

# Survey of COSY Compiler Options

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- 1 Motivation
- 2 High Precision Requirements
- 3 Speed Test
- 4 Consistency Check

# Motivation

- Implementation of Taylor Models and Interval Arithmetic require a great deal of reliance on preexisting architecture of computers
- Many different places to go wrong:
  - Floating Point Calculations
  - Compilation to Machine Code
  - Proper Input/Output
  - Machine Architecture

# 64 bit - IEEE 754 Compliance

- Extended Precision
  - 64 bit integers naturally lead to cheap 80 bit precision
  - 16 bits for sign and exponent and 64 bit significand
- Dekker's Algorithm
  - For calculating high precision exact bounds.
  - Requires precise 64 bit IEEE 754 floating point (53 bit significand, 11 sign and exponent bits)

# Overview of tests

- Two Compiler Groups
  - Intel Fortran 11.0 and 9.2
  - Gnu Fortran gfortran 4.3.2 and 4.2.3
- Optimization Flags Various optimization levels O0 to O3
  - gfortran -ffloat-store
  - Intel -fp-model strict
  - Intel for 64 bit machines -m32
    - IA-32 Architecture
- Tests
  - High Precision Code
  - Verified Integrator Speed Test
  - demo.fox Consistency

# Test Machines

- Vivaldi - Pentium 4 2GHz, 512 MB RAM  
Ubuntu Linux 8.10  
Intel Fortran 11, gfortran 4.3.2
- bt.pa.msu.edu - Pentium 4 2GHz, 512 MB RAM  
FreeBSD 7.2  
gfortran 4.3.4 (prerelease)
- MacMini - Core Duo 1.66GHz, 2 GB RAM  
Mac OS X 10.4.11  
Intel Fortran 9.2, gfortran 4.2.3
- MacBook - Core 2 Duo 2GHz, 2GB RAM  
Mac OS X 10.5.6  
Intel Fortran 11

# High Precision Test Suite

Speed and requirements for High Precision Numbers. Written and compiled in Fortran.

- Comparison of bitwise representation of number with calculated values.
  - $\pi$ ,  $\log(2)$
  - Addition checking to obtain exactly representable numbers.
  - Order of operation checking for Dekker Operations.

## Magnetic Sector Test

- COSY Beam Physics Package
- Calculation of transfer map for 90 degree homogenous dipole.
- Loop calculation of 12 - 30 degree homogenous dipoles. (Identity)

## High Precision Suite - gfortran

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
gfortran -fno-range-check ...				
-00	HF	113	118	-
-01	SF	113	89.5	-
-02	SF	105	86.6	-
-03	SF	109	86.5	-
-00 -ffloat-store	HF (177)	394	139	-
-02 -ffloat-store	HF (131)	283	107	-

## High Precision Suite - Intel Compilers

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
ifort ... (Version 11.0) Version 9.2 for MacMini				
-00	90.3	-	68.76	HF
-00 -m32	-	-	-	59.28
-01	SF	-	SF	SF
-01 -m32	-	-	-	SF
-02	SF	-	SF	SF
-02 -m32	-	-	-	SF
-03	SF	-	SF	SF
-03 -m32	-	-	-	SF
-00 -fp-model strict	87.8	-	68.57	HF (54.55)
-00 -m32 -fp-model strict	-	-	-	58.71
-02 -fp-model strict	50.2	-	40.35	22.66
-02 -m32 -fp-model strict	-	-	-	25.31

# Integrator Speed Test

- Speed test only - Solution sets and enclosures are not compared.
- Version 1.0 of the COSY-VI tool
- Verified Integrator Code for Apophis Integration - ESA Ariadna Contract
  - Restricted 11 body system.
  - Suitably scaled for a quick speed run
  - Done in an easy region
  - Many Taylor Model operations done at order 17 weight 3 in 6+1 variables.

## Integrator Speed Test - gfortran

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
gfortran ...				
-00	162.13	248.78	107.43	-
-01	60.12	61.71	55.33	-
-02	Err	Err	50.80	-
-03	Err	Err	50.48	-
-00 -ffloat-store	202.16	509.36	118.93	-
-02 -ffloat-store	111.73	319.81	70.61	-

## Integrator Speed Test - Intel compilers

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
ifort ... (Version 11.0) Version 9.2 for MacMini				
-00	109.85	-	108.38	78.36
-00 -m32	-	-	-	80.00
-01	43.81	-	39.59	29.41
-01 -m32	-	-	-	23.08
-02	43.97	-	39.84	30.38
-02 -m32	-	-	-	24.40
-03	43.87	-	40.81	28.82
-03 -m32	-	-	-	24.98
-00 -fp-model strict	211.99	-	108.37	77.41
-00 -fp-model strict -m32	-	-	-	81.19
-02 -fp-model strict	56.02	-	-	36.06
-02 -fp-model strict -m32	-	-	47.98	31.02

# COSY demo.fox consistency check

- Standard COSY demo suite
  - Various calculations from Beam Physics
    - Repetitive Symplectic Tracking
    - Storage Ring Design
    - Fitting Triplet of Magnetic Quadrupoles
- 10000 lines of ascii output
- Per byte character data comparison.

# COSY demo.fox gfortran

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
gfortran ...				
-00	/	D	C	-
-01	/	/	C	-
-02	H	D	C	-
-03	H	D	C	-
-00 -ffloat-store	E	G	C	-
-02 -ffloat-store	E	G	C	-






# COSY demo.fox - Intel Compilers

	Vivaldi	bt.pa.msu.edu	MacMini	MacBook
ifort ... (Version 11.0) Version 9.2 for MacMini				
-00	A	-	A	/
-00 -m32	-	-	-	A
-01	A	-	F	A
-01 -m32	-	-	-	A
-02	B	-	B	B
-02 -m32	-	-	-	B
-03	F	-	B	B
-03 -m32	-	-	-	B
-00 -fp-model strict	A	-	A	A
-00 -fp-model strict -m32	-	-	-	A
-02 -fp-model strict	A	-	A	A
-02 -fp-model strict -m32	-	-	-	A

# Summary and Conclusions

- Only consistency checks. Does not examine correctness of results.
- Intel Compilers have shown more reproducible results across machines.
- If reliance on IEEE754 Floating point standard is required, care must be taken.

# Selected References I

-  A. Wittig and M. Berz.  
Computation of high-order maps to multiple machine precision.  
*International Journal Modern Physics A*, in print, 2008.
-  Intel Fortran Compiler User and Reference Guides,  
[http://www.intel.com/software/products/compilers/docs/flin/main\\_for/index.htm](http://www.intel.com/software/products/compilers/docs/flin/main_for/index.htm).
-  Quick-Reference Guide to Optimization with Intel Compilers version 11, [http://www.intel.com/software/products/compilers/docs/qr\\_guide.htm](http://www.intel.com/software/products/compilers/docs/qr_guide.htm).
-  Using the GNU Compiler Collection,  
<http://gcc.gnu.org/onlinedocs/gcc.pdf>.
-  gfortran(1): GNU Fortran 95 compiler - Linux man page,  
<http://linux.die.net/man/1/gfortran>