

Aislinn

- Aislinn is a dynamic verifier for MPI programs. For a fixed input it covers all possible runs with respect to nondeterminism introduced by MPI. It allows to detect bugs (for sure) that occurs very rare in normal runs.
- Aislinn detects problems like invalid memory accesses, deadlocks, misuse of MPI, and resource leaks.
- Aislinn is open-source software; you can use it without any licensing limitations.
- Web page of the project: <http://verif.cs.vsb.cz/aislinn/>

Note

Aislinn is software developed at IT4Innovations and some parts are still considered experimental. If you have any questions or experienced any problems, please contact the author: stanislav.bohm@vsb.cz.

Usage

Let us have the following program that contains a bug that is not manifested in all runs:

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

int main(int argc, char **argv) {
    int rank;

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

    if (rank == 0) {
        int *mem1 = (int*) malloc(sizeof(int) * 2);
        int *mem2 = (int*) malloc(sizeof(int) * 3);
        int data;
        MPI_Recv(&data, 1, MPI_INT, MPI_ANY_SOURCE, 1,
                 MPI_COMM_WORLD, MPI_STATUS_IGNORE);
        mem1[data] = 10; // <----- Possible invalid memory write
        MPI_Recv(&data, 1, MPI_INT, MPI_ANY_SOURCE, 1,
                 MPI_COMM_WORLD, MPI_STATUS_IGNORE);
        mem2[data] = 10;
        free(mem1);
        free(mem2);
    }

    if (rank == 1 || rank == 2) {
```

```

        MPI_Send(&rank, 1, MPI_INT, 0, 1, MPI_COMM_WORLD);
    }

    MPI_Finalize();
    return 0;
}

```

The program does the following: process 0 receives two messages from anyone and processes 1 and 2 send a message to process 0. If a message from process 1 is received first, then the run does not expose the error. If a message from process 2 is received first, then invalid memory write occurs at line 16.

To verify this program by Aislinn, we first load Aislinn itself:

```
$ module load aislinn
```

Now we compile the program by Aislinn implementation of MPI. There are `mpicc` for C programs and `mpicxx` for C++ programs. Only MPI parts of the verified application has to be recompiled; non-MPI parts may remain untouched. Let us assume that our program is in `test.cpp`.

```
$ mpicc -g test.cpp -o test
```

The `-g` flag is not necessary, but it puts more debugging information into the program, hence Aislinn may provide more detailed report. The command produces executable file `test`.

Now we run the Aislinn itself. The argument `-p 3` specifies that we want to verify our program for the case of three MPI processes

```

$ aislinn -p 3 ./test
==AN== INFO: Aislinn v0.3.0
==AN== INFO: Found error 'Invalid write'
==AN== INFO: 1 error(s) found
==AN== INFO: Report written into 'report.html'

```

Aislinn found an error and produced HTML report. To view it, we can use any browser, e.g.:

```
$ firefox report.html
```

At the beginning of the report there are some basic summaries of the verification. In the second part (depicted in the following picture), the error is described.

Error: Invalid write (mem/invalid-write)

Description	Invalid write of size 4 at address 0x802401038
Process rank in COMM_WORLD	0
Stack trace	0x40090B: main (test.cpp:16)
Output (stdout) for pid 1	
Output (stdout) for pid 2	
Output (stdout) for pid 3	
Error output (stderr) for pid 1	
Error output (stderr) for pid 2	
Error output (stderr) for pid 3	

Events

#	0	1	2
1	MPI_Comm_rank	MPI_Comm_rank	MPI_Comm_rank
2	MPI_Recv	MPI_Send	MPI_Send
3	Continue	Continue	Continue
4		MPI_Finalize	MPI_Finalize
5		Exit	Exit

Arguments: 68702686988,1,267387145,0,1,52226
0x403703: aislinn_call (aislinn.c:61)
0x401D21: MPI_Send (mpi_generated.c:104)
0x4009AA: main (test.cpp:25)

It shows us:

- Error occurs in process 0 in test.cpp on line 16.
- Stdout and stderr streams are empty. (The program does not write anything).
- The last part shows MPI calls for each process that occurs in the invalid run. The more detailed information about each call can be obtained by mouse cursor.

Limitations

Since the verification is a non-trivial process there are some of limitations.

- The verified process has to terminate in all runs, i.e. we cannot answer the halting problem.
- The verification is a computationally and memory demanding process. We put an effort to make it efficient and it is an important point for further research. However covering all runs will be always more demanding than techniques that examines only a single run. The good practise is to start with small instances and when it is feasible, make them bigger. The Aislinn is good to find bugs that are hard to find because they occur very rarely (only in a rare scheduling). Such bugs often do not need big instances.
- Aislinn expects that your program is a “standard MPI” program, i.e. processes communicate only through MPI, the verified program does not interacts with the system in some unusual ways (e.g. opening sockets).

There are also some limitations bounded to the current version and they will be

removed in the future:

- All files containing MPI calls have to be recompiled by MPI implementation provided by Aislinn. The files that does not contain MPI calls, they do not have to recompiled. Aislinn MPI implementation supports many commonly used calls from MPI-2 and MPI-3 related to point-to-point communication, collective communication, and communicator management. Unfortunately, MPI-IO and one-side communication is not implemented yet.
- Each MPI can use only one thread (if you use OpenMP, set `OMP_NUM_THREADS` to 1).
- There are some limitations for using files, but if the program just reads inputs and writes results, it is ok.