

## Chapter 1

# Parallel solution of a 2D Poisson problem with flux boundary conditions

This document provides an overview of how to distribute the [2D Poisson problem with flux boundary conditions](#). It is part of a [series of tutorials](#) that discuss how to modify existing serial driver codes so that the `Problem` object can be distributed across multiple processors.

A feature of this problem is that the flux boundary conditions are applied by attaching "flux elements" (derived from the `FaceElement` base class) to the "bulk elements" adjacent to the appropriate mesh boundary. As discussed in the [tutorial for the serial driver code](#), the `FaceElements` are not involved in any adaptation within the bulk mesh. Instead, they are detached before the bulk mesh is adapted and re-attached afterwards, which ensures that the `FaceElements` are only attached to bulk elements present in the adapted mesh.

The same issue arises when the `Problem` is distributed: all `FaceElements` must be attached before the problem is distributed to allow METIS to analyse the interaction between face and bulk elements correctly. However, after the `Problem` has been distributed, some of the bulk elements on each processor will have been deleted, leaving the corresponding `FaceElement` dangling. To deal with such problems, `oomph-lib` provides the empty virtual functions

```
Problem::actions_before_distribute()
```

and

```
Problem::actions_after_distribute()
```

which are called automatically by `Problem::distribute(...)`. Specifically, `Problem::actions_before_distribute()` is called **after** the problem distribution has been determined by METIS but **before** the actual distribution (during which elements are deleted) takes place. `Problem::actions_after_distribute()` is called after the problem distribution is complete.

In the present problem we overload the functions `Problem::actions_before_distribute()` and `Problem::actions_after_distribute()` to perform the same functions as `actions_before_adapt()` (i.e. delete the flux elements) and `actions_after_adapt()` (i.e. re-attach the flux elements). We note that any `FaceElement` that is attached to a halo element in the bulk mesh becomes a halo element itself; see the [general MPI tutorial](#) for further details.

Most of driver code is identical to its serial counterpart and we only discuss the changes required to distribute the problem. Please refer to [another tutorial](#) for a more detailed discussion of the problem and its (serial) implementation.

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### 1.1 The main function

The only changes required to the main function are the usual calls to initialise and finalise `oomph-lib`'s MPI routines and a single call to `Problem::distribute()` after the problem has been constructed. The source code is actually slightly more complicated because the distribution is read in from a file so that the driver can be used as a self-test. Note that the file must specify the partition for **all** elements, including the `FaceElements`. (We refer to [another tutorial](#) for details on how to create the distribution file.)

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## 1.2 The problem class

The only additions to the problem class are the functions `actions_before_distribute()` and `actions_after_distribute()`. As explained above, these perform exactly the same functions as `actions_before_adapt()` and `actions_after_adapt()`, respectively.

```
/// Actions before distribute: Wipe the mesh of prescribed flux elements
/// (simply call actions_before_adapt() which does the same thing)
void actions_before_distribute()
{
    actions_before_adapt();
}
/// Actions after distribute: Rebuild the mesh of prescribed flux
/// elements (simply call actions_after_adapt() which does the same thing)
void actions_after_distribute()
{
    actions_after_adapt();
}
```

---

## 1.3 The doc\_solution() function

As with other driver codes, the output files are modified to allow each processor to output its elements into files that include the processor number.

```
///=====start_of_doc=====
/// Doc the solution: doc_info contains labels/output directory etc.
///=====
template<class ELEMENT>
void RefineableTwoMeshFluxPoissonProblem<ELEMENT>::doc_solution(DocInfo& doc_info)
{
    // Doc refinement levels in bulk mesh
    unsigned min_refinement_level;
    unsigned max_refinement_level;
    Bulk_mesh_pt->get_refinement_levels(min_refinement_level,
                                       max_refinement_level);
    cout << "Ultimate min/max. refinement levels in bulk mesh : "
         << min_refinement_level << " "
         << max_refinement_level << std::endl;

    ofstream some_file;
    char filename[100];

    // Number of plot points
    unsigned npts;
    npts=5;

    // Output solution with halo elements
    //-----
    Bulk_mesh_pt->enable_output_of_halo_elements();
    sprintf(filename, "%s/soln_with_halo%i_on_proc%i.dat",
            doc_info.directory().c_str(),
            doc_info.number(), this->communicator_pt()->my_rank());
    some_file.open(filename);
    Bulk_mesh_pt->output(some_file, npts);
    some_file.close();
    Bulk_mesh_pt->disable_output_of_halo_elements();

    // Output solution
    //-----
    sprintf(filename, "%s/soln%i_on_proc%i.dat", doc_info.directory().c_str(),
            doc_info.number(), this->communicator_pt()->my_rank());
    some_file.open(filename);
    Bulk_mesh_pt->output(some_file, npts);
    some_file.close();

    // Output exact solution
    //-----
    sprintf(filename, "%s/exact_soln%i_on_proc%i.dat", doc_info.directory().c_str(),
            doc_info.number(), this->communicator_pt()->my_rank());
    some_file.open(filename);
    Bulk_mesh_pt->output_fct(some_file, npts, TanhSolnForPoisson::get_exact_u);
    some_file.close();

    // Doc error and return of the square of the L2 error
    //-----
    double error, norm;
    sprintf(filename, "%s/error%i_on_proc%i.dat", doc_info.directory().c_str(),
            doc_info.number(), this->communicator_pt()->my_rank());
    some_file.open(filename);
    Bulk_mesh_pt->compute_error(some_file, TanhSolnForPoisson::get_exact_u,
```

```
                                error,norm);
some_file.close();

// Doc L2 error and norm of solution
cout << "\nNorm of error   : " << sqrt(error) << std::endl;
cout << "Norm of solution: " << sqrt(norm) << std::endl << std::endl;

} // end of doc
```

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The remainder of this driver code is unchanged from the [serial version](#).

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## 1.4 Source files for this tutorial

- The source files for this tutorial are located in the directory:

```
demo_drivers/mpi/distribution/two_d_poisson_flux_bc_adapt/
```

- The driver code is:

```
demo_drivers/mpi/distribution/two_d_poisson_flux_bc_adapt/two_d_↵
poisson_flux_bc_adapt.cc
```

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## 1.5 PDF file

A [pdf version](#) of this document is available.