `size(sendbuf) = sizeof(int) * sendcount`
- `size(recvbuf) = process_count * sizeof(int) * recvcount`

Using this, we see that we could first use a `recv_tmp_buf` to store the data we did in the ring communication, and then after all that finished, we could copy the data `recv_tmp_buf` according to the `recvbuf`. The size `size(recvbuf)` should equal to `process_count * sizeof(int) * max_recvcount`. Therefore, we need to first calculate `max_recvcount`, this could be done just by applying the ring communication again. That means we need to do the ring communication twice, first to calculate the `max_recvcount`, and second time to actually transfer the data.

Code

Note: this code use the macros

```
#define max(a,b) ((a)>(b)?(a):(b))
```

and it uses

```
#include <stdlib.h>
#include <string.h>
```

for `malloc`, `free`, and `memcpy`. The code is down below

```
void My_Allgather_Int(
    const void* sendbuf, int sendcount,
    void* recvbuf, int recvcount,
    MPI_Comm comm
) {
    int rank, size;
    MPI_Comm_rank(comm, &rank);
    MPI_Comm_size(comm, &size);

    // we want to know the max(recvcount) of all processes
    // use ring communication to gather the data
    // we will use MPI_Sendrecv to implement the ring communication
    // we will use MPI_Barrier to make sure the data is ready
    int* recv_count_array = (int*) malloc(sizeof(int) * size);

    // move the itself's recvcount to the right position
    recv_count_array[rank] = recvcount;

    for (int i = 0; i < size - 1; i++) {
        MPI_Sendrecv(
            recv_count_array + (rank - i + size) % size, 1, MPI_INT,
            (rank + 1) % size, 0,
            recv_count_array + (rank - i - 1 + size) % size, 1, MPI_INT,
            (rank - 1 + size) % size, 0,
            comm, MPI_STATUS_IGNORE
        );
        MPI_Barrier(comm);
    }

    // calculate the max(recvcount) of all processes
```

```
    int max_recv_count = 0;
    for (int i = 0; i < size; i++) {
        max_recv_count = max(max_recv_count, recv_count_array[i]);
    }

    // free the recv_count_array
    free(recv_count_array);

    // cast the sendbuf and recvbuf to int*
    int* sendbuf_int = (int*)sendbuf;
    int* recvbuf_int = (int*)recvbuf;
    int* recv_tmp_buf_int = (int*) malloc(sizeof(int) * max_recv_count * size);

    // move itself's data to the right position
    memcpy(recv_tmp_buf_int + rank * max_recv_count, sendbuf_int, sizeof(int) *
max_recv_count);

    for (int i = 0; i < size - 1; i++) {
        MPI_Sendrecv(
            sendbuf_int + (rank - i + size) % size, max_recv_count, MPI_INT,
            (rank + 1) % size, 0,
            recv_tmp_buf_int + (rank - i - 1 + size) % size, max_recv_count,
MPI_INT,
            (rank - 1 + size) % size, 0,
            comm, MPI_STATUS_IGNORE
        );
        MPI_Barrier(comm);
    }

    // copy the data from recv_tmp_buf_int to recvbuf
    for (int i = 0; i < size; i++) {
        memcpy(recvbuf_int + i * recvcount, recv_tmp_buf_int + i * max_recv_count,
sizeof(int) * recvcount);
    }

    // free the recv_tmp_buf_int
    free(recv_tmp_buf_int);
}
```