TMA4280 - Problem set 6

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1 The poisson program

In the beginning I tried to take advantage of our professors framework of several poisson solvers, which uses vectors and matrices in Fortran format. This however turned out to be hard for me. When I tried to create a transpose operation in parallel I could not make it work. So I made a switched to the code distributed with the problemtext, which is written by Einar M. RÃ¸nquist.

2 Parallelization

To parallelize the problem I chose to split up the problem in lesser parts, each solvable by it self. Each process generates it own matrix B, and modifies it through the program, before it shares it result with each of the other processes and the maximal error is calculated. During each process' execution the only communication, except for in assembly, between the threads are done in the transpose operation.

2.1 The transpose operation

Since each process has a part of the matrix b, a transpose will need to swap elements with other processes. This communcation is done through MPI_Alltoallv (see figure 1), a MPI call which sends a sendarray along with a countarray and a displacement array. The countarray contains the number of elements to be sent to each process. The displacement arrays entry i specifies the displacement relative to the sendarray, entry i is sent to process i.

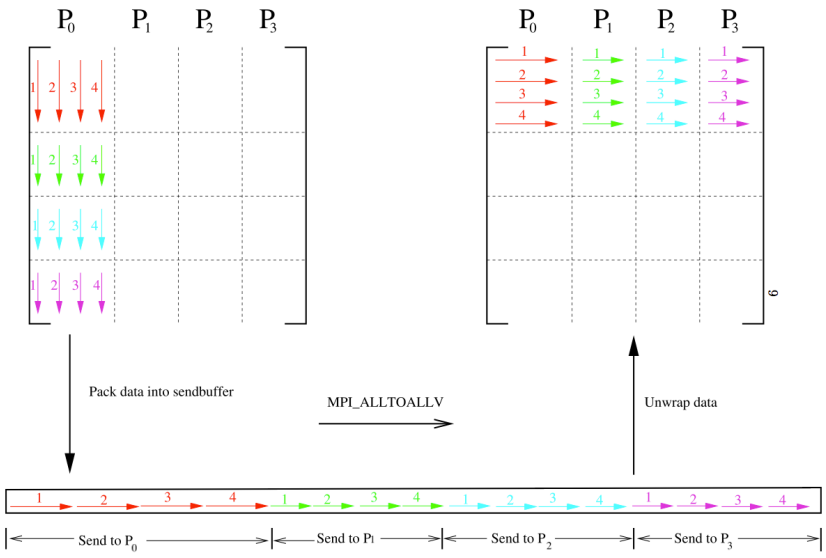
During the writing of this report, and after results had been obtained, I found that I had created a duplicate matrixAsVec operation. In the transpose operation I believe a less effective version of this has been used, a version not using memcpy(). This may have some small effect on runtime, but no real testing has been performed to confirm this.

2.2 The error computation in parallel and and results

At computation of error there is also some need for paralellization. Generation of the problem's exact solution is done for each process', and the exact solution can therefore be compared with the solution found on each process. I here took advantage of our professor's common files, and blaslapack.

I created a matrixToVec() operation, which transforms the processes part matrix b to a vector, as well as the process' exact solution. After this, an axpy operation is performed on the solution v.s. the exact solution. This performs the following vector operation $y < -(-1.0 * solutionVector) + exactVector$. This generates the relative errors for this process' solution.

Then the maximal local error is found with blas routine idamax, which returns the element of largest magnitude. Now each process has found the max error in it's own part solution. Global max error is computed with a call of MPI_Reduce with MPI_MAX, which result in the maximal pointwise error.



Figur 1: Transpose operation through MPI_Alltoallv

For a time I also assembled the final matrix on the root process using MPI_Gatherv. I however found that this was unnecessary, when the results from the program is available in each process, and only the pointwise error is needed for report.

2.3 Use of OpenMP

3 Kongull

Kongull has 108 compute nodes, each having 2 processors. This is divided in 96 nodes using an AMD Opteron processor with 6 cores, and 12 nodes using Intel(R) Xeon(R) processors. Depending on which rack of the compute nodes are being used, the node has 24 GiB/node or 48 GiB/node. This means that each processor has at least 12 GiB of memory (create reference to https://www.hpc.ntnu.no/display/hpc/Kongull+Hardware Compute-nodes).

To compile and run the program I have used Intel's compilers for Fortran and C, ifortran and icc. Cmake was used to perform the compilation with these compilers. This generates a build system with portability and simplicity. The program uses MPI, OpenMP and BLAS/Lapack. In addition support for C99 has been added for simplicty of writing code. All of these are installed on Kongull.

4 Verification of correctness

To verify that the code works correctly, I have performed a convergence test. To obtain a correct error estimate an exact solution were computed. The exact solution has been entered as

$$u(x, y) = sin(\pi x) \cdot sin(2\pi x) \tag{1}$$

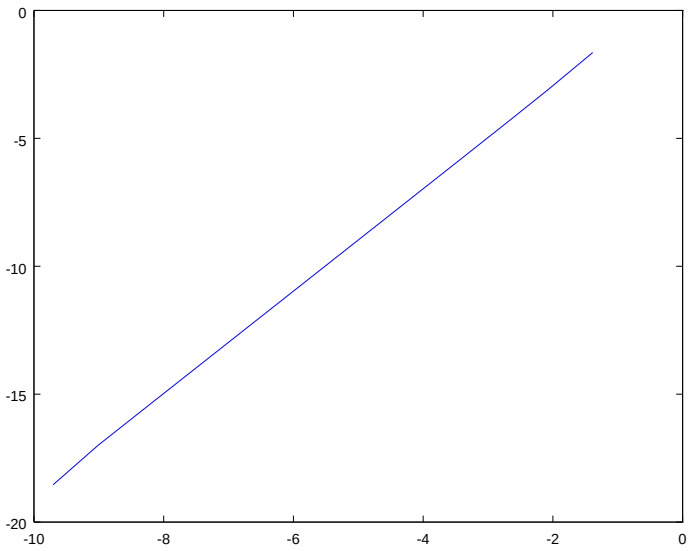
Which satisfies the homogeneous boundary conditions $u = 0$ on $\partial\Omega$. If we then evalueate $-\nabla^2 u$ which should be equal to

$$u(x, y) = 5\pi^2 \cdot sin(\pi x) \cdot sin(2\pi x) \tag{2}$$

The error gained from comparison of the exact and computed solution is then used to check whether the program performs correctly.

This test has been performed with 3 nodes with 2 processors each having 6 cores. Assigned number of threads per MPI process was 6, which perhaps is not ideal, but nevertheless. The program was executed with this setup for a number of problem sizes from $n = 4816...16384$, and the errors for each problem size is compared with $h = (1/n)^2$. This then was processed in a octave plot using loglog, resulting in the following plot 2 where the gradient $a = 2.0309$ is just about two. This verifies the correctness of the solution. I believe that our student projects in TMA4280 only have access to the section having 24 GB memory per node.

5 Hybrid v.s. Pure distributed memory model



Figur 2: loglog plot of h, max pointwise error