



## Introduction to Testing and Debugging

Note: these examples often invoke **undefined behaviour** so the results can vary depending on platform, optimisation compiler etc.

### - 01\_RoundingAndTruncation

- Demonstrates how single and double precision floats can be inexact, and what this can do unexpectedly

#### Info:

Try the program with a few optimisation levels, as this can affect results

The double version of pi is correct to about 15 dp, the float version to about 7dp

In Fortran when we set the value of d we must specify a 64-bit literal

Summing a rather small number many times often doesn't give quite the expected result. This makes it risky as a loop condition as you can get 1 (or rarely more) fewer or extra loops depending on platform, optimisation levels etc

#### Try:

What we set as 0.01 might not come out that way, and what we do see depends on formatting. Try different numbers and compare the results. In particular, try setting n to a power of 2

### - 02\_CombiningBigAndSmall

- This code prints a variety of values found by summing floats. In particular it sums small numbers onto a larger one

#### Try:

Adjust the number or range of values in the array

Adjust the init value to see the effect of a large number on the accuracy of the final sum

Check what difference it makes to change eg\_kind to a double (real64). What sort of value for init then makes the error a similar size to the array elements?

## - 03\_Overflows

- This code demonstrates the min and max values of integers and floats and what happens when they're exceeded

### Info:

See e.g. [http://earth.uni-muenster.de/~joergs/doc/f90/unix-um/dfum\\_034.html](http://earth.uni-muenster.de/~joergs/doc/f90/unix-um/dfum_034.html)

Fortran has Ints of various kinds. Default is 4 bytes. Can also get 8 bytes or short 2 byte ints etc

Floating point numbers also have limits. The IEEE (I triple-E) standards define strictly what behaviour must be. The program 03-05\_InfAndNanTable (C so compile with gcc {name} -o {outputname}) shows the required values of operations on Inf and NaN (see also 05) values.

**Note 1:** Here `FLT_MAX + 1` is still `FLT_MAX` because the finite Epsilon for a value this large is more than 1. Try finding the minimum needed to add to get inf

**Note 2:** Here we are running into what are called denormal numbers. Usually the base part of the number is a number between 0.0 and 1.0 as in normal scientific notation. In denormal numbers this is a pure decimal. This allows the representation of smaller numbers, but at lower precision.

### Try:

Try adjusting the number or range of values

Create an 8-byte int and compare its Huge to that for int

Also try short 2-byte ints

## - 04\_MixedMode

- This code demonstrates the dangers of combining int and float in calculations

### Info:

### Try:

In general operands are promoted to the "biggest" type involved in a single operation (biggest here means that ints will be boosted to longs, but can also be boosted to floats). Using the order of operations (BODMAS, PEMDAS etc) work out

what is happening. Note that the division operator "associates with" a number to its right. Note also that Fortran doesn't guarantee the order things are evaluated

adjust the erroneous calculation on line 23 to be correct

#### - 05\_NaNContagion

- This program explores NaN, how it arises and how it behaves

##### **Info:**

See also the 03-05\_InfAndNanTable, the slides or the notes

##### **Try:**

Using the facts about NaN comparisons implement an isNaN function using the stub definition in the code. Test it with some numbers.

Modern Fortran has an isNaN function. Look it up and try it

#### - 06\_UninitialisedErrors

- This program shows what can happen if you fail to initialise variables

##### **Info:**

This program does something a little subtle: it allocates an array, frees it, and then reallocates it. Depending on what has happened in the meantime, you may or may not happen to reallocate exactly the same block of memory.

Run the program, supplying one integer between 0 and 100.

The first array should be the numbers 1 to 15.

This memory is now freed.

Next is an array of whatever size you entered.

Last is another array.

Depending on the sizes, sometimes one or other array gets that chunk of memory we just freed, and contains what seems to be "data"

*This sort of error is very hard to spot, and is a good reason to always initialise your variables!*

##### **Try:**

Run the program a few times: try passing values of 15, 11, and 18 You probably find that which array contains the apparent data changes

Try also with optimisation on. You probably find the ``junk'' is more junky.

There is also an unintended initialisation effect demo'd by the function total. Initialising in the declaration gives the running\_total variable the "SAVE" attribute, which means it keeps its value between calls of the function. It looks like we properly initialised the value, but each time we call the function the result grows. Here the error is obvious: in practice it can be very tricky to spot. Fix it and check it then works

#### - 07\_AccessErrors

- This program shows what happens if you access outside the bounds of an array

##### **Info:**

These sorts of errors are very unpredictable. The code writes beyond its array bounds. It randomly chooses to write to one of two arrays. On my system this alternates between an access violation, and overwriting the start of the next array.

##### **Try:**

Adjust how far out of bounds the write goes.

gfortran offers -fbounds-check and most compilers have something similar. This will make array bounds errors fatal errors. Note it can be costly for performance so is best used as a debug option. Check it catches the errors here as you expect

#### - 08\_BadPointer/BadAllocation

- This program shows what happens with failed Pointer or Allocations

##### **Info:**

This code tries to access unallocated memory. It also tries to do bad things like allocate an already allocated array.

If you're familiar with Fortran pointers, there is an example using these too. You can ignore these if not.

**Try:**

Fix the first bug and explore the second: what happens if trying to allocate an already allocated array

**- 09\_Tarpit**

- This code has a logic bug which makes it very very slow.

**Info:**

If you compile and run, you'll see numbers printed. If it takes a very long time or no time at all, adjust the reps parameter until it takes 2-3 seconds

The code is writing to a file, but accidentally opening it every iteration. You may notice the numbers go in pulses, when the writing actually flushes to disk.

Use the command-line option ``-q'` to omit printing `i` at every step

**Try:**

Recompile the program with `-DFIX` and see how much faster it is without the unneeded work.