Introduction to Eclipse III: Debugging MPI and OpenMP code

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SHARCNET | Compute Ontario | Compute Canada

Outline

- Eclipse
- Scope of the talk
- Developing C/C++ and Fortran code
- Debugging serial code
- Debugging parallel MPI code
- Debugging OpenMP code
- Q&A

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About Eclipse

About Eclipse

What is Eclipse. An IDE for development and debugging

- C/C++
- Fortran
- Other languages
- MPI, OpenMP, threaded
- Others?

It runs on your local computer (and remote systems), available for Windows, Linux and MacOS.

About Eclipse

What Eclipse is not. It is a front-end, with an editor and code analyzer for C/C++, Fortran, MPI and others, to the underlying compilers and debuggers. It DOES NOT come with

- Compilers
- Debuggers
- Memory analyzers
- Schedulers

About Eclipse

Why Eclipse. Debugging parallel code is not straightforward. Options for debugging parallel, MPI code

- DDT (cost)
- TotalView (cost)
- gdb (free) – command line based, hard to use.
- Eclipse (free) – GUI, reasonably intuitive to use.
- Others?

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Tools for C, C++, Fortran, and UPC, including MPI, OpenMP, OpenACC, a parallel debugger, and remotely building, running and monitoring applications.

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Eclipse IDE for Scientific Computing

Package Description

Tools for C, C++, Fortran, and UPC, including MPI, OpenMP, OpenACC, a parallel debugger, and remotely building, running and monitoring applications.

This package includes:

- C/C++ Development Tools
- Git integration for Eclipse
- Parallel Tools Platform
- Eclipse XML Editors and Tools

Detailed features list

Maintained by: Eclipse Packaging Project

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Bugzilla

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Resolved Bugs: 14

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New and Noteworthy

Eclipse PTP
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Testing Details

Package Testers

Greg Watson

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Requirements

- Windows
  - Compilers, debugger, e.g. from cigywin distribution.
  - But **WSL** - a true Linux environment running on top of Windows by Microsoft - is recommended. See a tutorial on enabling WSL on Windows at https://youtube.sharcnet.ca/.
- Linux, Mac OS
  - GCC compilers, gdb.
  - make, cmake.
  - OpenMPI

General advice

- It's always a good practice to install an MPI implementation on your own machine (laptop or desktop), so you have immediate access and can practice and develop code.
- For Windows, we recommend
  - Enable **Windows Subsystem for Linux** (WSL) and
  - Install a Linux distro, e.g. Ubuntu, Debian, etc. on it.
- Install latest GNU compilers and gdb.
- Install **OpenMPI** or **MPICH**.

Scope of The Tutorial

What are covered and what aren't

What to be introduced in this tutorial

- Eclipse on Linux.
- C/C++ and Fortran code.
- MPI code.
- OpenMP code.
- Debugging on local computer.

What NOT to be covered

- OpenACC code.
- Non GCC compilers, debuggers.
- Running and debugging code on remote systems.
- Use of git.

Debugging MPI Code

Stepping through MPI ranks. A simple MPI code to examine variables.

```
MPI_Init(&argc, &argv);
MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);
MPI_Comm_size(MPI_COMM_WORLD, &num_tasks);

if (my_rank !=0) // Non root ranks
{
   sprintf(message, "Hello MPI World from process %d!", my_rank);
   message[strlen(message)] = '\0';
   MPI_Send(message,strlen(message)+1,MPI_CHAR,0,tag,MPI_COMM_WORLD);
}
else // Root
{
   printf("Hello MPI World from process 0: Num of processes: %d\n", num_tasks);
   for (p=1; p<num_tasks; p++) {
      MPI_Recv(message,100,MPI_CHAR,MPI_ANY_SOURCE,tag,MPI_COMM_WORLD, &status);
      printf("From process %d: %s\n", status.MPI_SOURCE, message);
   }
}
```

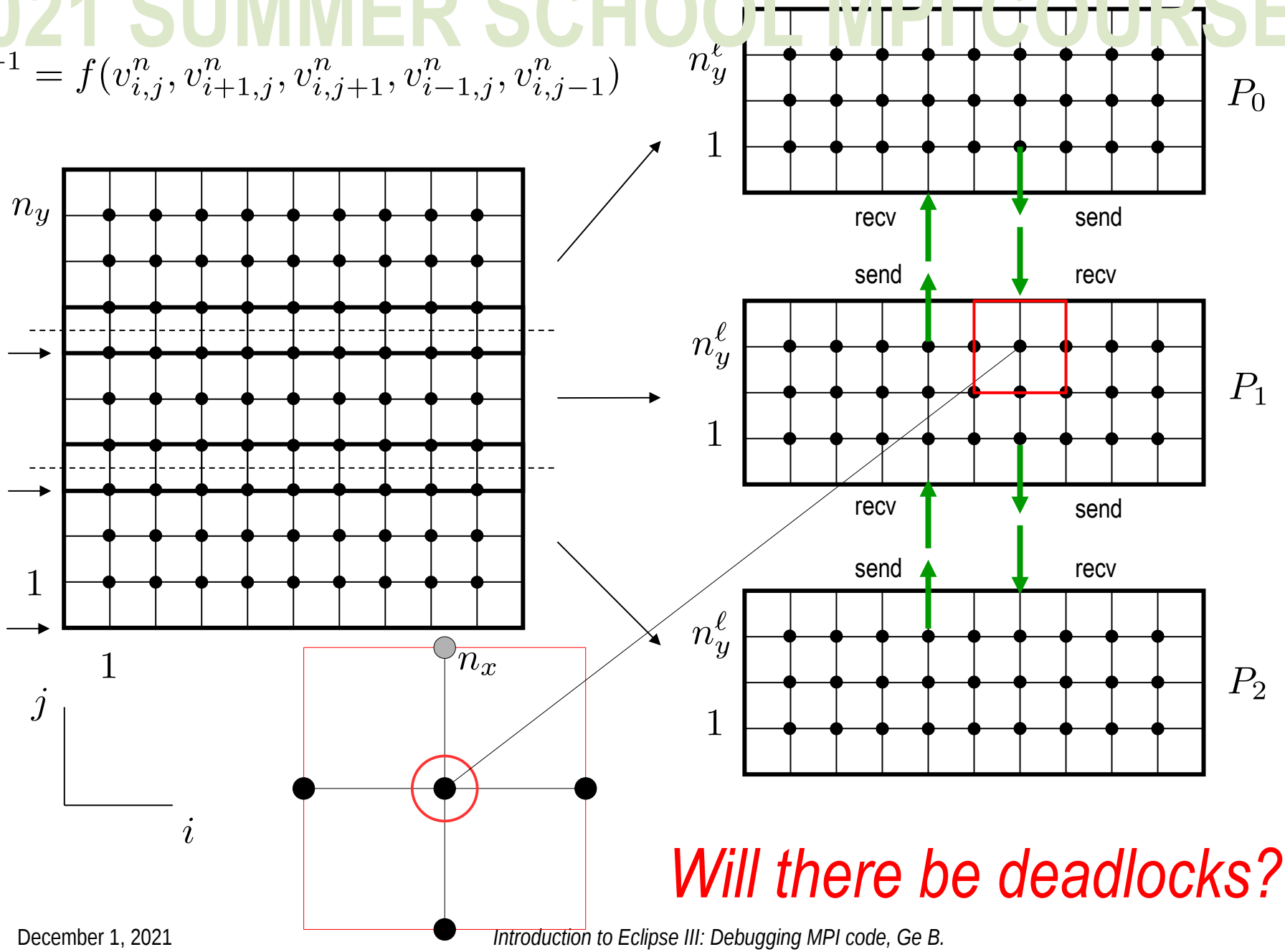
MPI code with segmentation fault.

```
#define N_src 10000
#define N_dest 100
#define TAG 99

int main(int argc, char* argv[])
{
   int num_tasks, rank, root, dest;
   int sbuf[N_src], rbuf[N_dest];
   MPI_Status status;

   MPI_Init(&argc, &argv);
   MPI_Comm_size(MPI_COMM_WORLD, &num_tasks);
   MPI_Comm_rank(MPI_COMM_WORLD, &rank);

   root = 0;
   dest = 1;
   if (0 == rank)
      MPI_Send(sbuf, N_src, MPI_INT, dest, TAG, MPI_COMM_WORLD);
   else
      MPI_Recv(rbuf, N_dest, MPI_INT, root, TAG, MPI_COMM_WORLD, &status);

   printf("Done.\n");
   MPI_Finalize();
   return 0;
}
```

Original Author: Sergey Maschenko

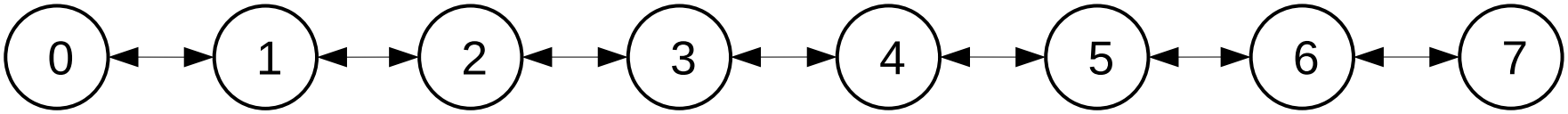
Parallel Algorithm

$$v_{i,j}^{n+1} = f(v_{i,j}^{n}, v_{i+1,j}^{n}, v_{i,j+1}^{n}, v_{i-1,j}^{n}, v_{i,j-1}^{n})$$

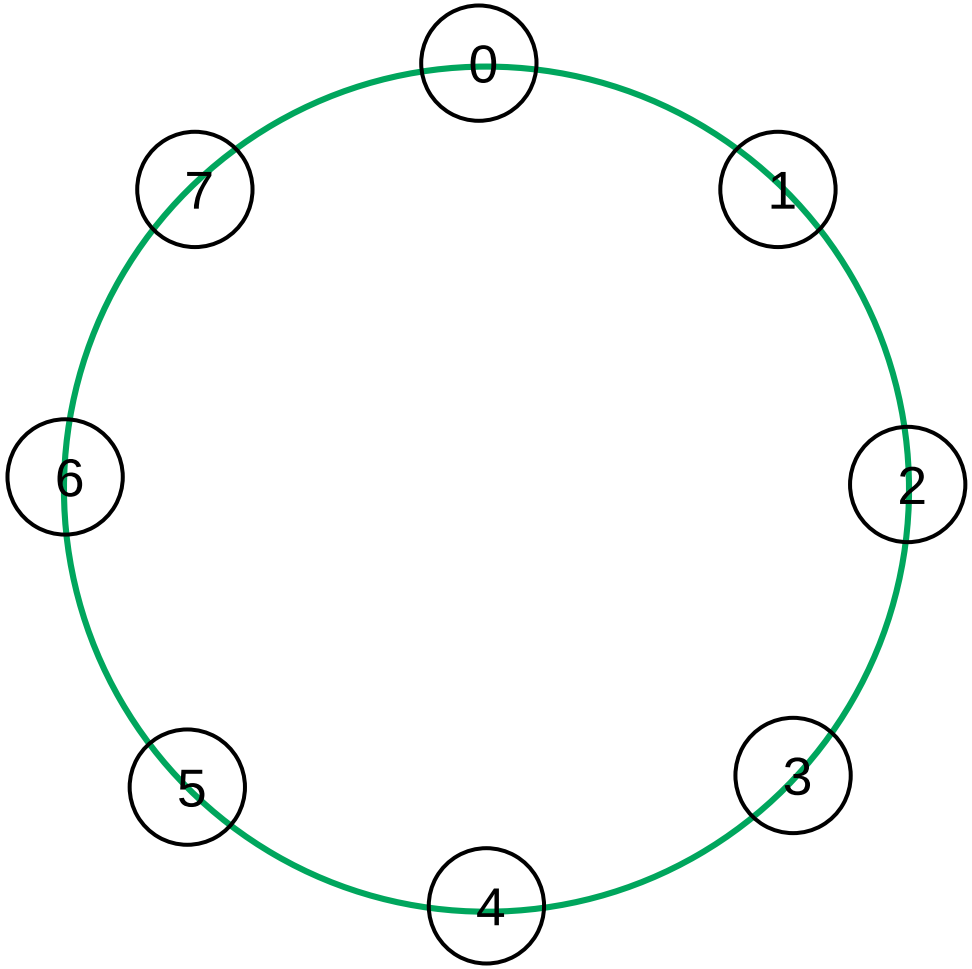


Will there be deadlocks?

Domain decomposition with boundaries



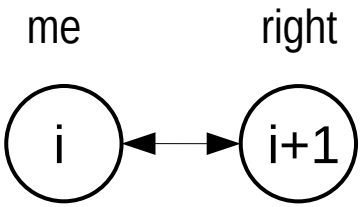
Domain decomposition with periodic conditions



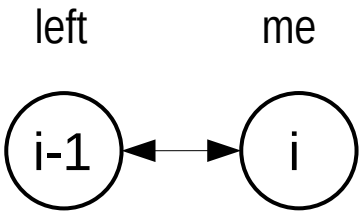
Blocking vs Non-blocking: Deadlock

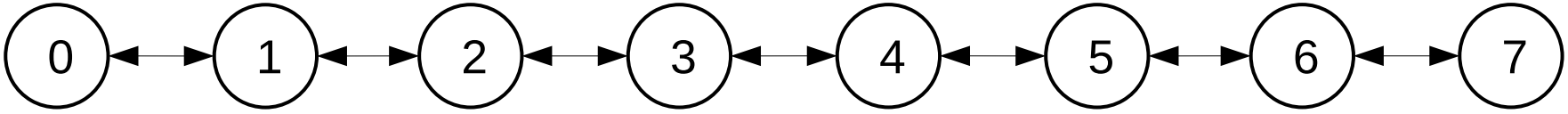
Example: Think about writing a code that involve N processes in order in a chain. Each one sends and receives a message to/from both its left and right neighbours. The key code segment is sketched below. Will there be a deadlock?


```
left = rank - 1;
if (left < 0) left = MPI_PROC_NULL;
right = rank + 1;
if (right == num_procs) right = MPI_PROC_NULL;

MPI_Send(rsmsg,n,MPI_DOUBLE,right,rtag,MPI_COMM_WORLD);
MPI_Recv(rrmsg,n,MPI_DOUBLE,right,rtag,MPI_COMM_WORLD,&rstat);
```




```
MPI_Send(lsmsg,n,MPI_DOUBLE,left,ltag,MPI_COMM_WORLD);
MPI_Recv(lrmsg,n,MPI_DOUBLE,left,ltag,MPI_COMM_WORLD,&rstat);
```





Debugging MPI code

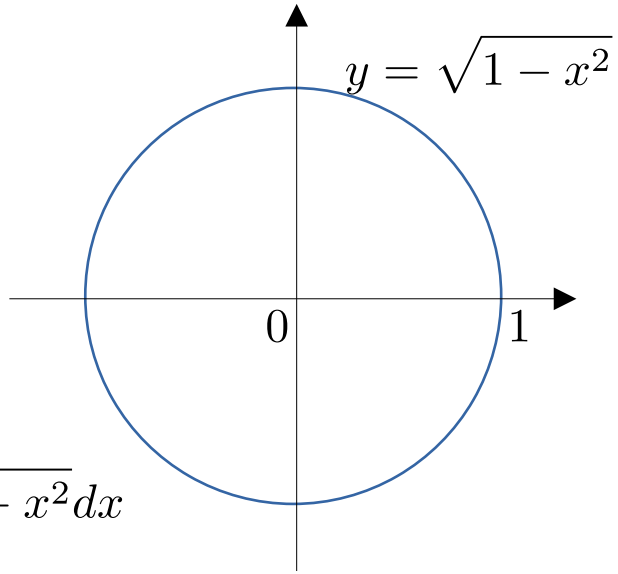
MPI code causing deadlock. We are looking at a simplest scenario: sending and receiving messages to/from the same peer.

```
// This example requires two ranks involved
MPI_Init(&argc, &argv);
MPI_Comm_size(MPI_COMM_WORLD, &num_tasks);
MPI_Comm_rank(MPI_COMM_WORLD, &rank);

peer = 1 – rank;

// The following is unsafe, there is a good chance  that it blocks
MPI_Send(sbuf,n,MPI_FLOAT,peer,TAG,MPI_COMM_WORLD);
MPI_Recv(rbuf,n,MPI_FLOAT,peer,TAG,MPI_COMM_WORLD,&stat);
printf("Rank %d send, receive calls completed.\n", rank);
```

Debugging OpenMP Code

Computing pi – race condition

```
for (int i=0; i<n; i++)
{
    x = (i + 0.5)/n; // Midpoint rule
    s += sqrt(1 = x*x);
}

pi_est = 4.0/n*s;
```



$$\pi = 4 \int_0^1 \sqrt{1 - x^2} dx$$

The OpenMP code in omp-pi.c is simple but buggy. We first consider a rather simple problem: add natural numbers from 1 to N in parallel.

Parallel regions – deadlock

```
flag=0;
#pragma omp parallel shared(flag)
{
  int id = omp_get_thread_num();
  #pragma omp sections
  {
    #pragma omp section
    {
      while (flag != 0) // If 0 then break, otherwise spin forever
      {
      }
      printf("Section 1\n");
      flag = 1;
    }
    #pragma omp section
    {
      while (flag != 1) // If 0, 2 or 3, then break
      {
      }
      printf("Section 2\n");
      flag = 2;
    }
    #pragma omp section
    {
      while (flag != 2) // If 0, 1 or 3, then break
      {
      }
      printf("Section 3\n");
      flag = 3;
    }
  }
}
```

Original Author: Sergey Maschenko

Q&A